National Renewable Energy Laboratory

A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

Innovation for Our Energy Future

A New Market Paradigm for Zero-Energy Homes: The Comparative San Diego Case Study

Technical Report
NREL/TP-550-38304-01
December 2006

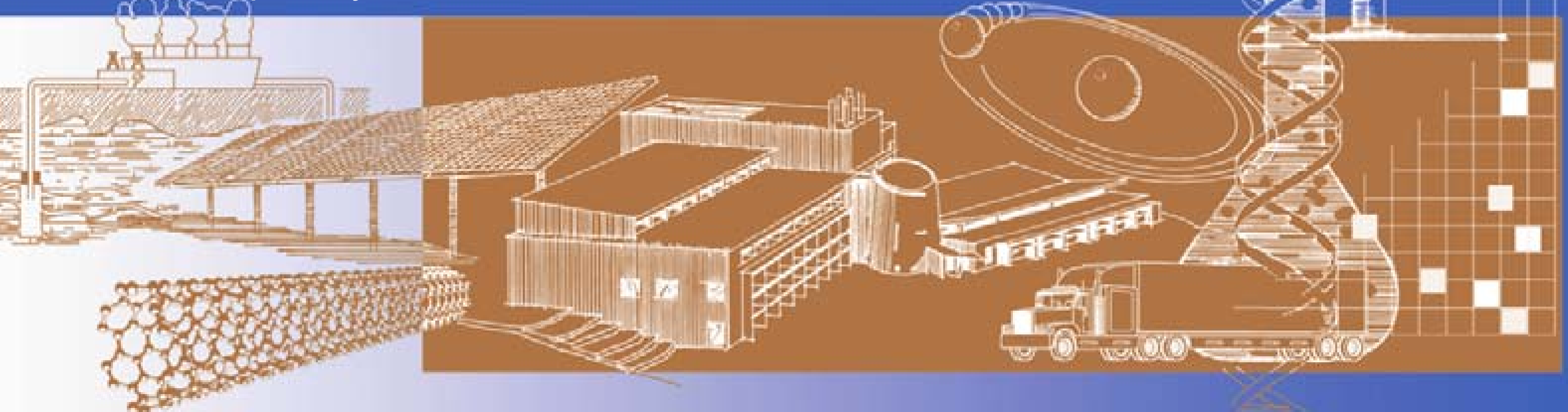
Volume 1 of 2

B.C. Farhar
National Renewable Energy Laboratory

T.C. Coburn
Abilene Christian University

Link to Volume 2: Appendixes

NREL is operated by Midwest Research Institute Battelle Contract No. DE-AC36-99-GO10337



A New Market Paradigm for Zero-Energy Homes: The Comparative San Diego Case Study

Technical Report
NREL/TP-550-38304-01
December 2006

Volume 1 of 2

B.C. Farhar
National Renewable Energy Laboratory

T.C. Coburn
Abilene Christian University

Prepared under Task No. ZB03.3003

National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401-3393
303-275-3000 • www.nrel.gov

Operated for the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
by Midwest Research Institute • Battelle

Contract No. DE-AC36-99-GO10337

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy
and its contractors, in paper, from:
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: mailto:reports@adonis.osti.gov

Available for sale to the public, in paper, from:
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

Printed on paper containing at least 50% wastepaper, including 20% postconsumer waste

FOR RELEASE JANUARY 23, 2001 AT 8:00 A.M. PST

SHEA HOMES SAN DIEGO INTRODUCES THE SHEA HIGH PERFORMANCE HOME

Leading U.S. Homebuilder Unveils New High Performance Home That Generates Some of Its Own Electricity, Produces Hot Water and is up to 38 Percent More Efficient Than Strict California Title 24 Guidelines

San Diego, CA – January 23, 2001 – Shea Homes San Diego announced today that it is introducing the ultra-efficient new Shea High Performance Home. By combining the advanced technologies of three program partners with its own premier building practices, this leading San Diego builder has set a new industry standard for energy efficiency. In addition to being up to 38 percent more efficient than homes built under strict California Title 24 guidelines, the Shea High Performance Home offers solar electric home power generation and solar water heating as standard features.

The Shea Homes program partners are AstroPower, Inc. (NASDAQ: APWR) of Newark, DE, with its SunChoice™ Solar Electric Home Power Systems; ConSol of Stockton, CA, through its ComfortWise℠ energy-efficiency program; and Sun Systems of Scottsdale, AZ, offering the latest solar hot water technology.

"We set out to address both sides of the equation," said Mark Brock, Shea Homes San Diego president. "First, we committed to building the most efficient home we possibly can, ensuring comfort and value for our customers by reducing their consumption of electricity and natural gas. Then, by adding a solar electric home power system, we actually offer our buyers the opportunity to produce some of their own electricity.

It's like buying a car that makes its own gas," Brock added.

In light of the current unprecedented turmoil in Western electric markets and rising natural gas prices, San Diego homeowners are paying 10 times more for electricity and more than twice as much for natural gas than they did in May 2000. As a result, the Shea High Performance Home may become even more significant.

"The Shea High Performance Home gives our buyers much greater control when there are energy issues like we're experiencing now," Brock noted. "We do see it as innovative — no other builder is doing anything like it — but we really developed it because it's the right thing to do for the environment and for our customers. It's all about comfort, performance, and adding value to their investment."

Shea Homes San Diego will feature the Shea High Performance Home in its new Scripps Highlands community, located in the Scripps Ranch area of San Diego. Fifteen miles north of downtown San Diego, these new homes will incorporate the latest in solar electric home power generation, solar water heating, and energy-efficiency technology, enabling homeowners to reduce their utility bills by 30 to 50 percent over a conventionally built home.

— more —

10721 Treena Street, Suite 200, San Diego, California 92131-1039, tel: 858·549·3156 fax: 858·549·0112

Throughout the development of the Shea High Performance Home, Shea Homes has worked closely with the San Diego Regional Energy Office to develop even more energy-efficient features.

"The real innovation with this project is that Shea Homes is combining energy efficiency with solar electricity and water heating technologies," said Scott Anders, project manager of the San Diego Regional Energy Office. "If just 10 percent of the homes built in San Diego over the next 20 years were as energy efficient and able to fulfill some of their own energy needs, the region would realize significant energy and air quality benefits. It would be the equivalent of saving enough electricity to power more than 15,000 homes."

###

About Shea Homes

Founded in 1985 and headquartered in Scripps Ranch, Shea Homes San Diego is a division of the J.F. Shea Co. Established in the 1880s as a Nevada plumbing contractor, the Shea name is known for such noteworthy landmarks as the Hoover Dam and Golden Gate Bridge. Today the six Shea Homes divisions – operating in San Diego, Orange County/Los Angeles, northern California, Arizona, Colorado, and North Carolina – represent the largest privately owned building firm in the nation and the 10th largest of all home builders. Further information may be obtained by visiting J.F. Shea's website at www.JFShea.com or the Shea Homes website at www.SheaHomes.com.

About AstroPower

Headquartered in Newark, Delaware, AstroPower is the world's largest independent manufacturer of solar electric power products, and one of the world's fastest growing solar electric power companies. AstroPower develops, manufactures, markets and sells PV solar cells, modules, panels and systems for generating solar electric power. Solar electric power systems provide a clean, renewable source of electricity in both off-grid and on-grid applications. In December 2000 AstroPower was added to the S&P SmallCap 600. For more information, please visit www.AstroPower.com.

About ConSol

ConSol, energy consultants, has been working for builders since 1981 providing a full range of services to improve quality control of energy-related features in new homes. ConSol created ComfortWise℠ from its experiences developing successful resource-management programs and training more than 200 builder companies on quality construction. ConSol is heavily involved in the building industry at the local, state and national levels and won the Energy Star Homes Ally of the Year award in 1997. ConSol is committed to assisting the builder in cost-effectively achieving the highest level of quality. For more information, please visit www.ComfortWise.com.

About Sun Systems

Sun Systems is the primary supplier to the new-home construction market for solar water heaters. The new CopperSun Integrated Collector Storage (ICS) solar water heating system is the only patented roof-integrated designed heater in the US marketplace today. The unique "skylight"design of the CopperSun, combined with its ability to offset 40 to 70% of a homeowner's utility costs to heat hot water, makes the CopperSun the perfect choice for homebuilders and homeowners. Sun Systems is a vertically integrated company from manufacturing, sales, installations and service. Sun Systems provides homebuilders with a complete package including training of plumbers, roofers, support staff and sales people. For more information, contact Sun Systems at (480) 998-5858.

About the San Diego Regional Energy Office

The San Diego Regional Energy Office (SDREO) is an independent, non-profit energy organization dedicated to conducting energy policy and planning activities, managing public-interest energy programs and providing vital energy information to the region. The San Diego Regional Energy Office, the only energy planning organization of its kind in California, was formed in 1996 as a result of the implementation of the San Diego Regional Energy Plan. For more information on the Regional Energy Office, please visit www.sdenergy.org.

Contact Information:

Ryan Green
Community Development Manager
Shea Homes, Inc. (858) 653-4116

Michael Hodgson
President
ConSol (209) 474-8446

Michael Wright
Director, Marketing Communications
AstroPower, Inc. (302) 366-0400 Ext. 195

Tom Bohner
President
Sun Systems Inc. (480) 998-5858

Scott Anders
Project Manager
San Diego Regional Energy Office (619) 594-2579

Preface

Preface

This study was built from the ground up. Its foundation is the pilot work in the field with SheaHomes staff, the advisory committee, and the homeowners. This study is *not* an engineering and economic analysis. It is a statistical, empirical analysis of the homes at the Scripps Highlands developments in San Diego that involved observation and qualitative interviews with the homeowners, SheaHomes' professional staff, and the staff of the utility company (San Diego Gas & Electric).

Early findings have been published previously in three papers presented at the American Council for an Energy Efficient Economy Summer Study in 2002 and 2004. Not all the findings from the preliminary qualitative pilot work are included here.

The Home Builder

SheaHomes was the innovator in this project. The company took the risk of using new technologies in its homes. Its staff was incredibly generous in sharing information with us about which homes were planned as PV standard and which were PV eligible. We spent time at the sales center taking virtual tours of the homes, observing, and reading informational materials. The builder also shared with us a contractor's study of the media coverage and videos of coverage on the evening news in the San Diego area.

SheaHomes also provided a list of people who had visited the Scripps Highlands sales center but who did not buy homes. We did a separate analysis (called the "lost lookers" study) to follow up on their experiences.

The Homeowners

The homeowners were also very generous and patient with our surveys and interviews, even though they had been subjected to a good many of both before we had a chance to talk to them. We asked SheaHomes owners to tell us their stories. We asked them: "Please tell us the story of how you came to buy your home," with many probes and follow-ups. We also asked them to tell us about living in their new homes. If they did not bring up their homes' energy features (which they often did not), we brought up the subject and asked them to show us these features. This was important because we could then determine what they knew about them and if the energy features mattered to the homeowners.

We visited 25 highly energy-efficient homes with solar water heating, both with and without solar PV, and looked at the solar water heating panels, the temperature of the water coming into the water heaters, the PV panels, the air-conditioning units, the refrigerators, dishwashers, windows, and thermostats. We also looked at utility bills and spreadsheets that some homeowners maintained to track their energy use. Some homeowners showed us compact fluorescent lights (CFLs) that they had installed in their kitchens after move-in.

The Utility

We met with staff at San Diego Gas & Electric Company in San Diego to discuss the study, the utility analysis, and the requirements for accomplishing the transfer of data with homeowner permission. The staff described their experiences in net metering and interconnectivity agreements with residential customers.

The approach of building the quantitative study, which is the subject of this report, on earlier qualitative field work is a highly reliable method. The relevance of survey questions, their exhausting the range of potential responses, and the mutual exclusiveness of the responses help to assure an interpretable set of findings. The cooperation of SheaHomes, the homeowners, and all of the organizations who helped us was invaluable. We hope the results warrant the trust and confidence they have invested in us.

Any errors in this report are the responsibility of the authors.

Acknowledgments

Lew Pratsch of the Building Technologies Program, U.S. Department of Energy, Washington, D.C., was the Program Manager for the study.

The National Renewable Energy Laboratory (NREL) was advised in this study by a study advisory group. The following individuals served on the study advisory group and contributed their insights to this project:

- Scott Anders, then at the San Diego Regional Energy Office; now at the Energy Policy Initiative Center, University of San Diego
- Tom Bohner, Sun Systems, Inc.
- Jonathan Done, then at SheaHomes, San Diego
- Rob Hammon, ConSol, Inc.
- Russ Hewett, National Renewable Energy Laboratory
- Les Nelson, California Solar Energy Industries Association
- Marc Roper, then at AstroPower, Inc.; now at Schott Solar
- Teri Shusterman, SheaHomes, San Diego

Ryan Green, formerly on the SheaHomes-San Diego staff and now at Centex Homes, San Diego, also provided valuable insights to the study.

Extensive assistance to the study was provided by other SheaHomes' staff in San Diego, including, among others, Diane Rivera, former Director of Marketing; Pattie Walker, former Director of Sales; and Pam Beaird, Sales Agent.

Bob Keithly of San Diego Gas & Electric Company (SDG&E) coordinated the company's protocol review for the utility release forms and utility consumption and cost data for customers agreeing to have their utility records released to NREL for inclusion in the study's analysis. SDG&E also provided utility records to NREL in electronic form for the accounts that had formally released their data.

The late Nancy Collins of Q^4 Associates, Oakland, California provided invaluable consulting assistance during the qualitative phase of the study, and was also principal investigator of the "Lost Lookers" study.

In addition, the Building Industries Institute of California contributed $4,000 to the Colorado Energy Science Center (CESC) to provide $10 financial incentives for homeowners in the universe of study to encourage them to respond to the mail questionnaires. With this assistance, and with the help of Pat Keegan (CESC director), it was possible to achieve the response rates accomplished.

The participation of the many homeowners who took their time to respond to the questionnaires they were sent is acknowledged and is very much appreciated.

The report was peer reviewed by the study advisory group who provided numerous helpful suggestions and comments. All errors are the responsibility of the authors.

Don Hagengruber, NREL's Chief Counsel, provided extensive support and oversight in the Human Research Review process. The Human Research Committee of the University of Colorado-Boulder served as the Institutional Review Board (IRB) and reviewed and approved the protocols used in this research.

Ron Judkoff, Director, Center for Buildings and Thermal Systems, NREL, provided unflagging support throughout this effort. Tim Merrigan, NREL, was the NREL Program Manager for this study. Jay Burch and Ron Judkoff, Center for Buildings and Thermal Systems, NREL, provided technical assistance to the statistical analysis comparing electricity and gas consumption and utility costs between the high performance and comparison homes. Megan Murphy, doctoral candidate, Department of Sociology, University of Colorado, Boulder, Colorado, provided extensive research assistance to Dr. Farhar. A. J. Sterling, student at Abilene Christian University, provided research assistance to Professor Coburn.

Co-editors of the report provided yeoman efforts; they were Stefanie Woodward and Nancy Wells. Kay Vernon provided superior word-processing expertise. Diane Littau assisted manuscript preparation in a variety of ways.

The authors would also like to acknowledge

- Susan Sczepanski, NREL, for excellent graphics for the study's questionnaires
- Fay Hoover and the NREL Copy Center
- Alexander's Data Services, Inc., for data entry and cleaning.

Executive Summary

Introduction and Background

> *"It's good for society."*
>
> *- This and other quotes are from comments made by owners in the SheaHomes Scripps Highlands communities.*

In April 2001, SheaHomes began to offer high-performance homes at Scripps Highlands in San Diego, California. This was the first such offering in the United States by a production builder. The 306 homes, sold by November 2003, were highly energy efficient; 293 had solar water heating systems; and 120 had photovoltaic (PV) systems.

The National Renewable Energy Laboratory (NREL) used a diffusion-of-innovations theoretical perspective to follow this development over time. The study focused on the builder experience, market response to high-performance homes, increases in home values over time, and the consumption and cost of electricity and gas in the high-performance and adjacent comparison homes.

We began our work by meeting with a project advisory group to define key research questions. During the first, qualitative phase of the study, we conducted numerous interviews of executives and staff of SheaHomes, organizations partnering with the builder, and other interested parties. Field work was conducted at the SheaHomes community with early buyers and lost lookers. Researchers collected background information on the home sales processes. Qualitative interviews focused on the homeowners' reasons for purchase and their perceptions of the energy features of their new homes. In this early phase, a total of 43 respondents in 25 households were interviewed; the information obtained was used to formulate questions for a more extensive survey of all homeowners.

We also selected a comparison community of 103 homes built by a different builder of similar vintage, size, and price adjacent to San Angelo and Tiempo. Although they were built to Title 24 building codes, thus providing more energy efficiency than conventional building codes in other states, the comparison homes were offered with no special energy or solar features standard.

The quantitative phase consisted of a comprehensive mail survey and detailed statistical analysis of the responses from SheaHomes and comparison homeowners. Questionnaires were mailed early in 2004 to all homebuyers. The overall survey response rate was 63% (65% from the SheaHomes communities and 56% from the comparison community). The survey addressed perceptions and preferences of the new homebuyers and the roles, if any, that energy played in their home purchase decisions. The survey also examined homebuyer satisfaction, willingness to pay for solar PV, preferences about energy policies, experiences with the homes, aesthetics of solar PV, satisfaction with utilities, and demographics, including environmentalism and innovativeness.

Respondents were asked to sign release forms for SDG&E to provide data on electricity and natural gas consumption and costs. The utility company provided the data to NREL, which performed analyses to determine if statistically significant differences in energy consumption and energy costs can be attributed to the energy efficiency and solar features of the high-performance homes. These analyses controlled for an annual usage cycle, climate, square footage, number of occupants, and other variables. This unique research opportunity gave us the chance to put conventional wisdom about ZEH markets to the test; the detailed findings from our study are contained in this comprehensive 800-page report.

Home Sales Prices

High-performance homes are competitive on the market. Based on actual sales data, per square foot, they sold for 9.2% less than comparison homes of the same vintage, on average. This difference, though small, is statistically significant. When house size is controlled for, the difference remains. Thus, even when controlling for the fact that housing prices per square foot decrease with house size, we find that the SheaHomes were competitively priced.

Uptake of Optional PV Systems

> *"It's best to integrate the solar electric system into the entire home purchase rather than having it offered as an option in a piecemeal way. It should all be rolled into the overall price."*

Ultimately, 120 of the 306 SheaHomes were sold with some sort of PV system. Hence, 39% were sold with PV systems and 61% were not. However, only 260 homes were PV-eligible; hence, 46% of these were sold with PV systems. Clearly, the uptake on optional PV equipment was not as strong as it might have been. A total of only 12% of all PV-eligible homes were sold with PV systems optionally. Most of the PV systems sold came standard.

> *"We feel the builders know what they are doing, so if they offer the solar as part of the package, there must be a reason."*

However, we believe the lackluster sales of optional PV systems was the result of sales staff failure to offer the optional PV systems to buyers of PV-eligible homes. In fact, our data show that a majority (56%) of those who could have purchased optional PV systems were *not told* about the option. Thus, *the uptake rate is not 12%, but 44% of those actually offered the PV systems*. Homebuyers relied heavily on sales staff for information about PV systems, and staff were more concerned about closing home sales and less focused on sales of PV systems that might complicate the deal. Staff received no extra compensation for sales of PV systems.

Who Are These Homebuyers?

The buyers of high-performance homes and the buyers of new conventional homes share the same characteristics. SheaHomes and comparison homebuyers brought virtually identical attributes to their home purchase decisions, such as demographics, environmental attitudes, and early adopter characteristics.

As expected, residents of both communities mostly represent upper-middle class married couples with children, or mature couples. They are relatively affluent with well-paying occupations. Fifteen percent more of the SheaHomes owners (19%) than of the comparison owners (4%) enjoy an annual income of more than $200,000. Yet, because SheaHomes' sales prices were competitive, higher income would not have influenced their decisions to buy there. No differences between SheaHomes and comparison homebuyers are found in results on measures of early adopter characteristics or environmentalism.

Three-quarters of the buyers visited both the SheaHomes and comparison communities when they were shopping for new homes. However, neither group was well informed about home energy features, although buyers of SheaHomes knew a bit more at the time of purchase. A majority of the comparison buyers were unaware that they featured energy efficiency and solar energy, even though they may have visited SheaHomes.

Variables on which the types of homeowners differ were by and large those *affected by their experiences in living in their new homes* (survey data were collected after owners had lived in their new homes for at least six months). For example, six in ten of SheaHomes owners agree that solar water heating systems are cost effective, and half of SheaHomes owners agree that solar PV systems are cost effective. The corresponding percentages of comparison homebuyers are 40% and 36%, respectively.

Despite some difficulties with interconnectivity issues, owners of SheaHomes with PV systems have more positive attitudes toward SDG&E than other homeowners. These differences are significant. A majority of PV homeowners are pleased with SDG&E's billing processes. Similarly, almost one-third of PV owners believed that electricity rates had come down since they moved in, compared with 18% of SheaHomes owners without PV systems.

> *"We isolate things to see what the electricity hogs are. We're already more energy conscious because of the feedback device."*

It is not the qualities the homebuyers brought to the home purchase decision, but rather *the experience of PV ownership that changes attitudes and perceptions.* It also seems to change energy behavior. Living in highly energy efficient homes with solar water heating and PV systems promotes increased familiarity with and interest in those systems, which ultimately leads to heightened awareness of household energy practices. The behavioral interaction of consumers with PV technology based on the digital display of kWh production and consumption—and to some extent the electric meter—provides feedback that seems to affect homeowner energy behavior. Feedback may be significant in bringing about behavioral changes that optimize energy and cost savings. To a limited degree, the PV owners also seem more sensitive than others to savings from solar water heating systems, even though these have no feedback devices.

Aesthetics and Resale Value

> *Regarding aesthetics—*
>
> *"Huh?"*
>
> *"Satellite dishes are more offensive."*

Neither qualitative nor quantitative data identified aesthetics as barriers to purchase of homes with solar panels. However, because we primarily studied homeowners who bought such homes, we cannot conclude that no one objects to the aesthetics of solar panels. It seems fair to conclude that the new homebuying market is large enough that it does not matter if some people object; in fact, home sales at Scripps Highlands were brisk.

Similarly, based on our data, any concerns about solar panels diminishing resale value appear unwarranted. In the first 3.5 years, 13% of the comparison homes were resold compared with 5% of the SheaHomes, suggesting a more rapid turnover of comparison homes. SheaHomes experienced a mean dollar gain of 55.4% for a mean ownership length of 22.5 months. Comparison homes experienced a mean dollar gain of 44.7% for a mean ownership length of 28.1 months. The mean dollar gain per month owned was $14,500 for SheaHomes and $9,300 for comparison homes.

Home Purchase Decisions

The most important reasons for purchase for both categories of buyers were the home's location in a safe and secure quality neighborhood, the overall home value, and the investment potential. The relative rankings of reasons for purchase were the same for both categories of homebuyers. Concerns about the San Diego 2001 electricity crisis did not influence home purchase decisions. Energy was not an important factor in the purchase decisions of most of the study's new homebuyers. The reputation of the builder was more important to SheaHomes than to comparison buyers. Buyers who were more concerned about their residential energy consumption were more likely to buy SheaHomes than comparison homes. Every home feature mentioned in our study had a higher average importance rating for those who did not purchase PV homes than for those who did, suggesting that home characteristics other than energy features were more important to those not purchasing homes with PV systems.

The findings on willingness to pay (WTP) more for PV systems suggest that $5,000 may be a threshold for 1.2 PV systems. More than one-third of non-PV-purchasing homebuyers indicate a WTP at least $5,000 more for PV systems that could replace 50% to 70% of their electricity needs. This level of savings would require a larger PV system. SheaHomes buyers who upgraded from 1.2 to 2.4 PV systems paid an additional $4,000; those who purchased optional 1.2 PV systems paid $6,000 (later raised to $7,000). Those who purchased optional 2.4 PV systems paid $10,000 (later raised to $11,000). Reasons for not purchasing PV systems tend to center around the expense. Subsidies and amortization would be required to permit installation of larger 2.4 to 3+ PV systems that would be needed to reduce electricity costs by 60% to 70%.

Satisfaction

> *"When people come to visit, the first thing we do is show them the solar equipment."*

Most buyers are satisfied with their new homes, but SheaHomes buyers, and especially buyers of homes with PV systems, are more satisfied than are comparison buyers. A significantly higher percentage of SheaHomes owners than owners of comparison homes (77% versus 67%) indicate they would buy the same houses again. Although this would not be the only factor affecting satisfaction, the comparison homeowners report significantly higher monthly utility bills than do the SheaHomes owners. Both sets of homeowners find their homes comfortable, but comparison buyers pay higher utility costs to maintain their comfort levels. Owners of SheaHomes believe their homes are energy efficient.

By owners' estimates, living in PV homes has resulted in significantly lower utility bills than those reported by the rest of the homebuyers. Two-thirds of PV owners have bragged to others about their utility bills, compared to one-quarter of owners without PV. A majority of PV owners indicate their expectations for utility bills have been met, compared with less than one-third of other SheaHomes owners.

> *"We brag about our windows."*

Three dimensions of advantages of PV ownership result from factor analysis. The first of these is "altruistic" benefits (such as helping to reduce global warming, helping the local economy, benefitting future generations, and helping to improve local air quality). The second is the financial advantage (such as reduced electricity bills, free electricity once the system is paid for, selling electricity back to SDG&E, and increasing the home's resale value). Finally, personal satisfaction includes increased self-sufficiency, being technologically innovative, and feeling good about owning the home.

Policy Preferences

> *"Solar electricity should be available and affordable on all housing."*

SheaHomes and comparison owners agreed on energy efficiency and solar energy policy preferences. For example, 92% of both sets of homeowners agree or strongly agree that "builders should build very energy-efficient homes if they cost less per month to own and operate." Eighty-five percent of SheaHomes and 81% of comparison buyers agree or strongly agree that "the federal government should support research on highly energy-efficient homes that produce all the energy they use." Interestingly, majorities of both sets of homeowners agree that solar water heating and solar PV systems are desirable innovations for new homes.

Are Energy and Costs Saved?

SheaHomes advertised that its homes, incorporating "the latest in solar electric home power generation, solar water heating, and energy-efficiency technology," would enable homeowners to reduce their utility bills by 30% to 50% over conventionally built homes. *The original SheaHomes concept has been validated by our utility analysis.* Among the homes studied, SheaHomes consume less electricity and gas, on average, than adjacent comparison homes. Similarly, SheaHomes households incur lower utility costs, on average, than comparison households. For example, the combined average monthly total utility bill for homes with 2.4 PV systems is 54% lower than for comparison homes, a result that is statistically significant.

A New Market Paradigm

"All builders should be doing it."

The value of our study does not lie in describing the motivations of recent new homebuyers, but rather in suggesting a conceptually fresh alternative paradigm for the building and marketing of new ZEHs. When this paradigm is used, builders, new homebuyers, and utility companies will benefit. When appropriately applied to business practice and public policy, this new paradigm will help builders create the sustainable communities so necessary for our well-being and that of future generations.

Conventional wisdom on the markets for ZEHs, relying on a diffusion-of-innovations tradition, holds that ZEHs will appeal only to niche early-adopter markets. It posits that ZEHs cost more to build and therefore are more expensive to buy than conventional homes. It would follow that production builders should offer them optionally to buyers with unique motivations, such as environmentalism. In this view, ZEH aesthetics (in particular, the solar PV panels) are often considered barriers to most mainstream homebuyers, and as impediments to resale, negatively affecting home values. Conventional wisdom also assumes that mainstream homebuyers are motivated by economic payback on an incremental financial investment for zero-energy features for which they have opted. Homebuyers' satisfaction, then, is considered contingent on the perceived payback of energy features.

Our results suggest a new market paradigm for ZEHs that appears to stand conventional wisdom on its head. This paradigm, though it originates from the San Diego case study, may be useful elsewhere in California and in the rest of the country, and, indeed, internationally. The table below captures some of the notions that we have termed conventional wisdom and summarize the new market paradigm along these same dimensions.

The results of this case study suggest that the markets for new housing are essentially equivalent to the markets for ZEHs standard, assuming a policy frame that provides subsidies and builder pricing similar to those in effect when San Angelo and Tiempo were built and sold. However, this does not mean that the diffusion-of-innovations approach is irrelevant to the widespread acceptance of ZEHs. Rather, the early adopters are the *builders*, *utility companies*, and *policy-makers* whose adoption of ZEHs will make these homes available standard to many willing homebuyers. For us to benefit from ZEHs, the innovative building practices for which

SheaHomes has led the way and the ZEH-supportive policies for which California is becoming increasingly famous are the innovations that must diffuse.

Market Paradigms for Zero-Energy Homes

Attributes	Conventional Wisdom	New Market Paradigm
Sales Prices	ZEHs cost more to build than other homes and are more expensive on the market.	Quality upscale high-performance homes with market appeal can be built by production builders and sold competitively and profitably, especially where subsidies are in place.
Uptake	In new developments, builders should offer ZEHs optionally, and only a few will be sold.	Builders should offer ZEHs standard; most buyers will buy them. In addition, the pace of sales may well be accelerated over that of conventional homes.
Homebuyers	Only innovators and early adopters will buy ZEHs (a very small percentage of the market).	High-performance homebuyers are ordinary buyers of new production homes in their price ranges; they have no special demographic attributes; their environmentalism and early-adopter characteristics are no different from those of other buyers; some may, in fact, be "unwitting adopters."
Aesthetics	Aesthetics are major barriers to ZEH purchase for most buyers and negatively affect resale value.	Enough buyers are unconcerned about aesthetics that they purchase homes with solar panels, at least in a seller's market, at an accelerated pace. Resale homes with solar panels have higher value than comparison homes.
Home Purchase Decisions	Other than early adopters, buyers of ZEHs would be motivated by economic payback for an incremental financial investment for which they have opted.	ZEH buyers, for whom energy features are only "icing on the cake," may be *unaware* of any potential additional financial investment if the costs of energy systems are built into the homes' sales prices and into their mortgages. In fact, some buyers are "unwitting adopters." However, buyers *are* aware of their substantial benefits from reduced utility bills. In this model, financial incentives (e.g., rebates) go to the builder, although buyers may receive income tax credits or renewable energy credits.
Satisfaction	Homebuyer satisfaction is contingent on perceived payback of energy features.	Owners of high-performance homes with PV systems perceive three major kinds of benefits: (1) altruistic, (2) financial, and (3) personal satisfaction. These owners appear to become increasingly satisfied over time as they receive feedback from their systems, modify their behavior, and observe (and brag about) their utility bills.

Recommendations and Concluding Remarks

> *"We wanted to get the house because the system was already there. We didn't have to decide about it. We're glad it's here. We're lucky to have the PV."*

A recommendation from our findings is that builders should offer ZEHs standard (rather than optional). Highly efficient, and with solar water heating, these homes should have at least 2.4 PV systems and should include digital feedback displays showing consumption and production of electricity. Transaction costs are too high when homes and solar energy systems are sold separately, and homebuyers have difficulty determining the value of solar features as home options when juxtaposed with other options. Our research suggests that from a marketing perspective using this standard-package approach when offering homes with specific energy packages is simply more effective.

In conclusion, this study is replete with findings that support the rapid development of high-performance homes with PV systems, near-ZEHs, and ZEHs. Once offered standard, the costs of these homes to the builder appear to be manageable, the product provides differentiation on the market, and ordinary homebuyers want to buy these homes. Once they live in them, homeowners become even more enthusiastic. Policies that support the deployment of ZEHs, such as net-metering legislation, simplified interconnectivity agreements, building codes and standards, utility rebates, and subsidies for solar water heating and PV systems, will be rewarded by rapid diffusion of an idea whose time has come.

Through its pioneering work in building the nation's first high-performance home development at the highly desirable Scripps Highlands location from 2001 through 2003, SheaHomes has provided a tremendous service to its homebuyers, San Diego, the California and U.S. housing industry, and energy professionals everywhere. The upscale homes it built are very energy efficient with solar water heating systems. Because SheaHomes offered one-third of its homes with solar photovoltaic (PV) systems standard, and left solar PV adoption for the rest up to the homebuyers, a rare opportunity for insight into the behavior of the ZEH market emerged.

Glossary

Term	**Definition**
Analysis of variance (ANOVA)	A one-way ANOVA is a parametric statistical test that performs a comparison of means among more than two groups (see t-test).
Chi square (χ^2)	A nonparametric test of statistical significance for bivariate tabular analysis that relies on differences between observed and expected frequencies.
CNA homeowners	Owners of PV-eligible SheaHomes who were offered solar PV systems but who chose not to purchase them.
Coefficient of variation	Stated in percent, an index ranging in size from 0 to 100 that indicates the variability in a specific set of responses above and beyond the average response value, computed as 100*(Standard deviation/mean). See Appendix F.
Comparison homes	Homes in the comparison community adjacent to San Angelo and Tiempo developments by SheaHomes, which were not offered as energy efficient or with solar energy features
Ineligible/early homes	Homes without PV systems because their owners had no opportunity to purchase PV systems. The first 13 homes were "early" and, though highly energy efficient, had no solar water heating systems.
Main homes	SheaHomes in San Angelo and Tiempo without solar PV systems even though they were PV-eligible.
Mean	The arithmetic average, or sum of all scores divided by the number of scores; a measure of central tendency.
n	The number of cases included in an analysis.
Non-PV owners	Owners of all SheaHomes without solar PV systems.
n.s.	Not significant; that is, results of statistical analyses are not significant at the p=.05 level.
p-score, p-value, or p	The probability that the results are due to chance.
PV homes	SheaHomes in San Angelo and Tiempo with solar PV systems
SEE homes	SheaHomes that are highly energy-efficient and have solar water heating systems

Spearman rank correlation coefficient	A non-parametric (distribution-free) rank statistic proposed by Spearman in 1904 as a measure of the strength of the associations between two variables. The Spearman rank correlation coefficient can be used to give and is a measure of monotone association that is used when the distribution of the data make Pearson's correlation coefficient undesirable or misleading.
Statistically significant; significantly	Analytical results have a p-value $\leq$ .05. This is a technical term-of-art, not a lay term.
Standard deviation (s.d.)	The square root of the variance; at least 75% of the values of any population are within two standard deviations from the mean; a measure of statistical dispersion.
t-test	A parametric statistical test that computes the difference between the means of two groups by dividing the variance in each group by the number of cases in the group and dividing the variances by the standard error of the difference.

Contents

Contents
(Continued)

Contents
(Continued)

Contents
(Continued)

Contents
(Continued)

Contents
(Concluded)

Appendixes
(Volume 2 of This Report)

Page

Note: The letters "I" and "O" are not used in these appendix designations.

Appendixes
(continued)

List of Tables

List of Tables
(Continued)

List of Tables
(Continued)

List of Tables
(Continued)

List of Tables
(Continued)

* Table 64 is intentionally out of order.

List of Tables

(Continued)

List of Tables

(Continued)

List of Tables

(Continued)

List of Tables
(Continued)

List of Tables

(Concluded)

List of Figures

List of Figures
(continued)

List of Figures
(continued)

(This page left intentionally blank.)

Chapter 1
Introduction and Background

Background of the SheaHomes Development

A zero energy home (ZEH) combines state-of-the-art, energy-efficient construction and appliances with commercially available renewable energy systems to reward its owner with significantly reduced energy consumption. A ZEH, like any other home, is connected to the utility grid, but overall it produces as much energy as it consumes. With net metering, the home's electric meter runs backward when the home is producing more power than it is using. With its reduced energy needs and solar energy systems, a ZEH can, over the course of a year, produce as much energy as it uses. ZEHs are thought to have a number of advantages, including improved comfort, protection against electricity price spikes, reduced peak load on the utility grid, and environmental sustainability.

The SheaHomes Scripps Highlands development near San Diego, California, was the first offering of its kind in the United States. The homes provide homebuyers with the potential to reduce their utility bills from 30% to 50% over a conventionally built home. SheaHomes decided to pursue the idea by partnering with ConSol, Inc., to design homes more energy efficient than 5-star ENERGY STAR® Homes (homes that exceeded California's Title 24 standards for energy efficiency), with Sun Systems, Inc. to provide solar water preheating for the homes, and with AstroPower, Inc., to provide solar photovoltaic (PV) systems for on-site electricity to the homes tied to the utility grid. SheaHomes decided to call its homes "high-performance" homes to reflect their solar energy and energy-efficiency features. Although technically the homes are not true ZEHs because they do not provide, in the net, all of their own energy, they are the first examples of high-performance homes offered by a large-production home builder in the United States. Today's near-ZEHs being built in California cut overall utility bills by at least 50%. For the nation, by 2020 ZEHs are expected to be commonly available.

SheaHomes began closing on homes in its San Angelo and Tiempo developments at Scripps Highlands in April 2001 and, 31 months later, in November 2003, all 306 homes had been sold. The homes ranged in price from $400,000 to $840,000. The Scripps Highlands area, situated on a mesa north of San Diego close to Interstate 15, is considered highly desirable. The view from the area includes rolling hills, valleys, and the Pacific Ocean 15 miles to the west. New homebuyers in this area were exempt from certain property taxes that new homebuyers elsewhere in the San Diego area had to pay.

Working with its partners, SheaHomes designed its San Angelo and Tiempo developments in such a way that all of its homes were highly energy efficient, and all but the first 13 homes featured standard solar water preheating that resembled a skylight to bring heated water to the hot water tank in the garage. Natural gas then brought the preheated water to the desired temperature.

Figure 1 is a photograph of a home in the SheaHomes communities with a 1.2-kW DC PV system. Figure 2 exhibits some of the technical features of the high-performance homes; these included the following:

Figure 1: A Home in the SheaHomes Community with a 1.2-kW Solar PV System

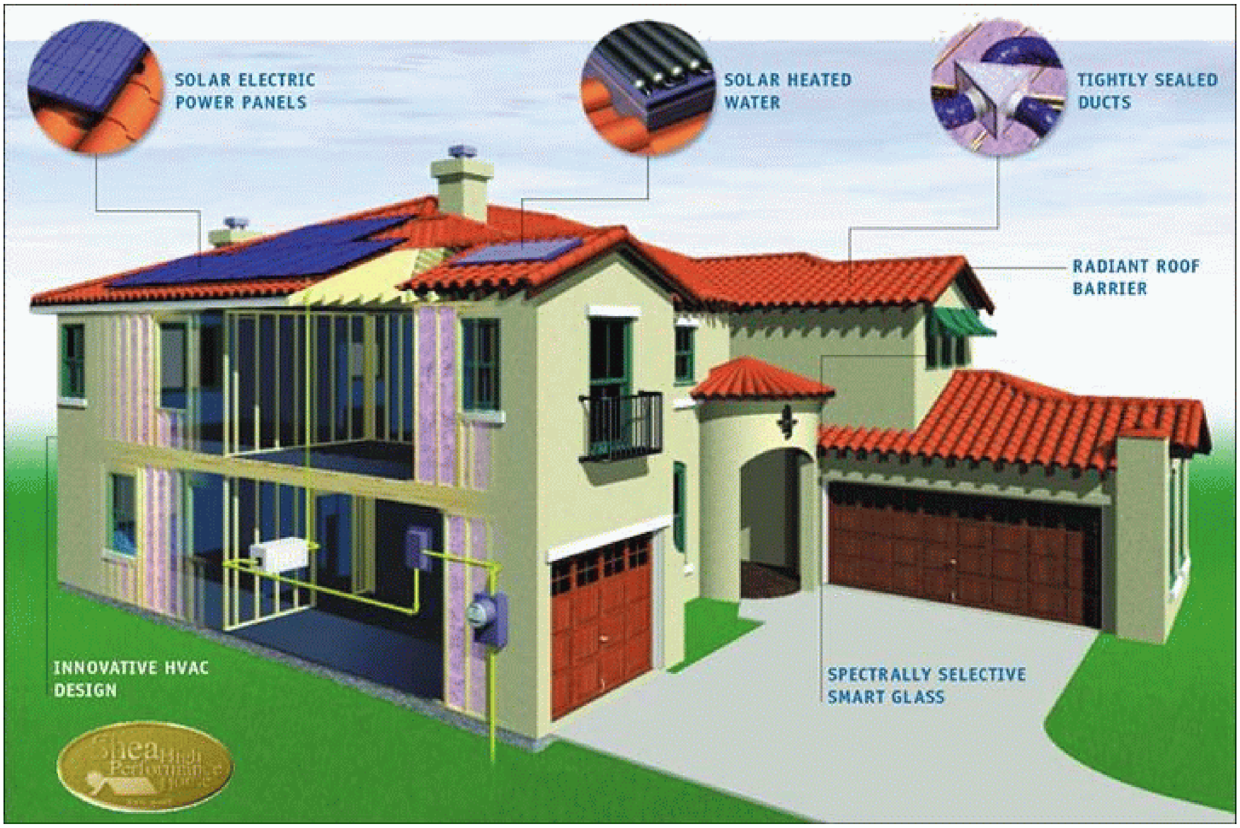


Figure 2: Technical Attributes of a High-Performance Home

• Solar radiant barriers
• Windows with spectrally selective glass
• Tight, sealed ducts and pipes
• Thermal expansion valves
• Inspection and diagnostic blower door tests.

Figure 3 shows the site map for the SheaHomes San Angelo community, and Figure 4 shows the site map for the SheaHomes Tiempo community.

The SheaHomes communities at Scripps Highlands featured five to six bedrooms, three-car garages, granite tile counter tops standard, and spacious layouts. Most homes had two floors, but a single-story option was also available. Four different floor plans were offered. In addition to being built to Title 24 energy codes, the homes were more highly energy efficient, had solar water heating systems standard, and in one-third of the homes, a solar electric system standard, as noted.

A Field Experiment

A member of the SheaHomes staff, Ryan Green, was instrumental in the inception and initiation of the ZEH concept at San Angelo and Tiempo. Green had attended a seminar on ZEHs at the National Renewable Energy Laboratory (NREL) in October 2000, where he learned about the concept and potential of ZEHs. Enthused about his new knowledge, Green returned to San Diego and became a champion of the ZEH concept at SheaHomes as the company planned its San Angelo and Tiempo developments at Scripps Highlands. In four months time, SheaHomes issued its press release announcing its new high-performance homes. The builder took a subdivision already under construction in January 2001 and shifted to the high-performance home concept.

Ryan Green wanted to use San Angelo and Tiempo as a field experiment to discover if the ZEH concept that he had embraced so enthusiastically was marketable. Therefore, instead of offering solar PV systems standard on all the PV-eligible homes, he decided to make standard solar PV systems available on only a portion of them. For homes that came with solar PV systems, Green decided to include 1.2-kW systems standard and offer optional upgrades of 1.2-kW, resulting in 2.4-kW DC systems, for $4,000. For the remaining PV-eligible homes, solar PV systems (either 1.2-kW for $6,000 or 2.4-kW for $10,000) would be offered as optional upgrades.

In essence, buyers of homes with PV systems standard had their PV costs rolled into the prices of the homes and did not have to make separate purchase decisions about solar PV, except to determine if they wanted to upgrade their systems. Buyers of homes for which PV systems were not available (PV-ineligible homes) did not have to choose at all. On the other hand, buyers of PV-eligible homes that came without solar PV had to decide (1) about systems they barely understood or didn't understand at all and (2) whether to pay an extra $6,000 to $10,000 for them.[1] In the context of hundreds of decisions homebuyers had to make at the time of home

[1]By comparison, buyers could upgrade to solid granite countertops in their sizable kitchens for $10,000.

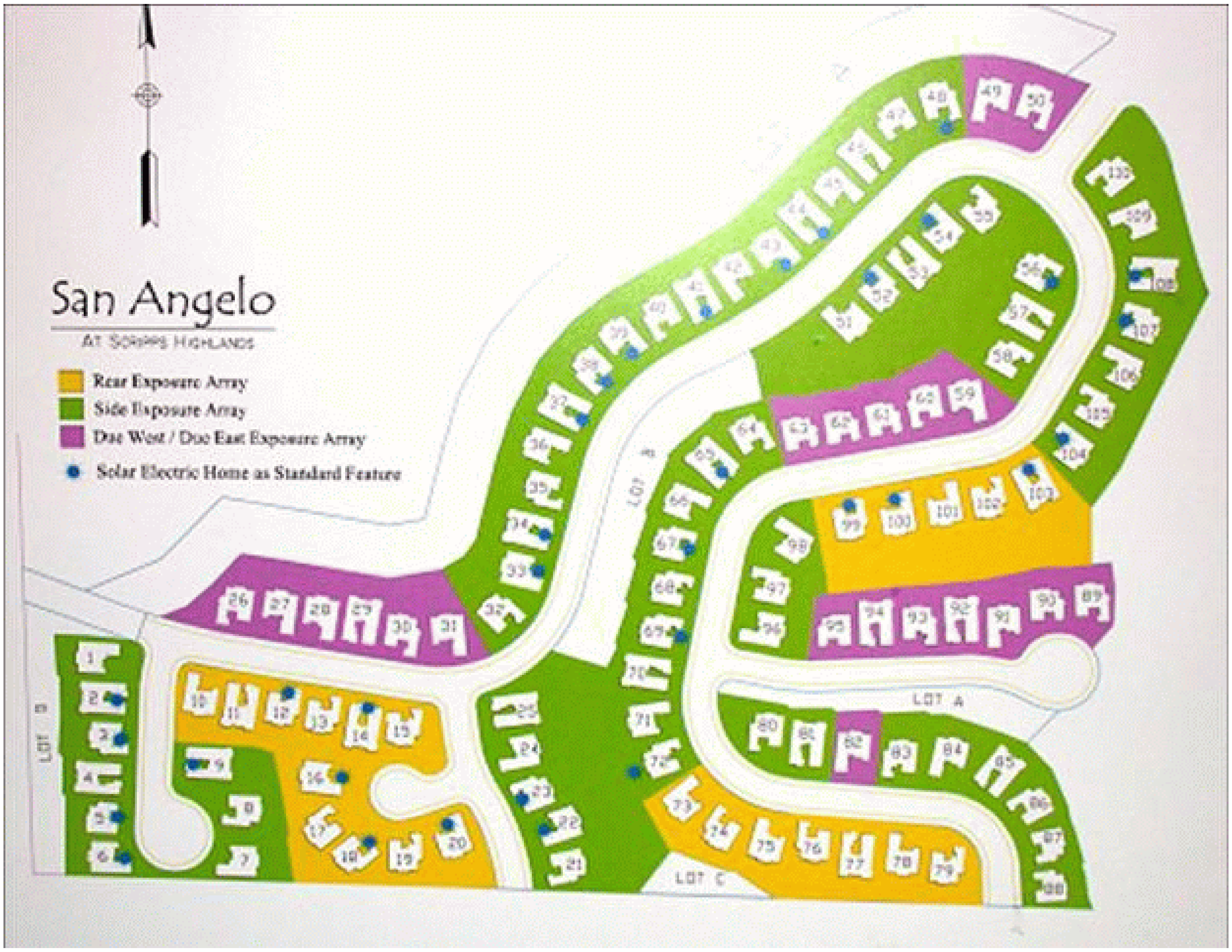


Figure 3: Site Map for the San Angelo Neighborhood

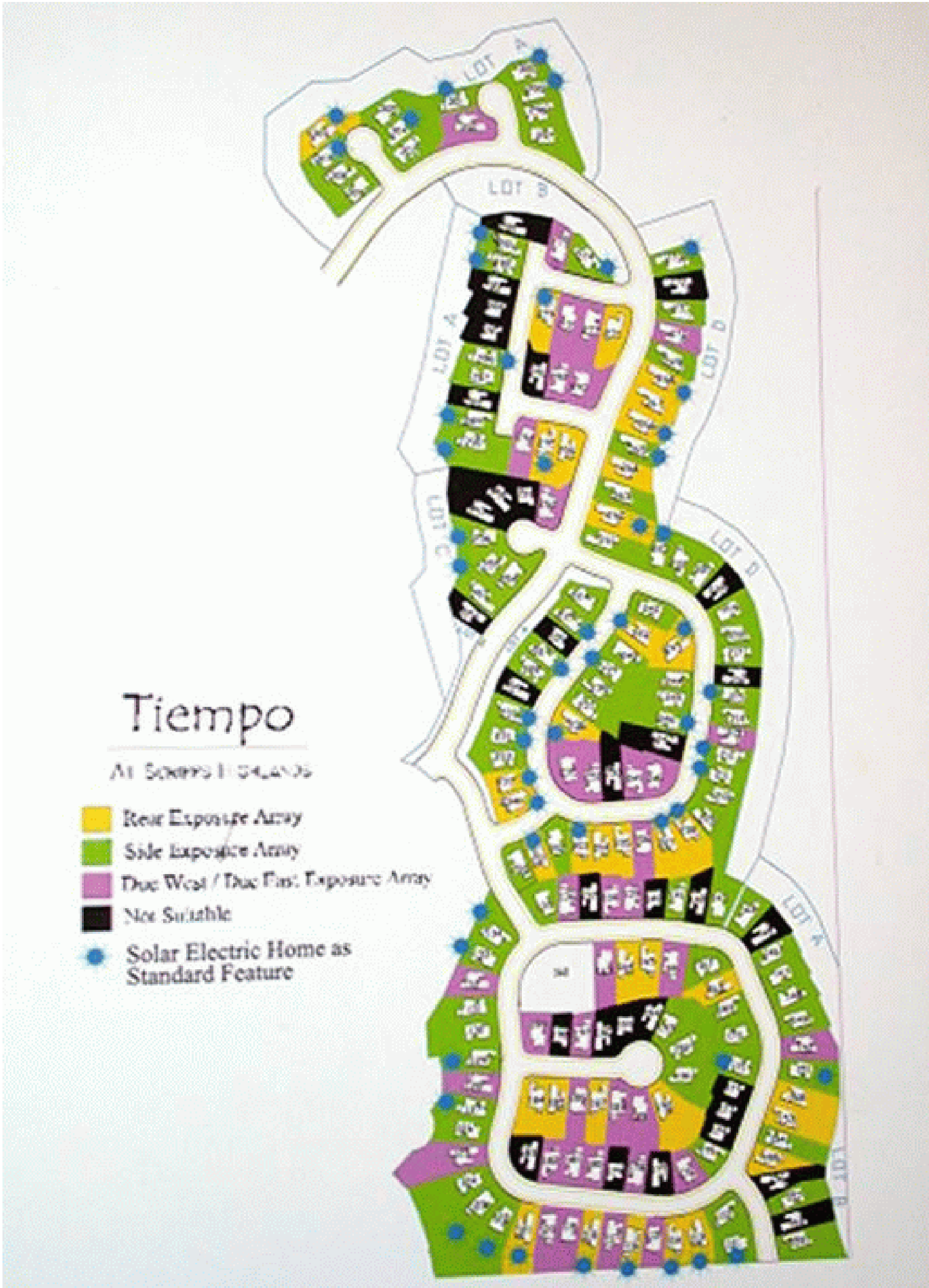


Figure 4: Site Map for the Tiempo Neighborhood

purchase on all manner of options, such as paint colors, flooring, rooms, window sills, and counter tops—all of which are well-understood choices—the purchase of PV was a difficult decision to make.

Green had not understood at the time that the field experiment he had designed stacked the deck in such a way as to make it difficult for buyers to opt for PV systems. He also had not fully comprehended the implications of the fact that sales staff—who are there to sell new homes—would also have to sell optional PV systems one buyer at a time and would receive no financial reward for doing so. Nonetheless, SheaHomes proceeded with its innovative project to build and market high-performance homes in San Diego.

The Comparison Community

The 103 homes in the comparison community used in this study were constructed by a different builder. The first home closed on May 22, 2001, and the last closed on November 10, 2003, a period of 30 months. Although they were built to Title 24 building codes, thus providing more energy efficiency than other state building codes, the comparison homes were offered with no special energy or solar features. Also, like San Angelo and Tiempo homes, the comparison homes had no Mello-Roos tax requirements.[2] Figure 4a shows a home in the comparison community adjacent to the SheaHomes communities.

The comparison homes featured three floor plans with five or six bedrooms, and two- or three-car garages. One of their flyers mentioned their energy-efficient construction, which featured dual glaze windows and increased insulation. Options available included low-e windows, increased insulation to R19 or R30, roller shades, setback thermostats, and high-efficiency furnaces. Their appliances were guaranteed to meet or exceed state and federal energy standards. Bathrooms came with water-saving faucets and showerheads.

Study Background

This quantitative study is based on NREL's earlier qualitative investigation of new homebuyers in two adjoining residential communities—San Angelo and Tiempo—developed by SheaHomes, Inc., in the Scripps Highlands area of San Diego (Farhar, Coburn, and Collins 2002). The earlier qualitative study centered on the homeowners' reasons for purchase and their perceptions of the energy features of their new homes.

---

[2]Mello-Roos taxes are a form of property taxation for new home developments passed by legislation; these taxes provide for the development of new infrastructure such as roads and schools. Certain land holdings, including the Scripps Highlands parcels owned by SheaHomes and the comparison builder, were exempted from Mello-Roos taxes at the time the bill was passed.

Figure 4a. A Comparison Home

The study also includes responses from the original buyers of new homes in a community that is geographically close to the SheaHomes yet offered by a different builder. These are considered the comparison responses. Although the comparison homes were required to be built to California statewide Title 24 building code—which increased their energy efficiency beyond that found in most new construction outside of the state—they were otherwise conventional homes. Further, the comparison homes' energy-efficiency features were not emphasized by the sales staff or by brochures and other advertising.[3] The homes were also located at Scripps Highlands and were priced similarly to the SheaHomes.

The inclusion of a comparison group is important for four reasons. First, it permits comparative analysis of differences between utility performance attributes of high-performance homes and conventional housing in the identical market and climatic regimes. Second, it permits comparison of the knowledge, attitudes, and practices of the buyers of SheaHomes and conventional homes. Third, it controls for the influence that the California electricity crisis of 2000–2001 might have had on home purchase decisions in the San Diego area where the crisis was particularly acute. SheaHomes had already planned to build its San Angelo and Tiempo developments before the electricity crisis occurred; therefore, the offering of high-performance homes subsequent to this crisis happened serendipitously. Fourth, it controls for the upward spiraling of real estate values in the San Diego area.

The research has four specific objectives:

- To provide credible findings that will increase understanding of the customer response to ZEHs, as compared with customer response to similar conventional housing
- To compare the electricity and gas consumption of the SheaHomes with that in the comparison community.
- To compare the utility costs of the two communities.
- To develop a research protocol (the methodology used in this study) that can be adapted and applied by others to assess local-area markets for new ZEHs.

A key question of the research is how attractive high-performance homes, near-ZEHs (cutting at least 50% of utility bills) and ZEHs are to new homebuyers and whether they represent a marketing advantage for builders. Although the homes built by SheaHomes at Scripps Highlands are not, strictly speaking, ZEHs, it was estimated when they were planned that they would save 38% of heating, cooling, and water-heating energy beyond the strict California Title 24 guideline.[4] All of the homes are highly efficient, above the level of a 5-star ENERGY STAR

---

[3]This is known from researcher visits to model homes and conversations with the SheaHomes and comparison homes sales staffs.

[4]The 38% energy savings is Title 24 savings, which include heating, cooling, and water heating. The whole-house energy use includes the additional end-uses of appliances, lighting, and plug loads (such as computers and instant-on television sets). Gas cost savings because of the solar water heating and electricity cost savings because of the solar

Home. They were termed ComfortWise Homes by ConSol, Inc. Most (293) of the 306 homes have solar water preheating systems. In addition, 120 of the homes have solar PV systems interconnected with the utility grid. SheaHomes sales agents referred to these as “solar PV” systems.

The study’s findings are intended to inform state, federal, and utility policy-makers and incentive program designers concerning the production and purchase of ZEHs, as well as to inform builders in California and elsewhere about the market perception of desirability and importance of energy efficiency and solar features in new homes. No quantitative studies currently address consumer response to ZEHs; therefore, this investigation begins to fill a significant gap in this field of knowledge.

Overview of the Report

The report presents comprehensive findings from the study. The report essentially has five sets of chapters.

- The first set of chapters (Chapter 1 to Chapter 3) introduces the study’s purposes and research approaches.

- The second set of chapters (Chapter 4 and Chapter 5) describes the business and financial aspects of the project. This includes the SheaHomes experience as an innovative large-production builder in terms of the company’s competitiveness in offering the high-performance homes, sales of the homes, and the benefits and costs of the project to the company. Chapter 5 describes how these homes have increased in resale value compared with the overall San Diego market. Lessons learned from the SheaHomes experiment are then discussed. Appendix A (New Developments in San Diego) describes a new initiative in San Diego to foster the building of new sustainable homes.

- The third set of chapters (Chapter 6 to Chapter 19) presents the comparative univariate analysis of the homeowner survey findings, describes a data-reduction analysis, describes the development of PV home adopter categories relevant to this study, and presents an analysis of their factor scores. In addition, this section discusses respondent characteristics; reasons for the home purchase decision; knowledge and information about the new homes and their energy features, including the role of the sales staff and how informed buyers are about energy-efficiency and solar features; the decision to purchase a new home with a PV system; willingness to pay for PV systems; homebuyers’ satisfaction with their new homes; experience with PV systems; attitudes toward San Diego Gas & Electric (SDG&E)—the local utility company; attitudes toward solar features in new housing; self-reported resource conservation behaviors; policy preferences relative to high-performance homes; and environmentalism and early adopter characteristics.

---

electric system would be in addition (Hammon 2006).

- The fourth set of chapters (Chapter 20 to Chapter 22) deals with a comparative analysis of the utility cost and consumption data, modeling of the study variables that affect electricity and gas consumption in different categories of homes, and a comparison of perceived and actual utility bills.

- The final set of chapters (Chapter 23 and Chapter 24) discusses the study's conclusions and recommendations for builders, policy-makers, and researchers. An epilogue reviews the recent literature on electricity cost savings in near-ZEHs in California built since the SheaHomes development and compares percentages of electricity cost savings in the current study to the published findings.

This report includes numerous appendixes, including the four survey data collection instruments; details on respondent characteristics; base n's, means, standard deviations, and coefficients of variation of each scaled survey variable; complete factor analysis results; utility cost and consumption charts by each category of home; histograms of the 12-month utility data; and line graphs of electricity and gas consumption by each home in the study with utility data.

Chapter 2
Guiding Ideas

Diffusion-of-innovations theory has guided much research in public acceptance of solar energy and energy efficiency innovations (Rogers and Shoemaker 1971; Rogers 1995). The theory is based on numerous studies of national, regional, and statewide populations that involve a myriad of innovations. Diffusion-of-innovation theory is widely accepted in the energy analysis community.

Chapter Highlights

- The concept of diffusion of innovations guided the research.
- The innovation being studied is new high-performance homes built by a large-production builder and tied to a utility grid.
- Sub-innovations in the study are solar PV systems and solar water-preheating systems.
- Innovation attributes that affect the rate of their adoption are perceived relative advantage, compatibility, complexity, trialability, observability, and perceived risk.
- Builders must adopt and build high-performance homes, near-ZEHs, and ZEHs before homeowners can buy them. Thus, builders, not homebuyers, are the early adopters of ZEHs.
- The attributes of high-performance homes, near-ZEHs, and ZEHs may, on balance, be perceived as disadvantageous by large-production builders.
- The attributes of these homes, when offered standard, may on balance be perceived by buyers of new homes as quite advantageous.

Rates of Adoption

Generally, diffusion theory is applied to populations of potential users or customers of an innovation. These can be individual customers, organizations and companies, or entire communities. Generally, innovations diffuse more quickly if individuals can decide, more slowly if organizations must decide, and even more slowly if communities have to decide (Farhar and Coburn 2000, pp. 4–5). Obviously such decisions increase in complexity when more people are involved and, thus, take longer.

A large body of empirical research has shown that the adoption of an innovation usually follows a normal bell curve. If the cumulative number of adopters is plotted, the result is an S-shaped curve. Figure 5 shows the bell-shaped curve for an adopter distribution and an S-shaped curve for the data on a cumulative basis (Rogers 1995).

The product diffusion process is classically launched by “innovators” and “early adopters.” Gradually, the number of adopters builds until saturation is reached. The length of time this process takes varies by the complexity of the innovation and its perceived relative advantage, among other factors. For example, the Internet began in 1969 as ARPANET with only a handful of users. By 1981, it became BITNET, used by 14 universities. After the University of California at Berkeley joined BITNET in 1982, critical mass was achieved, and the number of nodes doubled every 6 months. As of mid-1993, there were 15 million Internet connections, a number that was doubling annually at that time.

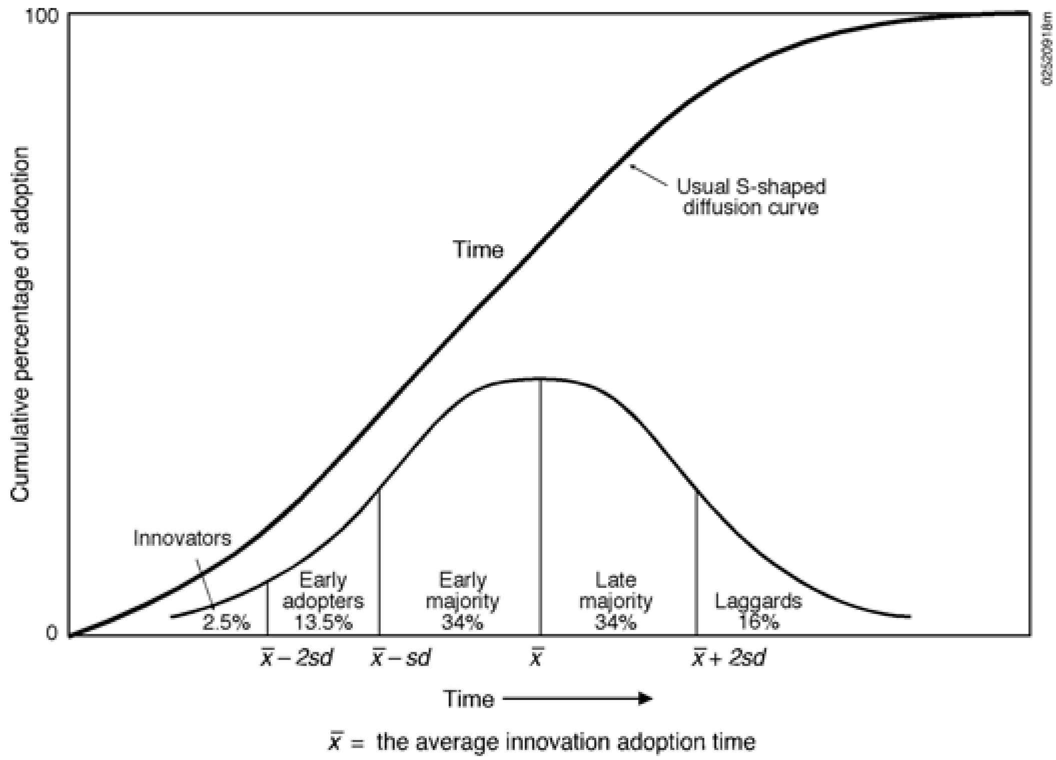


Figure 5. The Bell-Shaped Frequency Curve and the S-Shaped Cumulative Curve for an Adopter Distribution

Source: Adapted from Rogers (1995)

Innovations take varying lengths of time for adoption. Innovations that can be adopted by individuals, such as the birth control pill, can reach "saturation" within 5 years. Those that require organizational and community change, such as kindergarten, can take as long as 50 years to reach saturation. Figure 6 shows rates of adoption of three innovations over time.

Stages in the Adoption of Innovations

To help explain the potential market for any innovative product or practice, we should understand the innovation-adoption decision process. Figure 7 shows the accepted model of the decision process that underpinned the research in this report.

Social conditions and the characteristics of decision makers affect the dynamic innovation-adoption process, which moves through stages.

1. The *knowledge stage* refers to individuals, households, and organizations (called market "actors") who have heard about the innovation. They might be interested because of prior experience, professional interest, business interest, interest in technology, social pressure, and social values. At the end of this stage, an actor may be eager to know more, be disinterested, be opposed, or be somewhere between.

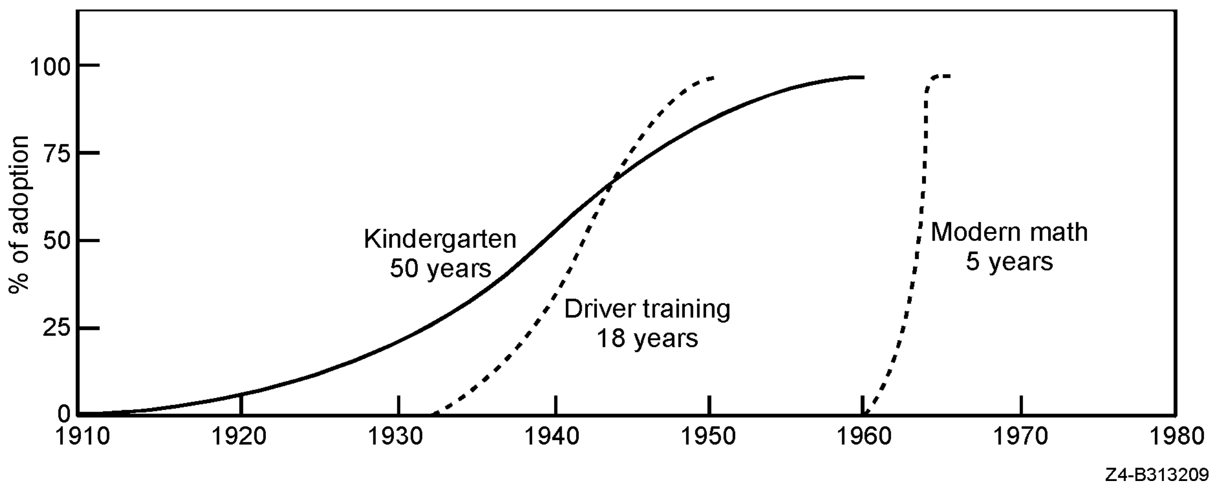


Figure 6. Examples of Diffusion Curves

Source: Adapted from Rogers and Shoemaker (1971)

2. The *persuasion stage* refers to the aware actor's exposure to more information about the innovation, how it works, how much it costs, who is using it and with what results, who is for and who is against it, and how it might fit in the actor's own situation. By the end of this stage, an actor has formed a stronger favorable or unfavorable attitude—a position—toward the innovation, both in terms of its general use and its specific relevance to the actor. Actors may be generally favorable to the new idea but unfavorable to their own involvement with it.

3. If favorable to becoming involved, the actor moves to the next stage of the process: the *decision stage*. During this stage, the actor decides to become involved with the innovation and makes plans to adopt it within the foreseeable future. The actor's "behavioral intention" is to adopt the innovation. If no major obstacles intervene, the actor will probably pass to the next stage.

4. In the *implementation stage*, the actor purchases or otherwise implements the innovation. This stage is not yet considered full adoption because experience with the innovation may cause the actor to reject it. Once the implementation stage has been reached, the last stage inevitably follows.

5. In the *confirmation stage*, the actor lives with the positive and negative consequences of implementation. After a time, the actor decides whether the choice is satisfactory. If problems arise during this stage, the actor tries to resolve them.

The end result of the process is a *continuance* or *discontinuance* of the adoption decision made in the decision stage.

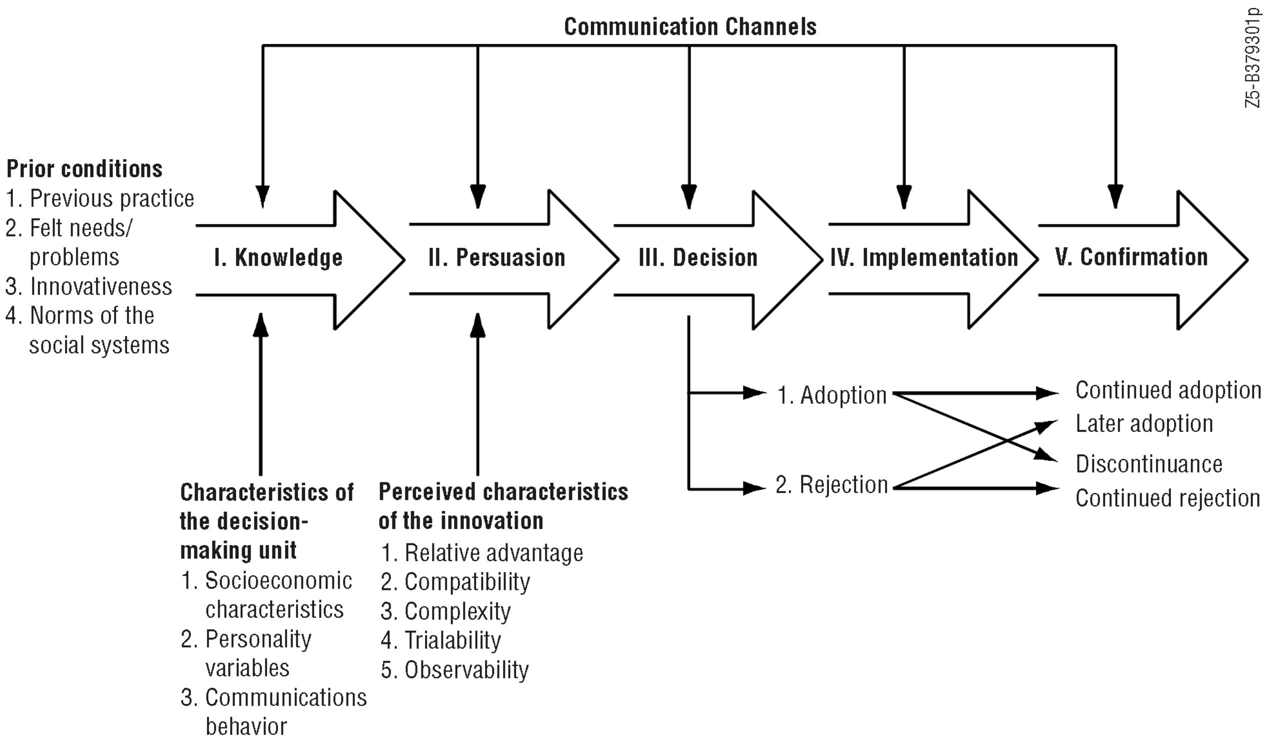


Figure 7. Model of the Innovation-Adoption Decision Process

Source: Diffusion of Innovations, 4th Edition by Everett M. Rogers (p. 163). Copyright © 1995 by Everett M. Rogers. Copyright © 1962, 1971, 1983 by The Free Press. Reproduced with the permission of The Free Press, a division of Simon & Schuster, Inc.

Characteristics of Innovation Adopters

As noted earlier, individuals, organizations, and communities adopt innovations. The characteristics of organizational and individual innovation adopters are as follows.

Organizational Innovation Adopters

Rogers (1995) reviewed numerous studies of the organizational diffusion of innovations. After several decades of studies on individual adoption decisions, the attention of researchers turned toward studies in which the units of analysis were organizations. Rogers states: “Important innovations spread among the firms in an industry in a diffusion process that is similar to the way that an innovation diffuses among individuals in a community or some other system.” (p. 377). An informal network links the companies together.[1]

The role and importance of innovation “champions” within organizations is well documented. Rogers (1995) states: “The involvement of an innovation champion contributes to the success of

---

[1]Later, researchers focused on the innovation process *within* organizations, examining variables related to more- or less-innovative organizations. These related to size and structural characteristics such as centralization, complexity, formalization, interconnectedness, and slack. This body of research findings is less germane to this study than is the rest of diffusion research.

an innovation in an organization" (p. 398). Indeed, without a champion, the new idea would, in fact, die. Champions tend to be more charismatic than others, higher risk takers, and more frequent initiators of action. For successful innovations that are costly, visible, or that represent radical new directions for organizations, champions are generally powerful individuals holding high offices within the organizations.[2]

Individual Innovation Adopters

The population is distributed along a bell curve, with time to adoption as the y axis. The first 2.5% of the population to adopt are "innovators." Next, a group of approximately 13.5% is defined as "early adopters"—those who benefit from the experience of innovators and maximize their advantages in adopting the innovation while minimizing their risks. Early adopters are also frequently "opinion leaders" who catalyze shifts in the innovation's penetration from the select few to the "early majority" (34%). Gradually, the "late majority" (34%) adopts the innovation, for not doing so would leave them in a worse position relative to everyone else. Finally, the "laggards" (16%) get around to adopting. When most people have adopted an innovation, the market is said to be "saturated" (Rogers 1995).

Innovators tend to be venturesome and members of social groups of like-minded individuals. They tend to control substantial resources, have complex technological knowledge, and tolerate uncertainty in outcomes.

Early adopters are well integrated into local communities and tend to be people to whom others look for advice before adopting an innovation.

The *early majority*—the most numerous adopter category—are more deliberate than the first two groups, taking longer to adopt new ideas.

The *late majority* are skeptical of new ideas and cautious about adopting them. They tend not to adopt until others have done so.

Laggards are the last in the social system to adopt an innovation; they are more local than cosmopolitan in orientation and may be less well integrated in social networks. Their resources are relatively limited, and their caution is often financially necessary (Rogers 1995, pp. 263–267).

Some demographic characteristics of earlier adopters compared with later adopters are as follows (Rogers 1995, p. 269):

- Earlier adopters tend to have higher levels of formal education
- They tend to have higher socioeconomic status
- They have a great degree of upward social mobility
- They control larger units (such as companies)
- They are no different in age from others.

---

[2]The innovation champion at the San Diego division of SheaHomes was a development planner; he was not in a top management position.

Importantly, adopter characteristics are relative to the innovation under consideration. For example, some members of a population may be innovators relative to high-technology electronics and laggards relative to sports equipment. Nevertheless, these patterns of adopter characteristics have been found to hold across many kinds of innovations.

In summary, then, among other aspects, diffusion theory classifies individuals in terms of their likelihood to be adopters of innovation. Approximately 16% of the population are innovators and early adopters, who are posited to have higher levels of formal education, higher socioeconomic status, upward social mobility, and broader spans of social control. They are not predicted to be different in age than others. Innovativeness tends to be linked with wealth, yet wealth does not explain innovative behavior.

High-Performance Homes as an Innovation

The high-performance homes built by SheaHomes in San Diego, California, are innovative for several reasons. Although the concepts of whole-building energy efficiency have been implemented by builders in various parts of the United States (particularly under the ENERGY STAR homes and Building America programs), the resulting homes did not necessarily contain solar water heating or solar electric systems. On the other hand, many custom homes are energy efficient and contain either solar water heating or solar electric systems, or both, but they have generally been built one-at-a-time, and most are not tied to an electricity grid.

The SheaHomes high-performance home project is innovative because it offers homes that approach the ZEH concept *built by a large-production builder* and *tied to a utility grid*. Thus, the innovation of focus in this study is the high-performance home as a precursor of near-ZEHs and ZEHs built by large-production builders. These homes contain four key elements of ZEHS: (1) they are highly energy efficient; (2) their water is preheated by the sun; (3) they produce electricity; and (4) they can supply electricity to, store electricity on, and take electricity from a utility grid. The significance of such an offering by a large-production builder is that it potentially makes the offer of these types of homes *routine* rather than unique specialty commodities offered only by custom builders.[3] The successful routinization of ZEHs will ensure higher quality homes that are widely available, less expensive than conventional homes to operate (all other things being equal), and environmentally friendlier than conventional homes.

Although much of the focus of this study is on the performance and market acceptance of high-performance homes compared with conventional homes, a subinnovation is solar PV systems tied to the utility grid with net-metered electricity. Consequently, some of the study focuses on the response to the solar PV subinnovation. Certain homebuyers may have desired to adopt the solar PV system more than the high-performance home as a whole. However, separating the adoption of solar PV systems from the adoption of high-performance homes is difficult.[4]

---

[3] *Routinization* occurs when the innovations are incorporated into regular activities of organizations, and they are no longer thought of as new ideas (Rogers 1995, p. 399).

[4] A second sub-innovation is the presence of solar water preheating systems in the high-performance homes. The presence of these systems in and of themselves did not seem to drive home purchase decisions. Nevertheless, they were part of the package of energy features that were important to some homebuyers.

Innovation Attributes

According to an extensive review of the empirical literature on diffusion of innovations (Rogers 1995), from 49% to 87% of the variance in rate of adoption can be explained by five attributes: (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability.

Relative Advantage

The perceived relative advantage of an innovation is positively related to its rate of adoption. Relative advantage is "the degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers 1995, p. 212). Often, the relative advantage of an innovation is expressed in terms of economic and prestige advantages. When prices decrease rapidly, or when a great deal of value is added, or both, a rapid rate of adoption is encouraged.

Compatibility

The perceived compatibility of an innovation is positively related to its rate of adoption. Compatibility is "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (Rogers 1995, p. 224). Innovations may be compatible or incompatible with sociocultural values and beliefs, with other ideas, and with the adopter's needs. If PV water pumping in a village disrupts the patterns of sociability among women, even though it reduces their manual labor, it could be rejected.

Complexity

The perceived complexity of an innovation is negatively related to its rate of adoption. Complexity is "the degree to which an innovation is perceived as relatively difficult to understand and use" (Rogers 1995, p. 242). The first adopters of home computers loved technological gadgets; many were engineers with extensive mainframe experience. But most people had difficulty using personal computers and had to join computer clubs, take courses, obtain help from friends, or find other means to cope with the difficulties their computers posed. This slowed the rate of adoption. Eventually, personal computers became more user friendly and, by 1994, about 30% of households owned one.

Trialability

The more the innovation can be tried out, the faster its rate of adoption. Trialability is "the degree to which an innovation may be experimented with on a limited basis" (Rogers 1995, p. 243). If new ideas can be tried out without too much risk, uncertainty can be dispelled. The perceived trialability of an innovation is positively related to its rate of adoption. Early adopters are more concerned with trialability than are later ones.

Observability

The perceived observability of an innovation is positively related to its rate of adoption. Observability is "the degree to which the results of an innovation are visible to others" (Rogers 1995, p. 244). The effects of some ideas are readily observable; the effects of others are difficult to discern. The observability may include how visible adoption is to others, thereby conferring status on the adopter, or showing that the innovation indeed "works." Observability may also include the ability to actually see the effects of the innovation.

Perceived Risk

In addition to Rogers' five innovation attributes, the perceived risk of adopting innovations has been found to be negatively associated with favorability to an innovation (Farhar et al. 1978; Farhar, Pilgrim, and Unseld 1982).

Other Factors

Assuming that innovations may be perceived as having characteristics desirable for adoption, other factors come into play that can expedite or impede decisions to adopt them. These include the following:

- The innovation has to be available through regular organizational channels.
- The adopters have to understand enough about the innovation to make a decision.
- The adoption decision has to have salience—it has to be important enough to be at or near the top of an individual's or a household's action list.
- The adopters need a support system, preferably the organization from which the innovation was purchased, and access to friends or others who understand the innovation.
- The adopters need the financial wherewithal to purchase the innovation, or financing arrangements to make purchase possible.

Innovation Attributes and High-Performance Homes

As discussed above, five attributes of innovations are thought to influence their rate of adoption. We can examine each in turn for their potential relevance in the acceptance of high-performance homes, near-ZEHs, and ZEHs. In these cases, there are two levels of adopters: (1) builders must adopt these kinds of homes before (2) homebuyers have the opportunity to do so.

The diffusion of innovations in the form of "best building practice" applies to the voluntary spread of innovative practices through networks of builder companies. Innovative builders, such as the San Diego Division of SheaHomes, set the initial example—in this case, the Scripps Highlands project. Other builders hear about the innovation and, depending on the SheaHomes experience, a few might be interested in emulating it. If diffusion theory is correct, however, most will not be interested. A very small percentage of large-production builders—$\leq$2.5%—will be interested in building innovative high-performance homes or near-ZEHs. The builder decisions are likely to be based on the perceived "attributes of innovations" discussed in the following sections.

Table 1 summarizes the innovation attributes of ZEHs[5] as potentially perceived by builders and by homebuyers. The information in Table 1 highlights the different interests of builders and homebuyers in deciding about ZEHs in the context of innovation attributes. These are perceptions, not necessarily facts, and they are important because what people believe to be real is real in its consequences.

As described in Table 1, from the builder standpoint, the potentially perceived disadvantages of adopting ZEHs appear to significantly outweigh the potentially perceived advantages. Just the opposite is the case for homebuyers, for whom the potential advantages are numerous and substantial, compared with the disadvantages. If this characterization of differential perceptions is accurate (and all other things being equal), diffusion theory would predict that, on the basis of innovation attributes, builders will resist the adoption of ZEHs, whereas homebuyers will rapidly adopt them when they are made available. Of course, for new ZEHs to become widely available, builders will have to adopt the ZEH concept.

Prior Research on PV Adoption

The relationship between diffusion theory and interest in adoption of grid-tied photovoltaic (GPV) systems on the part of Colorado homeowners was described in Farhar and Coburn (2000). A majority (68%) of respondents in that study favored GPV being made more widely available to Colorado residents. However, homeowners knew little about GPV, as would be expected; there was more favorability than familiarity. Perceived benefits of GPV made it seem advantageous compared with conventional energy sources, such as coal. The highest scoring benefits included long-term environmental benefits (including conserving natural resources), homeowner financial benefits, and the prestige and pioneering advantages associated with adopting GPV. The potential barriers to GPV included initial system cost and maintenance, technical performance and reliability of PV systems and providers, and situational aspects, such as codes or covenants that prohibit GPV adoption, what friends and neighbors might say, or the amount of space needed at one's home. Clearly, the perception of a majority of respondents was that the advantages outweighed the disadvantages, even though the example prices mentioned in the study ranged as high as $28,000. Interestingly, the demographic characteristics ordinarily associated with early adoption of innovations (such as higher socioeconomic status) did not differentiate the homeowners most likely to adopt GPV in the near term.

Hypotheses and Research Questions

These findings refer to the *retrofit market* for PV; that is, the potential interest of Colorado homeowners in retrofitting their homes with solar electric systems tied to the utility grid. The current study focuses on the *new home market*. Also, unlike the Colorado respondents, all of the San Diego respondents have the demographic characteristics associated with early adopters. Thus, we anticipated that distinguishing early adopters from later adopters within the San Diego study would be difficult. We hypothesized that, in the unlikely case that such differences could be

---

[5]ZEH is the generic term used here to refer to high-performance homes and near-ZEHs, as well as true ZEHs.

measured, early adopter characteristics would more likely be found among the SheaHomes buyers than buyers of conventional housing.

Environmental concern has often been linked to interest in renewable energy (e.g., Buhrmann and Farhar 1998; Farhar 1993; Farhar and Coburn 2000). This study hypothesized that environmental concern would be linked with purchase of PV systems and possibly of ZEHs.

Advisory Group Guidance

The study's advisory group (see Acknowledgments section for the list of members) recommended that the research answer the following questions:

- How much did buyers know about the energy features of the homes? How well do the consumers understand them? What messages are the sales staff communicating about the energy features?
- What is the role of the home builder "image" and reputation in the sales of the ZEHs?
- Do ZEHs have more market value than conventional homes and resale homes? Did energy features bring out people who were originally shopping for resale homes as well as new homes?
- What is the additional value to the customer of these systems? What price could be added to the price of a ZEH over a conventional home?
- To what extent are energy performance features important in drawing people to look at the homes? To buy the homes?
- Should solar features be standard or optional? Are optional upgrades a good idea?
- How are ZEH purchasers different from purchasers of conventional homes in motivation, attitudes, and demographics?
- Among energy features, which are the most important to homebuyers—efficiency features, solar water heating systems, or solar electric systems? Which feature has the most appeal? Or does an integrated ZEH house with all features have the most draw?
- Is aesthetics a barrier? Is it positive, negative, or neutral? How important were they in the purchase decision? Does it matter if solar equipment is on the front or back of the house?
- How important is the feedback device (showing the amount of electricity the house is using and the amount the PV system is producing)?
- How satisfied are customers with their home purchases?

The advisory committee believed that answers to these questions would be valuable to builders, policy-makers, utility companies, trade and professional organizations, and the energy-efficiency and solar-energy communities, as well as to marketers, researchers and energy analysts, and homebuyers.

The questions were completely focused on the buyers of SheaHomes' high-performance homes. The advisory committee asked no questions about the SheaHomes experience in pursuing the building of high-performance homes or about whether SheaHomes perceived the experience as, on balance, positive or negative. Thus, the major focus of this investigation was on individual homebuyers; however, qualitative information was also inevitably gathered on the SheaHomes experience as an inherent part of the study.

A Limited Continuance Decision

Although this investigation did not set out to study the organizational characteristics that led to SheaHomes' adopting the idea of building high-performance homes, qualitative information about the builder's experience was inevitably gathered and is reported in Chapter 4. Even before the Scripps Highlands project was complete, the San Diego Division of SheaHomes had decided to pursue its adoption of high-performance homes only in the Ladera Ranch and Bella Rosa Developments. The management at that time stated that they wanted to study market acceptance further before committing to building more large-scale new home developments of high-performance homes or near-ZEHs.

Summary

The innovation being studied is new high-performance homes built by a large-production builder and tied to a utility grid. Sub-innovations are solar PV systems and solar water-preheating systems. Innovation attributes that affect the rate of their adoption are perceived relative advantage, compatibility, complexity, trialability, and observability. Builders must adopt and build high-performance homes, near-ZEHs, and ZEHs before homeowners can do so. The attributes of high-performance homes, near-ZEHs, and ZEHs may, on balance, be perceived as disadvantageous by large-production builders. The attributes of these homes, when offered standard, may on balance be perceived as quite advantageous by buyers of new homes. SheaHomes-San Diego was awaiting the results of this study.

Table 1. Innovation Attributes of ZEHs Related to Potential Builders and New Homebuyer Perceptions*

Innovation Attribute	Potential Builder Perceptions	Potential New Homebuyer Perceptions
Relative advantage is "the degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers 1995, p. 212), usually in economic and prestige advantages. The perceived relative advantage of an innovation is positively related to its rate of adoption. In the decision process, advantages are weighed against disadvantages, and against doing nothing.	***Advantages*** • Receiving rebates for PV systems (in California, SheaHomes received 50% rebates for PV systems) • Free advertising for ZEHs through media coverage of ZEH developments (in the case of SheaHomes this amounted to more than $1 million worth in less than a year) • Free market research funded by utility companies or federal or state governments • Free technical assistance from national laboratories and state and local programs • Testimonials from satisfied customers • Favorable treatment on the part of local and state officials (for example, the speed with which building permits are granted) • Sizable profits • Enhanced builder reputations for producing quality homes • Reduced number of callbacks • Faster rate of ZEH home sales.	***Advantages*** • Up-front costs amortized in mortgages; improved monthly cash flow • Significant savings on electricity bills • Modest savings on gas bills • Selling excess electricity back to the utility grid and using the grid as storage for their electricity • Greater value at resale than conventional homes • "Bragging rights" and increased prestige for owning ZEHs • Helping to protect the local environment, now and for future generations • Supporting the local economy • Learning about how PV technology works • Learning about "energy hogs" in homes and adapting energy-related behavior to maximize the benefits of ZEH features.

*These attributes are *potential* perceptions, not necessarily established social facts.

Table 1. Innovation Attributes of ZEHs Related to Potential Builders and New Homebuyer Perceptions,* continued

Innovation Attribute	Potential Builder Perceptions	Potential New Homebuyer Perceptions
Relative advantage, continued	***Disadvantages*** • Reduces competitive edge • Costs of changing building practices; climbing the learning curve • Requires finding reliable suppliers of unfamiliar equipment • Uncertainty about demand/market • Complicates relationship with the utility company • Upsets collegial relationships with other builders • Results in a greater number of transactions with state and local government officials • Requires extensive education of homebuyers • Involves a great number of call backs • Slows down the rate of sales • Results in an influx of curious visitors with no intentions of buying, but who take staff time.	***Disadvantages*** • For some, up-front costs • For some, aesthetics (*Note:* Aesthetics appears to be a nonissue for many) • Complex interconnectivity agreement with the utility company.
Compatibility is "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (Rogers, p. 224). The perceived compatibility of an innovation is positively related to its rate of adoption.	Builders may perceive ZEHs as incompatible with standard building practices and accepted industry norms. They may view policies to foster ZEHs as unacceptable attempts to control builders, which have traditionally been unacceptable to them.	Because California has experienced severe electricity shortages that have caused social disruption and hardship, spiking electricity costs, widespread antinuclear sentiment, and strong concern for the environment, California homeowners may view ZEHs as compatible with cultural norms. Subcultural conditions will probably vary by state and locality across the country.

*These attributes are *potential* perceptions, not necessarily established social facts.

Table 1. Innovation Attributes of ZEHs Related to Potential Builders and New Homebuyer Perceptions,* continued

Innovation Attribute	Potential Builder Perceptions	Potential New Homebuyer Perceptions
Complexity is "the degree to which an innovation is perceived as relatively difficult to understand and use" (Rogers 1995, p. 242). Perceived complexity is negatively related to an innovation's rate of adoption.	The components that make up a ZEH (energy-efficiency measures, solar water heating, and PV equipment) may be seen as difficult and time-consuming for a builder to schedule into a large housing development. The purchase of these components requires that new business relationships be established with previously unknown suppliers.	Because ZEHs "just sit there and produce electricity" (in the words of a PV householder) and save energy and heat water using the sun without much intervention on the homeowner's part, they are simple for homeowners to "use." Complexity is not a barrier to homeowner use. On the other hand, a decision as to whether to purchase a PV system is extremely complex; this is definitely an impediment in situations in which PV is offered as an option.
Trialability is "the degree to which an innovation may be experimented with on a limited basis" (Rogers 1995, p. 243). If new ideas can be tried out, uncertainty about them can be overcome.	Builders may know very little about advances in efficiency, water heating, and solar electricity. They may be unfamiliar with the "whole building" concepts that underlie ZEHs. Because few ZEHs have been built, few builders have been able to "try them out." Building a custom ZEH as an experiment is an expensive proposition.	Purchasing a ZEH is an either/or proposition for homebuyers. They can try out ZEHs only by living in them. For technologically inexperienced homebuyers, trialability is probably a barrier to purchase of ZEHs.
Observability is "the degree to which the results of an innovation are visible to others" (Rogers 1995, p. 244). The perceived observability of an innovation is positively related to its adoption.	Builders may want to know if the markets and profits are there for ZEHs. They may want to know if they will get an edge on their competitors if they build them. This is difficult because the information on profits is proprietary. Observability can be improved by research and by more builders building ZEHs.	If ZEH homeowners brag about their utility bills, they will gain the attention of neighbors and the media. If researchers can document lower utility bills, the observability of ZEHs will be greater.

*These attributes are *potential* perceptions, not necessarily established social facts.

Table 1. Innovation Attributes of ZEHs Related to Potential Builders and New Homebuyer Perceptions,* concluded

Innovation Attribute	Potential Builder Perceptions	Potential New Homebuyer Perceptions
Concern about risk is the perceived financial or other harm that the adopter of an innovation could incur. Perceived risk is negatively associated with adoption.	Builders may be concerned that building an entire ZEH development could be quite expensive and that the homes might not sell. They could also be concerned about unanticipated costs or scheduling delays that could detract from the bottom line. Concern about financial risk could be a barrier for builders.	Homebuyers will want a warranty on their solar water heating and solar PV systems to protect them from unexpected maintenance and repair costs.

*These attributes are *potential* perceptions, not necessarily established social facts.

Chapter 3
Study Methods and Data Resources

Overview

This study is an empirical and statistical investigation of the differences between buyers of new high-performance homes and buyers of new conventional homes. It includes contextual, qualitative, and quantitative data, but it does not include engineering data or engineering analyses. The study encompasses two distinct phases of work—a qualitative phase and a quantitative phase—during which different types and sources of data were investigated.

The homes covered by the study were constructed and offered for sale by two different builders. The principal target population consisted of 306 homebuyers in SheaHomes' San Angelo and Tiempo developments at Scripps Highland in northern San Diego County. All homes in these developments are highly energy efficient, and most of them are high-performance homes with solar features. The comparison group was 103 buyers of conventional homes constructed by a different builder in an adjacent community.

Chapter Highlights

- This study comprises an empirical and statistical investigation of the differences between buyers of new high-performance and comparison homes.
- The study encompasses two phases of work—qualitative and quantitative phases—during which different types of data were collected.
- The study includes contextual data, household and homeowner data, and utility data.
- The new homebuyer surveys had a 63% overall response rate (65% from SheaHomes respondents and 56% from comparison respondents).
- A broad-based approach to statistical analysis was taken, including descriptive statistics, factor analyses, t-tests, analyses of variance, and regression analysis.

The comparison community was chosen because of its proximity to the San Angelo and Tiempo developments and the similarity of price range and housing type. The weather and climate of the two communities is identical. The homes in the comparison community do not have any special energy-efficiency and solar features, unlike the homes in San Angelo and Tiempo.

The first, or qualitative, phase of the study included meetings with the project advisory committee, as well as numerous interviews of staff members and representatives of SheaHomes, organizations and companies partnering with SheaHomes, and the builder of the comparison homes. Other interested parties within the ZEH community were also interviewed. Field researchers visited homes in the SheaHomes community that were already occupied. They also spent time at the SheaHomes sales centers to observe the manner in which the sales staff interacted with the potential homebuyers, especially relative to the homes' energy-efficiency and solar features. Researchers visited the comparison home sales office and show homes, posing as interested home shoppers to learn whether the sales staff said anything about energy efficiency in the comparison homes (they didn't). Although the SheaHomes sales staff was aware of the researchers' role, the comparison home staff was not. In total, field researchers visited five developments before they selected one as the comparison community to San Angelo and Tiempo.

These meetings, observations, and interviews facilitated the collection of contextual data and information necessary to appropriately focus future data-collection efforts. Also during this phase, information about "lost lookers"[1] was obtained through a telephone survey of visitors to the SheaHomes' Scripps Highlands Sales Center. Results of these interviews are reported in Collins (2003). Finally, a significant component of the first phase of the study consisted of qualitative interviews of early homebuyers in SheaHomes' Scripps Highlands development. Results of these interviews are reported in Farhar, Coburn, and Collins (2002). Along with the contextual data, the findings from the interviews of early homebuyers served as a foundation for the study's second phase.

The second, or quantitative, phase consisted of a comprehensive mail survey, along with a detailed statistical analysis of the survey responses. This survey encompassed all homebuyers in SheaHomes' San Angelo and Tiempo developments, as well as all homebuyers in a nearby development of similar but conventional homes. As suggested above, the questionnaires used in the survey were based, in part, on the results of the qualitative interviews of early homebuyers in the SheaHomes communities. Preliminary findings from the quantitative phase of the study are reported in Coburn, Farhar, and Murphy (2004).

The second phase also included collection and analysis of utility billing and consumption data among respondents in SheaHomes and comparison homes who gave permission for San Diego Gas and Electric Company to share their utility records with NREL.

Types and Sources of Data

Three categories of data were collected and analyzed during this study: contextual data, household data (including homeowner survey data), and utility data. Table 2 further defines these categories, identifies the sources of the information, and describes the data-collection techniques employed.

Contextual Data

Many of the conclusions about the builder experience in this report are based on contextual data. In addition, these data represent important background information that is relevant to the analysis of homeowners' responses to survey questions. During the course of the study, interviews were conducted between 2002 and 2004 with Ryan Green and Dale Holbrook, SheaHomes, San Diego, and with various other members of the SheaHomes staff at the time, including Teri Shusterman, Diane Rivera, Pam Beaird, and Pattie Walker. Representatives of companies partnering with SheaHomes were also interviewed, including Kirk Stokes of Altair Energy, a Colorado PV systems and services provider; Scott Anders, then of the San Diego Regional Energy Center; Rob

[1]A "lost looker" is someone who visited the sales center but did not purchase a home.

Hammon of ConSol, Inc., in Stockton, California; Marc Roper, then of AstroPower, Inc., in California; and Tom Bohner, Sun Systems, Inc., in Phoenix, Arizona.

Table 2. Types and Sources of Study Data

Category of Data	Phase 1 - Qualitative Data	Phase 2 - Quantitative Data
Contextual data	• Interviews with builder staff • Observation at sales centers • Studies sponsored by SheaHomes • Other artifacts (e.g., news clippings, magazine articles, and TV news clips)	• Home sales and characteristics (builder data) • Public records on sales
Household and homeowner data	• Focused interviewing of homebuyers • Focused interviewing of lookers for new homes	Survey of homeowners' attitudes, opinions, and practices (both SheaHomes and comparison home owners)
Utility data	Interviews with utility staff about their experience with grid-tied PV on residences, dates of meter reading of study households, utility rates, and other relevant points	• Actual therm usage by households in SheaHomes and comparison communities • Actual kWh usage by households in SheaHomes and comparison communities • Actual utility cost/billing data for all households who gave permission

SheaHomes also provided other documentation, including reports from its contractors on market response and media coverage, videotapes of television broadcasts, newspaper clippings, sales materials, site maps, and related materials.

Other contextual data were obtained from the public records on home sales and from SheaHomes records on the energy features of homes in the Scripps Highlands development.

Public Records on Home Sales

Data on the closing dates, sales price, and square footage of the new homes purchased were obtained from the San Diego Assessor's Office.

SheaHomes Records on Energy Features of Homes

SheaHomes provided data from its records on the energy features included at each new address in the San Angelo and Tiempo neighborhoods.

Household and Homeowner Data

Data on households and homeowners were obtained through focused interviewing of selected homebuyers, focused interviewing of selected individuals looking for new homes, and the formal mail survey of all homebuyers in the study universe. The mail survey was the most comprehensive source of household and homeowner data.

Universe of Study for the Homeowner Survey

As previously suggested, the universe for the study consisted of two different groups of homes and households: all households in the 306-home SheaHomes San Angelo and Tiempo developments at Scripps Highlands in San Diego and all 103 households in the adjacent comparison community of conventional homes constructed by the different builder.

Survey Operations

On January 22, 2004, questionnaires were mailed to 271 homebuyers in the 306-home Scripps Highland community (high-performance homes) and 98 homebuyers[2] in an adjacent 103-home community (conventional homes) who had lived in their homes for at least 6 months. Data collection continued for 12 weeks. The 6-month restriction on time of residence was imposed to ensure that all respondents had experienced living in their homes for at least two seasons of the year. On May 8, 2004, questionnaires were mailed to the remaining 35 SheaHomes buyers who had purchased their homes late in 2003 and who would have lived in them for at least 6 months by that time. This phase of the data concluded on July 15, 2004.

Over the time period in which the survey was conducted, the following five mailings were sent in stages in an effort to maximize the survey response rate: an initial postcard alerting potential respondents that they were part of a study, a questionnaire package containing a crisp new $10 bill[3] and a utility release form, a reminder postcard, a reminder letter, and a final package containing a second copy of the questionnaire.

Questionnaire Development and Construction

Based on results from the qualitative phase of the study, four different respondent groups were identified and separate questionnaires were developed for each group. The four questionnaires

---

[2]Only 98 of the 103 comparison community households could be identified.

[3]Funding to cover this expense was provided by the California Building Industries Institute to the Colorado Energy Science Center, which oversaw the preparation of the questionnaire mailings and delivered the sealed mailings to the NREL Mail Room.

contained a number of similar, and even identical, items; but they also contained some items unique to the respective respondent groups for which they were designed. Although the administration of four separate questionnaires required more organization and administrative control, it actually helped streamline data collection while providing comparable information from the different respondent groups.

The four homeowner respondent groups are defined as follows:

- ***SheaHomes homeowners with PV systems.*** The questionnaire for this group was termed the "PV" questionnaire; "PV" is also the moniker assigned to the associated homes, homeowners, and survey respondents.

- ***SheaHomes owners of homes without PV systems even though they were PV-eligible***. The questionnaire for this group was termed the "main" questionnaire; "main" is also the moniker assigned to the associated homes, homeowners, and survey respondents.

- ***SheaHomes owners of homes without PV systems because they had no opportunity to purchase them***. The questionnaire for this group was termed the "ineligible/early" questionnaire; "ineligible/early" is also the moniker assigned to the associated homes, homeowners, and survey respondents.

  The first 13 homes constructed by SheaHomes at Scripps Highlands (called "early" homes) were highly energy-efficient homes. However, unlike all other SheaHomes, these had no solar water preheating or solar PV systems because the builder had not yet integrated these features into the homes. AstroPower, Inc., designated another 33 sites as unsuitable for PV systems because of orientation of the home or because the roof line of the home was unsuitable. These homes, which were marked black on the site map are termed "ineligible" because they were ineligible for PV systems. These 46 (33+13) homes did not have PV systems and are collectively termed "ineligible/early."

- ***Comparison homeowners***. The questionnaire for this group was termed the "comparison" questionnaire; "comparison" is also the moniker assigned to the associated homes, homeowners, and survey respondents. Homes in the comparison community, which is adjacent to Scripps Highlands, were not advertised as energy efficient nor as offering any solar energy features.

As suggested above, the four questionnaires included general questions permitting comparisons across each of the groups, as well as items specific to each group. For example, only owners of homes with PV systems were asked questions about their experience with PV systems.

Response Rate

A total of 271 questionnaires were successfully delivered to SheaHomes homebuyers in the two questionnaire mailings, and 96 were successfully delivered to comparison community homebuyers.[4] A total of 231 completed usable questionnaires were received at NREL. Of these, 177 were received from homeowners in the SheaHomes communities (72 PV, 85 main, 20 ineligible/early), and 54 were received from homeowners in the comparison community. The overall survey response rate was 63% (65% from the SheaHomes communities and 56% from the comparison community).

The respondent pool is deemed to be representative of the entire study universe. Table 3 shows the numbers and associated percentages of the four categories of homeowners in the universe and in the respondent pool. A $\chi 2$ test suggests there is no significant difference in the corresponding percentage distributions ($\chi 2=1.60$; $p=.66$).

Table 3. Numbers and Percentages of the Four Categories of Homeowners among All Homeowners and among Survey Respondents

Homeowner Category	All Homeowners		Survey Respondents	
	n	%	n	%
PV	120	29%	72	31%
Main	140	34%	85	37%
Ineligible/early	46	11%	20	9%
Comparison	103	25%	54	23%
Total	409	99%*	177	100%

*Does not add to 100% because of rounding

Table 4 shows a more restricted comparison of all homeowners in SheaHomes communities to those responding to the survey with regard to PV ownership. This is important because, if homeowners with PV systems were more likely to complete the questionnaire than homeowners without PV systems, the responses from homeowners in the SheaHomes communities could be more representative of, or more heavily slanted toward, PV owners than non-owners. The information in Table 4 suggests that homeowners with PV systems were not more apt to complete questionnaires than were other homeowners in the SheaHomes communities. In fact, a $\chi 2$ test suggests that there is no significant difference in the corresponding percentage distributions ($\chi 2=.10$; $p=.75$).

[4]Some of the original home buyers had moved on and were not included.

Table 4. Comparison of Homeowners in SheaHomes Communities with and without PV Systems: All Homeowners versus Survey Respondents

Homeowner Category	All Homeowners in SheaHomes Communities		SheaHomes Survey Respondents	
	n	%	n	%
Homeowners with PV	120	39%	72	41%
Homeowners without PV	186	61%	105	59%
Total	306	100%	177	100%

Reasons for Non-Response

As part of the information provided in the survey mailings, all prospective respondents were supplied with a study contact name, telephone number, mailing address, and e-mail address. The return address on the 9" x12" manila envelope for the National Renewable Energy Laboratory in Colorado may have been unfamiliar to the San Diego respondents. As a result, a few respondents telephoned after receiving follow-up mailings to say that they had thrown out the original mailing, not realizing what it was. (The $10 financial incentive to complete the questionnaire was also thereby lost.) Thus, it seems reasonable to assume that some of the addressees threw out the envelope without opening it. A few other respondents called to say that they were too busy to complete the questionnaire and asked to be taken off the mailing list. One or two callers indicated they had an illness in the family. It would be reasonable to assume that these callers represented some other potential respondents who were too busy or had an illness. A certain number of questionnaires were not successfully delivered by the U.S. Postal Service either because the homeowners had moved or because they refused the mailing. A few respondents may have opened the envelope, pocketed the $10, and thrown away the questionnaire. There is no evidence to suggest how many fell into each of these categories. However, none of the reasons for non-response of which we are aware suggested a bias for or against the study or the questionnaire itself.

We learned from the SheaHomes sales staff that the San Angelo and Tiempo homebuyers had been incessantly pursued by the media seeking interviews; private companies that collect information for homebuilders had also sent them questionnaires. Reportedly, one or two homeowners had told the SheaHomes staff that they were going to refuse any further requests for interviews. Therefore, it seems reasonable that a certain degree of respondent fatigue had set in by the time the NREL questionnaires arrived and this, too, could have affected the response rate. Nevertheless, this fatigue was not directly related to the study or the data-collection instruments.

Some respondents phoned to ask questions about their PV systems, indicating a need for more information and education for PV homeowners. Eventually (and after data collection had ended), to assist the PV owners the research staff prepared a letter listing PV information sources (such as SheaHomes and AstroPower, Inc.) and their contact information to assist the PV owners.

Thus, it seems reasonable to conclude that study non-response did not bias the study's findings in any particular direction.

Survey Data Coding and Reconciliation

The protocols for data handling were approved by the University of Colorado Human Research Committee. These protocols follow established federal regulations and guidelines for the protection of human subjects.[5] All returned questionnaires were received at NREL in the sealed return envelopes provided to the prospective respondents. Outer envelopes were opened and separated from the unmarked sealed white inner envelopes. The outer envelopes were used to check respondents off the list for follow-up mailings and were filed in a locked file. The inner envelopes were opened and marked with a unique three-digit respondent identification number. The name of the type of questionnaire (PV, main, ineligible/early, or comparison) was written in the upper right-hand corner. The questionnaires were then hand-delivered to Alexander's Data Services, Inc., the firm responsible for data entry.

In cooperation with Alexander's, NREL developed the codebook, which was reviewed, revised, and approved by the senior author. Questionnaires were checked and data were entered by two independent coders and checked by computer for consistency. Data were stored in Excel files and delivered to NREL. NREL staff cleaned the data of all anomalies and inconsistencies.

At NREL, staff imported the data into an SPSS-11 file. The codebook was maintained at NREL in a Word file. All corrections and recodings were recorded in the codebook, and each new Master File was dated. Electronic records were checked against hardcopy questionnaires to ensure accuracy.

Duplicates of the master files were maintained at NREL and at Abilene Christian University[6] in Abilene, Texas. All hardcopy and electronic files identifying respondents were stored at NREL in locked file cabinets in a locked storage room.

Utility Data

As previously noted, each homeowner was asked to sign and return a utility release form, in addition to completing a questionnaire, for San Diego Gas & Electric (SDG&E) to release to NREL their monthly electricity and natural gas consumption and costs. Utility release forms[7] with valid signatures[8] were received from 132 homeowners, and the original forms were forwarded to SDG&E. These 132 homeowners represent 57% of all those responding to the survey questionnaires (56% of the SheaHomes survey respondents and 61% of the comparison community survey respondents). With respect to the total number of surveys mailed, the response

---

[5]Protocol number 0603.04 Human Research Committee, Office of Research Integrity, Office of the Vice Chancellor for Research, University of Colorado at Boulder.

[6]Abilene Christian University is the organizational affiliation of this report's second author.

[7]The utility data release forms were prepared by the NREL legal staff and approved by the SDG&E legal staff.

[8]Four of the utility release forms were signed by an occupant of the household other than the person in whose name the utility account was listed; therefore, data could not be obtained for those households.

rate for utility release forms is only 36%, considerably lower than response rate (63%) for the survey questionnaires themselves.

Upon receipt of the utility release forms, SDG&E provided NREL with actual monthly billing and consumption data from the first date of service for each household represented in Excel format. Data were obtained for all households through the June 2004 billing cycle. A typical monthly utility bill for one of these households from initial occupancy contains the following items: days of service in the billing month, amount of electricity used (in kWh), cost and tax for electricity used, and miscellaneous costs associated with electricity usage, plus amount of gas used (in therms) and cost and tax for gas usage. Other information associated with the dates of service is also included.

Because respondents moved into their homes and initiated service on different dates, the number of months of data for each household varies. Table 5 shows the earliest and latest first dates of utility service, as well as the mean number of months of service, for households in the SheaHomes and comparison communities. The earliest first date of service among the 132 households was June 2001; the latest date of service was June 2004. From this information it can be determined that the overall time period encompassed by the utility data provided by SDG&E is approximately the same for households in the SheaHomes and comparison communities, but that the mean length of utility service is significantly shorter for households in the SheaHomes communities (23.8 months) than for those in the comparison community (27.5 months) ($t= -2.578$; $p=.012$). This finding suggests that, although SheaHomes and the builder of the comparison homes started developing their communities about the same time, SheaHomes was building many more homes and approached build-out at a later date.

Table 5. Comparison of Length of Utility Service for Homes in the SheaHomes and Comparison Communities

Development	Earliest First Date of Utility Service	Latest First Date of Utility Service	Mean Months of Service*
SheaHomes	June 2001	November 2003	23.80
Comparison homes	June 2001	September 2003	27.45
All homes	June 2001	November 2003	25.52

*As of June 2004

As earlier discussed, geographically, the two housing developments are immediately adjacent to each other located on the top of a mesa in northern San Diego County. Hence, they experience identical climatological regimes. Nonetheless, climate can only be considered constant and controlled between the two developments during time frames that encompass the same months of utility service. This constraint impacts the selection of data for analysis of the utility data (see Chapter 19, Comparative Analysis of Utility Consumption and Cost), because the number of households and months of service is effectively restricted.

Data Analysis

A master data file containing household survey responses and associated utility data was developed. All respondent households were identified with three-digit identification numbers. The data were analyzed with statistical routines available on Version 11 of the Statistical Package for the Social Sciences (SPSS-11), Version 8 of the Statistical Analysis System (SAS v8), and Microsoft Excel (Office 2000).

Various graphical displays, such as histograms, box plots, and time-series line graphs were invaluable to the early formulation of analytical trends and further screening and cleaning of the data. Pearson product moment correlation and Spearman rank correlation were used to establish the basic linear relationships between pairs of items and variables.

A broad-based approach to statistical analysis of the data was taken. Considering each individual question as a stand-alone response item, descriptive statistics were computed, including percentages, means and/or medians, standard deviations and/or ranges, and coefficients of variation. Tables containing these descriptive statistics are contained in Appendix E (Base n's, Means, Standard Deviations, and Coefficients of Variation for Scaled Responses).

The results of the statistical tests were evaluated using p=.05 (95% confidence level) as the criterion of the statistical significance. Thus if the p-score (probability) is ≤.05, the results of the statistical tests are considered statistically significant, whereas if the p-score is >.05, the results are generally considered not significant (n.s.). A p-score of .05 means that there are only five chances in 100 that the results are due to chance. When results are almost significant (e.g., .055), we point out that they "near" statistical significance. We use the p-score of .05 because it is the standard accepted in professional statistical and social sciences research.

Conventional Z-tests, t-tests, and analyses of variance were used to determine the significance of observed differences in proportions and mean responses on key study variables and other items given by different respondent groups or household categories. Such tests provided important comparative results to facilitate an overall interpretation of the data. Comparisons of percentages and mean responses between SheaHomes and comparison community homeowners were essential to the study. Other analyses focused on the differences between the PV owners and non-PV owners (both those who did and did not have an opportunity to purchase PV). Such comparisons are detailed throughout the main body of this report.

Homeowners were classified into various categories to permit useful analyses and interpretations of the data, once the data set was better understood. Such classifications are described in the chapters in which findings from their analyses are presented and discussed.

In addition, numerous cross-tabulations were performed comparing response patterns on various items for different respondent groups or home and household categories (e.g., demographic characteristics), or response patterns on pairs of items for one specific respondent group. The

Chi-square ($\chi 2$) tests of significance were used to guide the interpretation of these cross-tabulations.

After a thorough univariate assessment of the data was concluded, numerous multivariate statistical analyses were performed. The first step in the multivariate analysis involved the use of factor analysis to help reduce the data to a more manageable and interpretive form. Although it is highly informative and descriptive, the univariate analyses of such a large number of survey items proved somewhat difficult to synthesize. Therefore, factor analysis was used to collapse this large body of information into a smaller collection of "factors" that could be used to more succinctly characterize the distribution of responses. One important aspect of factor analysis is that it takes into account the linear relationships among items that are sometimes difficult to identify when considering items one at a time from a univariate perspective. The procedures available in SPSS-11 were used to conduct the factor analysis, including the application of a conventional varimax rotation to refine the computations and make the results more interpretable (see Kinnear and Gray 1997; Dillon and Goldstein 1984). The results of the factor analysis are detailed in Chapter 17 on Data Reduction.

After the factors were calculated, individual factor scores were computed for each survey respondent (i.e., based on their individual responses to survey items, each respondent was assigned a series of new values in the database, one per factor). These scores were subsequently standardized using a conventional Z-score transformation resulting in uniform scaling of the factor scores. The scores representing the factors were then further analyzed using conventional univariate procedures (see details in Chapter 18, Analysis of Factors by PV Adopter Categories).

Similar analytical techniques were applied to the utility data, but the objectives were somewhat different. In addition, analysis of the utility data had to account for differences in the number of months of usage per household and the number of days per billing cycle. Consequently, some of the procedures incorporated weighting to produce accurate computations. To standardize the time frame for utility service and to cover all the seasons of one year, data for homes with a service period shorter than 12 months were eliminated from all computations. In addition, box plots, line graphs, and other visual displays were used to identify outliers in the utility costs and consumption amounts. Further, three Early homes were excluded on the grounds they were not strictly comparable to other homes in SheaHomes communities because they had no solar water preheating systems which could have affected their energy consumption. The results of these techniques are presented in the chapters and appendixes on the analysis of utility data.

Subsequent to these database refinements, descriptive statistics on utility cost and usage were computed. T-tests and analyses of variance were used to determine the significance of observed differences in the mean values for different groups or types of homes. Finally, multiple regression analysis was used to construct models of utility cost and consumption based on the most important home and respondent characteristics.

Limitations of the Data

The data reported derive from a case study of new homes in the San Diego climate regime. As such, although they are suggestive for high-performance home projects in California and elsewhere, they cannot be generalized to any other location. Respondents to the questionnaires are heads of household and original buyers of a newly constructed home in either the SheaHomes' San Angelo or Tiempo communities or in the comparison community. The questionnaires were voluntarily completed by either the male or female head-of-household at the householders' discretion. The voluntary responses, therefore, reflect the perceptions of that one respondent on behalf of the household. The other non-responding head-of-household could have responded somewhat differently. However, the study's assumption is that, because the home-purchase decision and the experience of living in the new home are both highly significant and are likely to be thoroughly discussed by the purchasers, the respondent who opted to "speak for" the household probably reflected, in general, the shared views of the household heads. However, where gender analyses are discussed in this report, the assumption is made that differences between male and female respondents are based on gender—rather than household—differences.

Queries about purchase decision factors rely on the respondents' memories of a decision made some 6 to 18 months earlier. Still, although these are retrospective data, the decision in question is one of the most important and financially significant decisions most families make in their lifetimes. For this reason, the data are probably more reliable than most retrospective data would ordinarily be.

In some of the study's analyses, as data were categorized, the number of cases became quite small, either because of the increased number of cells or because non-response to even one item meant that 10 or 12 items from that household could not be included in an analysis. Given the limitation that the universe of study itself numbered approximately 400 homes and that not all homeowners responded, it is unavoidable that certain analytical cells contain smaller numbers than would be desirable. Nevertheless, because the concepts being analyzed are important, the statistical tests were completed with the caveat that the number of individuals responding is small. The findings from such analyses with a small number of individuals responding are instructive and suggestive of directions for future research.

As is usual in studies of human knowledge, attitudes, preferences, opinions, and behavior, not all of the variance in response is accounted for. There are clearly variables beyond those measured in this study that affect responses. On the whole, however, the amount of variance explained generally ranges from 55% to 90%. In addition, there were items or factors which we were unable to observe, measure, or record, such as orientation of the house; information about roof lines; amount of roof space; number of bedrooms, bathrooms, and living areas, total number of rooms in the house, and exact ages of household occupants.

Despite these limitations, this investigation is the most comprehensive study of its kind. No other study is available that covers market response to high-performance homes, as well as large-production builder experience with them, their resale value, and their actual electricity and gas consumption and costs. Also, this study has adhered to a rigorous research design.

Chapter 4
The SheaHomes Experience

An important question for builders is whether high-performance homes, near-ZEHs, or ZEHs can be built and sold competitively in the new housing market. This chapter compares data on the sales prices of SheaHomes and comparison homes and compares data on the SheaHomes experiment between standard and optional solar PV systems. The chapter also describes the benefits and costs to SheaHomes of completing this innovative project.

Chapter Highlights

- High-performance homes are competitive in the market. Per square foot, they sell for 9.2% less than comparison homes on average. This difference, though small, is statistically significant.
- When controlled for by house size, smaller SheaHomes sold for less on average than comparison homes. The differences are statistically significant. Larger SheaHomes also sold for less than comparison homes, but the differences are not statistically significant.
- Thirty-nine percent of the 306 SheaHomes high-performance homes (n=120) were sold with solar PV systems.
- Thirty-one percent of the 306 high-performance homes (n=96) came with 1.2 solar PV systems standard.
- Only an estimated 44% of the buyers of PV-eligible homes were offered the option of purchasing solar PV systems.
- Of the estimated 72 buyers of SheaHomes who were offered solar PV systems on an optional basis, 44% (32) chose to purchase them.
- SheaHomes enjoyed significant benefits by offering innovative high-performance homes, including financial incentives, partnerships, valuable media exposure, an enhanced reputation, and greater exposure to the home-buying market.

Are High-Performance Homes Competitive?

Prices of the homes in the SheaHomes communities ranged from $437,900 to $840,938. The mean price was $601,984. Homes in the comparison community were somewhat more expensive, ranging from $473,990 to $875,000. The mean price was $615,029.

To address the issue of whether SheaHomes could offer high-performance homes and still price them competitively, we compared the mean sales price, the mean square footage, and the price per square foot between the SheaHomes and the comparison homes. The data, summarized in Table 6, support the conclusion that SheaHomes was able to deliver highly energy-efficient homes equipped with solar water heating systems, a percentage of which also included PV systems, at competitive prices. In fact, despite their quality and amenities, the homes built by SheaHomes sold for less per square foot than those built by their competitors.

Table 6. Sales Prices and Sizes of SheaHomes and Comparison Homes

Variable	SheaHomes (n=306)	Comparison Homes (n=103)	% Difference	Significance
Mean sales price	$601,984 SD*: $74,222	$615,029 SD.: $88,149	2.12	n.s.
Range, sales price	Low: $437,900 High: $840,938	Low: $473,990 High: $875,000		
Mean square footage	3,091 ft^2	2,860 ft^2	7.47	t=5.961; $p \leq .000$
Mean price per ft^2	$195.96 SD.: $24.81	$215.89 SD: $30.85	9.23	t=6.569; $p \leq .000$
Range, sales price per ft^2	Low: $147.61 High: $266.22	Low: $156.90 High: $303.25		

*SD= standard deviation

Table 6a. ANOVA on Sales Prices and Sizes of PV Homes, Other SheaHomes, and Comparison Homes

Variable	SheaHomes with PV Systems (n=120)	SheaHomes without PV Systems (n=120)	Comparison Homes (n=103)
Mean sales price (F=3.646; p=.027)	$614,465	$593, 932	$615,029
Mean square footage (F=18.118; p=.000)	3,112 ft^2	3,078 ft^2	2,860 ft^2
Mean price per ft^2 (F=22.487; p=.000)	$198.45	$194.36	$215.89

To further refine this analysis, the differences in closing prices for PV homes and homes without PV were compared with those of comparison homes. Table 6a summarizes the results. The analysis of variance summarized in Table 6a shows significant differences as follows. Although the mean closing price of PV homes is lower than that of comparison homes, the difference is not significant (p=.957). However, SheaHomes without PV systems cost significantly less, on average, than did comparison homes (p=.027), and also less than PV homes (p=.024). In terms of square-footage, the analysis shows that SheaHomes with and without PV systems are each significantly larger, on average, than are comparison homes. Thus, the mean price per ft^2 for PV homes ($198.45) is significantly lower than that for comparison homes ($215.89)(p=.000). Similarly, the mean price per ft^2 for SheaHomes without PV systems is lower ($194.36) than the mean price per ft^2 for comparison homes ($215.89).

Because sales price per square foot can decrease with increased size of home, an additional analysis of sales price controlled for square footage. Table 6b presents the results of this analysis.

Table 6b. Analysis of Sales Prices Controlling for Square Footage

Home Size Categories	SheaHomes (n=306)	Comparison Homes (n=101)*
≤ 2,600 ft^2 (t= –2.133; p=.037)**	Mean: $536,246 SD: 61,791 (n=35)	Mean: $567,471 SD: 58,717 (n=33)
2,601 – 3,002 ft^2 (t= –1.970; p=.052)***	Mean: $590,373 SD: 63,844 (n=53)	Mean: $621,289 SD: 87,542 (n=40)
3,003 – 3,300 ft^2 (t= –.999; p=.319)§	Mean: $607,166 SD: 72,653 (n=140)	Mean:: $627,653 SD: 78,159 (n=14)
3,301 – 3,376 ft^2 (t= –1.733; p=.103)§	Mean: $630,071 SD: 70,346 (n=78)	Mean: $679,755 SD: 103,055 (n=14)

*Of the 103 comparison homes, square footage was available for 101.
**Statistically significant difference
***Result nears statistical significance at the 95% confidence level
§n.s.

As the results show, the smallest SheaHomes sold for 5.5% less than comparison homes of the same size, a result that is statistically significant at the 5% significance level. The next smallest SheaHomes cost 5% less than the next smallest comparison homes, a result that is significant at the 5.2% significance level. Although the medium-size and largest SheaHomes sold for less than comparison homes in the same size ranges (3.2% and 7.3% less, respectively), these differences are not statistically significant. These findings show that SheaHomes, despite their energy efficiency and solar features, cost less per square foot than adjacent conventional homes when controlling for square footage.

Thus, SheaHomes' ability to offer the homes at competitive prices was not hampered by the inclusion of energy-efficiency features, solar water heating, and solar PV systems. Nor would other factors, such as lower land prices, have affected the closing prices because SheaHomes would have brought the sales prices up to market value. The comparison builder offered no standard features that would have made their homes more expensive. In fact, energy-efficient windows and increased insulation were optional features in the comparison homes. Therefore, the conclusion that SheaHomes sold high performance homes competitively seems warranted by the findings.

Costs of the Solar Features

Each solar water heating system included standard on 293 of the SheaHomes cost the builder approximately $1,800 installed. Each 1.2 PV system cost SheaHomes approximately $7,900 installed ($6,500 system cost plus $1,400 installation) (Roper 2006). Each 2.4 PV system cost the builder approximately $14,200 installed ($11,800 system cost plus $2,400 installation) (Roper 2006). Closely reflecting these estimates, the company submitted to the CEC a cost of $7,951 for the 1.2 PV systems and $14,631 for the 2.4 PV systems and received a 50% rebate for PV systems (Nelson 2006). The costs per system and in the net are discussed in the section in this chapter on "Benefits to the Builder."

Sales of Homes

The demand for housing in San Diego was high in 2001 and there was a waiting list and a lottery system for the first purchases of SheaHomes at Scripps Highlands. After a construction trailer was placed at the site, the SheaHomes office immediately began to receive numerous calls about the development. All of the initial homes built were sold without prospective buyers having the benefit of model homes. Only the land itself, floor plans, and sketches of house elevations were available for potential buyers to see. This represents a "sellers" market for both SheaHomes and the comparison builder.

Management's View

In July 2003, Dale Holbrook, then vice-president of the San Diego Division of SheaHomes and the decision-maker on high-performance homes, outlined in a background interview the management perspective on the Scripps Highlands project and this study. He indicated that one-third of the homes were "pre-plots" (which meant that they came with solar PV systems standard). From his perspective, solar water heating was "a given," but PV was the "big deal" because it added the largest cost. He commented that, despite rebates, the solar PV was not profitable for the company.

Holbrook observed that SheaHomes received "notoriety" because of the high-performance homes project. Although the project sold out a full year earlier than originally planned, he attributed the accelerated rate of sales to the desirable location. He said that SheaHomes had satisfied a "niche" demand for people interested in energy savings and environmental issues, and that was "probably the extent of it." San Angelo and Tiempo were built on the last available land in Scripps Ranch, ahighly desirable community, and homes could be purchased with no Mello Roos taxes (unlike most other new developments in the San Diego area).

He said he wanted to know answers to questions, as follows:

- How many people made their home purchase decision on the basis of PV?
- Which buyers were influenced by the fact that PV was available?
- How strong an influence on the purchase decision was the availability of PV systems?
- What benefits from the PV systems can be documented? What is the performance of PV systems over time in terms of utility costs?
- Will homebuyers, the next time they buy a house, look for PV and energy efficiency?
- Will homebuyers pay the extra $10,000 for a PV system or will they purchase a competitor's less costly home?
- How educated do homebuyers feel about making a decision on PV?[1]
- Did builder reputation play a role in the homebuying decision?
- After living in their homes, are the homebuyers still satisfied with their decisions?

Holbrook hypothesized that people were becoming accustomed to paying higher utility bills, and that "no one was still talking about it" (in July 2003), so that if SheaHomes came out with a product "today, it might not make much of a splash." If there were another spike in utility prices or concern about supply, he said, then perhaps it would create more market interest.

He said: "We're not offering solar [in our future developments] because *so few people opted for it* [emphasis added]. We don't see an advantage economically, so we haven't done it." Holbrook stated: "The results of the [NREL] study will have a great impact on our decision-making in the future."

SheaHomes did not actively promote the solar PV systems, according to several staff members. We observed that there were no brochures on solar electric systems in the SheaHomes sales center, although there were displays on one wall. The virtual tour on the sales center computer said nothing about high-performance homes, energy efficiency, or solar features. Sales staff were not trained about the homes' energy features. Staff considered solar PV "an extracurricular activity" in a highly competitive home-building environment and defined the learning curve as "enormous." Pam Beaird commented, "Solar is a big 'Wow!' when I am selling [preplotted][2] homes. But it is harder to add the $6,000 for the optional systems." From the sales agent's perspective, options are harder to sell, and "we get paid whether the home is solar or not. If it helps sell homes, it's something we talk about." Others told us that, at the sales center, most of the people looking at solar PV equipment were the people who were not there to buy homes.

One staff member said that the building industry saw solar PV in a negative light—it's unknown, expensive, the return-on-investment is not proven, and the prevailing attitude of builders is

---

[1]Holbrook noted that "Pam Beaird was evangelical in her sales of the solar PV," and that she was articulate about its benefits.

[2]"Preplotted" homes featured 1.2-kW PV systems standard.

"show me" that it works. This staffer said that customers and SheaHomes staff were uneducated about solar PV, and that "the customers see little value in it."

SheaHomes did not provide any financial analysis on the solar PV investment to its customers. Yet a staff member said that the utility bills were "amazingly low." However, the company included a disclosure in its contracts so that their customers would not think their PV systems would produce more than they would.

Percentages of Homes with Solar PV Systems

The percentage of SheaHomes with solar PV systems is an important finding of this study. Table 4 in Chapter 3 (Study Methods and Data Resources) shows that, ultimately, 120 homes were sold with some sort of PV system. Hence, 39% (120 ÷ 306) of the SheaHomes were sold with PV systems and 61% (186 ÷ 306) were not. Forty-six of the homes (46 ÷ 360, or 15%) were actually PV-ineligible (see the limitations noted in Chapter 3, page 5). Hence, of the 260 (or 306 – 46) PV-eligible homes, 46% (120 ÷ 260) were sold with PV systems of some sort, and 54% (140 ÷ 260) were not.

A key question for Ryan Green and SheaHomes was whether more PV systems would be sold if they were offered standard or as optional features. After the entire development was built out and the homes were sold, it became possible to give an accurate answer to this question.

Ninety-six of the homes were sold with 1.2-kW PV systems standard (which represents 80% of the total 120 sold with PV systems, or 37% of all homes that were PV-eligible). Those given the option of upgrading their systems to 2.4-kW (24 panels) could pay an additional $4,000, and eight homebuyers did so. The remaining 164 buyers of PV-eligible homes (or 260 – 96) could potentially have had the option of purchasing either a 1.2-kW system for $6,000 or a 2.4-kW system for $10,000.[3] Of these individuals, 16 purchased 1.2-kW systems and another eight purchased 2.4-kW systems. Counting those homebuyers that upgraded their standard 1.2-kW systems, a total of 32 homebuyers made some sort of optional PV purchase. These 32 homebuyers represent 27% of all the homes sold with PV systems or 12% of all PV-eligible homes. Tables 7 and 8 provide more details about these results.

Some important summary observations can be made. First, slightly fewer than half of the PV-eligible homes were actually sold with some type of PV system. Clearly the uptake on optional PV equipment was not as strong as it might have been. Second, a large percentage (80%) of the PV systems that were sold came standard. This finding suggests that offering PV systems as an optional feature is not an optimal marketing strategy. Third, the smaller 1.2-kW systems offered by SheaHomes were dominant among all those sold, a finding that impacts the analysis and modeling of actual utility data discussed in Chapters 20 (Comparative Analysis of Utility

---

[3]These prices increased to $7,000 and $11,000, respectively, late in the construction process.

Consumption and Cost) and 21 (Modeling of Utility Consumption and Cost). In fact, only 16 (13%, or 16 ÷ 120) of the homes have the larger 2.4-kW systems.

Table 7. Numbers and Percentages of Homes with and without PV Systems

Type of House	% of All Shea Homes	n	% of PV-Eligible Homes
With optional PV systems (wholly or in part)	10%	32	12%
With standard PV systems only	29%	88	34%
Total PV homes	39%	120	46%
PV systems not elected[4]	46%	140	54%
Total PV-eligible homes	85%	260	100%
PV-ineligible homes	15%	46	
Total homes	100%	306	

Table 8. Number, Percentages, and Decision Status of PV Systems on SheaHomes

Sizes and Decision Status of PV Systems on SheaHomes	n	%	% (n=260)
1. 1.2-kW PV systems as a standard feature	88	73	34
2. Optional 1.2-kW PV systems	16	13	6
3. Optional 2.4-kW PV systems	8	7	3
4. Standard 1.2-kW systems with optional upgrades to 2.4-kW systems 8		3 7	
Total homes with PV systems	120	100	46
Homes with optional systems only (Categories 2 and 3)	24	20%	9%
Homes involving optional systems (Categories 2, 3, and 4)	32	27%	12%
Homes involving standard systems (Categories 1 and 4)	96	80%	37%
PV systems that were 1.2-kW systems	104	87%	40%
PV systems that were 2.4-kW systems	16	13%	6%

[4]Many of these buyers of PV-eligible homes were apparently not offered PV systems, as discussed in the text.

Since SheaHomes only sold 96 of the 260 PV-eligible homes with PV systems standard, the remaining 164 homes could have had PV systems. We conjecture that they would all have been sold, and essentially within the same time frame. Certainly, none of them remain unsold today.

Our study suggests several reasons why homebuyers might purchase homes that include PV systems standard, but might not, on their own, purchase the same PV system as an optional feature. However, we believe the lackluster sales of optional PV systems was the result of ineffective marketing or even failure to offer the optional PV systems to buyers of PV-eligible homes. As will be discussed in Chapter 8 (The Solar PV Purchase Decision), the option to purchase solar PV systems was apparently not made to all buyers of PV-eligible homes. In fact, only 44% of the buyers of PV-eligible homes (36 out of 82 survey respondents in this category) recall being offered such a system at the time of purchase.[5] If we extrapolate this percentage to all SheaHomes buyers (that is, to the 164 buyers of PV-eligible homes who could have purchased an optional PV system), we estimate that only 72 of them (44%) were actually offered the option, leaving 92 (56%) having not been given the option.

These distinctions are important in understanding the actual rate of uptake of optional PV systems. Using the 72 homebuyers that we estimate above as having been offered optional PV systems, then the 24 who actually exercised the option (16 who opted for 1.2-kW systems and 8 who opted for 2.4-kW systems) would represent an uptake of 33% (24 ÷ 72) rather than the 12% reported above. If we include the additional eight homebuyers who optionally upgraded their standard 1.2-kW systems to 2.4-kW systems, then the uptake percentage is even higher (44%, or 32 ÷ 72).[6]

At the outset of our study, in obtaining background information from the SheaHomes staff, we understood that all buyers of PV-eligible homes were going to be offered the option to purchase PV systems. The lead sales agent (Pam Beaird) appeared to be enthusiastic about the PV concept, and indeed, she had purchased a PV home herself. Yet, even though a few respondents could have forgotten or ignored the offer, it seems highly unlikely that more than half of them would have forgotten it.

In trying to understand what might have happened, we examined the closing dates of all the PV-eligible home sales to determine whether the SheaHomes management had discontinued offering PV systems before building out the San Angelo and Tiempo communities, but we did not find any evidence to support this conjecture. Indeed, approximately half of the buyers of PV-eligible homes that closed prior to August 2001—near the beginning of the project—responded in the homeowner survey that they were not offered optional PV systems. As knowledgeable staff members described the situation in 2001, the sales staff was more concerned about finalizing actual home sales and less focused on sales of PV systems that might complicate the deal.

---

[5]These survey data are discussed in more detail in Chapter 8 (Solar PV Purchase Decision).

[6]We do not have data on the rate of uptake for other options offered by SheaHomes.

The PV option was apparently not aggressively marketed by sales staff. Further, Ryan Green, the original high-performance home champion, left the SheaHomes staff before October 2001 and no one stepped up to take his place. In any case, the fact that homebuyers were not actually offered the PV option substantially muddies the effort to quantify the uptake of the PV technology as accurately as had been planned at the outset of this study. Nonetheless, based on the foregoing analysis, *we believe the uptake for optional PV systems to be at least 40% when buyers are actually given the option*.

We return briefly to the discussion of why homebuyers might purchase a home that includes a PV system standard, but might not, on their own, purchase the same PV system as an optional feature. Qualitative data (Farhar, Coburn, and Collins 2002) and preliminary quantitative data (Coburn, Farhar, and Murphy 2004) show that homebuyers found it easier to purchase PV systems when they did not have to make separate decisions about it. Homebuyers reported that they found it difficult to make the trade-off between PV systems, on the one hand, and amenities that improved the aesthetics of their homes (e.g., granite counter tops, special window sills, or upgraded flooring), on the other. To some homebuyers, the latter seemed to be options in a totally different class (e.g., a choice about energy-saving equipment versus a choice about improving their homes' aesthetics). Finally, some of the data suggest that homebuyers who chose not to purchase PV systems thought they were too expensive.[7]

Benefits to the Builder

SheaHomes accomplished a complex technical and institutional achievement in completing the San Angelo and Tiempo developments. Besides selling out the 306-home development in 31 months, the builder also sold almost half with PV systems. The San Diego office of SheaHomes, in carrying out its innovative project, experienced both benefits and costs. Five major benefits appeared to accrue to SheaHomes because of its involvement in the construction of high-performance homes: (1) financial incentives and net costs related to solar features, (2) partnerships with organizations interested in solar energy and energy efficiency, (3) media coverage, (4) enhanced reputation through becoming an innovator with ZEH technology, and (5) greater exposure to the home-buying market.

---

[7]Although PV systems might be seen as expensive in an absolute sense, this perspective clearly results from homebuyers being unaware of the usual unsubsidized costs of PV systems, which are generally at least double the cost of those offered at Scripps Highlands. Survey data on this question are discussed in Chapter 8 (Solar PV Purchase Decision).

Financial Incentives and Net Costs

SheaHomes enjoyed economic advantages for building high-performance homes. The company received from the CEC a 50% subsidy on the cost of the PV systems—the first time a residential builder in California had received the subsidy from the state. The company also received a $750 rebate from SDG&E for the installation of each solar water preheating system. The $750 solar water heating rebates were provided through a CEC program called the "Solar Energy and Distributed Generation Grant Program," authorized by SB 1345 (Anders 2006). In addition, California provided a 15% tax credit for PV housing (Anders 2006).[8]

Taking the financial incentives into consideration, the cost to SheaHomes of providing solar water heating standard was approximately $950 per system. The cost of providing each 1.2 PV system standard was approximately $3,380. The original price to homebuyers for an optional 1.2 PV systems was $6,000.[9]

Table 8a summarizes the types and numbers of solar energy systems and the net costs and profits for each type. In summary, offering the solar features for 93 of its 306 homes under the scenario that SheaHomes was working at the time, the total net cost to the builder for all the homes was approximately $550,000, averaging approximately $1,872 per home. These figures are only estimates because they do not account for several other variables, as follows:

- A price increase to $7,000 for optional 1.2 PV systems and to $11,000 for optional 2.4 PV systems later in the project
- The cost of energy-efficiency measures throughout the project
- The benefit of any downsizing of equipment that was done
- The manner in which these costs were factored into the homes' market prices.

Still, if we estimate that SheaHomes was able to complete its San Angelo and Tiempo high-performance communities for a net cost of approximately $2,000 per home, it seems reasonable to estimate that the builder recovered the costs. However, this does not take into account other costs, such as those mentioned above and later in this chapter.

---

[8]This tax credit is no longer available.

[9]These calculations assume a 50% rebate plus a 15% tax credit on the full system cost.

Table 8a. Net Costs to SheaHomes of Offering Solar Features at Scripps Highlands

System Type	Number of Units	Net Cost per Unit	Totals
Solar water heating	293	$950	$278,350
1.2 PV standard	96	$3,380	$324,480
1.2 PV optional (assuming $6,000 price)	16	($2,620)	($41,920)
2.4 PV optional (assuming $10,000 price)	8	($3,782)	($30,256)
1.2 PV standard with 1.2 PV optional upgrade (2.4 PV system) (charged $4,000 for the upgrade)	8	$2,218	$17, 744
			Subtotal net costs: $620,574 Subtotal net profits: (72,176) Total net cost: $548, 398

Partnerships

SheaHomes increased its involvement with a number of business, nonprofit, and governmental organizations as a direct result of its decision to build high-performance homes. For example, the builder has worked with the U.S. Department of Energy's (DOE) Zero-Energy Homes initiative; NREL; the CEC; AstroPower, Inc.[10]; Sun Systems, Inc.; ConSol, Inc.; SDG&E; and the San Diego Regional Energy Office. Such partnerships give SheaHomes a business edge in innovative home building techniques and energy technologies. They provide a network of resources to which SheaHomes can turn for information about best construction practices and market research. These partnerships help to establish SheaHomes as a leader in the field of energy features in new housing. It is difficult to put a dollar value on such resources, but these types of contacts are generally understood to be "coin of the realm."

[10]AstroPower, Inc. has since been sold to General Electric Company.

Media Exposure

By its own contractor's estimate, SheaHomes received, without cost, print and broadcast media coverage on the San Angelo and Tiempo developments that would have cost $1 million in paid advertising. The coverage included San Diego television evening news, local newspapers, and trade journals.

Enhanced Reputation

Because nearly half of all buyers at SheaHomes' Scripps Highlands development purchased PV systems, it seems reasonable to say that SheaHomes was successful in marketing innovative ZEHs with efficiency and solar features. In doing this, SheaHomes in San Diego established its reputation as a visionary company willing to offer quality products that provide value to its customers and that benefit the broader San Diego community. Though it was difficult for the company, SheaHomes has no doubt benefitted through the increased goodwill of the community by attempting and carrying out this project. These qualitative benefits are likely to be longer range than the immediate impacts on the bottom line and will unfold for years to come, not only in the local area, but everywhere in the nation that the company builds and people hear about the San Diego project.[11]

Greater Exposure to the Once and Future Home-Buying Market

Owing in part to media coverage and the high demand for housing in the San Diego market, SheaHomes experienced a large volume of visitors to its visitor center (there were no model homes in the early stages of the development). Many were curious about the development's solar features, although they were not seriously shopping for new homes (Collins 2003). Conceivably, a small percentage of these visitors might shop for new homes in the future; they will have been exposed to SheaHomes and to the ZEH concept.

Costs to the Builder

The ZEH experience was something of a double-edged sword for SheaHomes. Several of the benefits also involved costs. For example, although SheaHomes climbed a steep learning curve regarding the incorporation of energy features into its new housing products, there was a cost in terms of staff time. Some lessons were hard won. It was difficult for SheaHomes to anticipate the problems it would encounter in these uncharted waters.

[11]Recent informal conversations on this study indicate that people want to know who the builder was so they could spread the word in a positive way.

Costs of Building High-Performance Homes

Although significant costs were involved in the building of high-performance homes, especially in the installation and interconnection of PV systems, the financial incentives available helped to offset at least some of the costs. SheaHomes management at the time believed that, despite rebates for solar water heating systems and PV systems, the high-performance homes did not result in an economic advantage. PV systems seemed expensive to SheaHomes and the management believed that relatively few buyers opted for them, apparently not necessarily realizing that the PV was *not* offered to most potential buyers of PV-eligible homes. Although our data do not bear this out, the management at the time believed some of the market interest may have occurred because of the electricity price spikes in San Diego in 2001,. Buyers become accustomed to higher electricity rates, the company believed. Although SheaHomes indicated that the ZEHs did not sell any faster because of the energy features, the Scripps Highlands development sold out a year faster than planned. The management attributed this to the desirability of the Scripps Highlands location, rather than to the energy attributes of its homes.

Climbing the Learning Curve

SheaHomes had no staff experienced in ZEHs except Ryan Green. The learning curve associated with producing the ZEHs was characterized as “enormous,” including all the new language, acronyms, companies, products, and governmental agencies. The company had no previous experience that would help it to anticipate and avoid problems. SheaHomes found climbing this curve to be a painful experience.

Transaction Costs of Selling and Scheduling Installation of Optional PV Systems

Because SheaHomes buyers had the option of upgrading PV systems that came standard or adding 1.2-kW or 2.4-kW PV systems to their homes, sales staff had to explain solar PV systems and the different ways the homebuyers could purchase them. In addition to this time-consuming chore, the SheaHomes staff had to schedule the installation of the two sizes of PV systems on a house-by-house basis. The fact that this was burdensome was illustrated by an anecdote from a SheaHomes buyer. He said: “When we were purchasing our system, it came with 12 panels. We were offered an additional 12 panels for $7,000. We jumped on it! However, when they built the house, we discovered that they had only put on 12 panels. We contacted SheaHomes who said, ‘How about we just give you back the $7,000?’ They really tried to get us to pass up our 12-panel addition. However, we insisted that they put in the additional 12 panels. They had to change out the inverter when they put in the additional 12 panels and put in a new top-of-the-line inverter that enables us to monitor our electricity use on the computer. We can put it in an Excel file. What matters to me is that I want to monitor my electricity use once a month starting on the day that SDG&E reads my meter.”

Obtaining the Rebate for PV Systems

The CEC was offering a rebate of 50% of the installed cost of PV systems to residential owners and businesses installing them, as well as to builders including them in new homes. The CEC's application procedures for obtaining the rebate were designed to deal with one system at a time. Because the SheaHomes project was so innovative, SheaHomes had to work with the CEC had to invent a procedure to collect the rebate for the group of PV systems it had purchased to install at San Angelo and Tiempo.

Interconnectivity issues

Net-metering legislation requires California utilities to allow net metering to zero for homes with PV systems tied to the utility grid. This means that the electric meters at homes with PV systems run forward and backward. SDG&E was still developing its own procedures for interconnectivity agreements with residential electricity producers when SheaHomes began building its Scripps Highlands project. The utility was sending to the homebuyers for their signatures highly complex legal documents dealing with interconnection to the utility grid appropriate for corporations. Neither SheaHomes staff nor homebuyers had any prior experience in dealing with interconnectivity agreements. New homebuyers did not understand these SDG&E interconnectivity agreements and turned to the SheaHomes staff for help. The staff, therefore, spent a good deal of time interfacing with SDG&E and homebuyers on interconnectivity issues. SDG&E eventually simplified its forms for residential electricity producers, who are billed separately for electricity and gas and have the option of being billed for electricity monthly or annually.[12]

Tax Implications

Various state and federal income tax credits were thought to be applicable to the SheaHomes. The San Diego Regional Energy Office worked on an analysis to define the tax benefits of ZEHs and shared its findings with the SheaHomes staff. Staff spent time trying to understand the income tax implications and how to explain them to the homebuyers so that they might benefit from them.

Education

SheaHomes provides orientation at "Shea University" to all of its new homebuyers. The class was usually held in the garage of one of the homes on Saturday mornings and covered many of the features of the new homes and the procedures for completing purchase, moving in, and dealing with problems. The staff responsible for orientation did not always include information on the energy features of the new homes, including efficiency, water heating, and PV systems.

---

[12]PV owners receive a monthly statement of their electricity use and costs regardless of whether they pay monthly or annually (which was at their option).

Thus, SheaHomes buyers were not sufficiently briefed on the benefits of their homes in terms of energy performance.

Visitors

Many general public visitors who were curious about the solar features, but who were not serious buyers, took up staff time with their questions. In addition, SheaHomes staff handled many other professional visitors working on media stories, research, government programs, nonprofit educational programs, and the like, including researchers for this study.

Complaints

A few homebuyers complained about hot water systems, but the complaints did not actually relate to the solar hot water systems. For example, one complaint was that it took too long for the hot water to reach the bathroom faucets located farthest from the hot water tank. This had nothing to do with solar water heating; nevertheless, in a few instances, it was perceived as such. One or two potential buyers asked to have standard PV panels taken off the roof, although there is no evidence that any home sales were lost because of PV panels.

Competitiveness Issues

Because of its innovative position relative to energy features, SheaHomes suffered from a certain amount of animosity (perhaps sparked by concern that they could be forced into dealing with ZEH technology to remain competitive) on the part of the San Diego builder community.

SheaHomes Position

The management has changed at the San Diego office of SheaHomes since the data for this study were collected. The new management has not been interviewed in connection with the study. SheaHomes was one of 10 builders who participated in the Ladera Ranch project of 500 high-performance homes. The builder also built the Bella Rosa affordable housing project in San Diego. However, otherwise its other developments since Scripps Highlands have not included high performance homes.

Summary

A central question of the Ryan Green experiment was whether optional solar PV systems would sell homes more quickly and whether standard PV systems would impede sales. Although the innovative high-performance homes generated a good deal of media and home-shopper interest, it was easier for people to buy homes with standard PV systems than to make decisions about optional PV systems. It was harder for SheaHomes sales staff to sell both homes and solar PV systems and conversely easier for them to sell homes with PV systems standard.

The data show that SheaHomes did not offer optional PV systems to the majority of buyers of all PV-eligible homes. Despite this, the estimated uptake of optional PV systems among those offered PV systems was 44%. Thus, if more buyers had been made aware of the PV option, more homes would almost certainly have been built with them.

On balance, the San Diego Division of SheaHomes enjoyed substantial benefits from its Scripps Highlands project, and the company subsequently offered high-performance homes in the Ladera Ranch and the Bella Rosa affordable housing developments.

Chapter 5
Increases in Property Values

Introduction

> **Chapter Highlights**
>
> - SheaHomes and comparison homes increased markedly in value (as of 2/7/05).
> - SheaHomes had been held an average 22.5 months and comparison homes 28.1 months before resale.
> - Resale prices for 29 resold homes show that the increase in value for SheaHomes averaged 55.4% and for the comparison homes 44.7%.
> - The mean gain in property value per month was $14,492 for SheaHomes and $9,301 for comparison homes.

One research question in this study relates to whether high-performance homes hold their value over time or, indeed, if they provide financial advantages to their owners at the time of resale. During the years between 2002 to 2004, housing prices in the San Diego area were increasing rapidly. For example, an Internet search in March 2005 showed that, between October 2003 and April 2004, average housing prices in San Diego County increased 14.4%.

Farhar, Coburn, and Murphy (2004) reported that the resale property value of both categories of homes had increased by January 2004 (based on a small sample of 10 SheaHomes and six comparison homes). Property values had increased more for the SheaHomes than the comparison homes.

Findings

Resale data were checked again on February 7, 2005. Table 9 shows the original and resale prices for the two developments as of that date. The same pattern of results continued to hold. Twenty-nine homes had been resold by that date—15 (approximately 5%) of the SheaHomes and 13 (approximately 13%) of the comparison homes.

The SheaHomes and the comparison homes have increased markedly in value since they were originally purchased but, based on the selling prices of this group of 29 resold homes, the SheaHomes have increased in value more. The increase in value for the SheaHomes averaged $306,510 (55.4%) whereas the increase in value for the comparison homes averaged $262,968 (44.7%). Thus, the resold SheaHomes have increased in value 14% more than the comparison homes on average.[1]

The data in Table 9 show that the homes in the two communities were held, on average, a comparable length of time before resale, although homes in the comparison community were held somewhat longer (a mean of 22.5 months by the SheaHomes owners and 28.1 months by the comparison owners). More strikingly, the data show that the mean gain in property value per month owned was $14,492 for the SheaHomes and $9,301 for the comparison homes, a gain 36%

[1]These calculations do not take into account the fact that SheaHomes originally sold for $10/ft^2 less than the comparison homes.

higher for SheaHomes than comparison homes. The mean gain in property value per square foot per month owned was $4.97 for the SheaHomes and $3.23 for the comparison community homes. The mean percentage gain in property value per square foot was .019 for the SheaHomes and .016 for the comparison homes.

The greatest single gain in value was $446,410 for a home in the SheaHomes communities with a PV system owned for 26.9 months (a 79% increase in value). In comparison, the single largest gain for a home in the comparison community was $378,769 for a home owned for 40.2 months (a 61% increase).

Data are not available in this study for many factors that can affect property values. However, the study does include information about the energy features of the resold SheaHomes. The average gains in value for SheaHomes with PV systems are higher than for those without PV systems (see Table 10). The average dollar gain per month of SheaHomes with PV installations was $16,302, whereas the average dollar gain for SheaHomes without PV installations was $13,834; PV homes appreciated 15% more per month. The average gain per month per square foot for PV homes was $5.71, and for homes without PV systems it was $4.70. The SheaHomes with PV systems appreciated 6% more overall than did SheaHomes without PV systems.

Of the 103 comparison homes, 13, or 12.6% (counting the home sold twice) were resold by 2/7/05. Of the 306 SheaHomes, 15, or 4.9% were resold by 2/7/05. This more rapid turnover of comparison homes compared with that of SheaHomes was unexpected. There is no reason to believe that the kinds of life changes that might cause homeowners to put their homes on the market—including changes in employment or financial situations, marital status, or health—would occur more frequently in one home development rather than the other. Thus, it may be reasonable to speculate that the turnover rate constitutes more evidence that the comparison homeowners are somewhat less satisfied with their homes (as other data in this study indicate) than the SheaHomes owners.

Based on this analysis of the property values of resold homes at Scripps Highlands, it seems fair to conclude that, at a minimum, high-performance homes not only hold their value but increase their value at a faster rate than do conventional homes.

Table 9. Comparisons of Gains in Property Values and Length of Ownership for Homes in the SheaHomes and Comparison Developments (as of 2/7/05)

Variable	Homes in SheaHomes Communities (n=15)	Homes in the Comparison Community (n=12)*
Original price	Range: $482,900–$701,184 Mean: $556,344	Range: $538,522–$711,887 Mean: $598,028
Resale price	Range: $680,000–$1,100,000 Mean: $862,853	Range: $760,000–$995,900 Mean: $862,590
Home size (in ft^2)	Range: 2,222–3,678 Mean: 2,961.8	Range: 2,486–3,502 Mean: 2,975.2
Mean length of ownership before resale	22.5 mos.	28.1 mos.
Length of ownership (range)	9.9–43.9 mos.	17–40.2 mos.
Mean $ gain in property value	$306,510**	$262,968
Mean % gain in property value	55.4%	44.7%
Range of percentage $ gain in property value	High = 80.5% (ineligible, owned 24.6 mos.) Low = 30.5% (main, owned 14. 9 mos.)	High = 69% (owned 39.7 mos.) Low = 21.5% (owned 22.2 mos.)
Range of $ gain	High = $446,410 (PV, owned 26.9 mos.) Low = $190,354 (main, owned 14.9 mos.)	High = $378,769 (owned 40.2 mos.) Low = $153,113 (owned 22.2 mos.)
Mean $ gain per mo. owned	$14,492	$9,301
Mean $ gain in property value per ft^2	$104.70	$92.99
Mean $ gain in property value per ft^2 per mo.	$4.97	$3.23
Mean % gain in property value per ft^2	.019	.016

*An additional home was resold twice by 2/7/05 but was excluded for purposes of this analysis
**The mean gain for SheaHomes was 16.6% more than for homes in the comparison community

Table 10. Comparisons of Gains in Property Values and Length of Ownership for SheaHomes with and without PV Systems (as of 2/7/05)

Attribute	Homes with PV Systems (n=4)	Homes without PV Systems (n=11)
Original price	Range: $505,700–$636,730 Mean: $564,329	Range: $482,900–$624,646 Mean: $553,440
Resale price	Range: $739,000–$1,010,000 Mean: $884,950	Range: $769,500–$1,100,000 Mean: $854,818
Home size (in ft^2)	Range: 2,584–3,165 Mean: 2,868.3	Range: 2,222–3,678 Mean: 2,995.8
Mean length of ownership before resale	20.3 mos.	23.2 mos.
Length of ownership (range)	13.6–26.9 mos.	9.9–43.9 mos.
Mean $ gain in property value	$320,621*	$301,378
Mean % gain in property value	56.8%	54.5%
Range of percentage $ gain in property value	High = 79.2% (owned 26.9 mos.) Low = 46.1% (owned 23 mos.)	High = 80.5% (ineligible home, owned 24.6 mos.) Low = 30.5% (main home, owned 14.9 mos.)
Range of $ gain	High = $446,410 (owned 26.9 mos.) Low = $233,300 (owned 17.9 mos.)	High = $425,100 (ineligible home, owned 43.9 mos.) Low = $190,354 (main home, owned 14.9 mos.)
Mean $ gain per mo. owned	$16,302	$13,834
Mean $ gain in property value per ft^2	$111.77	$102.13
Mean $ gain in property value per ft^2 per mo.	$5.71	$4.70
Mean % gain in property value per ft^2	.02	.019

*The mean gain for homes with PV systems was 6.4% more than for homes without PV systems

Chapter 6
Respondent Characteristics

Introduction

As described earlier, respondents in the survey are heads of households and original buyers of new homes in either the SheaHomes or comparison communities. Only 10% of the respondents were purchasing a home for the first time. Questionnaire respondents were asked to select one head of household for answering demographic questions about themselves and their households. For all but one of the demographic variables there is no statistically significant difference between respondents who are homeowners in the SheaHomes communities and those who are homeowners in the comparison community. Appendix F (Respondent Characteristics, Demographics, Values and Lifestyles, and Other Variables) contains tables detailing responses to all questions pertaining to respondent characteristics, including demographics, lifestyles, and values by SheaHomes and comparison respondents.

Chapter Highlights

- Respondents are male and female heads-of-household; more than half (56%) are male.
- They are original owners of the homes; 90% previously owned a home, whereas 10% were buying a home for the first time.
- A plurality of respondents (44%) are younger than 40 years of age; 75% are 25–50 years of age.
- Most respondents are married; two-thirds have families.
- Respondents are highly educated with professional, business, and scientific occupations consonant with their educational attainment.
- A significantly higher percentage of SheaHomes owners than comparison owners have annual incomes that exceed $200,000. Otherwise the SheaHomes and comparison homeowners are not significantly different in any demographic measure.

Findings

SheaHomes and comparison community respondents are similar on all but one of the demographic variables that were measured as follows:

- Respondents (heads of households) are predominantly male (male, 56%; female, 44%).
- The largest percentage (44%) of respondents are younger than 39 years old (30% are 40 to 49 years of age; 26% are 50 years of age or older).
- Ninety-five percent of the respondents are married.
- In terms of household composition, 68% have two adults living with children and 32% are adult-only households.
- Reported household size ranges from one to 11 people, with a mean of 3.53 occupants (77% of all respondent households are composed of two to four residents).

- The respondents are a highly educated group: 97% have completed at least some college; 80% have at least a bachelor's degree; 20% have a master's degree; and 16% have doctoral degrees.

- Reported occupations include business owners, investments/financial, health care, scientists and engineers, managers, and professionals.

- Thirty-two percent of all respondents indicate that they plan to stay in their homes permanently, whereas 44% do not know how long they will live in their new homes. The remainder of the data suggests a bimodal pattern with peaks at 5 years (7%) and 10 years (6%).

- Most respondents (86%) moved to the Scripps Highlands neighborhood from elsewhere in the San Diego area. This means that most buyers had been exposed to the publicity concerning the electricity price spikes in San Diego and the California energy crisis during 2000–2001, before buying their new homes.

As expected, all respondents report relatively high household income levels. However, SheaHomes buyers have significantly higher incomes than do those in the comparison community. Table 11 shows that an almost equal percentage of buyers in each group (22% of SheaHomes buyers and 20% of comparison homebuyers) have incomes less than $100,000. A higher percentage of comparison homebuyers report annual incomes in the $100,000 to $200,000 range (76%) than do SheaHomes buyers (59%). A higher percentage of SheaHomes buyers report annual incomes of at least $200,000 (19%) compared with comparison homebuyers (4%). These differences are statistically significant ($\chi 2=6.092$; $p=.048$).

Table 11. Percentage Distribution of Annual Household Income for SheaHomes and Comparison Homeowners*

Annual Income ($)	Percentage of SheaHomes Owners (n=155)	Percentage of Comparison Home Owners (n=45)
≤$99,999	22	20
$100,000–$199,999	59	76
≥$200,000	19	4
Totals	100	100

*Statistically significant difference, p=.048

The findings on demographic variables offer little support for the "early adopter" hypothesis. The findings for education and occupation do not support the expected pattern for early adopters because there are no significant differences between the homebuyer groups. The only difference in the predicted direction is income. These findings provide only limited evidence that the buyers of SheaHomes are more likely to be early adopter types than the buyers of the comparison homes. In fact, they may simply be a bit more able to afford upgrades than the buyers of the comparison homes.

Among the 72 respondents owning PV systems, the distribution of system size is as follows:

- A 1.2-kW system, whether standard or optional: 64 respondents
- A 2.4-kW system, always at least partially optional: 8 respondents.

Among SheaHomes owners, PV ownership was analyzed relative to the study's demographic variables.[1] Among these variables, two significant differences are found. First, the percentage of respondents that is male is significantly higher among respondents representing PV homes than those representing non-PV homes ($\chi2$=6.994; p=.03). This is probably because PV technology is somewhat more likely to be seen as within the purview of men than women. The second significant difference is among older and younger respondents. The percentage of respondents 50 years old or older is significantly higher among respondents representing PV homes than among those representing non-PV homes ($\chi2$=6.994; p=.03). Table 13 summarizes the data by age.

Table 13.[2] Percentages of Ownership of PV Systems by Age, among Owners of SheaHomes*

Type of owner	≤39 years old (n=73)	40–49 years old (n=55)	≥50 years old (n=42)	Totals (n=170)
PV owners	40	53	26	41
Non-PV owners**	60	47	74	59
Totals	100	100	100	100

*Statistically significant at p=.03

** "Non-PV owners" are owners of SheaHomes that do not have solar PV systems, including main and early homeowners.

Summary

As expected, residents of both the SheaHomes and comparison communities demographically constitute upper-middle-class married couples with children or adult couples. They are, as a group, highly educated with well-paying occupations, and they are relatively affluent. A significantly higher percentage of SheaHomes owners than comparison homeowners enjoys an annual income of more than $200,000.

[1]For the head of household completing the questionnaire: sex, age, marital status, household composition, household size, income.

[2]Table 12 is not used in this document.

Chapter 7
New Home Search and Purchase Decision

Introduction

Key study questions focused on differences between SheaHomes and comparison buyers. In particular, we looked at why they selected the homes they did and how significant the high-performance home features (e.g., energy efficiency, solar water preheating, and solar PV systems) were in influencing the home purchase decision. These questions are covered in this chapter.

This chapter discusses new home search and purchase decisions and compares SheaHomes and comparison homeowners on factors in the new home search process, purchase decision factors, and the importance of new home features in home purchase decisions.

Chapter Highlights

- Study respondents are the original owners of the SheaHomes and comparison homes.
- Approximately 25% of respondents purchased homes that had fallen out of escrow.
- Sixty percent of buyers had also visited resale housing during their new home search process.
- Three-quarters of the buyers visited both the SheaHomes and comparison developments when they were shopping for a new home; however, they were not well informed about high-performance home features.
- By and large, concerns about the California (and San Diego) 2001 electricity crisis did not appear to influence home-purchase decisions.
- Energy was not a very important factor in the purchase decisions of most of the study's new homebuyers.
- Buyers who were more concerned about their residential energy consumption were more likely to buy SheaHomes than comparison homes.
- The reputation of the builder was significantly more important to SheaHomes than to comparison buyers.
- The home's location and the financial aspects of the home purchases were the most important reasons for purchase for both categories of buyers. However, energy was in the top three reasons for 6% of SheaHomes buyers but none of the comparison buyers.

New Home Search and Purchase Decision Process

Ninety-nine percent of the respondents were original owners of the homes, with no statistically significant differences between SheaHomes and comparison buyers.[1] Ten percent of respondents indicate that these were their first homes. Approximately one-quarter of respondents (20% of SheaHomes buyers and 29% of comparison homebuyers) purchased new homes that had already been under contract, but had fallen out of escrow.[2]

During their searches for a home, 60% of the new homebuyers had also visited resale housing. Seventy-two percent of the

[1]Three respondents purchased their homes from previous owners (two SheaHomes buyers and one comparison homebuyer.)

[2]This meant that the options and amenities of the homes had been selected by the prior intended purchasers rather than by the final buyers. As we shall see in Chapter 18 (Analysis of Factor Scores by PV Adopter Categories), this could have important consequences relative to the markets for ZEHs and PV ownership in particular.

comparison homebuyers visited resale homes during their home searches, whereas 57% of the SheaHomes buyers did so, a difference that nears statistical significance ($\chi 2$=.835; p=.057). This finding suggests that the SheaHomes buyers may have been persuaded to purchase by the qualities of the SheaHomes more quickly during their new-home searches than the comparison buyers, who may have needed to search for a longer time.

Almost three-quarters (73%) of the new homebuyers indicate that, when they were searching for new homes, they visited both the SheaHomes and the comparison home developments. This suggests that homebuyers appear to have had choices within their price ranges and preferred location and that they selected homes with features they preferred. However, other evidence suggests that the homebuyers were not specifically well informed about the features of the high-performance homes. This is discussed in Chapter 9 (Knowledge and Information).

Most home purchase decisions (93%) were made by two people rather than one person (7%). All of the comparison home purchase decisions were joint decisions, whereas 91% of the SheaHomes purchase decisions were joint decisions ($\chi 2$ =5.308; p=.021). This finding suggests that at the higher end, most home purchase decisions will not be made by a single individual because few single people live in these types of neighborhoods, which are designed primarily for couples, families with children, and extended families.

All respondents were asked: "On a scale of 1 to 10, how concerned were you about the electricity costs in San Diego at the time you purchased your home?" SheaHomes respondents exhibited more concern (mean=6.31) than did comparison home respondents (mean=5.69), but the differences are not significant (t=1.465; p=.144). A $\chi 2$ test yields results similar to the t-test results. Although PV owners were more concerned (mean=6.54) than non-PV owners (mean=5.99), the difference is not significant (t= –1.420; p=.157). Thus, concern about the California electricity crisis, and in particular the crisis in San Diego, did not appear to influence the home selections of most of these new homebuyers. However, during the qualitative interviews, a few buyers had commented on the high electricity bills of their prior homes during the crisis, so the higher incomes of these buyers probably insulated most of them from serious financial impacts of the San Diego electricity crisis.

Comparison Buyer Awareness of SheaHomes

A majority of the comparison homebuyers were unaware of the SheaHomes high-performance homes when they were in the search process. Comparison respondents were asked: "At the time you were looking for a new home, were you aware that, in your price range and location, highly energy-efficient homes were available that featured solar electric (photovoltaic or PV) systems as well as solar water heating?"

A majority of the comparison community buyers (53%) indicated they were *not* aware of the SheaHomes offerings when they were shopping for their new homes; 43% indicate they were aware. Those aware were then asked: "Why did you choose not to buy one of these homes?" and the first three reasons were coded, yielding a total of 35 responses. These responses can be summarized as follows:

- Never saw SheaHomes (33% of reasons mentioned)
- Preferred the comparison house layout (31%)
- Preferred a better value in the comparison home (12%)
- Preferred the comparison lot (11%)
- Other (9%).[3]

Thus, the majority of comparison homebuyers were unaware of the SheaHomes high-performance home offerings. Of the plurality who were aware of the San Angelo and Tiempo homes, most preferred the comparison layouts and lots and perceived a better value in the comparison homes than in the SheaHomes. Only one person mentioned a desire to avoid solar features as a reason not to purchase a home in the SheaHomes development.

Reasons for Purchase

Questions about the importance of purchase decision factors were constructed in such a way that energy features would attain the level of importance they actually had within the context of the many variables known to affect housing purchase decisions. The four types of questionnaires asked respondents to rate the importance of a set of their homes' characteristics in their purchase decisions with the following question: "How important were each of the following features in your decisions to purchase your new home?" Respondents were asked to rate characteristics on a 1-to-5 scale (where 1=Not at all important and 5=Very important). SheaHomes respondents were asked to rate the importance of 23 characteristics, including four items specifically dealing with energy features. A single item pertaining to energy was asked of the comparison respondents. They were asked to rate how important "Energy use of the home" was to their home purchase decisions.

The two reasons eliciting significantly different responses from the SheaHomes and the comparison homebuyers did not pertain to energy features. These were "Desirability of the area" and "Reputation of the builder."

- A higher percentage of respondents from the comparison community rated "Desirability of the area" as an important reason for purchase (mean=4.58) than did those of the SheaHomes communities (mean=4.33; $t=-2.308$; $p=.022$)

- A higher percentage of SheaHomes respondents rated "Reputation of the builder" as an important reason for purchase (mean=3.96) than did comparison respondents (mean=3.57; $t=2.610$; $p=.011$).

Energy was not a very important factor in the purchase decisions for most of these new homebuyers. Average ratings of importance for all but two of the 23 listed reasons for purchase were the same for the SheaHomes and the comparison homebuyers. The reasons for purchase most frequently rated as most important by both categories of homebuyers are "Safe area/secure feeling," "Quality of neighborhood/community," "Overall home value (size and quality of home

[3]Other responses include one respondent who said the comparison home construction quality was better and one who wanted to avoid solar features. The total of the percentages does not add to 100 because of rounding.

for the price)," and "No Mello-Roos taxes." Other frequently mentioned reasons rated as important include "Investment potential," "Desirability of area," "Freeway access," and "Exterior designs." Table 14 summarizes the average rated importance of reasons for purchase and presents the percentages of SheaHomes respondents rating each reason as very important (a rating of 5 on the response scale) and of those rating each reason as at least important (a rating of 4 or 5 on the scale).

At the time they purchased their homes, SheaHomes buyers appear to have been more concerned about the homes' energy usage than were the comparison buyers. This finding suggests that homebuyers who are already concerned about residential energy use constitute a stronger market for ZEHs than those who are not. In addition, "Availability of very energy-efficient homes" (the item asked of SheaHomes respondents) is rated by them more frequently as a more important reason (mean=3.87) than is "Energy use of the home" rated by the comparison respondents (mean=3.54).[4]

Taken on the whole, the information contained in Table 14 provides additional perspective on the importance ratings assigned to 20 new-home purchase reasons[5] by homebuyers in the SheaHomes and comparison communities. Although respondents were not asked to specifically rank these various reasons, the order of the mean importance ratings, when listed high to low (ignoring the number of respondents associated with each value), is approximately the same for both homebuyer groups. In fact, the correlation between the two ordered listings is quite high and statistically significant (Spearman's Rho=.9323; $p \approx 0$). This would suggest that both homeowner groups tend to assign the same level of importance (in terms of the magnitude of the mean importance rating) to each of the 20 purchase reasons, providing some overall indication of their relative importance.

Most Important Reasons for Purchase for SheaHomes and Comparison Homebuyers

In addition to these findings, the importance of reasons for purchase was measured in another way. All respondents were asked to indicate the top three most important reasons for purchase. The 24 listed reasons for purchase were categorized into five types (shown on the questionnaires, see Appendixes A, B, C, D): (1) location, (2) financial, (3) builder, (4) community, and (5) energy. After they had responded, respondents were asked to go back over the list and indicate the three most important reasons for purchase. These responses were coded by category; results are summarized in Table 15 with percentages calculated on the number of responses in the top three choices. Location and financial reasons are far and away the most important factors in the home purchase decision. Although 23% of the SheaHomes buyers rate energy as an

---

[4]This difference cannot be tested for statistical significance because the item wording used for the two sets of respondents was not identical, although the intention of the questions was similar.

[5]Three of the new home purchase reasons listed in Table 14 are excluded from consideration here because they were rated by respondents from the SheaHomes communities only. On the other hand, a single item associated with home energy is included even though the item was not identically worded on the questionnaires completed by SheaHomes and comparison community respondents; the items are similar in meaning.

Table 14. Average Importance Ratings of Reasons for Home Purchase, Ordered by Mean Scores for SheaHomes Respondents*

Feature	Mean Score, SheaHomes Respondents	Mean Score, Comparison Respondents	SheaHomes/ Comparison Homes % Responding Very Important (5)	SheaHomes/ Comparison Homes % Responding Important or Very Important (4,5)
Safe area/secure feeling	4.67	4.74	70/80	97/96
Quality of neighborhood/community	4.58	4.52	61/63	97/93
Overall home value	4.52	4.52	58/59	93/93
No Mello-Roos taxes	4.49	4.48	64/67	87/85
Investment potential	4.35	4.35	50/52	90/83
**Desirability of area (p=.022)	*4.33*	*4.58*	*45/64*	*90/94*
Freeway access	4.07	4.04	38/35	74/76
Exterior designs	4.01	4.19	26/32	78/91
Quality of schools	3.99	4.24	52/52	70/83
Access to services, shopping, and entertainment	3.97	3.96	27/28	74/72
Closeness to work	3.96	3.98	38/33	71/72
**Reputation of builder (p=.011)	*3.96*	*3.57*	*29/23*	*73/49****
SheaHomes: Availability of very energy-efficient home Comparison homes: Energy use of the home	3.87	3.54	SheaHomes: 23 Comparison: 17	SheaHomes: 69 Comparison: 56
Helpfulness and knowledge of sales staff	3.81	3.61	25/26	64/54
Prior knowledge of area	3.8	3.57	29/30	63/54
Great view	3.71	3.66	33/36	58/55
Feeling of community spirit	3.68	3.60	22/25	60/54
The package of energy features taken together	3.56	--	14	58
Availability of solar water heating (SheaHomes only)	3.49	--	17	52
Discount or incentive	3.43	3.27	21/18	50/47
Availability of PV system (Main and PV only)	3.34	--	12	49
Closeness to friends/family members	3.29	3.13	20/19	44/40
Closeness to parks/playgrounds	3.08	3.09	12/13	34/28

*The reasons are listed in order from high to low mean scores for the SheaHomes respondent group. The comparison group's mean scores vary in order somewhat from the SheaHomes mean scores.
**Statistically significant difference in mean scores between SheaHomes and comparison respondent groups.
***$\chi 2$=12.439; p=.006.

Table 15. Three Most Important Categories of Reasons for Home Purchase, with Percentages of Responses for Buyers of SheaHomes and Comparison Homes*

Category of Reasons for Purchase	SheaHomes Responses (n=471)	Comparison Responses (n=149)
Location	48%	60%
Financial	31%	28%
Community	10%	9%
Energy	6%	0%
Builder	4%	–**
Other	–**	2%
Totals	99%***	99%***

*Responses for the three reasons are combined. SheaHomes respondents=159; Comparison home respondents=50 PV
**<.05%
***Percentages do not add to 100 because of rounding.

important decision category, none of the comparison homebuyers do so ($\chi 2$=16.505; p=.006).[6] Most of the SheaHomes buyers rating energy as important count it as their third most important reason for purchase, rather than as the first or second reason. This constitutes additional evidence that SheaHomes buyers were somewhat more concerned about energy issues than were the comparison homebuyers at the time they purchased their homes.

A $\chi 2$ analysis of the SheaHomes and comparison homes responses in Table 15, but omitting the "Other" category, results in a statistically significant difference. A higher percentage of SheaHomes buyers select "Energy" among their three most important reasons than do comparison buyers ($\chi 2$=16.4596; p=.0025).

Importance of New Home Features in Purchase Decisions

In addition to the importance of reasons for purchase relating to the area, location, builder, energy, and other factors, respondents were queried about the importance of a list of features of the home itself when they made their home purchase decisions. Based on earlier qualitative interviews and prior research, 15 features known to be important to homebuyers were identified. Consequently, all four questionnaires asked respondents to rate this set of home features on a scale of 1 to 5 (1=Not at all important and 5=Very important) with the following question: "How important were each of the following home features when you made your purchase?"

[6]Strictly speaking, the $\chi 2$ test may not be valid because there were empty cells where comparison respondents failed to include energy in their most important reasons for purchase. Nevertheless, the test shows the marked difference between the two groups of respondents on this variable.

Table 16 presents the average ratings, with features listed in descending order according to values of the mean scores associated with SheaHomes respondents. Table 16 also presents the comparative percentages of SheaHomes and comparison community respondents who rated each feature as very important, as well as the corresponding percentages of the two respondent groups who rated each feature as important *or* very important.

As is evident in Table 16, the features with the highest average importance ratings for both SheaHomes and comparison buyers are "Floor plan and layout," "Quality of construction," "Spaciousness and openness," "Size and square footage," and "Quality or sense of light." The lowest mean importance rating is associated with "Single-story option," again for homebuyers in both communities.

SheaHomes and comparison community homebuyers assign essentially the same mean importance ratings to all but three of the features: (a) quality of construction, (b) availability of a three-car garage, and (c) granite counter tops as a standard feature.

- SheaHomes respondents assign higher ratings, on average, to "Quality of construction" (mean=4.5) than do the comparison community respondents (mean=4.3). This difference nears statistical significance (t=1.903; p=.058).

- SheaHomes respondents assign higher ratings, on average, to "Availability of a three-car garage" (mean=4.02) than do the comparison community respondents (mean=3.65). This difference is statistically significant (t=2.074; p=.041).

- SheaHomes respondents assign higher ratings, on average, to "Granite counter tops as a standard feature" (mean=3.75) than do the comparison community respondents (mean=3.04).[7] Again, this difference is statistically significant (t=3.502; p=.001).

All the listed home features are important to both SheaHomes and comparison homebuyers. The differences suggest that SheaHomes buyers were particularly concerned about the quality of their new homes, a characteristic emphasized by SheaHomes, but not by the builder of the comparison homes. Granite counter tops appear to be a feature associated with higher quality and, possibly, more expensive homes, which could help account for its greater appeal to the SheaHomes buyers.

As in Table 14, the information contained in Table 16 provides additional perspective on the importance ratings assigned to the 15 new home features by homebuyers in the SheaHomes and comparison communities. Respondents were not asked to specifically rank these various features. The order of the mean importance ratings, when listed high to low (ignoring the number of respondents associated with each value), is approximately the same for both homebuyer groups. In fact, the correlation between the two ordered listings is quite high and statistically significant (Spearman's Rho=.9401; p<.0004). This suggests that both homeowner groups tend to assign the same level of importance (in terms of the magnitude of the mean importance ratings) to each of the 15 features, providing some overall indication of the relative importance of these features.

[7]Granite tile counter tops were a standard feature in the SheaHomes, but solid granite counter tops were an optional upgrade that cost on the order of an additional $10,000.

Table 16. Importance of New Home Features
Ordered by Mean Scores for SheaHomes Respondents

Feature	Mean Score, SheaHomes	Mean Score, Comparison	SheaHomes/ Comparison % Very Important	Shea Homes/ Comparison % Important or Very Important
Floor plan/layout	4.50	4.64	60/66	93/98
Quality of construction[a]	*4.50*	*4.30*	*58/46*	*94/85*
Spaciousness/openness	4.37	4.40	48/46	91/94
Size/square footage	4.36	4.30	44/35	92/95
Quality or sense of light	4.25	4.23	41/36	85/89
Number of bedrooms	4.14	4.25	32/35	84/90
Architectural design	4.10	4.17	33/42	80/79
Quiet area	4.09	4.18	37/40	77/84
Many amenities included as standard features	4.06	3.84	32/28	75/65
Three-car garage[b]	*4.02*	*3.65*	*38/29*	*74/56*
Large closets/pantries	3.95	3.73	29/23	71/60
Lot size/yard	3.83	4.09	31/38	66/79
Availability of many options	3.79	3.81	22/25	64/74
Granite counter tops as standard features[c]	*3.75*	*3.04*	*26/18*	*62/38*
Single-story option	2.52	2.17	14/6	26/17

a. $t=1.903$; $p=.058$ (nears significance); $\chi 2$ n.s.
b. $t=2.074$; $p=.041$; $\chi 2$ n.s.
c. $t=3.502$; $p=.001$; $\chi 2=23.048$; $p<.000$.

Table 16 shows that SheaHomes respondents (4.06) give a somewhat higher mean importance rating to the item "Many amenities included as standard features" than do comparison respondents (3.84), which provides support to the notion that even though SheaHomes cost less per square foot, buyers perceived them as including many desirable standard features. This was somewhat more important to them than comparison buyers, who less frequently perceived this as important relative to their home purchases. This finding suggests that SheaHomes came with more amenities than did the comparison homes, despite their lower cost per square foot.

Summary

It appears that, in terms of average ratings, the most important reasons that SheaHomes buyers decided to purchase homes at Scripps Highlands were the desirable location (including the quality of the neighborhood and the safety of the area), the financial aspects (including the overall home value, the lack of Mello-Roos taxes, and the potential for a sound financial investment); the reputation of the SheaHomes builder in offering quality homes; and the availability of energy features. The features that appeal most to SheaHomes buyers, in terms of average ratings, include the floor plans, the quality of construction, the size and openness of the homes, the spaces for bedrooms and closets, and—significantly more so than to the comparison community buyers—the availability of a three-car garage and the inclusion of granite counter tops standard. These seem to be features that buyers associate with the quality of homes.

The most important purchase reason for the comparison buyers appear to have been the location of the home, including the safety, quality, and desirability of the area. Investment potential also appears to have been important. A third reason frequently mentioned as important is the quality of the schools. The features that appeal most to the comparison buyers in terms of average importance ratings are the floor plans, the size and openness of the homes, the number of bedrooms, the size of the yards, the design, and the availability of many options.

Because SheaHomes prides itself on the quality of its homes' construction and positions its homes in the market based on quality, it is interesting that the average importance ratings assigned to construction quality as a purchase feature is significantly higher for the SheaHomes buyers than for the comparison homebuyers. The SheaHomes marketing message about quality may well be reaching the homebuying market.

Chapter 8
Solar PV Purchase Decisions

Introduction

PV owners received their own questionnaire containing a number of questions unique to owning a PV system, as well as duplicating questions asked of other categories of homeowners. In this chapter, responses of PV owners are analyzed relative to their decisions to purchase homes with solar PV systems. As was discussed in Chapter 4 (The SheaHomes Experience), most PV homeowners bought their PV systems standard. In general, they decided whether they liked the houses and purchased them more on those grounds than because they had PV systems. A minority of the PV owners opted to purchase PV systems; for these homebuyers, purchasing PV systems was a conscious choice.

In this chapter, home features important to PV owners and non-PV owners are compared and reasons for not choosing to purchase or to upgrade a solar PV system are explored. In addition, responses of main owners who did and did not have a choice to purchase PV systems are compared. A few homeowners have added solar PV since they purchased their homes; information is provided on the frequency of this. In addition, this chapter reports on stated willingness to pay for solar PV by non-PV owners in both the SheaHomes and comparison communities.

Chapter Highlights

- There are 72 PV-owner respondents in the study; the majority own 1.2-kW PV systems; 12% own 2.4-kW PV systems.
- Among respondents who were buyers of PV-eligible homes, only 44% were offered PV systems. Forty-six percent of respondents offered PV systems opted to purchase them.
- Energy items were not the most important reason for purchase for either the PV or main owners. The purchase reason with the highest mean importance rating for both categories is "Safe area/secure feeling."
- The average importance ratings of PV owners are lower than those of main owners for all home purchase reasons except for the "Availability of PV system" and "The package of energy features taken together."
- Every home feature considered has a higher average importance rating for the main purchasers than for the PV owners, suggesting that home characteristics other than energy features were more important to main homebuyers than to buyers of PV homes.
- The overall rankings of the reasons for purchase are the same, regardless of homebuyer category.
- The most frequently mentioned barriers to purchase of PV homes involve financial considerations such as initial costs and length of payback.
- The findings on willingness to pay (WTP) more for PV systems suggest that $5,000 may be a price cut-off point for 1.2-kW PV systems. More than one-third of non-PV-purchasing homebuyers indicate a WTP of at least $5,000 more for a PV system that could replace 50% to 70% of their electricity requirements. However, a 1.2-kW system will not save that much electricity.

Number of PV Homes among SheaHomes Respondents

Of the 177 SheaHomes respondents, 72 (41%) own homes with PV systems. These respondents have either standard PV systems (1.2-kW), optional PV systems (1.2-kW or 2.4-kW), or a combination (1.2-kW with an additional 1.2-kW optional upgrade).[1] Table 17 summarizes the system sizes and whether they were standard PV systems that came with the home. Among homes represented by these respondents, 72% bought solar PV systems standard. At least three of these were homes that had fallen out of escrow. A total of 28% of these respondents opted to purchase PV systems for their homes. Note that these figures are different for those reported in the section on "Sales of Homes." As described in this chapter, homes were analyzed only for SheaHomes with solar PV systems owned by study respondents.

As previously mentioned, demand for housing in San Diego was intense when SheaHomes first put up its construction trailer for the Scripps Highlands developments. The sales agents were operating in a seller's market and did not have to explain to prospective buyers the elements of the energy features of the SheaHomes to entice buyers.

Table 17. Percentages of PV Respondents with Standard and Optional PV Systems

Type of System	Percentage (n=72)
1.2-kW standard PV system (n=52)	72%
1.2-kW optional PV system (n=12)	17%
2.4-kW optional PV system (n=4)	6%
2.4-PV system (standard 1.2-kW system plus optional 1.2-kW system) (n=4)	6%
Total	101**

*Note: These percentages differ slightly from those reported in Table 8 (in Chapter 4) because these are only for study respondents and those are for all SheaHomes.
**Percentage does not add to 100 because of rounding.

As discussed in Chapter 4 (The SheaHomes Experience), not all buyers of PV-eligible homes were offered PV systems. Of the 177 SheaHomes respondents, 20 homebuyers (11.3%) (20 ÷ 177) had no opportunity to purchase PV systems because they were buyers of PV-ineligible or early homes. Eighty-five (48%) (85 ÷ 177) bought PV-eligible homes. The remaining 72 homebuyers (41%) (72 ÷ 177) purchased homes with PV systems.

Main respondents were asked: "Were you offered the option of purchasing a solar PV system at the time you bought your new home?" Eighty-two of the 85 main respondents answered, with the following results:

[1]These numbers and percentages reflect only the respondent pool of homes, whereas those discussed in Chapter 4 (The SheaHomes Experience) reflect all 306 homes at San Angelo and Tiempo.

- Yes, we were offered a PV system - 36 respondents (44%)
- No, we don't remember being offered a PV system - 45 respondents (55%)
- We were told a PV system would not be appropriate - 1 respondent (1%).

As discussed in Chapter 4, even though the builder reported that all main homebuyers (n=82) were to be offered PV systems, this apparently did not occur. Among the main respondents, 56% (46 ÷ 82) indicate that they never received an offer to purchase homes with PV systems or to upgrade PV systems; only 44% (36 ÷ 82) indicate they did receive such an offer.

This finding suggests at least two possibilities:

(1) The sales staff did not inform all of the potential purchasers of PV systems about the possibility of purchasing a PV system.

(2) Homebuyers did not recall being told about PV at the time of purchase. Perhaps the concept was unfamiliar to them, and they paid little heed to it.[2]

To speculate, both of these likely occurred during the hurly-burly of the early stages of the SheaHomes sales process. Nevertheless, it is highly unlikely that 56% would forget they were offered PV systems. In any event, if the homebuyers did not realize they had the option to purchase solar PV systems, they cannot comprise a group for analytical purposes that consciously chose whether to purchase PV systems.

Of the 82 main respondents, only 36 (44% [36 ÷ 82]) said they were offered PV systems. If we assume that the 52 PV owners were actually offered the opportunity to upgrade from 1.2-kW to 2.4-kW systems,[3] then a total of only 88 (52 + 36) of the buyers of PV standard and PV-eligible homes were given the opportunity to purchase or upgrade PV systems.

This implies that only 56% of the 157 (177-20 PV-ineligible=157) respondents who, theoretically "should have" been offered PV systems were actually offered them. It further shows that 46% (72 ÷ 157) of study respondents offered PV systems opted to purchase them. This percentage is slightly higher than the 44% uptake of PV systems among all SheaHomes buyers who were offered them as described in Chapter 4 (The SheaHomes Experience).

Because only 36 main respondents had the opportunity to purchase PV systems and subsequently chose not to purchase one, a separate analytical category for these buyers was defined. This distinction is conceptually important because main buyers could not be considered decision-makers about PV (and thus early adopters of the innovation) if they never had the opportunity to decide. The main buyers who knew about the option to purchase PV and who elected not to are

[2]These are retrospective data: the respondents were asked to think back to a purchase decision process that occurred at least six months before they completed the questionnaire. On the other hand, as previously noted, because any home-purchase decision is highly significant, recall about it is likely to be accurate.

[3]We did not collect data directly on this question.

termed main buyers who “chose not to adopt” (CNA) solar PV systems. Below, the responses of main CNAs, as well as of all main owners, are compared with those of PV owners to discern whether measurable differences exist between these two groups in their reasons for purchase.

Along these same lines, ineligible and early buyers were asked: “Which of the following statements best describes the situation regarding the availability of a solar PV system at your house?” Seventeen ineligible/early respondents answered each question by indicating whether the statement applied to them.

- “We were told a solar PV system could not be installed on our house for technical reasons.” Seventy-seven percent indicate that this statement applied to them; 23% indicate that it did not.

- “We bought a house before solar water heating and solar PV systems were available.” Thirty percent indicate that this statement applied to them; 70% indicate that it did not.

- “We purchased a house that fell out of escrow and the construction schedule prevented us from exercising the solar PV system option.” None of the respondents indicate that this statement applied to them.

Each of the first two statements is likely to be accurate. The third one is, in fact, not accurate, and none of the ineligible/early respondents indicated that this statement applied to them., suggesting a certain level of awareness at purchase time.

Factors Affecting the Decision to Purchase PV Homes

In analyses of factors affecting PV purchase decisions, only the purchase decisions of those who actually had the opportunity to purchase PV systems should be analyzed to determine the importance of the availability of PV systems in the home-purchase decision. The analysis of the purchase decisions presented here compares the following responses:

- The 72 respondents owning homes with PV systems (termed “PV owners”)
- The 85 respondents who theoretically had the opportunity to purchase PV but chose not to (termed “main” buyers).

Ineligible and early home owners are excluded from this analysis because they definitely had no option to purchase PV systems.

As described earlier, questions were asked of respondents about the importance of several purchase decision factors. As noted in Chapter 7 (New Home Search and Purchase Decision), this allowed energy features to attain the level of importance they actually had within the context of the many variables known to affect a housing purchase decision. During earlier qualitative interviews, approximately one-third of the PV owner respondents indicated that the availability of a PV system was one of the top three reasons they had purchased their homes, and it was of interest to determine whether this same opinion persisted beyond those homeowners involved in the qualitative investigation.

PV Owners Compared with Main Owners

Table 18 presents the average ratings on 23 different items from SheaHomes owners, some of whom have PV systems and some of whom do not, with the average item ratings listed in descending order according to the values associated with PV-owner respondents. For several of the 23 individual items, there are statistically significant differences in the mean responses for the two groups, and the percentage distributions of the item responses for the two groups are also significantly different. Table 18 also presents the comparative percentages of PV owners and main owners who rated each feature as "Very important," as well as the corresponding percentages of the two respondent groups who rated each feature as "Important" or "Very important."

As indicated in Table 18, the average importance ratings of PV owners are lower than those of main owners for all home purchase reasons except for some of those involving the energy package and the solar PV system. In fact, two of the energy items elicited a significantly different response for PV owners than for main owners:

- A higher percentage of respondents (69%) who purchased homes with PV systems rated "The package of energy features" as an important or very important reason for purchase than did respondents who purchased main homes (53%). In addition, the mean response was significantly higher for respondents who purchased homes with PV systems (3.75 and 3.34, respectively, with p=.043).

- A higher percentage of respondents (76%) who purchased homes with PV systems rated "Availability of a PV system" as an important or very important reason for purchase than did respondents who purchased main homes (68%). Again, the mean response was significantly higher for respondents who purchased homes with PV systems (3.60 versus 3.11, respectively, with p=.004). Obviously, in this case, such a difference would not be unexpected.

These findings suggest that, in terms of average ratings, those who purchased PV homes found the availability of energy features, and particularly the PV system itself, significantly more important than main owners.

On the other hand, there was no significant difference in response between PV owners and main owners for either of the following items: "Availability of a very energy-efficient home" and "Availability of solar water heating." This finding suggests that it was the availability of a solar electric system itself that appealed the most to those purchasing homes with PV systems. Such features appear to have been less important to buyers of main homes.

Also as shown in Table 18, other significant differences exist between PV owners and main owners with respect to the average importance ratings of reasons for purchase. For example, access to the I-15 freeway received a higher average rating (4.26) by purchasers of main homes than purchasers of homes with PV systems (3.86). Purchasers of main homes also gave significantly higher ratings to the following items: "Access to services, shopping and entertainment," "Great view," and "Feeling of community spirit." Clearly, then, in context, the solar energy features seem to have mattered somewhat more to those who purchased homes with PV systems than to those purchasing the main homes.

From a more macroscopic inspection of Table 18, it can be observed that energy items were not the most important reasons for purchase for either the PV owners or the main owners (in the sense that, for both groups, other items received higher average ratings). Although respondents were not asked to specifically rank the various reasons, the order of the mean importance ratings assigned to the individual items, when listed high to low (ignoring the number of respondents associated with each value), is approximately the same for both homebuyer groups. In fact, the correlation between the two ordered listings is quite high (Spearman's Rho = .899; $p \approx 0$). This would suggest that both PV and main owners tend to assign the same levels of importance (in terms of the magnitude of the mean importance rating) to this specific set of purchase reasons, providing some overall indication of the relative importance among them. As is evident in Table 18, the highest mean importance rating is associated with "Safe area/secure feeling" for homebuyers in both the PV and main buyer groups, and the lowest mean importance rating is associated with "Closeness to parks/playgrounds," again for homebuyers in both groups.

Most Important Reasons for Purchase for PV and Non-PV Homebuyers

In addition to these findings, the importance of reasons for purchase was measured in another way. All respondents were asked to indicate the top three most important reasons for purchase. The 24 listed reasons for purchase were categorized into five types (shown on the questionnaires; see Appendixes B, C, D, E): (1) location, (2) financial, (3) builder, (4) community, and (5) energy. After they had responded, respondents were asked to go back over the list and indicate the three most important reasons for purchase. These responses were coded by category; results are summarized in Table 19 with percentages calculated on the number of responses in the top three choices. Location and financial reasons are far and away the most important factors in the home purchase decision. Six percent of the PV owners and non-PV owner responses include "energy" among the three most important categories of reasons for purchasing their new homes. A $\chi 2$ analysis of the PV owners' and non-PV owners' responses are in Table 19, but omitting the "Other" category shows no statistically significant differences between these two groups ($\chi 2$=3.90; p=.419) on the top three most reasons for purchase.

PV Owners Compared with Main Owners Who Chose Not to Purchase PV Systems

As discussed earlier, the main buyers who had the opportunity to purchase PV and who chose not to purchase systems are termed "main CNAs." Table 20 summarizes the results of t-tests and $\chi 2$

tests measuring differences in responses regarding 23 reasons for home purchase between PV owners and main CNAs. In contrast to the findings presented in Table 21 that compared the responses of PV owners with all main owners resulting in several significant differences, these findings show only two significant differences between PV owners and the main CNAs.

Table 18. Importance Ratings of Home Purchase Reasons for SheaHomes Buyers with and without PV Systems (Ordered by Mean Scores for PV Purchasers)*

Feature	Mean Score, PV Owners (n=72)	Mean Score, Main Purchasers (n=85)	PV/Main Purchasers % Responding Very Important (5)	PV/Main Purchasers % Responding Important or Very Important (4,5)
Safe area/secure feeling	4.62	4.72	63/77	99/96
Overall home value	4.48	4.53	58/58	92/95
Quality of neighborhood/ community[a]	*4.46*	*4.70*	*52/71*	*97/99*
No Mello-Roos taxes	4.42	4.59	62/68	86/93
Desirability of area	4.27	4.40	39/51	81/93
Investment potential	4.24	4.40	47/51	86/90
Quality of schools	3.96	4.00	44/59	71/71
Exterior designs	3.94	4.11	25/29	75/82
Closeness to work	3.92	4.01	35/40	69/73
Reputation of builder	3.92	4.00	24/35	70/73
Availability of very energy-efficient home	3.89	3.91	21/27	76/68
Freeway access[b]	3.86	4.26	*28/49*	*66/81*
Access to services, shopping, and entertainment[c]	*3.83*	*4.11*	*17/35*	*72/75*
Helpfulness and knowledge of sales staff	3.79	3.87	24/28	63/67
The package of energy features taken together[d]	*3.75*	*3.43*	17/11	69/53

(Table 18 continued on next page)

Table 18. Importance Ratings of Home Purchase Reasons for SheaHomes Buyers with and without PV Systems (Ordered by Mean Scores for PV Purchasers) (concluded)

Feature	Mean Score, PV Owners (n=72)	Mean Score, Main Purchasers (n=85)	PV/Main Purchasers % Responding Very Important (5)	PV/Main Purchasers % Responding Important or Very Important (4, 5)
Prior knowledge of area	3.69	3.90	24/32	61/65
Availability of PV system[e]	*3.60*	*3.11*	*16/9*	*63/36*
Availability of solar water heating	3.54	3.52	3/21	61/52
Great view[f]	*3.46*	*3.89*	23/44	52/62
Feeling of community spirit[g]	*3.44*	*3.87*	*14/29*	*47/70*
Discount or incentive	3.40	3.51	17/27	51/53
Closeness to friends/family members	3.31	3.21	19/18	43/44
Closeness to parks/playgrounds	3.12	3.04	12/11	33/35

*See text for distinction between PV purchasers and main purchasers. The reasons are listed in order from high to low mean scores for the PV purchasers group. The main purchaser group's mean scores vary in order somewhat from the PV owners mean scores.

a. $t=2.562$; $p=.012$; $\chi2=6.610$; $p=.037$.
b. $t=2.700$; $p=.008$; $\chi2=9.629$; $p=.047$.
c. $t=2.157$; $p=.033$; $\chi2=8.163$; $p=.043$.
d. $t=-2.041$; $p=.043$; $\chi2$ test n.s.
e. $t=-2.894$; $p=.004$; $\chi2=10.893$; $p=.028$.
f. $t=2.207$; $p=.029$; $\chi2=9.350$; $p=.053$ (near significance).
g. $t=-2.684$; $p=.008$; $\chi2 =11.862$; $p=.018$.

PV owners rate the importance of the "Package of energy features taken together" in their home-purchase decisions significantly higher on average (mean=3.75) than do the main CNAs (mean=3.33) (t=2.126; p=.036). PV owners also rate the importance of the "Availability of a PV system" (mean=3.60) significantly higher, on average, than do the main CNAs (mean =2.97) (t=3.044; p=.003). The two groups do not differ significantly in the mean importance ratings they assigned to "Availability of a very energy-efficient home" or "Availability of solar water heating."

As is the case with the findings reported in Table 18, Table 20 shows the mean ratings of the main CNAs are higher, if only slightly so, for every home purchase reason except for the energy-related ones. This finding seems to indicate that the energy features were more important to the purchasers of PV homes than they were to the main CNAs, although CNAs gave a slightly higher rating of 3.56 to the availability of solar water heating than did PV owners (3.54). The lowest mean importance rating the main CNAs assigned to any of the reasons for home purchase is 2.97 for the "Availability of PV system." This is also the lowest mean rating in the entire table by either group.

Table 19. Three Most Important Categories of Reasons for Home Purchase, with Percentages of Responses for PV and Non-PV Owners*

Category of Reasons for Purchase	PV Owners Responses (n=196)	Non-PV Owners Responses (n=143)
Location	43%	52%
Financial	35%	29%
Community	10%	7%
Energy	6%	6%
Builder	6%	6%
Other	_**	_**
Totals	100	100

*Responses for the three reasons are combined. PV owner respondents=66; Non-PV owner respondents=93.
**<.05%.
***Percentages do not add to 100 because of rounding.

Despite these observations, the ordering of home features on the basis of mean ratings is approximately the same for both homebuyer groups. Although respondents were not asked to specifically rank the 23 reasons associated with a home purchase, the order of the mean importance ratings, when listed high to low (ignoring the number of respondents associated with each value), is approximately the same for both homebuyer groups. In fact, the correlation between the two ordered listings is quite high and statistically significant (Spearman's Rho=.9286; $p \approx 0$). This would suggest that both homeowner groups tend to assign the same level of importance (in terms of the magnitude of the mean importance rating) to each of the 23 purchase reasons, providing some overall indication of the relative importance of them. As is evident in Table 20, the highest mean importance rating is again associated with "Safe area/secure feeling" for homebuyers in both the SheaHomes and comparison communities, and the lowest mean importance rating is associated with "Closeness to parks/playgrounds," for PV homebuyers and "Availability of PV system" for comparison homebuyers. A similar analysis with essentially identical results was conducted on the information presented in Table 18.

Importance of Home Features in the PV Home Purchase Decision

Also as discussed earlier, respondents were queried about the importance of 15 different home features when they made their home purchases. For SheaHomes respondents, these data were analyzed with regard to PV ownership. Responses to this question were compared by PV owners versus main owners and by PV owners versus main CNAs.

PV Owners Compared with Main Owners

Every home feature listed has a higher average importance rating for the main purchasers than for the PV owners. In combination with the findings on reasons for purchase, this suggests that home characteristics other than energy features were more important to main homebuyers than to the buyers of high-performance homes with PV systems at the time of the home purchases.

Table 21 presents the average ratings, with features listed in descending order according to the values of the mean scores associated with PV-owner respondents. Table 21 also presents the comparative percentages of PV owners and main owners that rated each feature as very important, as well as the corresponding percentages of the two respondent groups that rated each feature as important or very important.

As indicated in Table 21, main owners assigned higher average importance ratings to all 15 of the home features than did PV owners. This difference is statistically significant for eight of the home features: “Floor plan/layout,” “Size/square footage,” “Quality or sense of light,” “Quiet area,” “Number of bedrooms,” “Architectural design,” “Large closets/pantries,” and “Availability of many options.” In addition, a ninth feature—“Many amenities included as standard features”—was assigned an average importance rating that is nearly significantly different between the two categories of homeowners. There are corresponding differences in the percentage distributions of responses for the two home groups for these same items. The main owners are apparently more enthusiastic, on whole, about these features of their new homes than are the PV owners.

Although respondents were not asked to specifically rank the various home features, the order of the mean importance ratings, when listed high to low (ignoring the number of respondents associated with each value), is somewhat different for the PV and main owner groups. In fact, the correlation between the two ordered listings is only moderately positive (Spearman’s Rho=.58; p=.0294). This would suggest that the two homeowner groups tend to assign different relative levels of importance (in terms of the magnitude of the mean importance rating) to the 15 features. In fact, differences in the orderings are readily apparent. PV owners assign the highest average importance ratings to “Quality of construction,” “Spaciousness and openness,” and “Floor plan/layout,” in that order, whereas main owners assign the highest average importance ratings to “Floor plan/layout,” “ Quality of construction,” and “Size/square footage,” in that order. In addition, the average importance rating given by PV owners to “Three-car garage” is sixth highest, whereas the average rating given to this feature by main owners is eleventh highest. In combination with the findings on reasons for purchase, these additional findings about the importance of home features suggest that home characteristics other than energy features are more important to purchasers of homes without PV systems.

PV Owners Compared with Main Owners Who Chose Not to Purchase PV Systems

The findings underscore the differences between those consciously choosing not to purchase homes with PV systems from those choosing PV homes. The new home features were, on average, less important to the PV owners than to the main CNAs at the time of purchase.

Table 22 summarizes the results of t-tests and $\chi 2$ analyses measuring differences in responses about the importance of the 15 home features between PV owners and main CNAs.

Table 20. Importance Ratings of Home Purchase Reasons for SheaHomes Buyers with and without PV Systems (Ordered by Mean Scores for PV Purchasers)[a]

Feature	Mean Score, PV Owners (n=72)	Mean Score, Main CNAs (n=36)	PV/Main CNAs % Responding Very Important (5)	PV/Main CNAs % Responding Important or Very Important (4, 5)
Safe area/secure feeling	4.62	4.79	63/79	99/100
Overall home value	4.48	4.53	58/59	92/97
Quality of neighborhood/ community[b]	*4.46*	*4.68*	52/68	97/100
No Mello-Roos taxes	4.42	4.62	62/71	86/91
Desirability of area	4.27	4.44	39/47	81/97
Investment potential	4.24	4.53	47/62	86/91
Quality of schools	3.96	4.21	44/65	71/77
Exterior designs	3.94	4.24	25/32	75/91
Closeness to work	3.92	4.15	35/39	69/83
Reputation of builder	3.92	4.06	24/36	70/79
Availability of very energy-efficient home	3.89	3.88	21/24	76/68
Freeway access	3.86	4.24	28/50	66/79
Access to services, shopping, and entertainment	3.83	4.09	17/35	72/77
Helpfulness and knowledge of sales staff	3.79	3.97	24/35	63/66

(Table 20 continued on next page)

Table 20. Importance Ratings of Home Purchase Reasons for SheaHomes Buyers with and without PV Systems (Ordered by Mean Scores for PV Purchasers)[a] (concluded)

Feature	Mean Score, PV Owners (n=72)	Mean Score, Main CNAs (n=36)	PV/Main CNAs % Responding Very Important (5)	PV/Main CNAs % Responding Important or Very Important (4, 5)
The package of energy features taken together[c]	*3.75*	*3.33*	17/9	69/46
Prior knowledge of area	3.69	3.85	24/32	61/68
Availability of PV system[d]	*3.60*	*2.97*	*16/6*	*63/24*
Availability of solar water heating	3.54	3.56	13/21	61/47
Great view	3.46	3.76	23/38	52/56
Feeling of community spirit	3.44	3.82	14/29	47/65
Discount or incentive	3.40	3.45	17/29	51/45
Closeness to friends/family members	3.31	3.16	19/16	43/41
Closeness to parks/playgrounds	3.12	3.12	12/12	33/30

a. See text for distinction between PV purchasers and main CNAs. The reasons are listed in order from high to low mean scores for the PV purchasers group. The main CNA mean scores vary in order somewhat from the PV owners mean scores.
b. $t= -1.949$; $p=.055$ (nears significance)
c. $t=2.126$; $p=.036$; $\chi2$ test n.s.
d. $t=3.044$; $p=.003$; $\chi2=14{,}420$; $p=.006$

Main CNAs give a higher mean rating to all 15 of the new home features than do the PV owners, suggesting that these features were more important to them than they were to the PV owners at the time they were deciding on which homes to buy. Seven of these differences in mean ratings are statistically significant. (Recall that there are 10 significant differences in Table 21, which compares PV owners to *all* main owners.) On average, main CNAs assign higher importance ratings to “Floor plan/layout” (mean=4.78) than do PV owners (mean=4.25). They also assign higher importance ratings, on average, to “Quality or sense of light” (mean=4.46) than do PV owners (mean=4.10), as well as to “Architectural design” (CNA mean=4.36 compared with PV owners mean=3.90), “Many amenities included as standard as standard features” (CNA mean=4.25 compared with PV owners mean=3.82), “Large closets/pantries” (CNA mean=4.31 compared with PV owners mean=3.73), “Availability of many options” (CNA mean=4.17

compared with PV owners mean=3.59), and "Granite counter tops as a standard feature" (CNA mean=4.03 compared with PV owners mean=3.59).

The feature that was most frequently rated as not important (1 or 2 on the 5-point importance scale) was the single-story option. Buyers who considered this option as important might have bought elsewhere because the number of single-story homes available was small.

Despite these observations, the ordering of home features on the basis of mean rating is approximately the same for both homebuyer groups. Although respondents were not asked to specifically rank these 15 features, the order of the mean importance ratings, when listed high to low (ignoring the number of respondents associated with each value), is not much different overall between the PV and CNA owner groups. In fact, the correlation between the two ordered listings is quite high and statistically significant (Spearman's Rho=.8565; p=.0014). This would suggest that both homeowner groups tend to assign the same level of importance (in terms of the magnitude of the mean importance rating) to each of the 15 features, providing some overall indication of the relative importance of these features. A similar analysis with essentially identical results was conducted on the information presented in Table 21.

Barriers to Purchasing Homes with Solar PV Systems

As already discussed above, buyers of homes classified as main respondents who were aware that they had an option to purchase homes with solar PV systems, but chose not to. A key study question was to determine why this is the case. It is particularly relevant because the cost of the PV systems offered by SheaHomes at Scripps Highlands was $6,000 for a 1.2-kW system and $10,000 for a 2.4-kW system—far lower than normal market prices. These low prices were made possible by the subsidies provided by the California Energy Commission (CEC) for the installation of grid-tied residential and commercial PV systems at the time Scripps Highlands was built. Although, in this case, these subsidies went to the builder rather than to the homebuyers (a situation of which the buyers may have been unaware), their effect was shown in the prices that SheaHomes charged for these systems.

Main respondents who were aware of the PV option were asked: "To what extent do you agree with each of the following potential reasons for your decision not to purchase a solar PV system?" A list of 13 reasons was presented; these reasons were based on the literature and qualitative research. The response categories comprised a 5-point Likert scale in which 1=Strongly disagree and 5=Strongly agree. Table 23 summarizes the responses to this question in order of percentages of agreement with statements.

The major barriers appear to be that potential PV purchasers believed at the time of home purchase that the system was too expensive (84%) and that payback would be too long (59%). They appear to have been reasonably certain of their views on this. Pluralities indicate that they were concerned about maintenance issues (49% agreeing and 26% indicating they were unsure) and were unsure about the reliability of the system (36% agreeing and 39% indicating they were unsure).

Table 21. Importance of New Home Features to Buyers in SheaHomes Communities with and without PV Systems (Ordered by Mean Scores for Purchasers of Homes with PV Systems)*

Feature	Mean Score, PV Owners (n=72)	Mean Score, Main Purchasers (n=85)	PV/Main Purchasers % Very Important	PV/Main Purchasers % Important or Very Important
Quality of construction	4.41	4.60	52/65	92/95
Spaciousness/openness	4.27	4.48	39/57	90/92
Floor plan/layout[a]	*4.25*	*4.67*	*45/69*	*86/99*
Size/square footage[b]	*4.17*	*4.47*	*32/51*	*86/96*
Quality or sense of light[c]	*4.10*	*4.42*	*31/52*	*82/90*
Three-car garage	3.99	4.17	31/46	72/80
Quiet area[d]	*3.93*	*4.26*	*25/48*	*73/82*
Number of bedrooms[e]	*3.90*	*4.26*	*18/39*	*75/89*
Architectural design[f]	*3.90*	*4.28*	*23/41*	*73/87*
Many amenities includes as standard features[g]	*3.82*	*4.25*	*21/43*	*63/83*
Large closets/pantries[h]	*3.73*	*4.19*	*19/41*	*64/80*
Lot size/yard	3.73	3.82	28/31	62/66
Availability of many options[i]	*3.59*	*3.92*	13/28	66/72
Granite counter tops as standard feature[j]	*3.59*	*3.95*	17/35	56/70
Single-story option	2.34	2.73	10/19	19/33

*See text for distinction between PV purchasers and main purchasers.

a. $t = -3.649$; $p < .000$; $\chi 2 = 13.969$; $p = .007$
b. $t = -2.946$; $p = .004$; $\chi 2 = 10.463$; $p = .034$
c. $t = -2.816$; $p = .006$; $\chi 2 = 8.611$; $p = .035$
d. $t = -2.401$; $p = .018$; $\chi 2 = 8.044$; $p = .045$
e. $t = -3.121$; $p < .002$; $\chi 2 = 11.255$; $p = .010$
f. $t = -3.109$; $p = .002$; $\chi 2 = 10.277$; $p = .016$
g. $t = -3.458$; $p = .001$; $\chi 2 = 11.491$; $p = .009$
h. $t = 3.437$; $p = .001$; $\chi 2 = 11.745$; $p = .019$
i. $t = -2.487$; $p = .024$; $\chi 2$ test n.s.
j. $t = 2.284$; $p = .024$; $\chi 2$ test n.s.

Table 22. Importance of New Home Features to PV Owners and Main CNAs (Ordered by Mean Scores for Purchasers of Homes with PV Systems)*

Feature	Mean Score, PV Owners (n=72)	Mean Score, Main CNAs (n=36)	PV/Main CNAs % Very Important	PV/Main CNAs % Important or Very Important	PV/CNA % Not at All Important or Not Important
Quality of construction	4.41	4.57	52/63	92/93	8/6
Spaciousness/openness	4.27	4.47	39/57	90/92	10/8
Floor plan/layout[a]	*4.25*	*4.78*	*45/78*	*86/100*	*4/0*
Size/square footage	4.17	4.36	32/44	86/92	14/8
Quality or sense of light[b]	*4.10*	*4.46*	*31/51*	*82/94*	*18/6*
Three-car garage	3.99	4.22	31/47	72/83	4/6
Quiet area	*3.93*	*4.20*	*25/40*	*73/80*	*27/20*
Number of bedrooms	3.90	4.17	18/33	75/86	25/14
Architectural design[c]	*3.90*	*4.36*	*23/47*	*73/89*	*27/11*
Many amenities included as standard features[d]	*3.82*	*4.25*	*21/42*	*63/83*	*37/17*
Large closets/pantries[e]	*3.73*	*4.31*	*19/47*	*64/86*	*7/3*
Lot size/yard	3.73	3.69	28/22	62/61	13/11
Availability of many options[f]	*3.59*	*4.17*	13/33	66/83	8/0
Granite counter tops as a standard feature[g]	*3.59*	*4.03*	17/47	56/69	11/8
Single-story option	2.34	2.80	10/20	19/37	69/49

*See text for distinction between PV owners and main CNAs.

a. $t = -4.240$; $p < .001$; $\chi 2 = 12.023$; $p = .017$
b. $t = -2.432$; $p = .017$; $\chi 2$ n.s.
c. $t = -2.910$; $p = .004$; $\chi 2 = 8.507$; $p = .037$
d. $t = -2.725$; $p = .008$; $\chi 2 = 7.112$; $p = .068$ (nears significance)
e. $t = -3.302$; $p = .001$; $\chi 2 = 11.604$; $p = .021$
f. $t = -3.489$; $p = .001$; $\chi 2 = 11.281$; $p = .024$
g. $t = -2.063$; $p = .042$; $\chi 2 = 12.714$; $p = .013$

Majorities of these main respondents disagree that "Energy is not that important" (79%), that the system "would negatively affect resale value" (70%), and that they "Did not like how the system looks" (57%). In general, main respondents who did not opt for PV systems indicate they were unsure whether homeowner insurance premiums would increase, property taxes would increase, or that the system could become outdated technologically. Sixty percent agree or are unsure whether they knew enough to evaluate the PV system option.

After living in their homes for six months or more, a majority of main respondents are less sure than they were at the time of home purchase that they made the right choice in not adopting the PV systems, or they now wish they had purchased PV systems. The questionnaire for main respondents asked: "Do you now wish you had chosen to purchase a solar PV system at the time you purchased your home?" Fifteen percent indicate that they wish they had purchased PV systems at the time they purchased their homes. Five percent say they wish they had purchased 2.4-kW systems for $10,000, and 11% say they wish they had purchased 1.2-kW systems for $6,000. Forty-four percent are unsure, whereas 40% say they do not wish they had purchased PV systems, thereby underscoring their original decision. We speculate that these buyers might have been comparing notes with their neighbors on utility bills. Of course, if these buyers had opted for PV systems, it would have affected the rate of uptake of PV systems.

Barriers to Purchasing Optional Upgrades to 2.4-kW PV Systems

The uptake rate was also affected by perceived barriers. Respondents who purchased homes that came with standard 1.2-kW solar PV systems were asked: "Why did you decide at the time not to purchase or upgrade to a 2.4-kW solar PV system (24 panels)?" Six response categories were provided, and 50 of the relevant 52 homebuyers responded. Table 24 summarizes the responses. The issue of expense is mentioned most frequently (by 36% of those responding), as is lack of knowledge about the level of system performance to expect (by 34%). An issue related to expense is that 28% say they wanted to select other options for the houses, and upgrading the PV systems was a trade-off they did not want to make. Approximately one-fifth of those responding say that they would have wanted to upgrade, but they missed making the decision in time to meet the tight construction schedule that SheaHomes was following. A few say they were unsure where the larger systems would be placed on their roofs. Sixteen percent of the respondents were unaware that the 2.4-kW option was available. Table 24 summarizes the responses to this question.

Adding PV Systems after Home Purchase

Owners of homes with solar PV systems were asked: "Have you added on to your solar PV system since you moved into your house?" Main homeowners and ineligible/early homeowners were asked: "Have you added a solar PV system since you moved into your house?" Of the 115 responding to the first question, two respondents—one PV owner and one owner of a main home—indicate that they have added a PV system to their homes. The PV owner indicates that

12 panels of PV totaling 1.44 kW were added.[4] The main owner indicates that five panels were added; the owner does not specify the number of kW. It is probable, given the system's size, that these panels are for a solar thermal pool-heating system and were erroneously identified as solar PV systems.

Sixteen percent of the respondents, although they have not added on to their PV systems, state: "No, but we have thought about it." Eighty-two percent indicate: "No, we haven't considered it."

Table 23. Percentages of Main Respondents Identifying Reasons for Not Opting for PV Systems*

Statements	% Agree or Strongly Agree	% Unsure or Neutral	% Disagree or Strongly Disagree	Totals %
It was too expensive	84	16	–	100
Payback would be too long	59	32	8	99**
Concerned about maintenance issues	49	26	26	101**
Unsure about the reliability of system	36	39	25	100
Wanted other options instead	29	55	16	100
Didn't know enough to evaluate system	22	38	41	101**
Thought property taxes would increase	20	46	34	100
Could become outdated technologically	16	43	41	100
Didn't know where it would go on the roof	15	28	58	101**
Did not like how the system looks	14	29	57	100
Thought homeowners insurance premium would increase	6	53	41	100
Thought it would negatively affect resale value	3	28	70	101**
Energy is not that important	3	18	79	100

*n's vary for each item from 34 to 38 responses. Items are listed in order of percentages of agreement with each statement.
**Percentages do not add to 100 because of rounding.

[4]The owner may have meant either that the added panels produce 1.2 kW or that the total system produced 2.4 kW.

Table 24. Percentages of PV Owners Citing Barriers to Purchase of Larger (2.4-kW) Solar PV System (n=50)

Barriers	Percentage of Buyers of Homes with Standard 1.2-kW PV Systems
Thought it was too expensive to upgrade	36
Didn't know what level of performance to expect	34
Wanted other options for the house instead of solar PV system upgrade	28
Missed the cut-off date in the construction schedule	22
Wasn't sure where it would go on the roof	16
Didn't know a 2.4-kW system was available	16

Stated Willingness to Pay More for Solar PV on the Part of Owners of SheaHomes without PV Systems and Comparison Homebuyers

All respondents in the study except owners of homes with PV systems were asked:

> "If it had been available as an option when you bought your home, what is the most you would have been willing to pay for a solar PV system that could replace 50% to 70% of your electricity requirements (depending on the way your household uses electricity)?"

Response categories ranged from "Nothing more" to "More than $11,000." Results are shown in Table 25, categorized by homebuyer category. A little more than one-third of each homebuyer type states a willingness to pay between $5,000 and $11,000 for PV systems. This is within the range of the costs of the PV options charged by SheaHomes. However, more than half of the comparison buyers (56%) and 42% of the ineligible/early buyers indicate they would have been willing to pay less than $5,000; the PV systems would have been too expensive for them. In addition, one in five of the ineligible/early buyers state they would have been willing to pay nothing more, an even higher percentage of 11% of main buyers and 10% of comparison buyers. Interestingly, more than one-third of the main CNAs appear to indicate they would be willing to pay the cost of solar PV systems (35% respond that they would pay at least $5,000 for a system). This suggests a kind of cut-off point in price at around $5,000 for a 1.2-kW PV system.

In all, then, more than one-third (ranging from 34% to 37%) of the homebuyers analyzed indicate they were willing to pay at least $5,000—approximately $1,000 less than the amount that the solar PV systems cost at the time the homes were purchased.

Table 25. Stated Willingness to Pay for PV Systems, Percentages of Main, Ineligible/Early, and Comparison Homebuyers

Stated Amount Willing to Pay	Main % (n=38)	Ineligible/Early % (n=19)	Comparison % (n=50)	Total % (n=107)
≤$4,999	55	42	56	53
$5,000–$6,999	24	32	14	21
$7,000–$8,999	8	0	6	6
$9,000–$10,999	0	5	14	8
≥$11,000	3	0	0	1
Nothing more	11	21	10	12
Totals	101*	100	100	101*

*Does not add to 100 because of rounding.

The comparison and ineligible/early respondents were asked an open-ended question regarding the amount they stated as willing to pay (or not pay) for solar PV systems. Volunteered responses were coded. Nine ineligible/early respondents discuss reasons having to do with inadequate or prolonged payback from PV system purchases. Thirty-nine comparison respondents mention the following ideas:

- Payback (56% mentioning)
- PV should have been standard equipment (26%)
- Unsure whether PV works well (13%)
- Better for environment and utilities (10%).

The economics of the PV system purchase—including original cost and payback—is as important a barrier for the comparison and ineligible/early respondents as it is for the main respondents. These findings suggest that these respondents would not have purchased solar PV systems, even if the opportunity had existed, unless they had been standard equipment.

Summary

A lack of knowledge of the PV option and sufficient information seems to have impeded homebuyers from purchasing PV systems.

A majority of 56% of the respondents who could have purchased PV homes were not given the opportunity. Comparison homebuyers were unaware of the energy features SheaHomes offered them.

A separate analytical category of main respondents who had the opportunity to purchase PV systems (n=36) was identified and termed main CNAs (for those who "chose not to adopt"). The comparison of responses of PV owners with main CNAs showed that PV owners rate the importance of the availability of the package of energy features and of PV systems as more important, on average, than do the CNAs, except for solar water heating.

When comparing important reasons for purchase between PV and main owners (as a group), in terms of average ratings, those who purchased PV homes identified the availability of energy features and, particularly, the PV system itself, as important reasons for purchase.

The most frequently mentioned barriers to purchase of PV homes involve financial considerations: the initial expense was considered too high and the perceived payback period was perceived as too lengthy.

More than one-third of each category of homebuyer, including comparison homebuyers, indicated a stated willingness to pay (WTP) at least $5,000 more for a solar PV system that could replace 50% to 70% of the respondents' electricity requirements. However, the economics of the PV system purchase remains an important barrier. The findings suggest that $5,000 may be a cut-off point in price for a PV system because majorities of main CNAs and comparison buyers indicate WTP at or below $5,000. Yet if the prices were rolled into the cost of new homes and the PV systems came standard, these decisions would not need to be directly weighed.

Chapter 9
Knowledge and Information

Introduction

The new-home market was sizzling in San Diego when the SheaHomes and comparison home developments were planned and built. In 2001, any new development stimulated significant interest, and this was particularly the case with a new development offering homes with innovative solar features located in one of the most desirable locations in northern San Diego.

The research sought to identify the ways in which high-performance homeowners and comparison homebuyers learned about the homes they ultimately bought and how satisfied they were with the information they received, especially on innovative energy features. It also measured how satisfied homeowners were with the response of the two different builder staffs to problems immediately after move-in. Another area of inquiry was the level of knowledge that high-performance homeowners had before they bought their homes and after living in them. An additional area of focus was the information sources used by PV owners, their level of knowledge about PV when they made PV purchase decisions, and PV attributes they learned about since living with their systems.

Chapter Highlights

- Majorities of SheaHomes and comparison buyers first learned about the homes they purchased by driving past the property.
- Seventy-eight percent of SheaHomes and 67% of comparison buyers indicate they were fairly to very satisfied with the information provided by the builders' sales staffs.
- SheaHomes buyers are significantly more satisfied with the builder's response to problems after move-in than are comparison buyers.
- SheaHomes buyers were, at the time of home purchase, significantly more informed than comparison buyers about energy efficiency and solar features.
- PV owners, after having lived in their homes for at least 6 months, are significantly more informed about energy efficiency and solar features than are non-PV owners.
- The single most important source of information on PV systems for new homebuyers is the builder sales staff.
- Majorities of PV owners indicate that, since living with their PV systems, they have learned about utility bill savings, financial incentives, and how PV systems work.

How Buyers First Heard about the SheaHomes and Comparison Communities

SheaHomes buyers—in particular PV homebuyers—relied more heavily on word of mouth through personal connections than did other buyers. The qualitative interviews with SheaHomes buyers showed that several homeowners had prior efficiency features and solar energy systems or knew people who had. Personal knowledge about these technologies appeared to contribute to their awareness of and interest in the SheaHomes communities.

SheaHomes respondents were asked, “How did you first hear about SheaHomes’ Scripps Highlands development?” and comparison respondents were asked, “How did you first hear about [the comparison home] development?” Table 26 shows the pattern of responses.

Buyers in both developments heard about the homes in similar ways. More of the SheaHomes buyers (62%) than the comparison buyers (52%) saw physical evidence that a new development was going up at Scripps Highlands (a construction trailer and a billboard). Comparison buyers were more likely to have heard about their new homes from real estate agents or brokers (17%)

Table 26. How Buyers First Heard about the Homes They Purchased*

Information Source	% SheaHomes Buyers (n=175)	% Comparison Buyers (n=52)
Drove by and saw flags, signs, or construction trailer	62	52
Heard about it from friends/relatives/acquaintances	21	20
Real estate agent or broker (volunteered)	3	17
Saw an ad in the newspaper	6	4
Saw it on the Internet	2	7
Had previous experience with the builder	3	–
Other	3	–
Totals	100	100

*Although a $\chi 2$ test resulted in a significant difference ($\chi 2$=12.183; p=.032), the test is not valid because there are two empty cells in the matrix

than were SheaHomes buyers, whereas 3% of SheaHomes buyers—and no comparison buyers—had previous experience with the builder offering the new homes.

The pattern of findings is similar between the buyers of homes with PV systems and homes without them (see Table 27). PV owners are slightly more likely to have heard about the developments by word-of-mouth than are non-PV owners and comparison buyers. PV owners are also slightly more likely to have read about the developments in the newspaper than are the other categories of buyers. To conjecture, these buyers might have been attracted by the rather extensive media coverage attending the launch of the SheaHomes San Angelo and Tiempo developments.

The demand for housing in San Diego was so high that even the appearance of a construction trailer caused an influx of customer contacts. As mentioned in Chapter 4 (The SheaHomes Experience), SheaHomes received so many customer inquiries that they decided to hold a lottery for prospective buyers; those winning the lottery had the first opportunities to select their building lots, floor plans, and other options.

Table 27. How SheaHomes Buyers First Heard about the Homes They Purchased, by PV Ownership*

Information Source	% PV Owners (n=71)	% Non-PV Owners (n=104)
Drove by and saw flags, signs, or construction trailer	55	66
Heard about it from friends/relatives/acquaintances	25	18
Saw an ad in the newspaper	10	4
Other	6	7
Had previous experience with the builder	3	3
Saw it on the Internet	1	2
Totals	100	100

*These results are not significantly different

Satisfaction with Information Provided by Builder Staff

Buyers in both communities indicate a fairly high level of satisfaction with the information that staff provided to them to support their home purchase decisions.

All respondents were asked: "How satisfied were you with the performance of the [SheaHomes] [comparison home] staff in providing you with accurate and adequate information to assist you in your home purchase decision?" Again, respondents were asked to respond on a 10-point scale, where 1=Not at all satisfied and 10=Very satisfied.

A majority of both SheaHomes and comparison buyers give a rating of 7 or higher on the 10-point scale (78% of SheaHomes and 69% of comparison home buyers). Forty-four percent of the SheaHomes buyers indicate that they are very satisfied (a rating of 9 or 10 on the scale), whereas only 32% of the comparison buyers give ratings that high. When a t-test is run, the mean score for the SheaHomes respondents is 7.77 and for the comparison respondents is 7.26; this difference in mean scores is not statistically significant.

Satisfaction with Staff Response to Problems after Move-in

The homebuyers were also asked to rate the responsiveness of the builder staff once they had moved into their new homes. The query was: "How satisfied were you with the performance of the (SheaHomes) (comparison home) staff in responding to problems and concerns after you moved in?" A 10-point response scale, from 1=Not at all satisfied to 10=Very satisfied, was provided. Findings show that although a majority of buyers in both developments give a positive rating, SheaHomes buyers more frequently give a positive rating of 7 to 10 on the scale (71%) than do the comparison respondents (56%). On the other hand, double the percentage of the comparison buyers (30%) give a negative rating of 1 to 4 on the 10-point scale, indicating that they are not very or not at all satisfied, compared with 15% of the SheaHomes buyers rating staff response that low. The mean scores are 7.34 for the SheaHomes buyers and 6.3 for the comparison buyers, a statistically significant difference (t=2.572; p=.011).

Satisfaction with Staff Information on Energy Features among SheaHomes Buyers

SheaHomes buyers were asked to rate how well the staff provided information on the energy features of the homes. The question was: "How satisfied were you with the performance of the SheaHomes staff in providing information on the energy efficiency and solar energy aspects of your home?" Again, the 1-to-10 response scale was provided, where 1=Not at all satisfied and 10=Very satisfied. A majority of each SheaHomes buyer type gives a rating from 7 to 10 on the scale (PV=67%, main=73%, and ineligible/early=60%). The mean satisfaction ratings are 7.34 for PV buyers, 7.31 for main buyers, and 6.55 for ineligible/early buyers. There is a slight indication that some of the ineligible/early and PV buyers may have wanted more information than they received on the energy efficiency and solar features of their new homes.

How Informed Buyers Were about Energy Efficiency and Solar Energy When Looking for New Homes

Although SheaHomes owners were more informed on energy features than comparison owners, PV purchasers were not more well-informed than non-PV purchasers. All respondents were asked: "When you were looking for your new home, how well informed would you say you were about energy efficiency and solar energy features?" Responses were requested on a 10-point scale, with 1=Not at all informed and 10=Very informed. Responses to this question were analyzed by the homebuyer categories. A t-test was used to compare how informed the SheaHomes and comparison buyers say they were at the time they were shopping for their homes.

On the 1-to-10 scale, the mean rating for the SheaHomes respondents is 5.73 and for the comparison respondents is 4.81 (t=2.44; p=.015). Thus, the average rating assigned by SheaHomes buyers is significantly higher than the average rating assigned by comparison home buyers, suggesting that SheaHomes buyers were more informed about energy efficiency and solar features at the time they were shopping for new homes.

The responses to this question were also analyzed by PV system ownership among the SheaHomes owners. No significant differences are found in the mean responses of these two groups. PV owners' mean score on how well informed they were at time of purchase is 5.77, compared with a mean score of 5.69 for non-PV purchasers.[1]

---

[1]The non-PV purchasers discussed in this chapter are all SheaHomes owners who did not purchase a PV system, whether they knew about them or not, and whether they were available to them or not. These analyses remain to be done for main CNAs.

How Informed Buyers Are about Energy Efficiency and Solar Energy after Living in New High-Performance Homes

Living in a PV home apparently enhances knowledge and awareness of energy efficiency and solar energy more than living in a high-performance home without PV. To measure whether living in high-performance homes for at least 6 months had increased their awareness of energy efficiency and solar features, SheaHomes respondents were asked: "How well informed would you say you are now?"[2] Responses were requested on a 1-to-10 scale where 1=Not at all informed and 10=Very informed. The responses to this question were analyzed by PV system ownership among the SheaHomes owners.

When PV owners and non-PV owners were asked about how informed they are now, significant differences emerge. Those who lived in PV homes for at least 6 months more frequently rate themselves as more informed about energy efficiency and solar features than do those living without PV systems. PV owners respond with a mean score of 7.63, whereas the mean score for non-PV owners is 7.13. This difference nears statistical significance (t=1.714; p=.088). When the responses are subjected to $\chi 2$ analysis, the difference between PV and non-PV owners is highly significant (p=.014). Table 28 presents the findings, which show that *the percentage of PV owners indicating that they are informed to very informed is more than double (at 77%) the percentage at the time of purchase (37%)*. The percentage of more-informed non-PV owners is higher as well (64% compared with 37% at time of purchase), indicating that—although PV owners believe they have learned a good deal about energy features by living in their high-performance homes—non-PV owners have also become more informed about energy efficiency and solar energy since living in their SheaHomes. Nevertheless, a significantly higher percentage of PV owners have become more well informed than non-PV owners on energy efficiency, solar water heating, and solar PV systems since living in their homes.

Most Important Information Source on PV Systems

PV owners were asked: "Who was the single most important information source of information on your solar PV system?" Table 29 summarizes the findings.

Far and away, the SheaHomes sales staff was the most important source of information on PV systems for buyers of SheaHomes than any other source and, indeed, than all other sources put together. The sales staff role was apparently pivotal in the PV purchase decision, as was noticed by direct observation, as well as documented by these survey findings. In fact, the sales staff controlled whether the PV system was even offered to the homebuyers.

---

[2]This question was not asked of comparison buyers because they did not have the experience of living in a high-performance home.

Table 28. Percentages of PV and Non-PV Owners Indicating Knowledge Levels about Energy Efficiency and Solar Energy before and after Buying Their Homes

Response	% PV Owners (n=71)		% Non-PV Owners (n=104)	
	Then	Now*	Then	Now*
Not at all informed/not very informed (1-4)	28	10	28	4
Moderately informed (5-6)	35	13	36	32
Informed/very informed (7-10)	37	77	37	64
Totals	100	100	101**	100

*Statistically significant difference ($\chi 2=12.515$; $p=.014$).
**Does not add to 100 because of rounding

Table 29. Single Most Important Information Source on PV Systems

Most Important Information Source on PV System	% PV Owners (n=69)
SheaHomes sales staff	61
AstroPower	16
Shea University	9
Friends, acquaintances, colleagues, personal network	7
Other	4
San Diego Gas and Electric Company	3
Total	100

Channels of Information on the Solar PV System

PV owners had difficulty getting information about their systems. A fact sheet on solar PV prepared by AstroPower, Inc., was available at the SheaHomes Sales Center in a plastic holder mounted on the wall. AstroPower, Inc., also prepared an operations manual for PV owners, although qualitative research suggested that not all PV owners received one. SheaHomes and AstroPower, Inc., maintain Web sites that homebuyers could use to gather information on solar PV systems. A portion of the PV owners, but not all, received a video about the AstroPower solar PV system.

PV owner respondents were asked: "Have you used any of the following to learn about the way your solar PV system operates?" A list of four possible responses was provided. The 52 respondents to this question most frequently check off the fact sheet about the solar PV system

(58%), followed by the operating manual for the PV system (54%), the Internet (27%), and the video on operations and maintenance (23%).

These findings and others suggest that it was not easy for homeowners to get information about their PV systems. Respondents in this study contacted researchers at NREL to request more information about their systems and how they operated. This occurred frequently enough that eventually the research staff sent a letter to the PV owners listing the names and contact information of organizations (such as SheaHomes customer service and AstroPower, Inc.) that PV owners could contact for reliable PV system information.

Qualitative field work also made it clear that no information on owning and operating a PV system was made available at "Shea University" classes. These classes, held in neighborhood garages on Saturday mornings, were designed to orient new SheaHomes buyers to their new homes and how they operated. Based on researcher observation and questioning, the instructors at Shea University were not trained in the energy features of the high-performance homes; therefore, they did not mention them in the Saturday morning orientation sessions.

Informed Decision-Making about PV Ownership and Upgrades?

PV home purchasers were, on average, not more informed than non-PV home purchasers about solar PV systems. One hundred sixty-four buyers of SheaHomes had the opportunity to make decisions about PV systems.[3] If homes came with 1.2-kW systems standard, the buyers supposedly had the option of upgrading to a 2.4-kW system. If the homes were PV-eligible, the buyers supposedly had the option of installing a 1.2 or a 2.4 PV system. The study explored how well informed the SheaHomes buyers felt they were in making the PV purchase decisions.

The question asked was: "How well informed did you feel you were about the solar PV system at the time of purchase? Did you know enough to make an informed decision about adding one to your home or upgrading the one that came with your home?" The 1-to-10 response scale was used, with 1=Not at all informed and 10=Very informed. Interestingly, there is no significant difference among the various categories of SheaHomes buyers in their assessment of how informed they were about energy features when shopping for their homes.

Among these categories of homes, the mean score for PV owners is 5.9 and for main CNAs is 6.66, not significantly different. A slightly, but not significantly, higher percentage (63%) of main CNAs rate their knowledge levels about PV as 7 to 10 on the 10-point scale. Only 43% of PV owners assign a rating this high.

[3]As discussed in detail in Chapter 4 (The SheaHomes Experience), of 306 homes, 46 were PV-ineligible; 96 came with 1.2-kW systems, the buyers of which could choose to upgrade to 2.4-kW systems; and 76 were main homes the buyers of which were offered PV systems and could elect to install 1.2-kW or 2.4-kW systems.

To speculate, it seems that at least a percentage of main owners[4] felt more confident in deciding not to purchase PV than certain PV owners felt about purchasing a home with a system. In fact, qualitative data show that a few of the PV owners were “unwitting adopters”—that is, they bought their homes unaware they came with PV systems.

For responses from main owners only, a t-test was run on the mean rating for level of knowledge on energy efficiency and solar energy between main CNAs and those who do not recall being offered a PV system on their homes. No significant differences are found between these two groups (mean scores=5.69 and 5.77, respectively) at the time of the home purchase decision.

What Has Been Learned about Owning PV Systems?

Although most PV owners have learned a good deal about their utility savings, tax credits, and how their systems work, they still do not understand the payback period. PV owners were asked: “Since living in your home, have you learned about the following aspects of solar PV?” A checklist of six potential characteristics that owners might have learned about was provided. Responses from 64 PV owners are as follows:

- Savings on the utility bill (69%)
- Tax credits or rebates to help offset the cost (61%)
- How the system works (61%)
- Net metering and interconnecting with the utility grid (48%)
- Amount or percentage of your electricity use the solar PV system produces (48%)
- Payback period for solar PV system purchase (17%).

Summary

SheaHomes and comparison homebuyers learned about their homes in similar ways, although a higher percentage of SheaHomes buyers than comparison buyers saw physical signs of the new development, and a higher percentage of comparison buyers than SheaHomes buyers heard about their new homes from real estate agents or brokers. A higher percentage of SheaHomes buyers (and especially of PV owners) than comparison homebuyers relied more heavily on word-of-mouth and personal contacts about the new homes and about solar technologies.

Large majorities of both categories of homebuyers give positive ratings to the builder staff on providing them with adequate information for their home purchase decisions. SheaHomes buyers give significantly higher ratings than comparison buyers on the responsiveness of staff to problems with the houses after move-in. A majority of SheaHomes buyers tend to be quite satisfied with the information on the energy features of their homes provided by the SheaHomes staff.

---

[4]This analysis remains to be done for CNAs.

The SheaHomes buyers, on average, give significantly higher ratings than do comparison buyers to their knowledge levels on energy efficiency and solar features when they were shopping for their new homes. However, when average ratings of PV and non-PV owners were compared on this point, no significant differences emerge. However, after having lived in their homes for at least six months, a significantly higher percentage of PV owners than non-PV owners indicate they are informed or very informed about energy efficiency and solar energy features. Thus, living in a PV home is found to increase knowledge about these features.

When they were buying their homes, a majority of PV homebuyers relied on the SheaHomes sales staff as the single most important source of information on PV systems. Although some information on PV systems was available through a fact sheet, an operating manual on PV systems, Web sites, and a video on operations and maintenance, it was not easy for PV owners to locate and obtain information on their PV systems. The PV system manufacturer did not provide follow-through to make certain that PV systems had been installed, were working properly, and that their owners knew how to use and maintain them. Also, although SheaHomes oriented their new homeowners, the company did not follow through in educating new PV owners about their systems.

Majorities of PV owners indicate that, since living with their PV systems, they have learned about savings on their utility bills, tax credits, or rebates to help offset PV system costs, and how the PV system works. Pluralities of nearly half indicate that they have learned about net metering and interconnectivity issues and about the performance of their PV systems in producing electricity. Only 17% of PV owners indicate that they understand the payback period for PV system purchases.

Chapter 10
Homebuyer Satisfaction with the Purchased Home

Introduction

There is every reason to believe that, because of cognitive dissonance,[1] homebuyers could be inclined to say they are satisfied with their new home purchases. Studies of buyer satisfaction are known to be fraught with difficulties in measurement and interpretation. In this instance, homebuyers had lived in their homes for at least 6 months, so the "honeymoon" could have worn off. The measures of satisfaction used in this study tended to be straightforward.

Findings are discussed on whether homebuyers would purchase their homes all over again, the perceived comfort and perceived energy efficiency of the new homes, satisfaction with key aspects of the homes (such as quality of construction), and features liked best and least once buyers had lived in their homes for a time.

Chapter Highlights

- Owners of SheaHomes (77%) are significantly more likely to agree that they would buy the same house over again than are owners of comparison homes (67%).
- Both SheaHomes and comparison homebuyers find their homes to be comfortable.
- Owners of SheaHomes significantly more often rate their homes, on average, as more energy efficient than do owners of comparison homes.
- Both SheaHomes and comparison owners are satisfied with their homes' investment potential, location, size, and layout, but SheaHomes respondents are more satisfied with lot size, builder reputation, storage space, and quality of construction.
- Non-PV owners give significantly higher mean satisfaction ratings to location, size of home, lot size, layout, and storage space than do PV owners. This bears out a pattern of findings that these characteristics were significantly more important to non-PV buyers than to PV buyers in the home purchase decision. PV owners give significantly higher mean satisfaction ratings to energy features than do non-PV owners.
- Two-thirds of PV owners have bragged to others about their utility bills compared with 26% of non-PV owners—a statistically significant difference.
- PV owners are significantly more satisfied with their utility bills than are non-PV owners.

Would Homebuyers Buy Their Homes Again?

For example, the homeowners were asked to what extent they agreed with the statement: "We would buy our same house again if we had it to do over." The intent of this question was to distill the essence of all the pluses and minuses of home ownership. SheaHomes owners significantly more frequently than comparison owners indicate they would buy their homes again.

Table 30 summarizes the responses. Although a high percentage of both groups tend to agree or strongly agree that they would buy their homes again, the percentage is significantly higher for SheaHomes (77%) than for comparison homebuyers (76%) ($\chi 2=6.061$; $p=.048$). Fifteen percent of the comparison homebuyers disagreed that they would buy their homes again, compared with 5% of SheaHomes buyers.

---

[1]The basic principle of cognitive dissonance is that buyers are psychologically inclined to remain favorable to their major purchase decisions once they are made to reduce the emotional discomfort resulting from the thought of having made the wrong decision. However, this concept fails to account for the phenomenon of regret.

Table 30. Percentage Comparison by SheaHomes and Comparison Homeowners with Regard to Repeat Purchase of the Same Home

Responses	Respondents from SheaHomes Communities (n=174)	Respondents from Comparison Community (n=52)	Total (n=226)
Agree or strongly agree	77%	67%	75%
Unsure/neutral	18%	17%	18%
Disagree or strongly disagree	5%	15%	7%
Totals	100%	99%*	100%

*Does not add to 100% because of rounding

The responses to this question were also analyzed by comparing the responses of SheaHomes owners with and without PV systems on their homes, but the responses are not significantly different. As the data in Table 31 show, very high percentages of both categories agree or strongly agree that they would purchase their homes again: 83% of PV owners and 73% of non-PV owners.[2]

Table 31. Percentage Comparison for the Two Respondent Groups with Regard to Repeat Purchase of the Same Home

Response	SheaHomes Respondents Owning PV Homes (n=71)	SheaHomes Respondents Not Owning PV Homes (n=103)	Total (n=174)
Agree or strongly agree	83%	73%	77%
Unsure/neutral	13%	21%	18%
Disagree or strongly disagree	4%	6%	5%
Totals	100%	100%	100%

Perceived Comfort of New Homes

Homeowners tend to rate their homes as comfortable, regardless of category. In addition, respondents were asked to rate the overall comfort of their homes on a 1 to 10 scale, with 1 being "Not at all comfortable" and 10 being "Very comfortable." The mean score for SheaHomes respondents is 8.31 and for the comparison respondents is 8.40. The difference is not statistically significant. This suggests that both groups believe their homes to be comfortable. Similarly, the mean score for PV owners is 8.24 and for non-PV owners is 8.36, a difference that is not statistically significant. Both PV and non-PV owners rate their homes as quite comfortable.

---

[2]These analyses remain to be done for main CNAs. Non-PV owners include all categories of SheaHomes households except PV owners.

Perceived Energy Efficiency of New Homes

Perceived energy efficiency of the new homes varies by homeowner category. Respondents were also asked to rate the overall energy efficiency of their new homes on a 1 to 10 scale, with 1 being "Not at all energy efficient" and 10 being "Very energy efficient." The mean score for SheaHomes respondents is 7.35 and for the comparison respondents is 6.31, a statistically significant difference ($t=3.787$, $p \leq .000$). The mean score for PV owners is 7.48 and for non-PV owners is 7.26, a difference that is not significant. The mean score for owners of home with PV systems is 7.48 and for non-PV owners is 7.26, a difference that also is not significant.

A significantly higher percentage of SheaHomes owners rate their homes as energy efficient (77%) than comparison homeowners (50%) ($\chi 2=19.763$; $p=.001$). In addition, a significantly higher percentage of PV owners rate their homes as energy efficient (84%) than do non-PV owners (65%) ($\chi 2=17.644$; $p=.001$).

Satisfaction with Key Aspects of the New Homes

Overall, based on the following data, the owners of SheaHomes are more satisfied with their homes than the comparison owners are with theirs. Respondents in both communities were asked to rate nine key aspects of their homes: "Please rate your satisfaction with each of the following now that you have lived in your home for a while," with 1 being "Not at all satisfied" and 5 being "Very satisfied." The aspects listed were location, investment potential, reputation of builder, size/square footage, layout/floor plan, storage space, lot size/yard, quality of construction, and number of thermostats. Table 32 summarizes the responses to this question by categories of homeowners.

In rating these aspects, the SheaHomes owners tend to give significantly higher average ratings than the comparison homeowners do on four of the nine features. Their average ratings of another four aspects are also more favorable than those of comparison community owners, but not significantly so. With one dimension of the homes—"Layout/floor plan"—the two groups of homeowners are equally satisfied, on average.

Investment potential is the highest rated aspect among SheaHomes respondents, whereas location is the aspect rated most highly by comparison respondents. "Lot size/yard," "Builder reputation," "Storage space," and "Quality of construction" are aspects with which owners of SheaHomes are significantly more satisfied than are their comparison counterparts.

The satisfaction ratings were also analyzed by PV ownership. In addition to the key aspects listed in Table 32, owners of SheaHomes with PV systems, main homeowners, and ineligible/early homeowners were asked about the package of energy features. Owners of homes with PV systems were also asked about their satisfaction with net metering. Table 33 summarizes the findings. The non-PV owners (main, ineligible, and early homeowners) tend to be more satisfied than the PV owners on nine of the 10 features asked about; their average ratings are significantly higher than PV owners for four of these nine features. On a fifth of these nine features, their higher average rating nears statistical significance. On only one feature—the package of energy features of the home—do PV owners give a higher average rating (mean=4.06) than do the non-PV owners (3.83), yet this difference is not statistically significant.

Table 32. Satisfaction with Key Aspects of the Home by SheaHomes and Comparison Homeowners**

Aspect of Home	Mean Score, SheaHomes Respondents	Mean Score, Comparison Respondents	% Very Satisfied SheaHomes Respondents	% Very Satisfied Comparison Respondents
Investment potential	4.67	4.55	71	66
Location	4.62	4.74	66	76
Size/square footage	4.38	4.23	51	43
Layout/floor plan	4.09	4.11	36	36
*Lot size/yard (t=2.479; p=.015) (χ2=10.296; p=.036)	*4.08*	*3.70*	*34*	*23*
*Builder reputation (t=4.627; p≤.000) (χ2=22.008; p≤.000)	*3.90*	*3.13*	*31*	*9*
*Storage space (t=2.472; p=.014) (χ2=9.316; p=.054)	*3.84*	*3.47*	*27*	*15*
*Quality of construction (t=5.009; p≤,000) (χ2=23.645; p≤.000)	*3.73*	*2.94*	*19*	*2*
Number of thermostats	3.51	3.17	21	11

*Statistically significant difference
**Ordered by the mean scores of the SheaHomes respondents

It is difficult to interpret why the non-PV owners give significantly higher mean satisfaction ratings to so many more home features than do PV owners. However, the findings bear out a pattern that these characteristics and features were significantly more important to non-PV buyers than PV buyers in the home purchase decision. Thus, they may contribute more to non-PV owners satisfaction than they do to PV owner satisfaction with their homes. Answers to these conjectures must await further research. However, it is fair to say that PV owners rate their satisfaction with their package of energy features, on average, higher than do the non-PV owners; 77% of them, compared with 67% of the non-PV owners, indicate they are satisfied or very satisfied with the package of energy features on their homes. Again, this is consistent with PV owners rating the package of energy features and the PV systems as more important in their purchase decision than did the non-PV owners.

Table 33. Satisfaction with Key Aspects of the Home by PV System Ownership***

Aspect of Home	**Mean Score, PV Owners (n=70)**	**Mean Score, Non-PV Owners (n=103)**	**% Satisfied/ Very Satisfied PV Owners**	**% Satisfied/ Very Satisfied Non-PV Owners**
Investment potential	4.63	4.70	31/66	22/74
*Location (t= −2.146; p=.034) (χ2 nears statistical significance; χ2 =7.518; p=.057)	*4.50*	*4.70*	*39/56*	*24/74*
**Size/square footage (t= −3.098; p=.002) (χ2 =9.52; p=.009)	*4.19*	*4.51*	*44/37*	*31/60*
Package of energy features	4.06	3.83	44/33	44/23
**Lot size/yard (t= −2.165; p=.032) (χ2 n.s.)	*3.91*	*4.18*	*47/24*	*42/40*
**Layout/floor plan (t= −3.575; p=.000) χ2 =14.017; p=.007)	*3.81*	*4.28*	*48/22*	*40/46*
PV owners only: Net metering	3.76	–	32/27	–
Builder reputation	3.73	4.02	41/24	41/36
Quality of construction	3.61	3.81	46/15	52/21
**Storage space (t= −3.084; p=.002) (χ2=13.083; p=.011)	*3.59*	*4.02*	*43/13*	*37/36*
Number of thermostats	3.46	3.54	32/20	36/22

*χ2 test nears statistically significance; t-test is statistically significant
**Statistically significant difference
***Ordered by the mean scores of the PV owners

Features Liked Best

Each of the four types of questionnaires asked respondents: "What three or four things do you like best about your new home?" with an open-ended item. The written responses were coded into seven categories; a total of 530 comments were received. The comments focused on (1) layout of the house, (2) location, (3) energy efficiency and solar energy features, (4) outdoor aesthetics, (5) quality of construction, (6) a safe and secure neighborhood, and (7) financial investment. Table 34 summarizes the distribution of the three responses mentioned first in order of frequency of mention, comparing the responses of the SheaHomes respondents with those of the comparison respondents and, within the SheaHomes buyers, the PV owners with the non-PV owners.

Table 34. Home Features Liked Best (open-ended)

Features Liked Best	Percentage of First Three Comments Mentioned			
	SheaHomes Owners % (n=390)	Comparison Owners % (n=140)	SheaHomes PV Owners % (n=157)	SheaHomes Non-PV Owners % (n=225)
Layout and features (kitchen layout, size, one-story, 5th bedroom, hook-ups, ceiling, doors, light)	44	41	39	48
Location (view, proximity to important places, neighborhood, close to freeway, schools, area, weather, community)	32	41	32	31
Energy efficiency/solar features (low utility bill, windows)	8	0	15	5
Outdoor aesthetics (exterior design, landscap4ing, modern, yard space)	4	6 4		
Construction quality (appliances, kitchen features,5engineering, new, low maintenance)		1	3	7
Safe/secure feeling 3 (comfort, quiet, privacy, neighbors, clean)		5	3	3
Financial aspects (value; no Mello Roos; investment)	3	6	4	1
Totals	99*	100	100	99*

*Does not add to 100 because of rounding

The distribution of responses is very similar between the SheaHomes and comparison homebuyers, with a few differences. The home layout is most frequently cited as a reason for liking the home (44% of the top three reasons given by SheaHomes respondents and 41% by the comparison respondents). The comparison responses (41%) more frequently concern the desirable location as a source of satisfaction than the SheaHomes responses (32%). However, the SheaHomes responses included mention of liking energy efficiency and solar features (8%), whereas none of the comparison responses reference energy features. Quality of construction is a more frequently cited source of satisfaction (5%) in the SheaHomes responses than in the comparison responses.

Among PV and non-PV responses (all SheaHomes owners), 48% of the non-PV responses mentioned an aspect of the home's layout, compared with 39% of the PV responses. As might be expected, the positive responses of PV owners more frequently dealt with energy features (15%) than did the positive responses of non-PV owners (5%).

Features Liked Least

Following the question about the three or four things respondents like best about their new homes, each of the four types of questionnaires asked an open-ended question: "Is there anything you are unhappy about? What do you like least?" A total of 299 comments were received, markedly fewer than the number of comments on features liked best. The volunteered responses were coded into eight categories. The comments focused on (1) quality of construction, (2) floor plan/layout, (3) outdoor aesthetics, (4) neighborhood issues, (5) customer service, (6) comfort, (7) energy efficiency and solar energy features, and (8) other complaints. Table 35 summarizes the distribution of the three responses listed first in order of frequency of mention, comparing the responses of the SheaHomes buyers with those of the comparison buyers and, within the SheaHomes buyers, the owners of PV systems with the non-PV system owners.

The pattern of response was similar by SheaHomes and comparison homeowners regarding complaints about construction quality, comfort, and other issues. Differences in response occurred among five of the complaint types, about half more concerning to SheaHomes owners and the other half more concerning to comparison owners.

More frequently mentioned among SheaHomes owners (19% of comments) are complaints that rooms and closets are too small, compared with 10% of comparison owner comments. Fifteen percent of SheaHomes comments, compared with 10% of comparison comments, mention complaints about lack of views, driveway layouts, and small backyards. More than one in five of comparison comments (22%) complain about noise, traffic, and unfriendly neighbors, compared with 9% of SheaHomes comments. Comparison comments also complain about poor customer service on the part of their builder (13%), compared with 5% of SheaHomes comments.

Table 35. Home Features Liked Least (open-ended)

Features Liked Least	Percentage of First Three Comments Mentioned			
	Shea Homes Respondents % (n=219)	Comparison Respondents % (n=80)	Shea Homes PV Owners % (n=95)	Shea Homes Non-PV Owners % (n=117)
Construction quality (bad products, quality of plumbing, windows, low flow cheap toilet, cheap equipment, bathtubs, drawers broke, hot water takes too long reaching faucets, wanted vaulted ceilings, walls rough)	33	35	29	39
Floor plan/layout (closets, room sizes, garage too small)	19	10	23	13
Outdoor aesthetics (no view, sandy ground, garage layout/driveway layout, houses too close, can't expand, backyard too small)	15	10	18	13
Neighborhood issues (noise, traffic, unfriendly neighbors)	9	22	8	9
Customer service	5	13	7	3
Comfort (too cool only one thermostat, location of thermostats, rooms cold in winter)	9	4	7	11
Energy efficiency/solar features (not enough insulation, house did not come with energy-efficient appliances, light fixtures didn't come with CFLs, we don't have solar packages, solar unit didn't work for 6 months, want to monitor each panel, high electric bill)	9	4	5	9
Other (CFLs, lots of options, wind at night, schools, costs, taxes)	2	3	1	3
Totals	101*	101*	98*	100

*Does not add to 100 because of rounding

Interestingly, 9% of SheaHomes complaints concern energy features, including complaints that not enough was done with energy efficiency, compared with 4% of comparison comments. Comments show that some homeowners wanted, but did not receive, compact flourescent lights (CFLs) in their lighting fixtures, solar packages, sufficient insulation, and energy-efficient appliances. Other comments involved complaints about high electricity bills (which came from both groups) and a non-working PV system (obviously a SheaHomes owner comment).

When comments are contrasted between PV and non-PV owners within the SheaHomes communities, 39% of the non-PV owner complaints deal with construction quality, compared with 29% of the PV owner comments. Nearly a quarter of PV owner complaints deal with floor plan or layout issues, compared with 13% of non-PV owner complaints. More non-PV owner complaints (11%) address comfort issues than do PV owner complaints (7%). Finally, more non-PV owner comments (9%) concern energy issues than do PV owner complaints (5%). These differences, however, are not statistically significant.

Bragging about Energy Features of the Homes

During the qualitative interviews, owners of SheaHomes had mentioned that they bragged to friends and family about various energy features in their new homes. Therefore, as another measure of satisfaction with the energy features of their new homes, the following survey question was included: "Have you ever bragged about your home's energy features to friends and acquaintances or shown them to visitors to your home?" Results are summarized in Table 36.

Table 36. Bragging about Energy Features by PV Ownership

Bragged about ...	**Percentages of PV Owners (n=68)**	**Percentages of Non-PV Owners (n=94)**	**Totals %**
Solar PV system (*PV owners only*)	84%	–	–
Solar water heating	71%	64%	67%
*Lower utility bills (χ2=29.218; p$\leq$.000)	69%	26%	45%
Home's comfort	62%	62%	62%
Digital readout for solar PV (*PV owners only*)	56%	–	–
*Low-e glass in windows (χ2=4.317; p=.038)	33%	50%	43%

*Statistically significant difference

The data indicate that a significantly higher percentage (69%) of owners of homes with solar PV systems have bragged about their utility bills. Only 26% of owners of homes without solar PV systems have done so. One PV homeowner commented: "I pay less than my friends. I have a bigger home by at least 1,000 square feet and a large family of six. They have a family of four."

On the other hand, a significantly higher percentage (50%) of owners of homes without solar PV systems report that they have bragged about their spectrally selective windows, suggesting that non-PV owners are concerned about energy efficiency. Only 33% of owners of homes with solar PV have done so. With regard to other related characteristics, the difference is less clear cut. There appears to be no significant difference in the percentages of PV and non-PV homeowners who say they have bragged about solar water heating or the overall comfort of the home.

Based on reported "bragging rights," homeowners with solar PV systems seem to be enthusiastic about them. Of those responding, 84% report having bragged about their PV systems and more than half (56%) say they have bragged about the digital readout that shows their kWh consumption and production in real time.

Role of Energy Efficiency and Solar Features in Future Home Purchase Decisions

Another way that satisfaction with the new home purchase was measured was to ask about the role that energy features would play in a hypothetical future home purchase decision. All respondents were asked: "To what extent do you agree with each of the following statements?" and presented with a 5-point Likert scale from "Strongly disagree" to "Strongly agree" for each statement:

- If we buy another new home, it will be a very energy-efficient home.
- If we buy another new home, it will have solar water heating.
- If we buy another new home, it will have solar PV.

SheaHomes owners (85%) agree or strongly agree significantly more frequently than do comparison owners (60%) that they would purchase an energy-efficient home in the future ($\chi 2$=14.966; p=.001). Similarly, two-thirds of SheaHomes owners agree or strongly agree that they would purchase solar water heating in a new home compared with 22% of the comparison owners ($\chi 2$= 34.532; $p \leq .000$). In addition, 54% of the SheaHomes owners agree or strongly agree that they would buy solar PV in a new home, compared with 28% of comparison respondents ($\chi 2$=12.108; p=.002).

Responses of PV system owners were compared with those of non-PV owners on these questions, resulting in no significant differences, except that PV owners (63%) are significantly more likely than non-PV owners (41%) to state that they would buy solar PV in a new home.

Satisfaction with Utility Bill Savings

SheaHomes respondents were asked about the extent to which they agreed with the following statement: "The savings on our utility bills have met or exceeded our expectations." Thirty-seven percent respond agree or strongly agree, 42% are unsure, and 21% respond disagree or strongly disagree. These results do not represent a ringing endorsement for the perceived efficacy of the homes from the standpoint of energy savings, particularly in light of the findings described above, and may reflect (1) a lack of knowledge about potential energy savings on the part of new homebuyers, (2) ineffective communication about potential savings on the part of sales staff, or (3) even possibly a disconnect about the intent or implications of the question since many of the homebuyers likely "moved up" to larger houses in which they might have expected higher overall energy costs than they experienced in their previous homes. In any case, there is little reason to believe owners knew what to expect in terms of utility bill performance.

More PV owners are convinced that their solar energy systems (both PV and solar water heating) are saving them money on their utility bills than are non-PV owners. On this point, it is informative to consider the differences in answers from respondents whose homes include PV and those whose homes do not. Table 37 summarizes the results. Among the SheaHomes respondents who are also PV owners, 52% agree or strongly agree with the statement: "The savings on our utility bills have met or exceeded our expectations," 32% are neutral or unsure, and 16% disagree or strongly disagree. Among the SheaHomes respondents whose homes do not include PV, 28% respond that they agree or strongly agree with the statement, 47% are unsure, and 25% respond that they disagree or strongly disagree. There is a statistically significant difference in the two distributions of percentages (χ^2=10.324; p=.006), suggesting that the PV owners experience greater satisfaction that their expectations for energy savings were met or even exceeded. Further analysis underscores this finding. A t-test shows that PV owners gave a 3.39 average positive rating on the 5-point satisfaction scale relative to satisfaction with utility cost savings, compared with a 2.97 average rating in the neutral range given by non-PV owners. This difference in mean satisfaction ratings is significant (t=2.791; p=.006).

Table 37. Percentage Comparison of Responses from PV Owners and Non-PV Owners by Their Satisfaction with Savings on Their Utility Bills

Response	All SheaHomes Respondents (n=166)	SheaHomes Respondents with PV (n=69)	SheaHomes Respondents without PV (n=97)
Agree/strongly agree	38%	52%	28%
Unsure	41%	32%	47%
Disagree/strongly disagree	21%	16%	25%

In addition, PV owners were asked the extent to which they agreed with the statement "Our electricity bills are lower than they would have been without our solar PV system." Sixty percent of the PV owners agree or strongly agree that their electricity bills are lower than they would have been without their PV systems; 17% are unsure; and 23% disagree.

Almost all SheaHomes respondents have homes with solar water heating systems (all but the first 13 homes, as previously noted). Because these homes use natural gas for water heating, a key study question was whether SheaHomes owners perceive a difference in their natural gas bills that they attribute to their solar water heating systems.

Because PV owners are billed separately for electricity and natural gas, it was possible to ask them directly about the extent to which they agreed or disagreed with the following statement: "Our natural gas bills are lower than they would have been without our solar water heating system." SheaHomes respondents who are non-PV owners were asked about the extent to which they agreed or disagreed with the following statement: "Our utility bills are lower than they would have been without our solar water heating system." The results are summarized in Table 38.

Table 38. Percentage Comparison of Responses from PV and Non-PV Homeowners in the SheaHomes Communities by the Perceived Impact of Solar Water Heating Systems on Utility Bills

Item	SheaHomes Owners with PV Systems (n=70)	SheaHomes Owners without PV Systems (n=97)
Our natural gas bills are lower than they would have been without our solar water heating system	49%: Strongly agree/agree 30%: Unsure 21%: Strongly disagree/ disagree	N/A
Our utility bills are lower than they would have been without our solar water heating system	N/A	51%: Strongly agree/agree 32%: Unsure 17%: Strongly disagree/ disagree

Of the PV owners, a plurality (49%) agree or strongly agree that their natural gas bills are lower than they would have been without the solar water heating systems, whereas 21% disagree or strongly disagree, and 30% say they are unsure. Of the respondents who do not have PV installations on their homes, a majority (51%) agree or strongly agree that their utility bills are lower than they would have been without the solar water heating systems. About 17% disagree or strongly disagree, whereas 32% are unsure. These results suggest that most homeowners in the SheaHomes communities with solar water heating systems believe they contribute to lower energy costs, although nearly one-third are unsure and nearly one in five disagree.

Summary

The most striking pattern of findings on the various measures of homeowner satisfaction used in the study is that, where statistically significant differences occur between SheaHomes and comparison homebuyers, SheaHomes buyers are consistently more favorable toward their experience than are comparison homebuyers.

Owners of SheaHomes (77%) are significantly more likely to agree that they would buy the same house if they had it to do over again than are owners of comparison homes (67%). Although both categories of homebuyers rate their homes as comfortable, SheaHomes buyers (77%) are significantly more likely to rate their homes as energy efficient than are comparison buyers (50%). PV owners significantly more frequently rate their homes as energy efficient (84%) than do non-PV owners (65%).

Both SheaHomes and comparison respondents are satisfied with their homes' investment potential, location, size and layout; however, SheaHomes respondents are significantly more satisfied than comparison respondents with their homes' lot sizes, builder reputation, quality of construction, and storage space. Non-PV owners are more satisfied than PV owners on these same characteristics, which were more important to them than to PV owners at the time of purchase. Conversely, PV owners are more satisfied than non-PV owners with their homes' energy characteristics; again, these were more important to them at the time of purchase decision.

Favorite home features among all categories of respondents are layout, certain features (such as size, extra bedroom, and the one-story option), and location. Least favored are problems involving quality of construction issues, storage space, and outdoor aesthetics—these seem to be similar among all categories of respondents.

PV owners are particularly likely to enjoy their "bragging rights" with respect to utility bills—more so than do non-PV owners. Eighty-four percent of PV owners report that they have bragged to others about their PV systems, and 56% say they have bragged about their digital readouts showing their kWh consumption and production in real time. Seventy-one percent of PV owners report that they have bragged about their solar water heating systems compared with 64% of non-PV owners.

Another way satisfaction was measured was to ask whether energy efficiency and solar features would be important to the homeowners in future home purchase decisions. Owners of SheaHomes are significantly more likely than owners of comparison homes to agree that they would buy a home with energy efficiency and solar energy features in the future.

Relative to utility bill savings, owners of SheaHomes do not seem to know what to expect from their homes' performance. Findings seem to reflect a lack of knowledge about potential energy savings or that respondents may not have known what to expect because they were moving to larger homes. In any event, only 37% indicate utility bills have met their expectations, 42% are unsure, and 21% indicate utility bills have not met their expectations.

On the other hand, a majority of PV owners (52%) indicate that their expectations for utility bills have been met, compared with 28% of non-PV owners. Clearly, the presence of PV makes a significant difference in perception of utility bill savings.[3] Sixty percent of PV owners agree that their electricity bills are lower than they would have been without their PV systems, and 49% agree that their natural gas bills are lower than they would have been without their solar water heating systems. Among non-PV owners, 51% agree that their utility bills are lower than they would have been without their solar water heating systems.

[3]Perceived and actual utility bills are discussed in Chapter 22 (Perceived and Actual Utility Bills).

Chapter 11
Experiences with PV Systems

Introduction

PV owners are experiencing an innovative technology in their homes. Ways of measuring their reactions to this experience include asking about the benefits they perceive in owning homes with PV systems, inquiring how happy they are with their systems and why, and the attributes owners believe are important. The role of feedback through the use of the digital display on electricity production and consumption was also investigated. Finally, owner knowledge of how their systems interact with the utility grid was also tested.

Chapter Highlights

- Most of the PV owners are, in general, satisfied with their PV systems, giving them a mean rating of 7.66 on a 10-point scale.
- Perceived benefits of owning a PV system are reduced electricity bills, increased resale value, environmental benefits, and feeling good about it.
- The most important attribute of PV systems is the amount of electricity they produce; also important are ease of maintenance and length of warranty.
- A majority of PV owners consult their digital displays on electricity production and consumption at least once a week; 15% do so daily.
- PV owners are not highly knowledgeable about the operational aspects of their systems and are unsure if they pay their electricity bills monthly or annually.
- PV owners need more information and education about their PV systems.

Demographic Differences between PV Owners and Non-PV Owners

Among SheaHomes owners, responding heads of households of PV owners are significantly more likely to be male than are heads of non-PV households. Two-thirds of heads of PV households are male whereas 50% of non-PV households are male ($\chi 2=5.9$; $p=.015$). This finding suggests that, among PV households, the male head of household was more likely to complete the questionnaire than was the case among the non-PV households. To speculate, this is probably because PV ownership is viewed as a technical topic about which men might be expected to know more than women.

Perceived Benefits of Owning a PV System

PV owner respondents were asked: "Listed below are some statements concerning the benefits of having a solar PV system on your high-performance home. Please indicate the extent to which you agree with each statement. Our solar PV system: . . ." Fifteen potential benefits of PV ownership were presented. Respondents were asked to respond on a Likert scale from 1=Strongly disagree to 5=Strongly agree. Findings are summarized in Table 39. The list of benefits was derived from qualitative interviews and prior research (cf., for example, Farhar and Coburn 2000).

A majority of the PV owner respondents agree with all but one of the statements about potential benefits. Most frequently agreed upon (by more than 80%) are that the PV system "Reduces electricity bills," "Increases our home's resale value," and "Allows us to help the environment."

Table 39. Benefits of PV Ownership Perceived by PV Owners (n=71)

Perceived Benefits	% Agree/ Strongly Agree	% Neutral/ Unsure	% Disagree/ Strongly Disagree
Reduces electricity bills	83.1	12.7	4.2
Increases our home's resale value	83.1	15.5	1.4
Allows us to help the environment	80.3	16.9	2.8
Helps conserve natural resources	78.9	18.3	1.4
Allows us to increase our awareness of our household's energy use	73.9	20.3	5.8
Helps to benefit future generations	73.2	23.9	2.8
Makes us feel good to have it	67.6	25.4	7.0
Helps improve air quality in our area	66.2	29.6	4.2
Allows us to sell excess electricity back to the utility company	60.6	25.4	14.1
Provides us an opportunity to be technologically innovative	59.2	33.8	7.0
Increases our self-sufficiency	58.6	34.3	7.1
Helps San Diego's economy	58.0	33.3	8.7
Helps reduce global warming	56.3	31.0	12.7
Protects us against rising electricity costs	50.7	35.2	14.1
Provides free electricity once our system is paid for	49.3	31.9	18.8

How Happy PV Owners Are with Their Systems

PV homeowners were asked: "How happy are you with your solar PV system?" Responses were requested on a 1-to-10 scale, where 1=Not at all happy and 10=Very happy. The mean response from 68 PV homeowners is 7.66; thus, on average, PV homeowners appear to be reasonably happy with their systems. More than three-quarters of PV homeowners indicate that they are happy with their systems; approximately 8% indicate that they are unhappy with them, and 15% indicate they are in the neutral range about the PV systems.

The PV respondents were asked two open-ended questions: “What have been the best things about having a solar PV system?” and “What drawbacks, if any, have there been to having a solar PV system?” Volunteered responses were coded.

PV owners gave 58 reasons for liking their systems. The most frequently mentioned of these can be classified as financial in nature. The positive aspects of PV ownership mentioned are as follows:

- Savings on utility bills – 74% of the reasons given
- Feedback on electricity consumption – 7% of the reasons
- Protects environment – 7%
- Self-sufficiency – 7%
- Investment – 3%
- Ease of maintenance – 3%
- Enjoy technology – 2%.

More than half (55%) of the PV owners say there are no drawbacks to owning a PV system. The remaining PV owners mentioned 19 drawbacks. The most frequently mentioned drawbacks appear to pertain to wishing the system were producing more electricity than is apparent to the owners. The drawbacks given are as follows:

- Performance – 32% of the drawbacks mentioned
- Unhappy with cloudy weather/unpredictability – 21% of the drawbacks
- Difficulty telling whether it is working properly – 16%
- Aesthetics – 5%
- No battery backup – 5%.

Importance of Solar PV Attributes

PV owners were asked: “How important to you are each of the following aspects of your solar PV system? They were presented with a list of nine attributes that had been mentioned in qualitative interviews. Respondents were asked to rate the attributes on a 1-to-5 scale where 1=Not at all important and 5=Very important. This question was followed by one which asked: “Now, please go back over the list and indicate below the number of the most important aspect.” Table 40 summarizes the findings.

Clearly, the attribute perceived to be most important is the amount of electricity the PV system produces. Other more important attributes are identified as “Ease of maintenance,” “Length of warranty,” “Attractiveness/unobtrusiveness of the system,” and “Digital display showing electricity production and consumption.” When asked to identify the single most important attribute, more than half of the PV owners (56%) cite the amount of electricity produced. The attribute identified as the most important in second place is the digital display, cited by 11%. Other attributes are cited as the single most important by fewer than 8% each, except for “Upgrade capability,” which is not selected as the single most important attribute by anyone.

This pattern of findings shows a set of diverse interests in the PV system attributes; however, the amount of electricity produced and a way to tell how much is produced (the digital display) seem to emerge as most important. Convenience and low risk of the systems are also important to PV owners.

Table 40. Average Importance Ratings of Attributes of Solar PV Systems by PV Owners (n=70) Ordered by Average Mean Score

Attributes of Solar PV Systems	Mean Rating	Percentage Rating This as a "Very Important" Attribute (5)	Percentage Rating This as the Most Important Attribute
Amount of electricity produced	4.24	50	55.6
Ease of maintenance	4.07	34	7.9
Length of warranty	4.04	30	1.6
Attractiveness/unobtrusiveness of the system	3.91	31	4.8
Digital display showing electricity production and consumption	3.88	25	11.1
Upgrade capability	3.64	21	0.0
Net metering	3.59	19	7.9
Finance through home mortgage	3.49	21	7.9
Owning the solar PV system outright	3.43	14	3.2

Uses of the Digital Displays

As just discussed, the digital display showing kWh production and consumption in real time is perceived as a key component of the PV system by a good many PV owners. In fact, 70% rate the display with a 4 or 5 on the 1-to-5 scale where 1=Not at all important and 5=Very important. PV owners were then asked: "About how often do you look at the solar electric digital display that tells you how much electricity your system is producing and how much your home is consuming?" Table 41 summarizes the results.

More than half of PV owner respondents (58%) indicate that they look at their display at least once a week; 15% say they look at it once a day. Forty percent report that they look at the display approximately once a month or less often; 2% say they never look at it.

PV owners were then asked: "In which of the following ways have you used your solar PV digital display? We use it to. . ." A list of seven potential uses of the display was provided. Table 42 summarizes the findings.

Table 41. Frequency of PV Owners Receiving Feedback from Their Digital Displays (n=67)

Frequency of Use of Digital Displays	%
Once a day	15
At least once a week	43
Approximately once a month	24
Between once a month and once every six months	16
Never	2
Total	100

Table 42. Percentages of PV Owners Indicating Uses of the Solar PV Digital Display (n=67)

Uses	% Indicating Use
Optimally schedule electricity-consuming chores	92.5
Record our cumulative electricity production and consumption	82.1
Determine whether anything has inadvertently been left on before we leave the house	76.1
Help change energy-consuming behavior	70.1
Obtain feedback on the electricity use of specific lights and appliances	53.7
Become more sensitive to our household's electricity consumption patterns	49.3
Determine whether our system is functioning	40.3

As Table 42 shows, the PV digital display is used to reduce the amount of electricity consumed in the home overall and to increase the proportion of electricity consumed by the home at times when the PV system is producing more electricity, such as on sunny afternoons. The PV system's digital display can be set to show the electricity consumption and production in real time or cumulatively. It has long been noted in the literature (cf., for example, Kempton and Layne 1988; Farhar and Fitzpatrick 1989) that feedback is an important component of energy-conserving behavior. In contrast to a monthly utility bill, the PV digital display provides real-time feedback on electricity consumption that interested homeowners can use immediately to modify their electricity-consuming behavior.

Operational Aspects of PV Systems

The research tested the extent to which PV owners are familiar with factual information about their PV systems and how it is interconnected with the utility grid. To do this, the questionnaire asked: “Regarding the operational aspects of your solar PV system, please tell us whether each of the following situations exists.” A list of eight situations was provided. Table 43 summarizes the findings, which are discussed briefly for each of the statements.

Table 43. Percentages of PV Owners Regarding Operational Aspects of Their PV Systems*

Situation	% Yes	% No	% Don't Know
Our solar PV systems automatically shuts down when there is a utility power outage. (*True*)	14	11	76**
SDG&E credits us at the retail rate for the amount of electricity we put into the grid. (*True, up to a point*)	25	11	65**
We have one electric meter. (*True*)	81	6	13
SDG&E bills us only for the net electricity we actually consume. (*True*)	68	2	30
The utility grid's demand for electricity is at its peak on hot sunny afternoons when our system produces the most electricity. (*True*)	69	2	29
We signed an interconnectivity agreement with SDG&E when we purchased our home. (*True*)	66	6	28
We pay our electricity bill once a year rather than once a month. (*Optional*)	14	3	83
We will receive a check from SDG&E at the end of the year if we produce enough electricity. (*False*)	16	39	45

*Items are presented in the order in which they were asked in the questionnaire
**Total does not add to 100 because of rounding

These findings seem to reflect the lack of knowledge and information discussed in Chapter 9, and the lack of information provided by the builder staff.

PV System Shutdown during Power Outages

The situation was stated as: “Our solar PV system automatically shuts down when there is a utility power outage.” This statement is actually true. The PV systems at Scripps Highlands have no battery backups. The reason for this decision, according to a SheaHomes staffer, was that the battery backup would have to go in the garage, and the garages were not deep enough to accommodate a battery backup system. Seventy-six percent of the PV owners do not know if their PV system would shut down during a power outage. Fourteen percent correctly respond that it would. Eleven percent incorrectly believe that their PV system will keep running when the utility grid goes down.

Utility Rate of Payment for Electricity Put Back into the Grid

The situation was stated as: "SDG&E credits us at the retail rate for the amount of electricity we put into the grid." This statement is also true, up to a point. Under California law, a PV system is net-metered to zero, meaning that a home that produces more electricity than it uses will not receive a check from the utility company. In fact, that homeowner will have to pay a nominal monthly charge to be hooked up to the utility grid. However, during the hours when a PV system is producing more electricity than the home is using, the electricity meter does, in fact, run backwards. This means that, in effect, the utility company is paying the homeowner the retail rate for the electricity that home is providing. Sixty-five percent of PV owners do not know whether they are, in effect, being paid the retail rate for PV electricity they provide to the grid. One-quarter correctly believe that they are, whereas 11% do not believe they are being paid for their excess electricity at retail rate.

Number of Electric Meters

The situation was stated as: "We have one electric meter." Because utility companies can only stay in business if they both buy electricity at wholesale rates and sell it at retail rates, they may be interested in having two electricity meters at homes with PV systems. One meter would measure the excess electricity produced by the home, which the utility would purchase at a wholesale rate. The other meter would measure the electricity the utility provides to the home, which the utility would sell to the homeowner at retail rate. However, there are problems with this approach; for one, it is expensive to install two electric meters. For another, the California net-metering legislation does not provide for two meters. Most PV owners at Scripps Highlands (81%) know that they have only one electric meter; 12% say they do not know; and 6% incorrectly believe they have more than one electric meter.

Utility Billing for Net-Metered Electricity

The situation was stated as: "SDG&E bills us only for the net electricity we actually consume." This statement is correct. The PV homes are net metered, allowing for the meter to run backward when the home produces more electricity than is it consumes. The utility only bills homeowners for the amount of electricity read on the meter monthly. Approximately two-thirds (68%) of the PV owners correctly believe that SDG&E bills them only for the net electricity they consume. Almost one-third (30%) do not know; and approximately 2% incorrectly believe that the statement is not true.

The Relationship between Utility Peak Demand and PV System Supply

The situation was stated as: "The utility grid's demand for electricity is at its peak on hot sunny afternoons when our system produces the most electricity." This statement is true; SDG&E is a summer peaking utility for electricity, especially because of air-conditioning, and PV systems produce the most power on hot sunny afternoons when air-conditioning demand is at its highest. More than two-thirds of the PV owner respondents (69%) know that this is accurate; 29% say they do not know, and almost 2% incorrectly believe this is not the case.

Interconnectivity Agreement

The situation was stated as: "We signed an interconnectivity agreement with SDG&E when we purchased our home." SDG&E staff indicate that it is impossible to have an operational PV system without the homeowner signing an interconnectivity agreement with the utility company. Almost two-thirds of PV owners (66%) state that this is correct; 28% do not know; and 6% believe that they do not have an interconnectivity agreement with the utility company. If they are correct, their PV system would not be producing electricity. However, according to SDG&E, every home with a PV system has an interconnectivity agreement to receive electricity service.

Frequency of Utility Bill Payment

The situation was stated as: "We pay our electricity bill once a year rather than once a month." SDG&E bills PV homeowners separately for gas and electricity, and it offers an option to PV homeowners to pay their electricity bills monthly or annually. The utility company provides a monthly statement of electricity usage so that homeowners will be aware of their electricity consumption even if they have opted to pay annually. The purpose of the question was to learn the percentage of PV owners choosing to pay their electricity bills once a year. The answer is 14%, whereas 83% say they pay monthly, and 3% answer that they do not know.

Receive Check from Utility Company at the End of the Year

The situation was stated as: "We will receive a check from SDG&E at the end of the year if we produce enough electricity." As discussed earlier, the California legislation only allows net metering to zero, such that the utility is not required to pay for any excess electricity it receives beyond that consumed by the home. Thirty-nine percent of PV owners realize that they will not be receiving yearly checks from the utility company. A plurality of 45% are not sure whether they will receive checks. Sixteen percent of PV owners will be or have already been disappointed to learn that they will not be receiving such checks.

Summary

The largest perceived benefit of owning PV systems is saving on utility bills. Also frequently mentioned are increases in resale value, helping the environment and future generations, and increasing awareness of household energy use. A majority of PV owners indicate there are no disadvantages to owning PV systems.

The most important attribute of PV systems perceived by their owners is the amount of electricity produced. Also mentioned as important, but by far fewer respondents, are ease of maintenance and length of warranty.

PV owners tend to look at their digital displays (which tell them the amount of electricity being produced and consumed in real time) at least once a week (the modal response); 15% look at their displays at least once a day. Most PV owners use their displays to schedule electricity-consuming chores, record electricity production and consumption, determine whether anything has been left on in the house before leaving, change energy-consuming behavior, and obtain feedback on which lights and appliances are using the most electricity.

PV owners are not highly knowledgeable about operational aspects of their systems. Majorities correctly identify that they have one meter, that they are billed only for the net electricity they consume, that their electricity production meets utility peak load, and that they signed an interconnectivity agreement with the utility company. However, most do not know if they pay their electricity bills monthly or annually. Most incorrectly believe or do not know if the utility will send them a check at the end of the year. Most do not know if their solar PV system shuts down where there is a power outage (it does). Most also do not understand if they are being credited with the retail rate when their meter runs backward (they are). It seems clear that PV owners could use a good deal more information about their PV systems and how they operate.

Chapter 12
Attitudes toward San Diego Gas & Electric Company

Introduction

The utility company plays a key role in any high-performance home development. The utility company provides the interconnection between PV systems and the utility grid and is responsible for billing homeowners with PV systems for electricity. Therefore, the utility company must help educate homeowners about net metering and interconnectivity agreements. In addition, the utility company may offer rebates to buyers of energy-efficient homes and appliances.

Chapter Highlights

- Attitudes toward electricity rates, power outages, and the utility billing process are quite similar between owners of SheaHomes and comparison homes and are in the neutral range. Problems with power outages and electricity rates were not a factor in home purchase decisions.
- PV owners are significantly more pleased with the utility billing process than are non-PV owners.
- PV owners are significantly more likely to believe that electricity rates have come down since they moved in than are non-PV owners.
- PV owners appear to be unsure or neutral about the way in which SDG&E treated them with regard to net metering and interconnectivity agreements.
- In general, PV owners exhibit attitudes far more favorable to SDG&E than do either the other SheaHomes owners or the comparison homeowners.

The study included several questions that elicited opinions regarding the utility company serving both SheaHomes and the comparison community—San Diego Gas & Electric Company (or SDG&E). Results from these are relevant to answering the following study questions.

- Were power outages perceived as a problem by new homebuyers in the San Diego area? If they were, this could be a reason for homebuyers being interested in purchasing high-performance homes.
- Did homebuyers believe that their electricity rates had decreased since they purchased their homes? (Utility rates had actually increased, but this is a question of perception.)
- PV owners receive separate bills for their electricity and gas services. They also have the option of being billed annually for electricity services; if they choose this option, they receive a monthly statement of account, but they do not have to pay it. Did this difference in billing make any difference in attitudes toward SDG&E compared with other homeowners receiving regular utility bills with gas and electricity combined?

PV owners had other special interactions with SDG&E that led to additional questions.

- Purchasers of SheaHomes with solar PV systems had to deal with the utility company to interconnect their systems. Were those interactions with SDG&E perceived as helpful or problematic by the PV homeowners?

- The PV systems are tied to the utility grid, requiring homeowner interaction with the utility company about net metering. How successfully did SDG&E communicate with owners of PV systems concerning billing and other questions related to net metering?

This chapter presents the findings on these study questions.

Attitudes toward the Utility by Household Category

No significant differences in attitudes toward electricity rates, power outages, and the utility billing process are found. All respondents were asked whether their electricity rates have decreased since they moved into their homes. Responses were solicited on a 5-point Likert scale from 1 = Strongly disagree to 5 = Strongly agree. The mean response for the SheaHomes respondents is 2.6 on the 5-point scale, and for the comparison respondents it is 2.32, showing a general tendency toward disagreement that rates had come down. Although a majority of 59% of the comparison owners disagree that electricity rates had declined and a plurality of 46% of SheaHomes respondents also disagree with the statement, the difference between the two groups is not significant. Table 44 summarizes the findings for this and the next two items.

Table 44. Attitudes toward SDG&E by SheaHomes and Comparison Homeowners*

Item	SheaHomes Owners Mean	Comparison Home Owners Mean	SheaHomes Owners %	Comparison Homeowners %
We are pleased with the billing process for utilities (*PV owners:* We are pleased with the billing process for electricity.)	3.11	3.12	A: 34** U: 44 D: 22	A: 27 U: 60 D: 13
Power outages are a problem in the San Diego area.	2.63	2.70	A: 18 U: 31 D: 51	A: 25 U: 30 D: 45
Electricity rates have come down since we moved in.	2.60	2.32	A: 22 U: 32 D: 46	A: 17 U: 24 D: 59

*Statistical test results: t-tests for differences in means are not significant; $\chi 2$ test results are not significant
**A=Agree or strongly agree; U=Neutral or unsure; D=Disagree or strongly disagree

No significant differences in patterns of response are found for the other two items. A majority of SheaHomes respondents (51%) disagree with the statement “Power outages are a problem in the San Diego area,” as does a plurality of comparison respondents (45%). Sixty percent of comparison respondents are unsure or neutral regarding the statement “We are pleased with the billing process for utilities,” whereas 44% of SheaHomes respondents are unsure or neutral. One-third of the SheaHomes owners agree with the statement, compared with 27% of the comparison homeowners.

Therefore, it appears that perceived problems with power outages and electricity rates were not a factor in home purchases. Utility billing processes are not particularly popular; however, possibly no billing process whatsoever could be popular.

Attitudes toward the Utility by PV System Ownership

A very different picture emerges when these items are analyzed with respect to PV ownership. Table 45 summarizes the findings. A significantly higher percentage of PV owners (53%) agree or strongly agree that they are pleased with the billing process for electricity than non-PV owners (22%). To underscore this contrast in perception, an $\chi 2$ test was run on this item comparing responses from PV owners with comparison homeowners. Fifty-three percent of PV owners are pleased with the billing process compared with 27% of comparison homeowners ($\chi 2$=9.778l; p=.008).

A significantly higher percentage of owners of SheaHomes without PV systems (54%) disagree or strongly disagree than homeowners with PV systems (34%) with the statement “Electricity rates have come down since we moved in,” suggesting that PV owners have a markedly different view of electricity pricing than do non-PV owners. Even though the question refers to electricity rates paid by everyone, PV owners seem to believe electricity rates have come down because they were using their lower electricity bills as a point of reference. Fewer non-PV owners, not having this experience with their utility bills, apparently see electricity rates as lower. An $\chi 2$ test was run on this item comparing responses from PV owners with comparison homeowners. Fifty-nine percent of comparison homeowners disagree or strongly disagree that electricity rates have come down compared with 34% of PV owners ($\chi 2$=7.343; p=.025).

There is no significant difference between the percentage of homeowners with and without PV systems who perceive power outages as a problem in the San Diego area.

PV owners were asked two questions about their experiences with SDG&E relative to purchasing homes with solar PV systems. The responses reflect an unsureness or neutrality with respect to the way that SDG&E treated them in this innovative situation. The first statement was “SDG&E sent clear, concise, and beneficial information about net metering.” The mean response is 3.1 on the 5-point scale, a response that is in the neutral range. A plurality of 40% are unsure; 36% agree with the statement, and 24% disagree.

Table 45. Attitudes toward SDG&E by PV Ownership*

Item	PV Owners Mean	Non-PV Owners Mean	t -test Results	PV Owners %	Non-PV Owners %	χ2 Results
We are pleased with the billing process for utilities (*PV owners*: We are pleased with the billing process for electricity.)	3.43	2.90	t=3.717 p≤.000	A: 53 U: 32 D: 15	A: 22 U: 51 D: 27	χ2 = 17.579 p≤.000
Power outages are a problem in the San Diego area.	2.68	2.60	n.s.	A: 18 U: 31 D: 51	A: 18 U: 30 D: 51	n.s.
Electricity rates have come down since we moved in.	2.87	2.42	t=2.674 p=.008	A: 28 U: 38 D: 34	A: 18 U: 28 D: 54	χ2 = 6.790 p=.034
(PV owners only): SDG&E sent clear, concise, and beneficial information about net metering.	3.10	–	–	A: 36 U: 40 D: 24	–	–
(PV owners only): SDG&E was helpful about connecting our solar PV systems with the utility grid	3.13	–	–	A: 31 U: 54 D: 15	–	–

*n.s.=not significant; A=Agree or strongly agree; U=Neutral or unsure; D=Disagree or strongly disagree

The second statement was "SDG&E was helpful about connecting our solar PV system with the utility grid." The mean response is 3.15, again in the neutral range; a majority of 54% of the PV owners are neutral or unsure about the statement, 31% agree, and 15% disagree.

Clearly, the PV homeowners' experiences with SDG&E in initiating their net-metering service was not overly positive. On the other hand, PV owners exhibit attitudes far more favorable to SDG&E than do either the other SheaHomes owners or the comparison homeowners.

Summary

When the responses of homeowners with PV systems are compared with other homeowners, significant differences are found. A significantly higher percentage of homeowners with PV systems agree that electricity rates have declined. Likewise, a significantly higher percentage of homeowners with PV systems are pleased with the utility billing process than those without PV systems. No difference is found by PV ownership on perception of power outages in the San Diego area. On the other hand, owners of homes with PV systems are relatively neutral about their experiences with SDG&E in terms of the interconnectivity agreement and the information provided to them about net metering.

Chapter 13
Attitudes toward Solar Features in New Housing

Introduction

General attitudes toward solar water heating and solar electric systems are important to measure because some buyers of new homes are still confused about the difference between the 1970s solar hot water systems and today's solar thermal and solar electric systems. To the degree that "horror stories" about the solar panels in the 1970s affect general attitudes about solar features in current markets, the demand for ZEHs could be negatively affected. In addition, many new homebuyers believe that solar features in housing are too expensive for what they receive in return.[1]

The questionnaires used Likert items to ask homebuyers whether they agreed that solar water-heating and solar PV systems are desirable innovations for new homes. They also asked whether they considered these features to be cost effective. The statements for which agreement or disagreement were sought were preceded by the question: "To what extent do you agree with the following statements about solar PV and solar water-heating systems?"

Chapter Highlights

- General attitudes toward solar water heating and solar PV systems were measured and analyzed by homeowner categories.
- Majorities of SheaHomes owners and of comparison homeowners agree that solar water heating and solar PV systems are desirable innovations for new homes.
- Fifty-nine percent of SheaHomes owners and 40% of comparison homeowners agree that solar water-heating systems are cost effective.
- Forty-nine percent of SheaHomes owners and 36% of comparison homeowners agree that solar PV systems are cost effective.
- Living with a PV system fosters a positive attitude toward the cost effectiveness of solar water heating (63% agree) and solar PV systems (62% agree).

Are Solar Features Desirable Innovations?

The two statements about the desirability of the innovation were "Solar PV systems are a desirable innovation of new homes" and "Solar water-heating systems are a desirable innovation for new homes." Responses were requested on a 1-to-5 scale where 1=Strongly disagree and 5=Strongly agree. Table 46 summarizes the findings by SheaHomes and comparison homeowners for these two questions.

The results in Table 46 show positive average agreement ratings with the statement that solar PV and solar water heating are desirable innovations for new homes on the part of both SheaHomes and comparison homebuyers. SheaHomes buyers respond to the statement about solar water heating with a mean rating of 4.14 on the 5-point scale. The positive mean rating for solar water

[1] These perceptions became evident, for example, during the qualitative interviews for this study.

heating on the part of SheaHomes buyers is significantly higher than the average mean rating of 3.73 given by the comparison homebuyers. To speculate, this higher rating by the SheaHomes owners could be the result of positive attitudes toward solar energy in general—or solar water-heating systems in particular—that they had before the new home purchase and may even have been causal in the selection of the new home. Alternatively, the higher mean rating about the desirability of solar water heating could be a result of living with solar water-heating systems, which were included standard on all SheaHomes except the early homes.

Table 46. Average Agreement Ratings on Desirability of Solar Features as Innovations for New Housing by Categories of Homebuyers

Statement	SheaHomes Owners Mean (n=170)	Comparison Homeowners Mean (n=53)	SheaHomes Owners % Responding Agree or Strongly Agree	Comparison Homeowners % Responding Agree or Strongly Agree
Solar water-heating systems are a desirable innovation for new homes.*	4.14	3.73	82	54
Solar PV systems are a desirable innovation for new homes.**	4.04	3.72	77	55

*Statistically significant difference in means: $t=3.361$; $p=.001$; statistically significant difference in percentages agreeing: $\chi2=17.043$; $p=.000$

**Statistically significant difference in means: $t=2.599$; $p=.011$; statistically significant difference in percentages agreeing: $\chi2=11.204$; $p=.004$

Similarly, SheaHomes owners give a significantly higher mean rating (4.04) to the desirability of solar PV systems than do comparison homeowners (3.72). This difference is statistically significant as well and is particularly interesting because, as previously noted, not all SheaHomes owners have homes with PV systems. Again, a reasonable speculation is that positive attitudes toward solar features could have preceded and played a role in the selection of the home purchased, or living with solar features could have positively influenced or reinforced positive attitudes toward them.

These variables were also analyzed by PV ownership (results summarized in Table 47). The pattern of responses shows that PV owners give significantly higher mean ratings to the statements about solar features as desirable innovations than do non-PV owners. In addition, PV owners give a mean positive rating of 4.35 to the statements that pertain to solar water heating, compared with a mean rating of 4.00 given by the owners of SheaHomes without PV systems. PV owners respond with a mean rating of 4.32 for the statements that pertain to solar PV systems, compared with the mean rating of 3.87 by the owners of SheaHomes without PV systems. These results again suggest both interpretations already mentioned in connection with the differences between the SheaHomes and comparison homeowners; however, the findings even more strongly support the idea that living with a PV system fosters positive attitudes toward the desirability of including such systems in new housing.

Table 47. Average Agreement Ratings on Desirability of Solar Features as Innovations for New Housing by PV Ownership

Statement	PV Owners Mean (n=68)	Non-PV Owners Mean (n=101)	PV Owners % Responding Agree or Strongly Agree	Non-PV Owners % Responding Agree or Strongly Agree
Solar water-heating systems are a desirable innovation for new homes.*	4.35	4.00	88	77
Solar PV systems are a desirable innovation for new homes.**	4.32	3.87	88	69

*Statistically significant difference in means: t=3.069; p=.003; no statistically significant difference by percentages agreeing.
**Statistically significant difference in means: t=3.967; p=.000; statistically significant difference in percentages agreeing: $\chi 2$=8.382; p=.015.

Are Solar Features Cost Effective?

The two statements about the cost effectiveness of the solar features were "Solar PV systems are cost effective" and "Solar water heating systems are cost effective." Responses were requested on a 1-to-5 scale where 1=Strongly disagree and 5=Strongly agree. Table 48 summarizes the findings for SheaHomes and comparison homeowners on these two questions.

Table 48. Average Agreement Ratings on Cost Effectiveness of Solar Features by Categories of Homebuyers

Statement	SheaHomes Owners Mean (n=170)	Comparison Homeowners Mean (n=53)	SheaHomes Owners % Responding Agree or Strongly Agree	Comparison Homeowners % Responding Agree or Strongly Agree
Solar water-heating systems are cost effective.*	3.70	3.49	59	40
Solar PV systems are cost effective.	3.54	3.36	49	36

*Statistically significant difference in percentages agreeing: $\chi 2$=6.199; p=.045

The results in Table 49 show average agreement ratings in the unsure to positive range with the statement that solar PV and solar water heating systems are cost effective. SheaHomes buyers respond to the statement on solar water heating systems with a mean rating of 3.70 on the 5-point scale. The mean rating for solar water heating on the part of SheaHomes buyers is not significantly higher than the mean rating of 3.49 given the comparison homebuyers. However, the percentage of SheaHomes owners who agree with the statement that solar water heating is cost effective (59%) is significantly higher than the percentage of comparison owners who so agree (40%). This higher percentage of SheaHomes owners, almost all of whom own solar water heating systems, tends to support the notion that, by and large, they are positive toward their experience with this technology. To speculate, the SheaHomes owners could have had favorable attitudes toward solar energy or solar water heating before their home purchases, and such attitudes may even have been causal in their new home selection.

Although the owners of SheaHomes give a higher mean rating (3.54) to the cost effectiveness of solar PV systems than do comparison homeowners (3.36), the difference is not significant. Also, both mean ratings tend to be in the neutral to mildly positive range. The findings suggest a higher degree of uncertainly about the cost effectiveness of solar PV systems on the part of the owners of SheaHomes than about the desirability of the innovation. This, in turn, suggests that the desirability of solar PV is not solely dependent on its cost effectiveness. The percentage of SheaHomes owners who indicate that solar PV systems are cost effective (49%) is 10 points lower than the percentage who indicate that solar water-heating systems are cost effective. It is, however, 10 points higher than the 36% of comparison homeowners who agree that solar PV systems are cost effective.

These variables were also analyzed with respect to PV ownership (results summarized in Table 49). PV owners give a mean rating of 3.78 to the statement on the cost effectiveness of solar water heating, compared with a mean rating of 3.64 given by the owners of SheaHomes without PV systems, a difference that is not statistically significant. Although 63% of PV owners agree with the statement about the cost effectiveness of solar water heating, compared with 56% of non-PV owners, the difference is not significant. The pattern of responses shows that PV owners give significantly higher mean ratings to the statements that solar PV systems are cost effective than do non-PV owners.

PV owners respond with a mean rating of 3.76 for the statement about the cost effectiveness of solar PV systems, compared with the mean rating of 3.39 given by the owners of SheaHomes without PV systems. In addition, 62% of PV owners agree with the statement about cost effectiveness, compared with 40% of the non-PV owners—again, a significant difference.

These results show favorable attitudes toward the cost effectiveness of solar features in new housing on the part of PV owners; non-PV owners are less certain. Again, this finding suggests that living with a PV system fosters a positive attitude toward the cost effectiveness of including solar features in new housing.

Table 49. Average Agreement Ratings on Cost Effectiveness of Solar Features by PV Ownership

Statement	PV Owners Mean (n=68)	Non-PV Owners Mean (n=101)	PV Owners % Responding Agree or Strongly Agree	Non-PV Owners % Responding Agree or Strongly Agree
Solar water heating systems are cost effective.	3.78	3.64	63	56
Solar PV systems are cost effective.*	3.76	3.39	62	40

*Statistically significant difference in means: $t=3.076$; $p=.002$; statistically significant in percentages agreeing: $\chi 2=7.596$; $p=.022$.

Chapter 14
Policy Preferences Relative to High Performance Homes

Introduction

The U.S. Department of Energy is interested in understanding the preferences of homebuyers concerning the ways in which builders and government at both the state and federal levels should support the development and offering of ZEHs. Several items were included in the study to explore these preferences.

The chapter includes consideration of whether homeowners believe that solar features, especially PV systems, should be offered on new homes. It also reports findings on questions about preferred home builder actions in offering ZEHs and on government actions to foster ZEHs.

Chapter Highlights

- A majority of owners of SheaHomes prefer that solar water heating systems be offered standard on new homes; 42% of comparison buyers agree.
- A plurality of 46% of owners of SheaHomes prefer that solar PV systems be offered standard on new homes; 34% of comparison homeowners agree.
- A plurality of comparison homebuyers prefer that PV systems be offered both standard and optionally.
- 96% of PV owners and 86% of non-PV owners agree that ZEHs should be the standard new home sold, if they are cost effective; 90% of both SheaHomes and comparison homeowners agree.
- Strong majorities of respondents support federal tax credits for buyers of energy-efficient homes and federal research on ZEHs.
- The CEC rebates for solar water heating are strongly supported.

Should Solar Features Be Standard or Optional in New High-Performance Homes?

Because SheaHomes had designed its program to include a percentage with PV systems standard and the balance with PV systems optional, the question arose as to which approach homeowners prefer.

Respondents were asked: “In your opinion, which of the following would be the best way to offer solar PV systems to buyers of new homes?” Table 50 summarizes the findings by categories of homeowners. A plurality of SheaHomes buyers prefer solar PV systems to be offered standard (46%), whereas a plurality of comparison home buyers prefer that both choices be available (42%). However, these differences are not statistically significant.

Similarly, respondents were asked, “In your opinion, which of the following would be the best way to offer solar water heating systems to buyers of new homes?” Table 51 summarizes the responses. A majority of SheaHomes buyers (59%) prefer that solar water heating be offered as a standard feature, compared with 42% of the comparison buyers. These differences are not statistically significant.

Table 50. Preferences for Standard or Optional Offerings of Solar PV Systems on New Homes by SheaHomes and Comparison Homebuyers

Statement	SheaHomes % Agreeing or Strongly Agreeing (n=168)	Comparison Homes % Agreeing or Strongly Agreeing (n=53)
Solar PV systems should be offered as a standard feature with the cost included in the price of the home.	46	34
Solar PV systems should be offered as an optional feature with the cost added to the price of the home.	15	15
Both choices should be available.	35	42
Don't know	4	9
Totals	100	100

Table 51. Preferences for Standard or Optional Offerings of Solar Water Heating Systems on New Homes by SheaHomes and Comparison Homebuyers

Statement	SheaHomes % Agreeing or Strongly Agreeing (n=168)	Comparison Homes % Agreeing or Strongly Agreeing (n=53)
Solar water heating systems should be offered as a standard features with the cost included in the price of the home.	59	42
Solar water heating systems should be offered as an optional feature with the cost added to the price of the home.	11	21
Both choices should be available.	26	33
Don't know	4	4
Totals	100	100

When responses are analyzed by PV ownership, the pattern of findings is approximately the same. Pluralities of 46% of each group prefer that PV be offered standard. Approximately 60% of both PV and non-PV owners prefer that solar water heating be offered standard. No significant differences in response are found between the PV and non-PV owners.

The reasons given by those preferring solar energy systems to be offered standard are (1) that buyers are unaware of the benefits, (2) it helps the energy situation and the environment, and (3) it saves buyers money and time. The reasons given by those who prefer that solar features be offered only optionally are that it provides freedom of choice and it helps the environment.

Should Utility Companies Provide Rebates for Energy-Efficient Appliances?

One ZEH policy question asked respondents for their opinions about whether utility companies should provide rebates for energy-efficiency appliances. Responses were solicited on a 1-5 scale where 1=Strongly oppose and 5=Strongly favor. When responses are analyzed by categories of homebuyers, no statistically significant difference between them is found. The mean response for SheaHomes owners is 4.35 and for comparison homeowners is 4.37. Ninety-one percent of SheaHomes buyers and 89% of comparison buyers agree that utility companies should give rebates for energy-efficient appliances, values that are statistically equivalent. The analysis with regard to PV ownership also reveals no statistically significant differences between PV and non-PV owners (most of whom also agree that utility companies should give such rebates).

Should Home Builders Offer ZEHs?

Large majorities of respondents indicate agreement with the statements that show preferences for the use of energy-efficiency and solar features in home building as a standard practice if cost effective. T-tests were run on all of these items by categories of homebuyers, with no significant results. Table 52 shows the percentages of SheaHomes and comparison homeowners, and of PV and non-PV owners, agreeing with each of the statements. As the data in Table 52 indicate, no significant differences in response are found between the SheaHomes and comparison homeowners based on $\chi 2$ tests. Between owners of homes with and without PV systems, only one difference in a $\chi 2$ analysis approaches statistical significance: PV owners more frequently agree (96%) than do non-PV owners (86%) that a zero-energy type of home should be the standard home offered by builders, if they are cost effective.

Should State and Federal Governments Foster ZEHs?

Items regarding policy statements about government actions supporting ZEHs solicit opinions on research, incentives (e.g., tax credits and rebates), and subsidies for solar features in housing. Strong majorities of at least 80% of respondents in all four categories indicate that they agree or strongly agree with statements favoring federal income tax credits for energy-efficient homes. (See Table 53.) Similar results show support for federal funding for research on ZEHs and state-funded rebates for the purchase of PV systems and solar water heating systems. Approximately three-quarters of respondents indicate that they favor subsidies for solar features in affordable housing developments.

Table 52. Percentages of Respondents Agreeing or Strongly Agreeing with Statements on Builder Decisions Concerning Efficiency, Solar Features, and Home Energy Labeling by Four Categories of Homeowners

Statement	SheaHomes % Agreeing (n=170)	Comparison % Agreeing (n=52)	PV Owners % Agreeing (n=68)	Non-PV Owners % Agreeing (n=102)
New homes that are technically rated as very efficient should be given an ENERGY STAR label.	86	87	88	84
Builders should build very energy-efficient homes if they cost less per month to own and operate than conventional homes.	92	92	93	92
Builders should build homes that cut energy bills if their appearance and comfort are superior to that of conventional housing.	88	89	85	90
A complete energy package (with efficiency and solar features) should be standard equipment in new homes today if cost effective.*	90	90	96*	86*

*The difference in response between PV and non-PV owners nears statistical significance ($\chi 2$=5.376; p=.068)

Summary

Among SheaHomes buyers, the weight of the responses is in favor of providing solar PV and solar water heating as standard features on new homes. Comparison buyers are somewhat less committed to this idea, although the differences in response are not statistically significant. Significant pluralities of both categories of homeowners would like to see both standard and optional solar water heating and PV systems offered on new homes.

Virtually all of the homebuyers agree that utility companies should provide rebates for energy-efficient appliances. Most of them also agree that builders should offer ZEHs routinely if they are cost effective.

Table 53. Percentages of Respondents Agreeing or Strongly Agreeing with Policy Statements on Government Incentives and Subsidies for Solar Features by Four Categories of Homeowners

Statement	SheaHomes % Agreeing or Strongly Agreeing (n=170)	Comparison % Agreeing or Strongly Agreeing (n=52)	PV Owners % Agreeing or Strongly Agreeing (n=68)	Non-PV Owners % Agreeing or Strongly Agreeing (n=102)
Federal income tax credits should be given to buyers of energy-efficient homes.	89	83	93	87
The federal government should support research on highly energy-efficient homes that produce all the energy they use.	85	81	91	80
The California Energy Commission should give a rebate for purchasing a solar PV system.	85	83	91	81
The California Energy Commission should give a rebate for purchasing a solar water heater.	84	85	91	79
Affordable housing developments should receive subsidies for installing solar PV systems.	73	75	79	69
Affordable housing developments should receive subsidies for installing solar water heaters.	71	75	81*	65*

*The difference in response between PV and non-PV owners on the last item is statistically significant ($\chi 2$=7.294; p=.026)

Chapter 15
Self-Reported Resource Conservation Behaviors

Introduction

The study addressed the question of whether living in high-performance homes is associated with a higher incidence of resource-conserving behaviors as reported by respondents. Respondents were asked about their agreement with 12 statements on energy-conservation behaviors such as turning off lights and adjusting thermostats, recycling, water conservation, ownership of fuel-efficient vehicles, and general thriftiness.

Chapter Highlights

- Most homebuyers in the SheaHomes and comparison communities agree that they practice energy-conserving behaviors, recycle, and try to conserve water.
- Minorities of both categories of homebuyers indicate that they drive fuel-efficient vehicles.
- No significant difference on self-reported conservation behaviors are found between SheaHomes and comparison homeowners.
- The findings suggest that PV owners may engage slightly more in environmental behaviors, such as recycling, than do non-PV owners.
- Male respondents (75%) are significantly more likely than female respondents (59%) to report that they turn off their computers when not in use.

Analysis by Ownership of SheaHomes and Comparison Homes

Respondents to all questionnaires were asked: “Please indicate the extent to which you agree or disagree with the following statements.” Responses to 12 statements concerning resource conservation behaviors were sought on a 5-point Likert scale from “Strongly disagree” to “Strongly agree.” As summarized in Table 54, most respondents agree or strongly agree with most of the statements presented.

Results from this item on self-reported conservation behaviors were analyzed by SheaHomes and comparison groups. Table 54 summarizes the results. It was hypothesized that SheaHomes buyers would be more inclined to engage in energy-conserving behaviors because of owning high-performance homes; however, no significant differences in reported energy-related behaviors are found by homeowners in the two communities. In fact, although the differences are not significant, there is a slight tendency for comparison homeowners to report more “energy conscious” behaviors than do SheaHomes owners, providing a very small bit of evidence for the existence of a “take-back effect” among SheaHomes owners. However, this evidence is so slight that it cannot be concluded such an effect exists.

Analysis by PV Ownership

The self-reported energy behavior results for SheaHomes owners were also analyzed by PV system ownership. Results are summarized in Table 55. Again, it was hypothesized that PV system owners would be more inclined to engage in energy conservation behaviors, either because they own PV systems with digital displays and would be more attuned to their energy usage, or because they already had a predilection to conserve energy before they purchased their homes, or both. This had been suggested by previous qualitative interviews with SheaHomes owners. PV owners are more likely to agree that they modify their thermostat settings when away, and during winter and summer. Yet a statistically significant difference in responses by PV ownership is found for only one of the 12 listed behaviors when t-tests and $\chi 2$ analyses are run. On the other hand, the mean scores are higher among PV owners for eight of the 12 listed items.

Among SheaHomes owners, a significantly higher percentage of PV owners than non-PV owners agree that they recycle regularly ($t= -2.332$; $p=.021$; $\chi 2=8.916$; $p=.012$). In fact, although the results are not significant, non-PV owners (95%) are more likely than PV owners (88%) to agree that they turn off lights when not in use, and that they turn off computers when not in use (74% of non-PV owners compared with 62% of PV owners). Thus, the hypothesized positive effect of PV ownership on energy conservation behavior over the short-term (from 6 to at least 12 months) is not supported by these data. The data do suggest that PV owners may engage in more environmental behavior, such as recycling, than do non-PV owners.

Analysis by Gender

The self-reported energy behaviors were also crosstabulated by gender of the head-of-household respondent. Only one significant difference is found among them: a higher percentage of male heads-of-household completing the questionnaire (75%) than female heads-of-household completing the questionnaire (59%) report that they turn off their computers when not in use. To speculate, this result may be a function of more frequent computer usage among the males than the females in the two groups. For example, as a relevant anecdote, during the qualitative phase of the study, one home was identified that housed a business involving significant computer usage that was run exclusively by men.

Table 54. Self-Reported Energy Behaviors by SheaHomes and Comparison Respondents

Behaviors	SheaHomes Owners Mean Score (n=175)	Comparison Home Owners Mean Score (n=52)	% Agree or Strongly Agree (both groups)
We turn off the lights in our house when we are not using them.*	4.41	4.60	SheaHomes: 93% Comparison: 98% Total: 94%
When we are away, we modify our thermostat settings to save energy and utility costs.	4.27	4.52	SheaHomes: 84% Comparison: 90% Total: 86%
We regularly recycle paper, plastic, or cans.	4.20	4.23	SheaHomes: 89% Comparison: 85% Total: 88%
We are more energy conscious than we used to be.	4.01	4.12	SheaHomes: 80% Comparison: 81% Total: 80%
In the winter months, we regularly set our thermostat to 70° F or lower.	3.98	3.98	SheaHomes: 75% Comparison: 73% Total: 74%
We work to conserve water.	3.93	3.98	SheaHomes: 74% Comparison: 77% Total: 75%
We turn off computers when we leave the house.	3.83	3.75	SheaHomes: 69% Comparison: 67% Total: 69%
In the summer months, we regularly set our thermostat to 75° or higher.	3.60	3.83	SheaHomes: 61% Comparison: 65% Total: 62%
We tend to be thrifty.	3.48	3.58	SheaHomes: 56% Comparison: 62% Total: 57%
In our new home, we use air conditioning less than we did in our previous home.	3.43	3.46	SheaHomes: 50% Comparison: 54% Total: 51%
We drive fuel-efficient vehicles.	3.07	3.16	SheaHomes: 38% Comparison: 42% Total: 39%
We practice xeriscaping.	2.80	2.76	SheaHomes: 13% Comparison: 17% Total: 13%

*Statistically significant difference found using a t-test but not found using a $\chi 2$ test, ($t = -2.036$; $p = .044$) ($\chi 2$ n.s.)

Table 55. Self-Reported Energy Behaviors among SheaHomes Owners by Ownership of PV Systems

Behaviors	PV Owners Mean Score (n=175)	Non-PV Owners Mean Score (n=52)	% Agree or Strongly Agree (both groups)
We turn off the lights in our house when we are not using them.	4.30	4.48	PV Owner: 88% Non-PV Owner: 95% Total: 93%
When we are away, we modify our thermostat settings to save energy and utility costs.	4.40	4.19	PV Owner: 90% Non-PV Owner: 81% Total: 84%
We regularly recycle paper, plastic, or cans.*	4.39	4.08	PV Owner: 97% Non-PV Owner: 83% Total: 89%
We are more energy conscious than we used to be.	4.12	3.94	PV Owner: 81% Non-PV Owner: 79% Total: 80%
In the winter months, we regularly set our thermostat to 70°F or lower.	4.01	3.96	PV Owner: 80% Non-PV Owner: 71% Total: 75%
We work to conserve water.	3.87	3.97	PV Owner: 73% Non-PV Owner: 75% Total: 74%
We turn off computers when we leave the house.	3.60	3.97	PV Owner: 62% Non-PV Owner: 74% Total: 69%
In the summer months, we regularly set our thermostat to 75° or higher.	3.72	3.51	PV Owner: 68% Non-PV Owner: 57% Total: 61%
We tend to be thrifty.	3.57	3.42	PV Owner: 57% Non-PV Owner: 55% Total: 56%
In our new home, we use air conditioning less than we did in our previous home.	3.46	3.41	PV Owner: 49% Non-PV Owner: 51% Total: 50%
We drive fuel-efficient vehicles.	3.03	3.10	PV Owner: 35% Non-PV Owner: 39% Total: 38%
We practice xeriscaping.	2.84	2.77	PV Owner: 12% Non-PV Owner: 13% Total: 13%

*Statistically significant difference resulted using both a t-test and a $\chi 2$ test; t= –2.332, p=.21; $\chi 2$=8.916; p=.012

Chapter 16
Environmentalism and Early Adopter Characteristics

Introduction

Two hypotheses were tested in this part of the project. These are (1) that buyers of SheaHomes would be more environmentally concerned than buyers of comparison homes, and (2) that buyers of SheaHomes would be more likely to exhibit early adopter characteristics. Both of these hypotheses are of interest to builders seeking to position their ZEHs in the home-buying market. For example, if builders advertise ZEHs as "green," can they expect to attract potential home buyers who are environmentally concerned? Are buyers of high-performance homes more interested in technological innovations?

Chapter Highlights

- Only one significant difference in seven environmentalism measures was found between SheaHomes and comparison community buyers. SheaHomes buyers are more likely to link household energy consumption with environmental problems.
- No significant differences in early adopter characteristics are found between SheaHomes and comparison community buyers.
- Among SheaHomes owners, no significant differences are found between PV owners and non-PV owners on either environmentalism measures or early adopter characteristics.

In a word, no significant differences in environmentalism are found between the SheaHomes and comparison community buyers. Similarly, no significant differences are found in early adopter characteristics between the SheaHomes buyers and the comparison buyers. Finally, no significant differences are found between PV owners and non-PV owners within the SheaHomes community.

Environmentalism

Generally, the marketing of products that are considered "green" because they help protect the environment is oriented toward the environmentally concerned segment of the public. High-performance homes could be considered as loosely falling in the category of "green" buildings because they are efficient, have solar water heating, and produce solar electricity, although they do not use recycled materials and other hallmarks of "green" buildings. Yet opinion supportive of the environment is quite widespread in the U.S. public (Dunlap et al. 2000; Dunlap and Van Liere 1978), although it has declined in recent years (Greenberg 2005; Jl 2004). The potential buyers of upscale SheaHomes and comparison homes might not be very different from each other. Still, research has shown that those interested in high-performance housing articulate environmental concern as one of their reasons. Those interested in the research wanted to know whether the SheaHomes buyers differ from the comparison community buyers in environmentalism.

Therefore, the first hypothesis is that the buyers of the high-performance SheaHomes would be more environmentally concerned than the buyers of the comparison homes. This idea derives from prior research suggesting that environmental concern is a key reason for adults to seek out and purchase products such as homes and cars offering greater environmental protection than other products.

Environmentalism was measured in two ways. The first was using items from the New Environmental Paradigm (NEP) that have been tested extensively in empirical research on adult populations (Van Liere 2003; Van Liere personal communication).

These five items—included in all four questionnaires—asked respondents, using a 5-point Likert scale, whether they strongly disagree (a score of 1) to strongly agree (a score of 5) with each statement. The five statements were as follows:

1. We have a serious responsibility to preserve the environment for future generations.
2. Many of the supposed threats to the environment have been greatly exaggerated.
3. Current federal regulations provide adequate protection for the environment.
4. Individuals need to take personal responsibility for protecting the environment.
5. Household energy consumption is not a major contributor to environmental problems.

For four of the five NEP items, no significant differences are found between SheaHomes and comparison home buyers. Although the frequency of responses is consistently in the expected direction, the hypothesis that SheaHomes buyers would be more environmentally concerned is not supported by the data. A significant difference is found for the fifth item, “Household energy consumption is not a major contributor to environmental problems” ($\chi 2=11.165$; $p=.004$). However, this difference is not found to be statistically significant when a t-test for differences in mean response is run. The mean score given by SheaHomes owners is 2.70 and by the comparison owners is 2.55. To speculate, the wording of this item in the NEP scale, inverting the “agree” and “disagree” response that would be needed to indicate environmental concern might have yielded this result. On the other hand, SheaHomes buyers could have been somewhat more concerned about energy issues than comparison buyers.

The NEP items were also tested for differences in response by PV versus non-PV ownership among the SheaHomes owners. Table 56 summarizes the findings for both the SheaHomes versus the comparison buyers and the PV versus the non-PV owners. PV owners respond more frequently than non-PV owners in the expected direction; however, no statistically significant results are found. For example, 38% of PV owners, compared with 28% of non-PV owners, disagree that threats to the environment have been exaggerated. Fifty-seven percent of PV owners compared with 45% of non-PV owners disagree with the thought that household energy consumption is not a major contributor to environmental problems. Yet these differences in patterns of response do not achieve statistical significance.

The second way environmentalism was measured was to include two environmental attitude items asking respondents to agree or disagree on a Likert scale from 1 to 5, as described previously.

1. I tend to buy environmentally friendly products, even if they cost more.
2. I am willing to accept modifications to my lifestyle if it helps the environment.

These items were included with the items measuring early adopter characteristics, discussed below, and were included on all four questionnaires. Presented in Table 57, the results from these two items show that a plurality of both SheaHomes and comparison buyers agree that they tend to buy environmentally friendly products even if they cost more (between 40% and 50%). Approximately two-thirds of both categories of homebuyers agree they are willing to accept modifications to their lifestyles to help the environment.

Early Adopter Characteristics

As discussed in Chapter 2, diffusion-of-innovation theory would suggest that, across the entire adult population in the United States, those most apt to adopt innovations first (innovators and early adopters) have certain fairly well-understood characteristics. Innovators (the leading edge innovation adopters comprising approximately 2.5% of the population) tend to be venturesome, control substantial resources, have complex technological knowledge, and tolerate uncertainty in outcomes. Early adopters are frequently "opinion leaders" who catalyze shifts in the innovation's penetration from the select few to the "early majority." Early adopters (the next 13.5% of adopters) are well integrated in local communities and tend to be people to whom others look to for advice before adopting an innovation.[1]

The second hypothesis in this study was that the SheaHomes buyers would exhibit more characteristics of innovators and early adopters than the comparison buyers. This idea also derives from diffusion-of-innovation theory, and is based on the concept that certain potential buyers could be interested in high-performance homes as technologically innovative, or as offering environmental benefits, financial advantages, or pacesetting benefits (including status and prestige of being among the first to own the innovation). The "early adopters" concept is generally accepted in the energy analysis community.

Four items were used to test innovativeness and two were used to further test the environmental attitudes of the respondents. Respondents were asked to agree or disagree on a Likert scale, as previously described. In all four questionnaires these four items were presented as a set. The four early-adopter items were:

1. I like to be as independent as possible so I don't have to rely on others to meet my needs.
2. I like to experiment with new ways of doing things.
3. I am seen as a leader in my work life, social life, or volunteer activities.
4. I am intrigued with new technology.

Table 57 summarizes the findings for responses by SheaHomes versus comparison owners and by PV versus non-PV owners. No consistent patterns of differences are found that distinguish owners of SheaHomes from owners of comparison homes. Further, the items do not differentiate between owners of homes with and without solar PV systems.

---

[1] Other demographic characteristics of early adopters are discussed in the section on the study's key dependent variables. See also Chapter 2, Guiding Ideas.

Summary

Although environmentalism and early adopter characteristics are often associated with purchase of innovative “green” products, and high-performance homes could be seen as both innovative and protective of the environment, apparently these motivations do not distinguish the purchasers of high-performance homes from other new homebuyers. Indeed, support for environmental protection is so widespread in the population that we would be unlikely to discern differences among the categories of homebuyers at Scripps Highlands. The one difference found among the environmental variables is that a significantly higher percentage of SheaHomes purchasers link household energy consumption with environmental problems than are comparison home purchasers. In addition, as we have discussed, other home features are far more influential in home purchase decisions than are energy and environmental characteristics.

Table 56. Environmentalism by Builder and by PV Ownership

Item	Shea Homes Mean Score	Comparison Mean Score	Shea Homes %	Comparison %	PV Owner Mean Score	Non-PV Owner Mean Score	PV Owners %	Non-PV Owners %
We have a serious responsibility to preserve the environment for future generations.	4.40	4.47	A: 94 U: 6 D: 0	A: 92 U: 8 D: 0	4.37	4.42	A: 94 U: 6 D: 0	A: 94 U: 6 D: 0
Individuals need to take personal responsibility for protecting the environment.	4.36	4.41	A: 94 U: 6 D: 0	A: 94 U: 6 D: 0	4.37	4.35	A: 97 U: 3 D: 0	A: 92 U: 8 D: 0
Many of the supposed threats to the environment have been greatly exaggerated.§	2.98	3.18	A: 34 U: 34 D: 32	A: 24 U: 43 D: 33	3.12	2.88	A: 31 U: 31 D: 38	A: 36 U: 35 D: 28
Current federal regulations provide adequate protection for the environment.§	2.99	3.26	A: 29** U: 41 D: 29	A: 18 U: 46 D: 36	3.13	2.90	A: 22 U: 44 D: 34	A: 34 U: 39 D: 27
*Household energy consumption is not a major contributor to environmental problems.§	3.30	3.45	A: 22 U: 28 D: 50	A: 8 U: 51 D: 41	3.38	3.24	A: 19 U: 24 D: 57	A: 24 U: 31 D: 45

*Statistically significant difference between SheaHomes and comparison home respondents ($\chi2$=11.165; p=.004; t-test results n.s.)
** Does not add to 100 because of rounding
A=Agree or strongly agree
U=Unsure or neutral
D=Disagree or strongly disagree

§Scoring was inverted for these items; the higher the mean score, the more positive toward the environment. The percentages for the "agree" and "disagree" responses are reported in their original form; that is, they are not inverted. In this case, "agree" means a less environmental response, and "disagree" means a more environmental response.

Table 57. Early Adopter Characteristics and Environmental Attitudes by SheaHomes versus Comparison Buyers and by PV Ownership

Item	Shea Homes Mean Score	Comparison Mean Score	Shea Homes %	Comparison %	PV Owners Mean Score	Non-PV Owners Mean Score	PV Owners %	Non-PV Owners %
I like to be as independent as possible so I don't have to rely on others to meet my needs.	4.19	4.31	A: 84** U: 13 D: 4	A: 88 U: 8 D: 4	4.28	4.13	A: 88** U: 9 D: 2	A: 80 U: 16 D: 4
I am intrigued with new technology.	4.09	4.08	A: 81 U: 16 D: 3	A: 80 U: 18 D: 2	4.16	4.04	A: 87 U: 13 D: 0	A: 77 U: 18 D: 5
I like to experiment with new ways of doing things.	3.92	3.75	A: 74 U: 24 D: 2	A: 63 U: 35 D: 2	4.01	3.85	A: 75 U: 25 D: 0	A: 73** U: 24 D: 4
I am seen as a leader in my work life, social life, or volunteer activities.	3.82	3.96	A: 67 U: 29 D: 4	A: 77** U: 22 D: 2	3.85	3.79	A: 67 U: 31 D: 2	A: 67 U: 27 D: 6
I am willing to accept modification to my lifestyle if it helps the environment.	3.74	3.76	A: 66 U: 29 D: 5	A: 67 U: 31 D: 2	3.75	3.75	A: 66 U: 31 D: 3	A: 66 U: 28 D: 6
I tend to buy environmentally friendly products, even if they cost more.	3.46	3.29	A: 47 U: 42 D: 11	A: 41 U: 43 D: 16	3.44	3.47	A: 44 U: 47 D: 9	A: 49 U: 39 D: 12

*No significant differences.
** Does not add to 100 because of rounding
A=Agree or strongly agree
U=Unsure or neutral
D=Disagree or strongly disagree

Chapter 17
Data Reduction

Introduction

Many surveys provide vast amounts of information that cannot be usefully interpreted without some preliminary synthesis. Various statistical techniques are available for accomplishing the synthesis. Factor analysis is one such statistical technique by which several variables can be reduced to a smaller number of "factors" or "dimensions" by considering and identifying which of the original variables are similar to each other (Morrison 1976). In the context of survey research, factor analysis can be used to distill the total number of questions, items, or response variables that constitute a survey instrument down to a smaller set of factors that more succinctly reflect the answers of all the respondents.

Each factor produced with factor analysis represents a weighted combination of some of the original variables. The numerical weights that are used to combine the variables to form factors are referred to as "factor loadings." Factor loadings may vary from −1.0 to +1.0. A positive factor loading for a contributing variable indicates it is positively associated with the overall factor. Similarly, a negative factor loading for a contributing variable indicates it is negatively associated with the overall factor.

Chapter Highlights

- All scaled items in the questionnaires were factor analyzed, resulting in 49 factors, 29 of which applied to all respondents, thus permitting differentiation among them.
- Reasons for purchase factors are builder reputation; safe, secure area; familiarity with area; convenience of access; and investment potential.
- Factors for importance of home features are overall design; size of home and number of bedrooms, and single-story option.
- Three factors for the perceived benefits of solar PV ownership are altruistic, financial, and personal satisfaction dimensions.
- Five dimensions of barriers to PV purchase are unsureness about efficacy, effect on resale value, up-front cost, uncertainty about placement of system on roof, and indifference.
- Satisfaction factors include the home's quality, investment potential, intent to purchase energy efficiency and solar features in any new home purchased, and estimated monthly utility bill.
- Factor analysis resulted in anti-environmentalism and pro-environmentalism factors.

The most important factors are determined to be those that collectively explain a high percentage of the data variability. These are often the factors for which the highest factor loadings are determined. A high positive or negative factor loading from any variable or item indicates that the item helps to "define" the factor. In the survey context, the key definers are variables that are truly able to differentiate respondents into categories.

Once the most important factors have been determined, they can be used to compute a factor response, or "factor score," in much the same way that each original variable yields a response, value, or score. These factor scores can then be substituted for the values of the original variables in further analyses.

Factor analysis was used to investigate many of the items and variables contained in the questionnaires for the present study.[1] A particular kind of factor analysis that involved varimax rotation (Dillon and Goldstein 1984) was used. The results of all the factor analyses from the study and all the items used in them are contained in Appendix H (Detailed Factor Analysis Results), and discussion of the factors and their defining items is provided in this chapter.

Having determined the most important factors that represent the study variables, factor scores for each were computed for every respondent, and the scores were subsequently standardized (by using the statistical Z-transformation). All standardized factor scores essentially range from −3.0 to + 3.0. These scores were ultimately used to help differentiate variations within market segments of the SheaHomes and comparison community respondents. All factor analyses were run on the entire set of respondents (including responses from SheaHomes and comparison community homeowners), unless the questions had been limited to a particular group, such as PV owners or main owners.

This chapter is divided into three parts. The first part presents results of the factor analyses conducted on items asked of all respondents; that is, responses from the main, ineligible/early, PV, and comparison questionnaires. The second part presents results of the factor analysis conducted on an item asked only of main respondents. The third part presents results of the factor analyses conducted on responses to items asked only of PV respondents.

[1]Appendix *F* presents, for the study's individual questions, base n's, means, standard deviations, and coefficients of variation for scaled responses.

PART ONE: ITEMS ASKED OF ALL RESPONDENTS

Introduction

This part details findings from factor analyses that deal with answers from all respondents on sets of items in the questionnaire, including reasons for home purchases, home features, attitudes toward solar features, equipment owned, self-reported conservation behaviors, energy policy preferences, environmental attitudes, early adopter characteristics, and homeowner satisfaction with their new homes.

Factor Analysis of Reasons for Purchase

Factor analysis of 20 of the 24 potential reasons for purchasing a particular home resulted in six dimensions. These 20 items are discussed in Chapter 7 (New Home Search and Purchase Decision), and were asked of all respondents.[2]

These six dimensions are as follows:

1. Company reputation and performance
2. Safe and secure area
3. Familiarity with area
4. Convenience of access
5. Investment potential
6. Other advantages of the location.

Company Reputation and Performance

The first dimension reflects respondent perception of and experience with the company that offered the home. The reputability of the builder, the helpfulness of the sales staff, and—to a lesser extent—the energy use aspects of the home combine to form this factor. The items that define this dimension and their factor loadings are shown below.

Factor One: Company Reputation and Performance
Eigenvalue[3]=3.148 and % of variance explained=15.738

Key Definers	**Factor Loadings**
Helpfulness of staff	.821
Builder reputation	.811
Availability of very energy-efficient home	.696

---

[2]The other four items were asked only of subsets of respondents.

[3]Eigenvalues are a special set of scalars associated with a linear system of equations that are sometimes also known as characteristic roots, proper values, or latent roots (Marcus and Mini 1988).

Safe and Secure Area

The second dimension reflects concerns that homebuyers with families exhibit, including if the neighborhood is safe and secure, if the schools are good, and, in general, if the home is in a high-quality neighborhood. Three-quarters of the buyers have children; therefore, this factor clearly represents their concerns. The items that define this dimension and their factor loadings are shown below.

Factor Two: Safe and Secure Area

Eigenvalue=2.034 and % of variance explained=10.168

Key Definers	**Factor Loadings**
Safe and secure feeling	.819
Quality of schools	.627
Quality of neighborhood/community	.609

Familiarity with the Area

The third dimension reflects previous knowledge of the area and the people who live there, as well as common areas for family and friends to gather. Although related to the idea of a safe, secure, and high-quality neighborhood, familiarity with places and people forms a separate dimension. The items that define this dimension and their factor loadings are shown below.

Factor Three: Familiarity with Area

Eigenvalue=1.998 and % of variance explained=9.991

Key Definers	**Factor Loadings**
Close to friends	.797
Close to parks/playgrounds	.759
Knows the area	.577

Convenience of Access

The fourth dimension reflects the convenience of access to and from the neighborhood in terms of closeness to work (for example, the I-15 freeway that runs north and south and can be taken to downtown San Diego) and the proximity of shopping centers and other services. The items that define this dimension and their factor loadings are shown below.

__Factor Four: Convenience of Access__
Eigenvalue=1.961 and % of variance explained=9.805

Key Definers	Factor Loadings
Close to work	.735
Near freeway	.703
Near services	.673

Investment Potential

At the time they purchased their homes, respondents considered the investment potential of the property. The fifth dimension reflects this as a distinct area of concern. The items that define this dimension and their factor loadings are shown below.

__Factor Five: Investment Potential__
Eigenvalue=1.439 and % of variance explained=7.193

Key Definers	Factor Loadings
Investment potential	.694
Desirable area	.613

Other Advantages of the Location

The sixth dimension reflects other advantages of the property considered by homeowners at the time of purchase. The fact that these homes were exempt from Mello-Roos taxes—which could have amounted to as much as $500 to $700 a month—was a positive consideration. In addition, because the homes were built on a mesa some 15 miles east of the Pacific Ocean, they had pleasing views of the surrounding hills and, in some cases, of the ocean. The items that define this dimension and their factor loadings are shown below.

__Factor Six: Other Advantages of the Location__
Eigenvalue=1.409 and % of variance explained=7.045

Key Definers	Factor Loadings
No Mello-Roos taxes	.586
Great view	.581

Together, these six dimensions (factors) account for 59.940% of the variance in responses to the 20 items. These findings convey the sense that homeowners in the upper-middle price range are differentiated in looking at their experience with the product and the sales staff; whether the homes are located in a safe, secure quality area; their familiarity with the area and its people; the convenience of the homes relative to their places of business, freeway access, and services;

whether the home will increase in value; and other distinct advantages the homes might have, such as lower taxes than other new homes and views. These dimensions together help to describe the key attributes and experiences that a variety of new homebuyers desire.

Factor Analysis of Home Features

The four questionnaires replicated 15 items that pertain to the importance of the features of the house in the home-purchase decision, and these were similarly factor analyzed. The items form three major dimensions:

1. Overall design
2. Size of home and number of bedrooms
3. Single-story option.

Overall Design

The first dimension reflects aspects of the house's overall design, including quality of light, sense of openness, spaciousness, layout, and architectural design. The items that define this dimension and their factor loadings are shown below.

Factor One: Overall Design
Eigenvalue=3.726 and % of variance=24.840

Key Definers	**Factor Loadings**
Quality or sense of light	.766
Spaciousness/openness	.741
Floor plan/layout	.699
Architectural design	.690

Size of Home and Number of Bedrooms

The second dimension reflects the homebuyers' interest in the number of bedrooms and the overall square footage of the home. SheaHomes offered a room that could optionally be a sixth bedroom or a study, playroom, or other space. This option was commented on favorably by several homeowners in the qualitative interviews before the survey. The items that define this dimension and their factor loadings are shown below.

Factor Two: Size of Home and Number of Bedrooms
Eigenvalue=2.253 and % of variance=15.022

Key Definers	**Factor Loadings**
Number of bedrooms	.764
Size/square footage	.693

Single-Story Option

The third dimension concerned the availability of a single-story option, offered only by SheaHomes. This option was critical to a subset of the homebuyers, according to information obtained in the qualitative interviews. Because SheaHomes had limited the number of single-story homes, some homebuyers reported they had reluctantly purchased two-story homes because they loved the area, builder, and other aspects of the homes, but that single-story homes were not available. Most homebuyers had children and were happy with the two-story option. The item that defines this dimension and its factor loading are shown below.

Factor Three: Single-Story Option
Eigenvalue=2.094 and % of variance=13.960

Key Definer	**Factor Loading**
Single-story option	.739

Together, these three dimensions (factors) account for 53.822% of the variance in response to the 15 items. The findings convey the sense that architectural design and, perhaps surprisingly, the quality of light, are key aesthetic aspects that appeal to different homebuyers. The size of the homes and the number of bedrooms (as well as the versatility of the bedrooms for other uses) is also a distinct consideration. For some buyers, a single-story option is important. The availability of this option may have contributed to age diversity in the SheaHomes neighborhoods.

Factor Analysis of Attitudes toward Solar Features

Four items queried respondents on how desirable and cost effective solar water heating and solar PV systems are in new homes, as discussed in Chapter 13 (Attitudes toward Solar Features in New Housing). Interestingly, the factors do not form around solar technologies, but instead form around the desirability of the innovations and their cost effectiveness. The factor analysis of these four variables resulted in two dimensions:

1. Desirable innovation
2. Cost effectiveness of solar features.

Desirable Innovation

The first dimension reflects the sense that solar PV and solar water heating systems are desirable innovations for new homes. The items that define this dimension and their factor loadings are shown below.

Factor One: Desirability of Solar Features as Innovations
Eigenvalue=1.804 and % of variance explained=45.092

Key Definers	**Factor Loadings**
Solar PV systems are a desirable innovation for new homes	.930
Solar water heating systems are a desirable innovation for new homes	.922

Cost Effectiveness of Solar Features

The second dimension reflects the sense that solar PV and solar water heating systems are cost effective. The items that define this dimension and their factor loadings are shown below.

Factor Two: Cost Effectiveness of Solar Features
Eigenvalue=1.737 and % of variance explained=43.430

Key Definers	**Factor Loadings**
Solar PV systems are cost effective	.927
Solar water heating systems are cost effective	.892

Together, these two dimensions (factors) account for 88.522% of the variance in response to the four items. The difference in perceived desirability and cost effectiveness of the solar features distinguishes among respondents.

Factor Analysis of Equipment Owned

Nine questions asked respondents if they owned the following equipment, which was potentially relevant to their energy use:[4] two refrigerators, ceiling fans, standalone freezers, dimmer switches for lights, CFLs, hot tubs, hot water flow regulators, pools, and dual-zone heating/air-conditioning systems. The factor analysis of these nine variables resulted in four dimensions:

1. Equipment for fun: pool and hot tub combination
2. Smaller efficiency measures
3. Convenience measures
4. Measures for comfort.

Equipment for Fun: Pool and Hot Tub Combination

The first dimension reflects a tendency to own both a pool and hot tub. The items that define this dimension and their factor loadings are shown below.

Factor One: Equipment for Fun: Pool and Hot Tub Combination
Eigenvalue=1.448 and % of variance explained=16.092

Key Definers	**Factor Loadings**
Pool	.797
Hot tub	.753

[4]See Appendix RC (Respondent Characteristics).

Smaller Efficiency Measures

The second dimension includes smaller efficiency measures such as dimmer switches and ceiling fans. The items that define this dimension and their factor loadings are shown below.

Factor Two: Smaller Efficiency Measures
Eigenvalue=1.399 and % of variance explained=15.549

Key Definers	**Factor Loadings**
Dimmer switches for lights	.778
Ceiling fans	.738

Convenience Measures

The third dimension seems to reflect a convenience factor. The hot water flow regulator keeps hot water on tap in the bathrooms distant from the hot water tank, which prevents several minutes of running the tap waiting for hot water to arrive from the other end of the house. Having a second refrigerator allows for extra storage of food and beverages for parties and large families. The items that define this dimension and their factor loadings are shown below.

Factor Three: Convenience Measures
Eigenvalue=1.316 and % of variance explained=14.617

Key Definers	**Factor Loadings**
Hot water flow regulator	.749
Two refrigerators	.679

Dual-zone Heating and Air-Conditioning

The fourth dimension seems to reflect a subset of respondents who owned features at opposite ends of a spectrum (note the negative value on CFLs). These respondents own dual-zone heating and air-conditioning systems particularly in two-story homes.

Factor Four: Dual-zone Heating and Air-Conditioning
Eigenvalue=1.164 and % of variance explained=12.939

Key Definers	**Factor Loadings**
Dual-zone heating/air-conditioning system	.702
Compact fluorescent light bulbs (CFLs)	–.690*

*Note negative value.

Together, these four dimensions (factors) account for 59.197% of the variance in response to the nine questions on equipment ownership. Only one expresses a preference for conservation and that on only a limited scale. Comfort and convenience are more strongly supported among these factors that differentiate among homeowners.

Factor Analysis of Self-Reported Resource Conservation Behaviors

Respondents were presented with 12 statements on energy conservation behaviors (Table 54 in Chapter 15). Ten of these were included in a factor analysis that optimized the best, most interpretable solution.[5] The questions were designed to elicit information on resource conservation and environmental behaviors. This factor analysis resulted in three dimensions:

1. Adjusting thermostats
2. Resource conscious (energy and water)
3. Conserve water and electricity.

Adjusting Thermostats

The first dimension reflects energy-conserving behavior by adjusting thermostats in winter, summer, and when away. The items that define this dimension and their factor loadings are shown below.

Factor One: Adjusting Thermostats

Eigenvalue=2.196 and % of variance explained=21.963

Key Definers	**Factor Loadings**
In winter, set thermostat at 70°F or lower	.902
In summer, set thermostat at 75°F or higher	.844
When away, modify thermostat settings	.756

Resource Consciousness

The second dimension seems to reflect energy and water resource consciousness. Interestingly, the practice of xeriscaping does not factor with conserving water, which is in the next dimension, but instead factors with using less air-conditioning, driving a fuel-efficient car, and being more energy conscious. The items that define this dimension and their factor loadings are shown below.

[5]The statements on being thrifty and regularly recycling were omitted from this analysis to optimize the solution.

Factor Two: Resource Consciousness
Eigenvalue=2.032 and % of variance explained=20.324

Key Definers	**Factor Loadings**
Practice xeriscaping	.767
Use air conditioning less than in previous home	.751
Drive fuel-efficient vehicles	.670
More energy conscious than we used to be	.559

Conserve Water and Electricity

The third dimension reflects both energy and water conservation. The items that define this dimension and their factor loadings are shown below.

Factor Three: Conserve Water and Electricity
Eigenvalue=1.958 and % of variance explained=19.579

Key Definers	**Factor Loadings**
Conserve water	.808
Turn off lights	.774
Turn off computers	.756

Together, these three dimensions account for 61.866% of the variance in response to the 10 items on resource conservation behaviors, as reported by respondents. Adjusting thermostats appears to be an energy-efficiency dimension that differentiates among respondents, as does resource consciousness.

Factor Analysis of Energy Policy Preferences

Eleven statements elicited respondents' preferences among policies relative to high-performance homes. The factor analysis of these items resulted in three major dimensions:

1. Financial incentives
2. Policies relative to builders and ZEHs
3. Subsidizing affordable housing.

Financial Incentives

The first dimension reflects responses that show preferences for financial incentives for energy efficiency and solar PV and water heating systems, including rebates and tax credits from various levels of government and utility companies. This reflects a preference for "money back" policies for energy efficiency and solar features.

Factor One: Financial Incentives
Eigenvalue=3.084 and % of variance explained=28.036

Key Definers	**Factor Loadings**
California Energy Commission should give rebates for PV systems.	.847
California Energy Commission should give rebates for solar water heating.	.817
Federal income tax credits should be provided to buyers of energy-efficient homes.	.804
Utility companies should give rebates for energy-efficient appliances.	.750

Policies Relative to Builders and ZEHs

The second dimension seems to revolve around the policies of builders and government policies that would affect builders. This dimension reflects a preference for private-industry approaches.

Factor Two: Policies Relative to Builders and ZEHs
Eigenvalue=3.081 and % of variance explained=28.011

Key Definers	**Factor Loadings**
Builders should build energy-efficient homes if they cost less.	.869
Builders should build energy-efficient homes if they are comfortable and look better.	.810
Energy packages should be standard if cost effective.	.704
Federal government should support research on ZEHs.	.622
Homes technically rated efficient should be given an ENERGY STAR label.	.608

Subsidizing Affordable Housing

The third dimension reflects a subset of responses that support subsidies for solar features so that they can be used in affordable housing. The items that define this dimension and their factor loadings are shown below.

Factor Three: Pro-Subsidies Position
Eigenvalue=2.222 and % of variance explained=20.199

Key Definers	Factor Loadings
Affordable housing subsidies for PV systems	.897
Affordable housing subsidies for solar water heating systems	.896

Together, these three dimensions account for 76.246% of the variance in response to the 11 items on energy policy preferences. Interestingly, the three dimensions that differentiate among respondents reflect a "money back" position, a "private industry" position, and a position that supports solar features in affordable housing.

Factor Analysis of the New Environmental Paradigm

Five items from the New Environmental Paradigm (NEP) scale, recommended by Van Liere (2003), were included to measure differentiation among buyers of high-performance homes on these attitudes. These items are discussed in Chapter 16 (Environmentalism and Early Adopter Characteristics, Table 56 in Chapter 16). The factor analysis of these items resulted in two dimensions:

1. Anti-environmentalism
2. Environmentalism.

Anti-Environmentalism

The first dimension reflects anti-environmentalist sentiments relative to environmental protection and to housing's role in environmental problems. The items that define this dimension and their factor loadings are shown below.

Factor One: Anti-Environmentalism
Eigenvalue=2.038 and % of variance explained=40.757

Key Definers	Factor Loadings
Current federal regulations provide adequate protection for the environment.	.844
Many of the supposed threats to the environment have been greatly exaggerated.	.836
Household energy consumption is not a major contributor to environmental problems.	.775

Environmentalism

The second dimension reflects a positive attitude toward environmental protection. The items that define this dimension and their factor loadings are shown below.

Factor Two: Environmentalism
Eigenvalue=1.561 and % of variance explained=31.221

Key Definers	Factor Loadings
Individuals need to take responsibility for protecting the environment.	.888
We have a serious responsibility to preserve the environment for future generations.	.863

Together, these two dimensions account for 71.978% of the variance in response to the five items from the NEP scale. This result suggests that both pro- and anti-environmental respondents were included in the study.

Factor Analysis of Early Adopter Characteristics

Six items derived from earlier studies of early adopter characteristics and environmental protection (Farhar and Coburn 2000) were included in the study to measure differences on early adopter characteristics (four items) and environmental attitudes (two items) among categories of homebuyers, resulting in two dimensions:

1. Early adopter characteristics
2. Environmental attitudes.

Early Adopter Characteristics

The first dimension includes the variables that are intended to measure early adopter characteristics. The items that define this dimension and their factor loadings are shown below.

Factor One: Early Adopter Characteristics
Eigenvalue=1.757 and % of variance explained=29.289

Key Definers	Factor Loadings
Seen as leader in work, social, or volunteer	.775
Like to be as independent as possible	.722
Like to experiment with new ways of doing things	.607

Environmental Attitudes

The second dimension includes the two items that are intended to measure environmental attitudes different from the NEP items. The items that define this dimension and their factor loadings are shown below.

Factor Two: Environmental Attitudes
Eigenvalue=1.673 and % of variance explained=27.881

Key Definers	Factor Loadings
Buy environmentally friendly even if it costs more	.867
Willing to modify lifestyle to help the environment	.835

Together, these two dimensions account for 57.171% of the variance in response to the six items on early adopter characteristics and environmental attitudes. Each factor represents an interpretable part of the six-item scale.

Factor Analysis of Satisfaction

Sixteen variables, asked of all respondents and intended as operationalized measures of homebuyer satisfaction, were factor analyzed. The variables are discussed in Chapter 10 (Homebuyer Satisfaction with the Purchased Home). They include questions about the perceived comfort and energy efficiency of the home; ratings of satisfaction on key aspects, such as location, investment potential, builder reputation, layout of the home, storage, lot size, construction quality, and number of thermostats; the respondent's estimated monthly utility bill for the home; and whether a respondent would, in the future, purchase a home that is highly energy efficient, has solar water heating, and comes with a solar PV system.

These items form four major dimensions:

1. Quality of construction, builder reputation, and comfort
2. Investment potential of home
3. Behavioral intention with respect to energy features in future home purchases
4. Estimated monthly utility bill.

The cumulative percentage of variance in response explained by these five dimensions is 67.643.

Quality of Construction, Builder Reputation, and Comfort

The first dimension reflects satisfaction with the quality and performance of the home. Items that define this dimension have to do with the perceived quality of construction, the reputation of the builder, and the home's comfort. These defining items and their factor loadings are shown below.

Factor One: Quality of Construction, Builder Reputation, and Comfort
Eigenvalue=4.725 and % of variance explained=20.703

Key Definers	Factor Loadings
Satisfaction with quality of construction	.831
Satisfaction with builder reputation	.743
Perceived comfort of home overall	.630

Certain buyers are more concerned about the quality of their homes. This dimension expresses the ways in which quality is "operationalized" in these buyers' thinking—a home's quality is enhanced by better construction, an excellent builder reputation, large size (i.e., 3,000 ft^2 or more), and comfort.

Investment Potential of Home

The second dimension reflects satisfaction with the home's investment potential. Factoring with the investment potential item is satisfaction with the home's location and size.

Factor Two: Investment Potential of Home
Eigenvalue=2.620 and % of variance explained=16.377

Key Definers	Factor Loadings
Satisfaction with home's location	.758
Satisfaction with investment potential of home	.726
Satisfaction with size/square footage	.724

This dimension appears to represent variables that, together, differentiate among homeowners on an aspect of satisfaction pertaining to the homes value because of where it is located, how large it is, and the expectation that it will have good resale value.

Behavioral Intention with Respect to Energy Features in Future Home Purchases

The third dimension reflects satisfaction as measured by statements about potential future decisions about energy efficiency and solar features in any new home the respondent might purchase. Expressions of intent to purchase these features are taken to mean that respondents are satisfied with their current experience with these features or wish they had them, if they do not currently own them.

Factor Three: Behavioral Intention with Respect to Energy Efficiency and Solar Features in Future House Purchases

Eigenvalue=2.356 and % of variance explained=14.726

Key Definers	Factor Loadings
Will buy solar water heating in new home	.879
Will buy solar PV in new home	.874
Will buy energy efficiency in new home	.827

The solar features especially define this dimension on behavioral intention. Whether homeowners lived in homes with solar features or interacted with neighbors who lived in such homes, this dimension reflects their interest in ZEH features.

Estimated Monthly Utility Bill

The questionnaires asked all respondents to estimate their monthly utility bills. These responses were recoded from the actual dollar amount reported by dividing the dollar amounts into five categories, with each category containing 20% of the responses. The categories are (1) ≤$80 per month, (2) $80.01–$110, (3) $110.01–$150, (4) $150.01–$210, and (5) >$210. The resulting scale, from 1 to 5, matched the scales of the other items used in the factor analysis. This item, thought to measure a part of satisfaction with the home's perceived performance, resulted in a fourth dimension of satisfaction.

Factor Four: Reported Monthly Utility Bill

Eigenvalue=1.152 and % of variance explained=7.201

Key Definer	Factor Loading
Estimated monthly utility bill	.865

The assumption is that the lower the estimated utility bills, the more satisfied homeowners would be.

Together, the four dimensions (factors) for satisfaction with the homes account for 67.643% of the variance in response. This tells us that these four dimensions—the home's perceived quality, its investment potential, whether the owners would purchase energy-efficiency and solar features in a new home they might buy, and their estimated monthly utility bills—represent important and distinct dimensions of homeowner satisfaction.

PART TWO: ITEMS ASKED OF MAIN RESPONDENTS ONLY

A multi-part question, asked only of main respondents, explored their reasons for deciding not to purchase a solar PV system. This part of the chapter presents the findings for these questions. These respondents had the option (at least theoretically) to purchase a 1.2-kW system for $6,000 or a 2.4-kW PV system for $10,000.[6]

Factor Analysis of Barriers to Solar PV Systems

Thirteen variables that could have been perceived as barriers to PV purchase were factor analyzed. These are described in Chapter 8, Solar PV Purchase Decision. They include statements about the added expense of the PV system, reliability, maintenance, trade-offs with other options being offered, lack of knowledge about how it would work, aesthetics, property taxes, homeowners insurance premiums, resale value, and indifference.

The factor analysis resulted in five dimensions:

1. Unsure about efficacy of solar PV technology
2. Solar PV might negatively affect resale value
3. Tangible, immediate financial barriers
4. Uncertainty about PV system placement on the roof
5. Indifference to PV.

Unsure about Efficacy of Solar PV Technology

The first dimension reflects some main respondents' concerns about the performance of solar PV systems—whether they would soon become outdated, whether they would require costly and difficult maintenance, and whether they would produce electricity reliably. The items that define this dimension and their factor loadings are shown below.

Factor One: Unsure about Efficacy of Solar PV Technology
Eigenvalue=2.644 and % of variance explained=20.335

Key Definers	Factor Loadings
Could become outdated technologically	.841
Concerned about maintenance issues	.788
Unsure about the reliability of system	.783

This dimension expressed concerns similar to those included in the first factor on perceived barriers to solar PV adoption among Colorado homeowners who might consider a PV retrofit (Farhar and Coburn 2000, p. 53).

---

[6]As discussed earlier, some main respondents do not recall being offered a PV system.

Solar PV Might Negatively Affect Home Value

The second dimension appears to reflect concerns of some main respondents that solar PV systems might negatively affect the home's resale value. Aesthetic considerations could play a part in these concerns because the second highest loading variable refers to how the systems look. Interestingly, the factor loadings are negative on (1) the length of payback and (2) the idea that the PV system was too expensive, which indicates that this factor is *not* about the up-front expense and operational performance of the system. The items that define this dimension and their factor loadings are shown below.

Factor Two: Solar PV Could Negatively Affect Home Value
Eigenvalue=2.158 and % of variance explained=16.601

Key Definers	**Factor Loadings**
Thought it would negatively affect resale value	.784
Did not like how the system looks	.598
Payback would be too long	–.822*

*Note negative values.

Tangible, Immediate Financial Barriers

The third dimension reflects concerns on the part of some main respondents that a PV system might result in unanticipated extra costs, such as increased homeowner insurance premiums and property taxes based on increased home valuation. These concerns suggest that the SheaHomes sales staff might not have explained the broader aspects of PV ownership to prospective homebuyers. The items that define this dimension and their factor loadings are shown below.

Factor Three: Immediate Financial Barriers
Eigenvalue=2.143 and % of variance explained=16.485

Key Definers	**Factor Loadings**
Thought homeowner's insurance premium would increase	.927
Thought property taxes would increase	.919

Uncertainty about PV System Placement on the Roof

The fourth dimension reflects the uncertainty that some main respondents experienced in trying to decide about a PV purchase. They knew they could afford to purchase the system (note the negative factor loading on the statement that the system was too expensive), yet they could not visualize how the system would fit on their roofs. The items that define this dimension and their factor loadings are shown below.

Factor Four: Uncertainty about PV System Placement on the Roof
Eigenvalue=1.773 and % of Variance Explained=13.637

Key Definers	Factor Loadings
Didn't know where it would go on the roof	.860
It was too expensive	–.679*

*Note negative value

Relative Indifference to PV

The fifth dimension reflects a sense of relative indifference to solar PV systems on the part of some main respondents. Other features were apparently more important to these buyers. They were concerned that the presence of solar PV systems could negatively affect the resale value of their homes. It appears that the SheaHomes sales staff did not convince these buyers that solar PV was a good deal. The items that define this dimension and their factor loadings are shown below.

Factor Five: Indifference to PV
Eigenvalue=1.364 and % of variance explained=10.496

Key Definers	Factor Loadings
Thought it would negatively affect resale value	.848
Wanted other options	.523
Didn't know enough to evaluate	.507

Together, these five dimensions (factors) account for 77.554% of the variance in response to the 13 items. The findings convey the sense that an extra educational effort about PV and its benefits, as well as conveying to potential buyers the bargain prices for which the PV systems were being offered, would have convinced more of the main buyers who were actually offered PV systems to purchase them. AstroPower, Inc., was not represented on site by personnel, and there was a paucity of literature about the PV systems at the sales office.

PART THREE: ITEMS ASKED ONLY OF PV OWNERS

Introduction

Certain questions were asked only of owners of homes with PV systems.[7] These included questions on (1) perceived benefits of PV ownership, (2) PV system attributes, (3) information channels on PV used, (4) uses of the digital display, (5) aspects learned about PV systems since living with them, and (6) operational aspects of PV systems.

Factor Analysis of Perceived Benefits of Solar PV Ownership

Fifteen statements on potential benefits of owning a PV system elicited respondents' agreement or disagreement (see Table 39 in Chapter 11, Experience with Solar PV Systems). The factor analysis of these items resulted in three dimensions:

1. Altruistic benefits
2. Financial benefits
3. Personal satisfaction.

Altruistic Benefits

The first dimension reflects responses for what are termed the "altruistic" benefits of PV ownership. These include helping to reduce global warming, helping the local economy, benefitting future generations, and helping to improve air quality in the area. This factor closely resembles the first factor of perceived benefits of PV ownership, termed "environmental benefits," in the study of Colorado homeowners (Farhar and Coburn 2000, p. 51). The items that define this dimension and their factor loadings are shown below.

Factor One: Altruistic Benefits

Eigenvalue=4.120 and % of variance explained=27.467

Key Definers	Factor Loadings
Helps reduce global warming	.877
Helps San Diego's economy	.849
Benefits future generations	.824
Helps improve air quality in the area	.724

[7]These are discussed in Chapter 11 (Experience with Solar PV Systems).

Financial Benefits

The second dimension reflects responses to items that focus on the financial advantages of PV ownership. These include reduced electricity bills, free electricity once the system is paid for, and selling excess electricity back to the utility. This factor is quite similar to the second factor of perceived benefits of PV ownership, termed "financial advantages," in the Colorado homeowner study (Farhar and Coburn 2000, pp. 51–52). The items that define this dimension and their factor loadings are shown below.

Factor Two: Financial Benefits
Eigenvalue=3.613 and % of variance explained=51.552

Key Definers	**Factor Loadings**
Reduces electricity bills	.792
Provides free electricity once system is paid for	.750
Sell excess electricity back to utility	.692
Increases home's resale value	.604

Personal Satisfaction

The third dimension reflects responses that appear to focus on the personal satisfaction that can be derived from owning and living with a PV system. These include a sense of self-sufficiency, being technologically innovative, increasing the home's resale value, and feeling good about the entire experience. The items that define this dimension and their factor loadings are shown below.

Factor Three: Personal Satisfaction
Eigenvalue=2.409 and % of variance explained=16.062

Key Definers	**Factor Loadings**
Increases self-sufficiency	.832
Technologically innovative	.713
Feels good to have it	.556

Together, these three dimensions account for 67.615% of the variance in response to the 15 items on the perceived benefits of PV ownership. Two of these dimensions—altruistic benefits (including benefits to the environment) and financial benefits are quite similar to factors that resulted from a study of Colorado homeowners when they were asked about the benefits of retrofitting a PV system. This suggests that these dimensions differentiate not only among new homebuyers, but also among homeowners who might contemplate adding PV systems to their homes.

Factor Analysis of Solar PV System Attributes

The importance of nine attributes of PV systems was measured (Table 40 in Chapter 11, Experiences with PV systems). These variables include amount of electricity produced, ease of maintenance, warranty, aesthetics, digital display, upgrade capability, net metering, financing through a home mortgage, and owning the solar PV system outright. The factor analysis of these items resulted in two dimensions:

1. Solar PV system performance
2. Investment qualities of PV systems.

Solar PV System Performance

The first dimension reflects responses on the importance of PV system performance and reliability, as well as feedback on the amount of electricity produced so that PV owners will know the system is performing well. The items that define this dimension and their factor loadings are shown below.

Factor One: Solar PV System Performance
Eigenvalue=2.966 and % of variance=32.960

Key Definers	**Factor Loadings**
Amount of electricity produced	.811
Digital display showing electricity production and consumption	.800
Length of warranty	.797
Ease of maintenance	.757

Investment Qualities of PV Systems

The second dimension appears to reflect the importance of financial and investment aspects of the PV system. System attractiveness and unobtrusiveness are perceived to be related to the resale value of the home. Financing through the mortgage ameliorates any difficulty of paying up-front costs. The inference in upgrade capability is that, if a system is performing well, a retrofit of additional panels would result in more electricity production, which would result in even lower electricity bills. As described earlier, net metering represents the ability to sell one's excess electricity back to the utility company and, in effect, to use the utility grid for storage and avoid the cost and space requirements for battery backups. The items that define this dimension and their factor loadings are shown below.

Factor Two: Investment Qualities
Eigenvalue=2.432 and % of variance explained=27.027

Key Definers	**Factor Loadings**
Attractiveness/unobtrusiveness of the system	.753
Finance through home mortgage	.740
Upgrade capability	.709
Net metering	.631

Together, these two dimensions account for 59.987% of the variance in response to the nine items that measure the importance of PV attributes. These two dimensions are similar to two of the factors identified in the Colorado homeowners study (Farhar and Coburn 2000, pp. 54–55), which suggests that solar PV system performance and the financial arrangements are two critical dimensions that differentiate among new homebuyers and among homeowners in the PV retrofit market.

Factor Analysis of Information Channels Used

PV owners were asked which channels they had used to gather information about their PV systems. The questionnaire mentioned four such channels: a video on operations and maintenance, a fact sheet about solar PV systems, an operating manual, and Web sites (see Chapter 9, Knowledge and Information). The factor analysis of these four items resulted in three dimensions:

1. Operating manual for the solar PV system
2. Web sites
3. Video.

Because the four items resulted in three factors that differentiate among homebuyers, we posit that different homebuyers must have used different information channels.

Operating Manual for the Solar PV Systems

The first dimension primarily reflects the operating manual for PV systems that AstroPower, Inc., provided. This item and its factor loading are shown below.

Factor One: Operating Manual for Solar PV System
Eigenvalue=1.164 and % of variance explained=29.111

Key Definer	**Factor Loading**
Operating manual for PV systems	.868

Web Sites

The second dimension primarily reflects Web sites. This item and its factor loading are shown below.

Factor Two: Web Sites
Eigenvalue=1.152 and % of variance explained=28.802

Key Definers	**Factor Loading**
Web sites	.920

Video

The third dimension primarily reflects a video on operations and maintenance. This item and its factor loading are shown below.

Factor Three: Video
Eigenvalue=1.135 and % of variance explained=28.375

Key Definer	**Factor Loading**
Video on operations and maintenance	.920

The fact sheet was not a defining item in any of the factors. Together, these three dimensions account for 86.288% of the variance in response to the four items on information channels used. The fact that these four items form three dimensions that differentiate among homeowners suggests that there were few information channels and that most homeowners, if they had information at all, had it from only one or two sources. This further underscores the relative lack of information on PV systems, even to PV owners, discussed earlier.

Factor Analysis of Uses of Digital Display

Seven statements about the potential uses of the PV system's digital display (see Table 42 in Chapter 11, Experiences with PV Systems) were factor analyzed. These items dealt with the effects of the display—which provides feedback on electricity production and consumption in a home in real time—on energy-related behaviors. The factor analysis resulted in two dimensions:

1. Use of the display for feedback on system performance and electricity use
2. Optimizing electricity cost savings.

Use of the Display for Feedback on System Performance and Electricity Use

The first dimension reflects responses that pertain to using feedback about electricity use to manage energy-related behaviors and monitor electricity production and use. The items that define this dimension and their factor loadings are shown below.

Factor One: Feedback on System Performance and Electricity Use
Eigenvalue=2.339 and % of variance=33.411

Key Definers	Factor Loadings
Help change energy-consuming behavior	.788
Obtain feedback on electricity use	.744
Become more sensitive to household electricity consumption	.621
Determine if the system is functioning	.592
Determine if anything is left turned on in the house	.579

Optimizing Electricity Cost Savings

The second dimension reflects responses relative to record keeping on electricity production and consumption and scheduling of electricity-consuming activities to optimize the financial benefits of the PV system. This suggests that, when possible, a household might try to use appliances on sunny afternoons when their electricity production is highest and might avoid other uses at that time or when their electricity production is lower. In the qualitative study, interviewees expressed surprise that their kitchen "can" lights used so much electricity and indicated that they are careful with their use of kitchen lights. One homeowner had replaced his can lights with CFLs. The items that define this dimension and their factor loadings are shown below.

Factor Two: Optimizing Electricity Cost Savings
Eigenvalue=1.552 and % of variance explained=22.170

Key Definers	Factor Loadings
Record cumulative electricity production and consumption	.878
Optimally schedule electricity-consuming chores	.780

Together, these two dimensions account for 55.581% of the variance in response to the seven items about uses of the PV system's digital display. Considering that most systems are small 1.2-kW systems that provide only a portion of a home's electricity, it seems remarkable that some PV owners are using their displays as much as they are to glean feedback about their electricity use and to adapt their behavior to optimize their PV systems' benefits to their households. Ownership of even small PV systems providing only a portion of household electricity seems to draw attention to electricity use.

Factor Analysis of Aspects Learned Since Living with Solar PV Systems

A factor analysis of seven items on aspects of PV systems about which PV homeowners might have gleaned knowledge since living in their homes (see Chapter 9, Knowledge and Information) resulted in two dimensions:

1. Monetary benefits
2. Technical aspects.

Monetary Benefits

The first dimension reflects responses about the advantageous monetary or financial benefits of PV ownership. The items that define this dimension and their factor loadings are shown below.

Factor One: Monetary Benefits
Eigenvalue=1.736 and % of variance explained=24.795

Key Definers	Factor Loadings
Learned about amount or percentage of electricity use that the solar PV system produces	.776
Learned about tax credits or rebates to help offset the cost	.699
Learned about payback period for PV system purchase	.689

Technical Aspects

The second dimension reflects responses that seem to pertain to the technical aspects of the PV system, such as net metering, interconnectivity, and how the system works. The items that define this dimension and their factor loadings are shown below.

Factor Two: Technical Aspects
Eigenvalue=1.645 and % of variance squared=23.500

Key Definers	Factor Loadings
Learned about net metering and interconnecting with the grid	.880
Learned about how the system works	.754

Together, these two dimensions account for 54.667% of the variance in response to the seven items on learning about PV systems that differentiate among PV system owners.

Factor Analysis of Operational Aspects of Solar PV Systems

As discussed in Chapter 11 (Experience with PV Systems), eight statements were provided to the PV owners to determine how well informed they were about some operational aspects of solar PV systems. Most of the statements presented were true but others were false. The inaccurate statements were based on misperceptions discovered by listening to interviewees who were PV owners during the qualitative phase of the research.[8] The factor analysis of these eight items resulted in three dimensions:

1. Relationship with the utility company
2. Electricity bill payments
3. One electric meter.

Relationship with the Utility Company

The first dimension reflects aspects of the PV owners' relationship with SDG&E. These statements are all accurate. The items that define this dimension and their factor loadings are shown below.

Factor One: Relationship with the Utility Company
Eigenvalue=1.750 and % of variance explained=21.871

Key Definers	**Factor Loadings**
Have interconnectivity agreement with utility	.685
Utility demand at peak on sunny afternoons	.663
Utility bills PV owners only for the electricity consumed	.603
PV owner is paid retail rate for electricity put into the grid	.518

Electricity Bill Payments

The second dimension pertains to the electricity bill payments. The PV owners had the option of paying their electricity bills annually (although they receive monthly statements that inform them about how much electricity they are using) or monthly in the traditional way. In addition, some respondents believe they will receive checks from the utility company at the end of each year. This perception is indeed inaccurate because California law provides net metering only to zero, which means any excess electricity produced by a home beyond the amount consumed by that home is provided *gratis* to the utility company. The negative value of the factor loading for this

[8]This item does not reflect an exhaustive list of misperceptions, but only the more commonly heard ones. For example, not asked about on this list was the efficiency of the PV system, which is, factually, less than its kilowatt rating, according to an AstroPower, Inc., spokesman.

item shows that respondents correctly *disagreed* with the item as posed in the questionnaire. The items and their factor loadings are shown below.

Factor Two: Electricity Bill Payments
Eigenvalue=1.460 and % of variance explained=18.249

Key Definers	**Factor Loadings**
Pay electricity bill annually	.783
Receive check from utility annually for extra electricity	–.684*

*Note the negative value.

One Electric Meter

The third dimension involves statements that tend to be perceived accurately. The statements pertain to having only one electric meter (this is correct) and the utility paying the retail rate for electricity put into the grid (this is, in essence, correct because the electric meter runs backward when the home is feeding electricity into the grid). However, the PV systems produce more excess electricity on sunny afternoons before SDG&E's demand reaches its peak because of air-conditioning loads. The items and their factor loadings are shown below.

Factor Three: One Electric Meter
Eigenvalue=1.239 and % of variance explained=15.492

Key Definers	**Factor Loadings**
Have one electric meter	.790
Is paid retail rate for electricity put onto the grid	.534

*Note negative value.

Together, the three dimensions account for 55.770% of the variance in response to the eight items on the operational aspects of PV systems. For the most part, the homeowner responses appear to be accurate. Interestingly, these dimensions of knowledge about PV systems differentiate among PV owners.

Summary

The reduction of the data to 49 factors permitted more efficient analysis of the breadth of the survey findings. Fifteen factors applied only to PV owners, and five factors applied only to main owners. The remaining 29 factors applied to all study respondents.

As suggested in this chapter, the key definers on these factors are those that differentiate among respondents. Among reasons for home purchase, for example, "overall home value" and "desirability of the area" are highly rated, yet their influence does not contribute to defining any of the reasons-for-purchase factors. This is because these are reasons that are important to most respondents and they do not distinguish among respondents. Conversely, reasons that are rated highly by far fewer respondents, such as “helpfulness and knowledge of sales staff” define factors and differentiate among respondents.

Chapter 18
Analysis of Factors by PV Adopter Categories

Introduction

The results of the factor analyses described in the preceding chapter were used to discern differences among various categories of homebuyers. As reported earlier, ownership of PV homes is a more important distinguishing characteristic among homebuyers than the ownership of homes built by SheaHomes or of nearby conventional homes. The importance of PV ownership holds sway throughout this study's analyses, including analyses of resale value, survey data, and utility data.

In this chapter, the development of empirically based adopter categories relative to PV ownership is described. The adopter categories are then analyzed by demographic variables, homeowner satisfaction factors, and other factors. The empirical support for a concept of witting and unwitting adopters is presented. Conclusions from this analysis of factor scores relative to adopter categories are discussed.

Chapter Highlights

- Three categories relative to PV adoption were developed from the responses of SheaHomes and comparison respondents: PV adopters (n=72), non-adopters (n=59), and unaware buyers (n=96).
- PV adopters are more frequently male than female, a difference that nears significance.
- The percentage of respondents who are scientists and engineers is highest among PV adopters and lowest among buyers in the unaware buyers category.
- PV adopters are more satisfied with the energy performance of their homes than are non-adopters.
- Witting and unwitting adopters of PV systems were identified and their responses analyzed. Unwitting PV adopters have significantly lower mean scores relative to how informed they were in making the PV purchase decision, yet a significantly higher percentage of them have doctoral degrees than do witting adopters.
- The significant differences found by PV adoption are likely to be the result of the experience of PV ownership than of qualities brought to the PV purchase decision.

The Development of Adopter Categories

The presence of solar PV systems, in addition to efficiency features and solar water heating, transformed SheaHomes into high-performance homes.[1] To be classified as adopters of high-performance homes, homebuyers had to decide to purchase homes that included solar PV systems. If the homebuyers were unaware of the availability or presence of solar PV systems when they purchased homes, they could not be considered adopters. In this study, 56 SheaHomes PV owners were aware of solar PV on their homes and purchased them. These are classified as PV adopters.

[1]Labeled "ComfortWise" Homes by ConSol, Inc.

Moreover, certain houses with solar PV systems fell out of escrow after the original buyers opted out of their contracts. These homes were resold and some of these buyers did not realize that they had purchased homes with solar PV systems. This phenomenon resulted in buyers that we termed “unwitting adopters.” This type of buyer was discovered during the qualitative interviewing process when an interviewee who owned a home with a solar PV system did not learn about the system until the time of the interview. The owners became aware of the PV systems they owned when the interviewer asked them to show and talk about the energy features of their homes.

It was known which houses fell out of escrow because all respondents were asked: “Did you purchase a new home that had already been under contract, but had fallen out of escrow?” The owners of homes with solar PV systems who had purchased these homes after they had fallen out of escrow were classified as unwitting adopters. Although some of these buyers could have been aware that the homes they were buying had solar PV systems, they had not made the original decision to include PV systems on their homes, which had been made by the earlier buyers had made that decision. Based on the qualitative research preceding the survey, some SheaHomes buyers clearly were unaware they were purchasing homes with solar PV systems.

The main questionnaire asked directly whether homeowners were offered the option of purchasing solar PV systems at the time they bought their new homes. As reported in Chapter 8 (PV Purchase Decision), more than half of the main respondents *do not recall* having been offered solar PV systems, whereas only 44% recall being offered one and turning it down. The group of 36 respondents who knew about the availability of solar PV systems and turned them down are termed “Non-adopters.” The remaining 46 main respondents who did not know about the availability of solar PV systems, and who could therefore not make a decision about adopting them, are counted in an unaware buyers category relative to solar PV adoption—they did not know of the availability of solar PV and they did not adopt it.

Finally, comparison homebuyers did not have the option to purchase solar PV systems at the comparison community. However, as reported in Chapter 9 (Knowledge and Information), the comparison respondents were asked whether they were aware that, in their price range and location, highly energy-efficient homes were available featuring solar PV systems as well as solar water heating. Twenty-three comparison respondents indicated they were aware of this offering at the time they were shopping for new homes. These 23 were classified as “non-adopters”—that is, they knew about the availability of solar PV systems but did not adopt them. Thirty-one comparison respondents indicate they were unaware of these systems; these are therefore counted in the unaware buyers category relative to solar PV adoption (i.e., they did not know of the availability of solar PV systems and did not adopt them).

To summarize, then, Table 58 defines four adopter categories based homeowners’ knowledge of the availability of solar PV systems and their purchase decisions. These four categories of homebuyers are as follows:

- PV adopters (aware of PV systems who decided to purchase them)
- Non-adopters (aware of PV systems who decided not to purchase them)
- Unwitting PV adopters (unaware of PV, yet who purchased homes with PV systems)
- Unaware buyers (those who were unaware of PV, or who did not have a choice, and who purchased non-PV homes)

Table 58. Distribution of Types of Solar PV Adopters and Non-Adopters among All Categories of Homebuyers (SheaHomes and Comparison Homes)*

PV Ownership Category	Knew of Availability of Solar PV Systems/ Had a Choice	Did Not Know of Availability of Solar PV Systems/Had No Choice	Totals
Own solar PV system	PV adopters (n=56)	Unwitting adopters (n=16)	n=72
Do not own solar PV system	Non-adopters (n=59)**	Unaware buyers (n=96)***	n=155
Totals	n=115	n=112	n=227

*Missing data for four respondents.
**Main=36; comparison=23.
***Ineligible/early=20; main=49; comparison=31. Ineligible and early respondents did not have a choice to purchase homes with solar PV systems, as described earlier, and thus are classified in this cell.

A series of analysis of variance (ANOVA) tests that used the four adopter categories to distinguish among differences in Z-scores[2] shows that the unwitting adopter category does not differentiate among witting and unwitting PV homeowner responses sufficiently to warrant keeping them as a separate analytical category. That is, no statistically significant differences were found between the unwitting and witting PV adopters when analyzed by the study's factors.[3] For this reason, the analysis of differences among adopter categories was pursued using the following three adopter categories:

- PV adopters (n=72) (those owning PV systems, regardless if they witting or unwitting adopters)
- Non-adopters (n=59) (those aware of PV systems who chose not to adopt them)
- Unaware buyers (n=96) (those not owning PV systems who were unaware PV systems were available or who had no choice in the matter).[4]

[2]Throughout this chapter, "Z-scores" refer to normalized factor scores.

[3]A univariate analysis of witting versus unwitting PV adopters resulted in a few significant differences; these are discussed toward the end of this chapter.

[4]As suggested above, these buyers are distinguished from unwitting adopters by the fact that they did not know about PV systems and do not own them.

These adopter categories (n=227) include respondents from both the SheaHomes and the comparison communities.[5]

Witting and Unwitting Adopters

As noted earlier in this chapter, no significant differences between witting and unwitting adopters were found. The measurement of unwitting adopters was somewhat imprecise in that respondents were not directly queried as to whether they were aware at the time of purchase that the homes they were purchasing had PV systems. However, as noted earlier, at least one homebuyer interviewed in the qualitative phase of the study who had purchased a home with a solar PV system was completely unaware of the system.

Consequently, a surrogate indicator for unwitting adopters was established with the survey data. As noted, buyers of PV homes were classified as unwitting adopters if their homes were purchased out of escrow. It was possible to make this determination because a question to this effect was directly asked of all respondents. The small numbers involved (n=15) could account for a lack of differentiation between the witting and unwitting PV adopters mentioned at the beginning of this chapter.

However, at least one piece of empirical evidence suggests that this distinction is on the right track. PV owners were asked: "How well informed did you feel you were about the solar PV system at the time of purchase? Did you know enough to make an informed decision about adding one to your home or upgrading the one that came with your home?" Responses were sought on a 1 to 10 scale, where 1=Not at all informed and 10=Very informed. The difference in the mean responses given by witting and unwitting PV adopters on this item is statistically significant. The mean score for witting PV adopters is 6.40, whereas for "unwitting" PV adopters, it is significantly lower at 4.25 (t=3.221; p=.002).

The existence of unwitting adopters is an interesting phenomenon because it departs radically from the notion that homebuyers willing to buy high-performance homes will exhibit, in ways perhaps theoretically predictable, characteristics of "innovators" or "early adopters" (see Chapter 2, Guiding Ideas). If, in fact, the homebuyers had no idea they were adopting an innovation—in this case, high-performance homes with PV systems—they could hardly be considered "early adopters" of the innovation. Thus, it was decided to pursue a descriptive analysis by these two categories of PV adopters with respect to the key study variables to determine whether anything further could be learned about them. Of all the variables encompassed by the study, significant differences were found with respect to only four of them, as follows:

---

[5]Outlier cases in the utility analysis (see Chapter 19, Comparative Analysis of Utility Consumption and Cost) were also examined to determine whether they were also outliers (that is, on the tails of the distribution) relative to Z-scores (normalized factor scores) for all respondents. The utility outlier cases were determined not to be outliers here.

- Educational level of head of household
- Purchase decision variable: availability of discount or incentive
- Purchase feature variable: quiet area
- Purchase feature variable: granite counter tops.

Educational Level of Head of Household

Table 64 suggests there is a statistically significant relationship between the highest level of educational attainment and type of PV adoption. The percentage of witting PV adopters with a bachelor's degree (48%) is much higher than for unwitting adopters (7%), whereas the percentage of unwitting adopters with a master's degree (33%) is quite a bit higher than for the witting adopters (19%). Similarly, a higher percentage of unwitting PV adopters have graduate work beyond the master's degree or a doctoral degree (27%) than do the witting adopters (19%), whereas a lower percentage of unwitting PV adopters have less than a bachelor's degree (33%) than do witting adopters (14%) ($\chi 2$=19.053; p=.023).

Table 64.[6] Level of Educational Attainment of Witting and Unwitting PV Adopters

Level of Educational Attainment	Percentage of Witting PV Adopters (n=52)	Percentage of Unwitting PV Adopters (n=15)	Totals (n=67)
Post-master's or doctoral degree	19	27	21
Post-baccalaureate or master's degree	19	33	22
Bachelor's degree	48	7	39
Less than bachelor's degree	14	33	18

Occupation may be a contributing or associated variable. As discussed earlier, the percentage of PV adopters that are scientists and engineers is higher than for the rest of the homebuyers. An analysis of occupation by witting and unwitting PV adopters shows that 46% of the witting and 33% of the unwitting adopters are scientists or engineers. Because the bachelor's degree is the qualifying degree for engineers, this may help account, at least in part, for the significantly higher percentage of baccalaureate degrees among the witting adopter group. Perhaps the advanced degrees held by the unwitting adopters are in other fields and specializations than science or engineering.[7]

Importance of a Discount or Other Incentive

Among the 24 purchase decision variables measured in the study, a significant difference was found between witting and unwitting adopters on only one—the importance of a discount or

[6] Table 64 is intentionally out of order. Tables 59 through 63 follow.

[7] Respondents were not asked for the fields in which they received their degrees.

other incentive in the home purchase decision when the buyers were deciding on their homes. The mean score for witting adopters (3.22 on a 1-to-5 scale, where 1=Not at all important and 5=Very important) is significantly higher than the mean score for unwitting adopters (4.00) (t= –2.384; p=.02). In general, several of the purchase decision factors were less important to PV adopters than to other types of buyers, and this could be another example of this pattern.

“Quiet Area” and “Granite Counter Tops”

Respondents were asked how important each of several home features were when they made their home purchases, using the same 1-to-5 response scale described above. Of 14 home features listed, significant differences are found for only two. Witting adopters give significantly higher responses on average to “Quiet area” (4.05) than do unwitting adopters (t=2.422; p=.018). “Granite counter tops as a standard feature” receives a higher mean score from unwitting adopters (4.00) than from witting adopters (t= –2.325; p=.026). These findings do not appear to evidence a clear pattern differentiating the home purchase decisions of the two types of adopters.

Summary of Analysis with Respect to Witting and Unwitting Adopters

Few significant differences emerge between the two types of adopters. This situation perhaps exists because, although they may have approached the purchases of their homes slightly differently, both types of PV adopters have experienced living in PV homes. That experience has almost certainly guided most of their questionnaire responses. The bits of evidence indicating that unwitting adopters have different types of education than witting adopters and that witting adopters knew more about solar PV systems before home purchase than did their unwitting counterparts serve to underscore the notion that these types of adopters are somewhat different from each other. To speculate, the highly educated unwitting adopters may have been too busy to pay much attention to the details about the energy features of their homes.[8] More research on the existence and characteristics of unwitting adopters may be worthwhile because many future buyers of ZEHs may very well be unwitting adopters.

Comparisons of Adopter Categories by Demographic Variables

The study’s respondent characteristics (see Appendix G—Respondent Characteristics, Demographics, Values and Lifestyles, and Other Variables) were analyzed with respect to the three adopter categories. There was a significant difference among the three categories for only one of the 10 relevant variables (age), although for two others the difference was nearly significant (gender and occupation).

Table 59 shows the percentage distributions of responding heads of households in the three adopter categories with respect to age. A much higher percentage of responding heads of PV households are 40 to 49 years old than in the other two categories. In the unaware buyers category, a much higher percentage of respondents is 50 years old or older. Further, a higher

[8] For example, one is a medical specialist with a busy practice.

percentage of responding heads of non-adopter households are in the youngest age group (39 years old or younger). Overall, the age distributions for the three adopter categories are significantly different (χ^2 = 12.918; p=.012). These results suggest that non-adopters are somewhat younger than the other two groups, PV adopters are more middle-aged, and unaware buyers are somewhat older.

Table 59. Adopter Categories by Age

Age category	Percentage of PV Adopters (n=69)	Percentage of Non-Adopters (n=59)	Percentage of Unaware Buyers (n=91)	Percentage of Total (n=219)
≤39 years old	42	53	40	44
40 - 49 years old	42	25	24	30
≥50 years old	16	22	36	26

Table 60 shows the percentage distributions of responding heads of households in the three adopter categories with respect to gender. The questionnaire could be completed by either male or female heads of household at their discretion. Of the responding heads of households in the PV adopter category, a higher percentage of the PV adopter category is male than in the other two categories. On the other hand, in the non-adopter category a higher percentage are female than in the other two categories. Overall, the difference in gender distributions for the three adopter categories nears significance (χ^2 = 5.837; p=.054). These results may be a function of the fact that PV, as a technological innovation, is perceived as more within the purview of male rather than female heads of household. If that is the case, the task of completing the questionnaire in the PV households may have fallen more readily to males than to females. It may also reflect the notion that men are somewhat more interested in PV systems than women, and thus gender differences could have played a somewhat more important role in adopting homes with PV systems.

Table 60. Adopter Categories by Gender

Gender Category	Percentage of PV Adopters (n=68)	Percentage of Non-Adopters (n=57)	Percentage of Unaware Buyers (n=89)	Percentage of Total (n=214)
Male	68	47	53	56
Female	32	53	47	44

Table 61 contains the percentage distributions of responding heads of household in the three adopter categories with respect to occupation. The percentage of responding heads of household who are scientists and engineers is highest (43%) among the PV adopter category and lowest (24%) in the unaware buyers category. Overall, the difference in occupation distributions for the three adopter categories is nearly significant (χ^2 = 5.870; p=.053). Further, as might be expected, there is a nearly significant relationship (χ^2 = 3.765; p=.052) between gender and occupation among the respondents represented by the three adopter categories. About two-thirds of the scientists and engineers are male, whereas 52% of respondents in other occupations are male.

The percentages of heads of households in the three adopter categories are not significantly different with respect to any of the other respondent characteristics, including:

- Educational level
- Income
- Marital status
- Household composition (adults only, adults with children)
- Number of occupants in the household
- Member of builder staff
- Planned length of stay in home.

Table 61. Adopter Categories by Occupation

Occupation Category	Percentage of PV Adopters (n=63)	Percentage of Non-Adopters (n=52)	Percentage of Unaware Buyers (n=76)	Percentage of Total (n=191)
Scientists and engineers	43	31	24	32
All others	57	69	76	68

Differences in Satisfaction Factors by Adopter Categories

As described in Chapter 17 (Data Reduction), four satisfaction factors were identified. These four factors were analyzed with respect to the three adopter categories to determine whether there were significant differences in homeowner satisfaction, particularly between PV adopters and those who did not purchase homes with PV systems. The results of this ANOVA are presented in Table 62.

Quality of Construction and Builder Reputation

The first satisfaction dimension deals with the perceived quality of construction and reputation of the builder as well as satisfaction with size and square footage of the home and the home's comfort. As Table 62 shows, no significant differences in mean factor scores are found among the homeowners in the three adopter categories on this satisfaction factor. Therefore, it seems reasonable to conclude that, although the mean scores vary somewhat, all the homeowners express similar levels of satisfaction with their homes on this dimension.

Investment Potential of Home

The second satisfaction dimension deals with the investment potential of the home, its location, and its size and square footage. As Table 62 shows, the ANOVA results in a significant difference among the three categories of homeowners on this dimension. The significant differences in mean factor scores occur between PV adopters and the other two categories. The mean factor score is significantly lower for PV adopters than for non-adopter buyers (p=.025). The mean factor score for PV adopters is also significantly lower than for unaware buyers (p=.003). There is no difference in mean factor scores between non-adopter and unaware buyers. Interestingly, although the analysis of resale values of PV homes shows them gaining value at a faster rate than other homes, apparently PV owners had not, at the time they completed their questionnaires, yet perceived the market edge that their homes enjoy.

Table 62. ANOVA on Satisfaction Factors by Adopter Categories

Satisfaction Factors[9]	Mean Z-scores PV Adopters (n=52)	Mean Z-Scores Non-Adopters (n=47)	Mean Z-scores Unaware Buyers (n=74)
Quality of construction and builder reputation (F=1.164; p=.315)	.146	.020	– .128
Investment potential of home (F=4.911; p=.008)	– .366	.079	.172
Behavioral intention with respect to solar features and energy efficiency in future home purchases (F=3.419; p=.035)	.288	– .188	–.098
Estimated monthly utility bill (F=13.955; p<.0001)	– .575	.316	.193

Behavioral Intention with Respect to Energy Features in Future Home Purchases

The third satisfaction dimension deals with behavioral intention measures relative to energy features in future home purchase; that is, how likely homeowners are to say that, in the future, they will buy new homes with solar water heating, energy efficiency, and solar PV. Again, with respect to this dimension, the PV adopters' mean factor score varies significantly from those of the other two groups (see Table 62). The mean factor score for PV adopters is significantly higher than the mean factor score for non-adopter buyers (p=.018), and is significantly higher than the mean factor score for the unaware buyers (p=.032). This suggests that PV adopters are more likely to select highly energy-efficient homes with solar water heating and solar electric systems if and when they are in the market for a new home.

Estimated Monthly Utility Bill

As described in Chapter 17 (Data Reduction), the respondents' estimated monthly utility bills were recoded into categories: (1) ≤$80 per month, (2) $80.01–$110, (3) $110.01–$150, (4) $150.01–$210, and (5) >$210. The resulting scale, from 1 to 5, matched the scales of the other items used in the factor analysis. This item resulted in a fourth dimension of homebuyer

[9] For a more detailed description of all factors discussed in this chapter, see Chapter 17 (Data Reduction).

satisfaction, the idea being that the lower the estimated monthly utility bill, the higher the satisfaction with the home's performance. As Table 62 shows, the ANOVA indicates a significant difference among these categories of homeowners on this dimension. With respect to the estimated monthly utility bills dimension, the PV adopters' mean factor score varies significantly from the scores of the other two groups. This means that PV adopters are significantly more likely to indicate a lower estimated monthly utility bill than are either non-adopter buyers (p=.000) or unaware buyers (p=.000).

Summary of the Analysis of Satisfaction Factors Analyzed with Respect to Adopter Categories

The value of the multivariate analysis is that it draws together findings from many survey questions into factor scores or dimensions that meaningfully reflect the data, making it more efficient to interpret them. Because of the careful empirical construction of the adopter categories that took into account whether homebuyers actually made choices about purchasing high-performance homes with solar PV systems, the results of the multivariate analysis are even more powerful than the univariate results presented in Chapter 10 (Homeowner Satisfaction). These findings clearly support a hypothesis that PV adopters (that is, those who knowingly selected homes with solar PV systems) are more satisfied with the energy performance of their homes (as rated by their estimates of monthly utility bills) than are non-adopters or unaware buyers.

Additionally, homeowners in each of the adopter categories are approximately equally satisfied with the quality of their homes, although the PV adopters have a higher mean score on this dimension. Least satisfied with the investment potential of their homes are the PV adopters, indicating their lack of experience with the actual resale market values of PV homes in the area at the time they completed their questionnaires. In this analysis, only PV adopters exhibit scores significantly different from other buyers; non-adopter and unaware buyers exhibit factor scores that, although not identical, are not significantly different from each other.

Differences in Other Factors by Adopter Categories

As described in Chapter 17 (Data Reduction), scaled study variables other than the satisfaction variables were also factor analyzed. These included all the variables on the purchase decision, home features, barriers to PV purchase,[10] attitudes toward solar features, equipment ownership, self-reported conservation behaviors, and policy preferences. An ANOVA was performed on the factor scores for these 25 dimensions, with significant differences found among the means on only four. These results are presented in Table 63.

Overall Design

The first dimension deals with the importance in the home purchase decision of aspects of the home's design, emphasizing the quality of light in the home, the home's spaciousness, and its

[10]For main respondents only.

sense of openness. As Table 63 shows, significant differences are found among the adopter categories' mean scores on this dimension. The mean factor score for the PV adopters is significantly lower than that of non-adopter buyers (p=.003), suggesting that this factor is less important in the home purchase decisions by the PV adopters than in those of the non-adopters and unaware buyers (p=.043). The mean factor scores for the non-adopters and unaware buyers are not significantly different on this dimension.

Table 63. ANOVA on Other Factors by Adopter Categories

Satisfaction Factor[11]	**Mean Z-Scores PV Adopters**	**Mean Z-Scores Non-Adopters**	**Mean Z-Scores Unaware Buyers**
Importance of overall design (quality of light, spaciousness, openness) in home purchase decision (F=4.564; p=.010)	– .275 (n=69)	.268 (n=51)	.056 (n=80)
Importance of size and number of bedrooms in home purchase decision (F=3.461; p=.033)	– .255 (n=69)	.027 (n=51)	.168 (n=80)
Solar features (both PV and SWH) are "desirable innovations" (F=13.946; p=.000)	.410 (n=68)	.133 (n=57)	– .371 (n=92)
Adjust thermostats (self-reported conservation behaviors) (F=3.166; p=.044)	.160 (n=60)	.128 (n=48)	– .221 (n=79)

Size and Number of Bedrooms

The second dimension deals with the importance of size and number of bedrooms at the time of the home purchase decision. As Table 63 shows, significant differences are found among the adopter categories' mean scores on this dimension. Although the mean score for the PV adopters is not significantly different from that of the non-adopter buyers, it is significantly lower than that of the unaware buyers (p=.01), indicating that this variable was rated as less important in the home purchase decisions of the PV adopters than those of the unaware buyers. This result is consistent with findings reported in Chapter 10, in which energy features were more important in the home purchase decisions of PV owners than were other home features. Again, the mean factor scores on this dimension for the non-adopters and unaware buyers are not significantly different.

[11]For a more detailed description of all factors discussed in this chapter, see Chapter 17 (Data Reduction).

Solar Features as Desirable Innovations

The third dimension deals with attitudes toward solar features (including solar PV and solar water heating) as desirable innovations for housing. As Table 63 shows, significant differences are found among the adopter categories' mean factor scores on this dimension. Although the mean factor score for the PV adopters is not significantly different from that of the non-adopters, it is significantly higher than that of unaware buyers (p=.000), suggesting that the PV adopters are more favorable toward solar features than are the unaware buyers. This is interesting because the PV adopters had lived in their homes a minimum of six months before completing the questionnaire, and some had lived in them for up to 1-1/2 years; therefore, they had some time to observe the performance of their homes. The non-adopter buyers' mean score is also significantly higher than that of the unaware buyers (p=.002), suggesting that they, too, favor the use of solar features in new housing. Although the PV adopters have a higher mean score than do non-adopters, the difference in their scores is not statistically significant.

Conservation Behaviors: Adjusting Thermostats

The fourth dimension deals with one dimension of self-reported conservation behaviors—adjusting thermostats. As Table 63 shows, significant differences are found among the adopter categories' mean factor scores on this dimension. Although the mean factor score for the PV adopters is not significantly different from that of the non-adopters, it is significantly higher than that of unaware buyers (p=.025), suggesting that PV adopters are more likely to report that they adjust their thermostats to promote energy efficiency than are the unaware buyers. The non-adopters' mean score is higher than that of the unaware buyers in a result that nears statistical significance (p=.055), suggesting that they, too, are more likely to adjust thermostats than are the unaware buyers. Although PV adopters have a higher mean score than do non-adopter buyers on this dimension, the difference is not statistically significant.

Summary of the Analysis of Other Factors with Respect to Adopter Categories

The 25 factors identified and described in Chapter 17 (Data Reduction), which were based on questions asked of all respondents, deal with purchase decision variables, home features, attitudes toward solar features, equipment ownership, self-reported conservation behaviors, housing and energy policy preferences, environmentalism, and early adopter characteristics. Only four of them differentiate among the three adopter categories. The four results show the following:

- Specific home features (overall design and size and number of bedrooms) were less important to the PV adopters than to the non-adopters and unaware buyers at the time of home purchase.

- The PV adopters are more likely to perceive PV and solar water heating as "desirable innovations" than are the rest of the homebuyers.

- The PV adopters are more likely to adjust thermostats for energy efficiency than are the rest of the buyers.

Summary

By and large, those who knowingly selected homes with solar PV systems are very much like all other homebuyers in the SheaHomes and comparison communities. The few differences detected through detailed data analysis are likely the *result* of their having lived in PV homes before completing the questionnaire, not of qualities they brought to the home purchase decision. The findings suggest that those consciously opting for homes with PV systems tend more frequently than non-PV households to be male heads of household in their 40s with training as scientists and engineers. Living in PV homes has resulted in significantly lower utility bills, by their own estimates, than those reported by the rest of the homebuyers.[12] The PV experience has also apparently resulted in an even more positive attitude toward the desirability of energy efficiency and solar features in new housing, and an intention to buy such housing in the future should the PV homeowners move.

Although the analysis suggests that PV owners are somewhat less satisfied than other buyers with the investment potential of their homes, objective analysis of home resale values (see Chapter 6) shows that PV homes more than hold their own in the resale market. The PV adopters will very likely become aware of this advantage over time, if they have not already done so.

These findings reasonably support a conclusion that, once homebuyers experience living in high-performance homes with PV systems, they become more favorable toward these homes. Thus, buyers of high-performance homes with PV systems are, by and large, like the buyers of other nearby homes of similar qualities and in a similar price range. The *experience of PV ownership* changes their attitudes and perceptions.

These PV homebuyers are not "early adopters" of an innovation: they do not have higher education, occupation, or income levels than others; they do not display more early adopter characteristics, such as opinion leadership, than others; and they are not more environmentally oriented than others. The diffusion-of-innovation concepts are not supported by the findings representing this case study of high-income homeowners.

---

[12]See Chapter 10 (Homeowner Satisfaction). Analysis of respondents' utility bills, reported in Chapters 19 (Comparative Analysis of Utility Consumption and Cost), Chapter 20 (Modeling of Utility Consumption), and in the Epilogue to this report buttresses these homeowner perceptions.

Chapter 19
Analysis of Factors by Demographic Variables

Introduction

The factors described in Chapter 17 (Data Reduction) were analyzed by key demographic variables. All respondents in the study were included in these analyses. Factors that result from questions asked only of main, comparison, or PV respondents include responses only from those categories of homebuyers.

In addition, the 49 factors were analyzed by ownership of SheaHomes compared with comparison homes, and by PV ownership. No significant differences were found in these sets of analyses. However, when all respondents are included, significant differences are found by demographic characteristics.

Mean standardized factor scores (Z-scores) for seven demographic variables were analyzed relative to the 49 factors described in Chapter 17, as follows:

- Gender
- Age
- Marital status
- Household composition (adults with children or adults only)
- Educational attainment
- Occupation (science and engineering occupations or all other occupations)
- Annual household income.

This chapter reports on the significant differences resulting from these analyses. Details of the analysis are presented in Appendix H-1 (Factors by Demographics).

Chapter Highlights

- The 49 factors defined in Chapter 17 were analyzed by ownership of SheaHomes versus comparison homes, and by PV ownership; no significant differences are found.
- The factor scores for all study respondents were analyzed by seven key demographic characteristics, resulting in 44 significant differences.
- The variables used were gender, age, marital status, household composition, educational attainment, occupation, and income.
- Women are significantly more interested in safe and secure housing, whereas men seem more interested in solar features and their attributes.
- Respondents aged 50+ are more sensitive to personal action to protect the environment than are those 39 or younger.
- The unmarried are more likely to exhibit early adopter characteristics than the married ones.
- At the time of home purchase, households with children are significantly more concerned with safety and security, familiarity with the area, convenience of access, and size of home than are adults-only households.
- High-school graduates and those with some college are significantly more interested in the single-story options than are other educational groups.
- Scientists and engineers are significantly more interested in the technical aspects of PV systems than those employed in non-scientific occupations.

Summary of the Differences in Factor Scores by Gender

All 49 factors were analyzed by gender; three of the analyses resulted in significant differences. These three factors relate to home purchase decisions, attitudes toward solar features in new housing, and solar PV system attributes. Table H1-1 in Appendix H1 (Factors by Demographics) summarizes the findings from these analyses.

Gender is not a distinguishing demographic variable for most of the findings identified in Chapter 17. However, gender does emerge as a significant variable when the importance of neighborhood safety, security, and quality are considered; females are more concerned about these matters than males are. On the other hand, males are more interested in solar PV and water heating systems as new home innovations and in the efficacy and reliability of PV systems than are females. These differences suggest that marketing high-performance new homes should be approached somewhat differently between the genders.

Summary of the Differences in Factor Scores by Age

The responses by age were recoded into three categories: (1) ≤39 years old, (2) 40–49 years old, and (3) ≥50 years old. All 49 factors were analyzed by these three age categories; nine of the analyses resulted in significant differences by age. These nine factors relate to home purchase decisions, home features, attitudes toward solar features in new housing, equipment owned, environmentalism and environmental attitudes, and PV information channels used. Table H1-2 in Appendix H1 (Factors by Demographics) summarizes the findings from these analyses.

Age emerges as a significant differentiating variable for the mean scores of nine factors. The buyers 50 or older are more concerned about builder reputation and performance in their home purchase decisions than are the middle and younger age groups. They are also less concerned about familiarity of the area than are the buyers who are 39 years old or younger. This may be because the younger buyers are more likely to have young families. The 50+ age category is more favorable toward the single-story option, which seems logical because the younger buyers would be looking for larger homes with many bedrooms for their families, and older folks don't want to climb stairs!

Those 40–49 years of age more strongly perceive solar features as cost-effective for new homes, whereas the 50+ age group less strongly views them this way. Those 40–49 years of age are also more strongly inclined to own a pool and hot tub combination than the youngest age group. On the other hand, those 39 years of age or younger are more strongly inclined than those 50+ to own smaller efficiency measures. Interestingly and unexpectedly, the 50+ group holds the strongest environmental attitudes of the three age groups in terms of being willing to buy environmental products and change lifestyles to help the environment. The 50+ group also tends to reject ideas that federal environmental regulations are adequate, that environmental threats have been exaggerated, and that household energy consumption is not a major contributor to environmental problems.

Summary of the Differences in Factor Scores by Marital Status

The responses on marital status were recoded in two categories: (1) married/in a committed relationship and (2) not married. All 49 factors were analyzed by marital status; seven of the analyses resulted in significant differences and the result of one additional analysis nears significance. These factors relate to home purchase decisions, home features, equipment owned, early adopter characteristics, barriers to PV purchase, and aspects learned since living with PV system. Table H1-3 in Appendix H1 (Factors by Demographics) summarizes the findings from these analyses.

in these analyses, marital status is a significant variable for seven factors, and a nearly significant variable in an eighth. More married than unmarried homebuyers are concerned about the convenience of access that the Scripps Highlands location provides them. Unmarried householders are significantly more interested in exemption from Mello-Roos taxes and in the views than are married ones. Married buyers seem to be more interested in the size of the home and the number of bedrooms than are unmarried buyers, presumably because many of the married couples are seeking housing for themselves and their children and need more rooms than unmarried people, who, in this respondent set, do not have children living with them. Married homeowners are more likely than unmarried ones to own pools and hot tubs. This may be an affordability issue, or it may suggest that people with spouses (and probably children) have a greater interest in owning these items as part of their family lifestyles.

Unmarried respondents less frequently agree with statements on early adopter characteristics in the dimensions of being opinion leaders, independent, and innovative. However, they are more inclined to express that they perceive greater tangible, immediate financial barriers to owning PV systems. Those married respondents who do own PV systems are more strongly inclined than their unmarried counterparts to have learned about various aspects of those systems after living with them. The results on the marital status variable no doubt overlap the results on the household composition variable, discussed next.

Summary of the Differences in Factor Scores by Household Composition

The responses by household composition were recoded into two categories: (1) households with adults and children and (2) households with adults only. All 49 factors were analyzed by these two categories; nine of the analyses resulted in significant differences. These nine factors relate to reasons for purchase, home features, equipment owned, barriers to PV purchase, conservation behaviors, policy preferences, and use of digital display. Table H1-4 in Appendix H1 (Factors by Demographics) summarizes the findings from these analyses.

There are nine statistically significant differences in the mean factor scores by household composition. Four of these differences relate to reasons for purchase. The aspects of a safe and secure area and familiarity with the area distinguishes households with children (higher factor scores) than from those without. Convenience of access in terms of closeness to work, shopping, and other services distinguishes homebuyers with children (higher scores) from adults-only households (lower scores). Other advantages (such as exemption from Mello-Roos taxes and a great view) differentiate homebuyers with children (higher scores) from those without (lower scores).

As would be expected, the size of the home and the number of bedrooms differentiates households with children (higher scores) than adults-only households (lower scores). This result overlaps that found for married and unmarried occupants, presumably because many unmarried people either do not have children or their children live elsewhere.

Relative to policy preferences, favorability toward financial incentives such as the CEC rebates for PV systems, federal tax credits, and utility rebates differentiates family households (higher scores) from adults-only households (lower scores). Adults-only households appear to find it easier to adjust their thermostats than do families. This may reflect a tendency for parents living with to spend more time at home than those without children. It may also reflect a higher level of distraction in households with children.

Summary of the Differences in Factor Scores by Educational Attainment

The questionnaire responses on educational attainment were recoded into five categories: (1) high school graduate or below, (2) some college, (3) bachelor's degree or bachelor's degree plus, (4) master's degree or master's plus, and (5) doctoral degree. All 49 factors were analyzed by these five categories of educational attainment; seven of these analyses resulted in significant differences by this variable. These seven factors relate to reasons for home purchase, importance of home features, attitude toward solar features in new housing, conservation behaviors, and early adopter characteristics. Table H1-5 in Appendix H1 (Factors by Demographics) summarizes the findings from these analyses.

Seven dimensions show statistically significant differences by educational attainment. Four of them revolve around reasons for purchase and home features. The others involve perceptions of solar features in new housing as desirable, adjusting thermostats, and early adopter characteristics.

Summary of the Differences in Factor Scores by Occupation

These responses on occupation were recoded into two categories: (1) science and engineering occupations and (2) all other occupations. All 49 factors were analyzed by these two occupational categories, resulting in four significant differences by occupation. These four factors relate to satisfaction with home purchase, appliances and equipment owned, solar PV system attributes, and aspects learned about since living with solar PV systems. Table H1-6 in Appendix H1 (Factors by Demographics) summarizes the findings from these analyses.

Most of the study's factors do not differ significantly by occupation. However, when occupation is bifurcated between those working in science and engineering and all other occupations, and factor analysis is performed, four factors are identified that differ significantly by occupation. The respondents in the science and engineering occupations score significantly higher on satisfaction with their estimated utility bills than do those in other occupations. Those in all other occupations score significantly higher in ownership of dual-zone heating and air-conditioning systems and CFLs than those in the science and engineering professions. Among PV owners, scientists and engineers score the importance of the technical aspects of their PV systems more highly and more frequently indicate that they have learned about the technical aspects since living in their PV homes than do those in other occupations.

Summary of the Differences in Factor Scores by Annual Household Income

These responses by income were recoded into three categories: (1) ≤$99,000, (2) $100,000 to $199,000, and (3) ≥$200,000. All 49 factors were analyzed by these three income categories; four of the analyses resulted in significant differences by income. These four factors relate to reasons for purchase, home features, equipment owned, and PV information channels employed. Table H1-7 in Appendix H1 (Factors by Demographics) summarizes the findings from these analyses.

Most of the study's factors do not differ significantly by income; however, four dimensions resulted in significant differences when analyzed by income. A safe and secure area is, on average, rated as more important to home purchase by those with household incomes of $100,000 to $199,000 than households with incomes of ≥$200,000. The importance of quality of light and spaciousness differentiates between those making $100,000 to $199,000 (higher scores) from those in the lowest income bracket (lower scores). Ownership of efficiency equipment such as ceiling fans and dimmer switches differentiates between households earning ≥$200,000 and those in the lowest income bracket.

Summary

In all, 343 t-tests and analyses of variance (ANOVAs) were run (49 factors by seven key demographic characteristics), resulting in 44 statistically significant results (13%). This lends additional support to the idea already discussed that, by and large, the purchasers of homes in the Scripps Highlands developments, whether SheaHomes or comparison, are relatively homogeneous demographically. Still, these significant results suggest potentially important differences among various demographic categories that could affect marketing strategies used by builders and others interested in selling high-performance homes, near-ZEHs, and ZEHs.

Because the differences on gender, household composition, marital status, and particularly on education do not appear to form an interpretable pattern, it seems reasonable to conclude that other demographic variables may be confounding the results, and further research and analysis involving control by third variables will be needed to elucidate subtle patterns of differences among demographic characteristics of upscale new home buyers. One potential conclusion, however, is that the findings provide little support for diffusion theory, suggesting that buyers of new high-performance homes are not different on key demographic variables from buyers of conventional new homes in the same price ranges.

Nevertheless, these demographic differences suggest ways in which marketing messages might be targeted toward the different interests of new upscale home shoppers. Clearly, people with children have needs that are somewhat different from those without them, which is already known by the housing industry. It may be less obvious that men in their 40s, especially those with science and engineering training, appear to be more interested in the technical aspects of ZEHs and, in particular, of PV systems. It may not be well understood that the oldest new homebuyers are more interested in protecting the environment through personal action than the are younger buyers.

Chapter 20
Comparative Analysis of Utility Consumption and Cost

Introduction

This chapter presents a comparative analysis of actual utility consumption and cost in homes encompassed by the study. The analysis consists of an empirical statistical examination that uses various measures of cost and consumption rather than an engineering investigation.

As discussed in Chapter 3, Study Methods and Data Resources, to obtain actual utility consumption and cost data for study homes, respondents were asked to sign a utility release form that permitted SDG&E to provide their utility data to NREL. Of the 231 questionnaire respondents, 132 (57%) returned the utility release forms with valid signatures. NREL provided the utility release forms to SDG&E, which then provided NREL with the monthly electricity and gas consumption and cost data in Excel format for each household that had given its permission.[1] The utility data cover the period from the time the house was occupied until June 30, 2004.

NREL has utility data for 132 homes. Table 72 summarizes the categories and numbers of homes for which we have utility data. Because these homes are subsets of the homes described earlier in the report, the terminology used to describe them is somewhat different than that used before. In particular, we use the acronym SEE here to refer to highly energy-efficient homes with solar water heating but without solar PV systems. We also here refer to PV homes as high-performance homes built by SheaHomes with solar water heating and solar PV systems.

Chapter Highlights

- A statistical and empirical comparative analysis of 12 months of data on utility consumption and cost by 109 SheaHomes and comparison homes was completed.
- Based on the analysis, SheaHomes households consume less electricity and gas on average than do comparison households, despite the fact that SheaHomes are larger than comparison homes. The two categories of households are essentially the same in terms of household composition and number of occupants.
- Utility consumption was not found to increase with square footage of homes.
- A significantly higher percentage of comparison households than SheaHomes households have energy-intensive appliances and amenities, which complicates the analysis.
- PV homes have significantly lower average monthly electricity and gas consumption than other SheaHomes or comparison homes irrespective of PV system size, when energy-intensive equipment is omitted from the analysis.
- PV homes with 2.4-kW systems have significantly lower electricity consumption than do PV homes with 1.2-kW systems.
- Mean average gas consumption is significantly lower in high-performance homes without PV than in comparison homes, yet these two categories do not vary significantly on overall utility bills. Thus, most of the utility consumption and cost savings in SheaHomes appear to result from the presence of PV systems.

[1] We were unable to obtain the specific rate structures for these homes from SDG&E.

Table 72. Categories of Homes Used in the 12-Month Utility Analysis

Categories of Households	Description
SheaHomes with solar PV systems (termed PV homes) (n=44; 33%)	SheaHomes high-performance homes with 1.2-kW or 2.4-kW solar PV systems to produce electricity and solar water heating, the owners of which permitted access to their utility data
SheaHomes energy-efficient homes (termed SEE homes) (n=55; 41.7%)	SheaHomes high-performance homes with solar water heating, but without solar PV systems (including main and ineligible homes), the owners of which permitted access to their utility data
SheaHomes (n=99; 75%)	Both categories of SheaHomes, including PV homes and SEE homes, the owners of which permitted access to their utility data
Comparison homes (n=33; 25%)	Comparison homes near the SheaHomes developments that were built to California's Title 24 energy standards, the owners of which permitted access to their utility data

An important overall objective of the research is to determine if there are statistically significant differences in total or average monthly utility consumption and cost (electricity plus gas, including any associated taxes and miscellaneous charges) between the SheaHomes and the comparison homes. Another important objective is to determine whether solar PV systems have a significant impact on total or average monthly utility consumption and cost. Secondarily, we identified factors (such as household composition or occupant behaviors that affect energy consumption) that may lead to significantly higher or lower average monthly energy bills. Several conventional statistical approaches, including t-tests, analysis of variance (ANOVA), Chi-square (χ^2) analysis, and correlation analysis, were used to investigate the possible effects.[2] Ultimately, it would be desirable to quantify and state the impact of such factors on utility consumption and cost so that both builders and consumers could be more adequately informed.

Average monthly utility cost can be viewed from several perspectives. Generally, homeowners themselves view their bills as the total of the combined electricity and natural gas expenditures, including associated taxes and add-on fees. Homeowner perceptions of their utility bills are discussed in Chapter 22 (Perceived and Actual Utility Bills). However, analysts' perspectives would call for examining the effects of energy features (such as efficiency measures and PV) on specific components of the utility record. With regard to PV, separating expenditures for electricity and natural gas is instructive because only the electricity portion of the monthly bills could be offset by PV systems. Hence, the analysis described here considers the consumption and dollar amounts for electricity and gas, as well as combined utility costs.

The effects of climate are automatically controlled throughout the analysis. The boundaries of the SheaHomes communities and the comparison community are literally within a few blocks of each other; both developments are on a mesa in northern San Diego County. Hence, there are

[2]Results were obtained using the Statistical Package for the Social Sciences (SPSS 11.0), the Statistical Analysis System (SAS 8), and Microsoft Excel.

effectively no weather or climate differences. In addition, the utility data for SheaHomes and comparison homes encompass the same 12-month period, which eliminates any possibility of variation caused by seasonality or timing of the data collection process. Because the computation of degree heating days would be identical, further adjustments to the data, such as those that might be accomplished through the application of PRISM[3], are unnecessary.

Many variables are known to affect residential utility consumption, such as the orientation of the house (Christensen and Barker 2001). However, data could not be collected on all such variables (this is a limitation of the analysis). Further, this is not a standard engineering analysis of energy usage in high-performance homes,[4] but instead relies on careful statistical analysis of actual utility records provided by the utility company in electronic format.

It is also instructive as context to understand the efficiency and renewables features of the different home categories and the fuels used for end-use applications at residences in the SheaHomes and comparison homes. Tables 73 and 74 summarize these data. As can be seen, SEE homes have all of the features that PV homes have except for PV systems. All homes were built to the Title 24 building code in effect at the time of construction. Residences in the area routinely use natural gas for space heating, water heating, pool and spa heating, clothes drying, and cooking. They use electricity for air conditioning, lighting, appliances, and plug loads.

Table 73. Energy Efficiency and Renewable Energy Features of Categories of Homes in the Utility Consumption and Cost Analysis

Features	Solar PV Homes	SEE Homes	Comparison Homes
Meets Title 24 code	X	X	X
ComfortWise efficiency rating	X	X	–
Solar radiant barriers	X	X	–
Thermal windows	X	X	–
Solar water heating	X	X	–
Solar PV systems	X	–	–
Tightly wrapped ducts	X	X	–

[3]PRISM is an acronym for the Princeton Scorekeeping Method. PRISM is a software package developed at Princeton University's Center for Energy and Environmental Studies that calculates a weather-corrected index of energy consumption.

[4]Such an analysis, for at least one of the SheaHomes and which involved instrumentation of the home, is being conducted by the National Association of Home Builders (NAHB) Research Center.

Table 74. Fuels Used for End-Use Applications in All Homes Encompassed by the Study

End-Use Application	Electricity	Natural Gas
Space heating	–	X
Water heating*	–	X
Air conditioning	X	–
Pool/spa heating**	–	X
Clothes drying***	–	X
Cooking	–	X
Lighting	X	–
Appliances	X	–
Plug loads (TV, computers, etc.)	X	–

*In SheaHomes, water heating is also provided by solar water pre-heating systems.
**A few pools are heated by solar water heating systems.
***Based on focused interviews with 43 homeowners in 25 households during the study's qualitative phase. Homeowners selected their own appliances, which may or may not have been highly energy-efficient.

Measures of Utility Consumption and Cost

Utility consumption and cost can be defined and measured in many ways. Several measures of both consumption and cost are used here to convey energy use and expenditures among the various categories of homes. However, because the present analysis constitutes an empirical statistical investigation rather than an engineering study, such measures are limited to conventional descriptive statistics (e.g., averages and totals of consumption and cost over specified periods of time) rather than more formal estimates of engineering parameters.

Utility consumption is taken to mean either the total or average household consumption of electricity or gas over a specified period of time. Six measures of utility consumption are presented and discussed here:

1. Total electricity consumption
2. Average monthly electricity consumption
3. Average monthly electricity consumption per square foot
4. Total gas consumption
5. Average monthly gas consumption
6. Average monthly gas consumption per square foot.

Total consumption represents all electricity or gas used by a household over a specified period of time. For example, total consumption per year represents household electricity or gas use over a 12-month period and encompasses the year's seasonal cycles. Average monthly consumption represents the average household use of electricity or gas each month. Twelve-month averages provide a measure of consumption across the year's seasonal variations. Average monthly consumption per square foot facilitates comparisons between homes with more or less square footage.

Electricity and gas consumption are measured in different units (kWh and therms). These units must be kept separate to specifically determine (1) the effect of the PV systems on electricity consumption in SheaHomes with such systems and (2) the effect of gas consumption in SEE homes (which are energy efficient and have solar water heating). However, combined utility consumption could be reported in terms of Btu. Because consumption and cost are closely correlated**,** the discussion of combined utility cost (see below) can also serve as a surrogate for combined utility consumption. (See also Figures J-1 to J-16 in Appendix J [Scatter Diagrams of Average Monthly Electricity Cost Consumption by Average Cost for All Homes in the Study] and Figures K-1 to K-16 in Appendix K [Scatter Diagrams of Average Monthly Gas Cost Consumption by Average Cost for All Homes in the Study].)

Utility cost is taken to mean either the total or average household expenditures for electricity, gas, or both over a specified period of time. Several measures of utility cost are considered here:

1. Total electricity cost, with and without taxes and miscellaneous charges
2. Average electricity cost, with and without taxes and miscellaneous charges
3. Average electricity cost per square foot, with and without taxes and miscellaneous charges
4. Total gas cost, with and without taxes and miscellaneous charges
5. Average gas cost, with and without taxes and miscellaneous charges
6. Average gas cost per square foot, with and without taxes and miscellaneous charges
7. Total combined utility bill, with and without taxes and miscellaneous charges
8. Average monthly combined utility bill, with and without taxes and miscellaneous charges
9. Average monthly combined utility bill per square foot, with and without taxes and miscellaneous charges.

Total cost represents the cost of electricity or gas (with or without taxes and miscellaneous charges) used by a household for a specified period of time. For example, total cost per year represents the cost of electricity or gas over a 12-month period and encompasses the year's seasonal cycles. Average monthly cost represents the average cost of electricity or gas (with or without taxes and miscellaneous charges) used by a household each month. Twelve-month averages provide a measure of cost across seasonal variations experienced during the year. Average monthly cost per square foot facilitates comparisons between homes with more or less square footage.

Calculating and communicating the concept of combined utility cost is quite easy, because both electricity cost and gas cost are expressed in terms of dollars. Combined utility cost can simply be stated as the sum of electricity and gas cost. Total combined utility cost, then, represents the total dollars spent by a homeowner on all utilities for a specified period of time, whereas average monthly combined utility cost represents the average monthly expenditures for all utilities. Again, average monthly combined utility cost *per square foot* facilitates energy cost comparisons among homes with more or less square footage.

Other Terminology

Throughout the following discussion, utility consumption and cost are attributed interchangeably to homes and households. Clearly, the homes or houses themselves do not consume energy, although the quality of home construction can certainly contribute to utility demand. Utility consumption, and hence cost, result from occupants' use of energy-related equipment and appliances to produce light, condition space, power appliances and plug loads (such as computers and television sets), and heat water. The attribution of utility consumption and cost to homes is generally used to more fully explain analytical results. In all cases, the context of the situation should make the intention clear.

Data Processing

A typical monthly utility bill for one household consists of days of service in the billing month, amount of electricity used (in kWh), cost and tax for electricity used, and miscellaneous costs associated with electricity use, plus amount of gas used (in therms) and cost and tax for gas use. Other information associated with the dates of service is also included. Because respondents moved into their homes and initiated service on different dates, the number of months of utility data for each household varies. Table 5 in Chapter 3 (Study Methods and Data Resources), presents descriptive statistics on months of service for some home categories. In addition, the number of days per monthly billing cycle varies slightly. However, meters are read on the same day each month at all houses in the study neighborhoods.

Restriction to a Minimum of 28 Service Days per Month

Because some households began service in the middle of a month, the number of days in the first billing month is particularly variable; so, for consistency, all records in the data set were omitted for which the number of days per billing cycle was fewer than 28. After imposing this restriction, the average number of days per billing cycle across all households and all billing months was determined to be 30.5.

Restriction to 12 Months of Data per Household

Because the time frame during which SheaHomes and comparison homes were sold spans approximately 2 years, there is considerable variability in the number of months that these homes received utility service. This inconsistency complicates conceptual and analytical comparisons on the basis of average or total energy consumption and cost. In fact, several homeowners had been in their homes for less than 1 year (but at least 6 months) at the time of the survey. Because utility consumption is seasonal, the decision was made to restrict the data set to homes that had experienced at least 1 full year of utility service and to use the last 12 months (July 2003 through June 2004) of the study period to include as many homes as possible. As a result, the utility data set was reduced to records from 122 homes (40 PV homes, 51 SEE homes, and 31 comparison homes). This restriction precludes having to incorporate weighting in the statistical analysis to accommodate differences in the numbers of months of utility service per home.

Graphical Comparisons of Month-to-Month Utility Consumption

Figures L-1 to L-14 in Appendix L (Line Graphs of Month-to-Month Consumption of Electricity and Gas for Individual Homes in the Study) are time-series plots that show the monthly consumption of electricity for July 2003 through June 2004 for each home in each of several categories (e.g., SEE or PV). Figures M-1 to M-10 in Appendix M (Line Graphs for Month-to-Month Consumption of Electricity and Gas for Homes in the Study with Recreational Equipment) are similarly grouped time-series plots that show the monthly consumption of electricity and gas for July 2003 through June 2004 for homes with and without pools and hot tubs. Figures L-1 to L-14 and Figures M-1 to M-14 show substantial fluctuation in electricity and gas consumption among the homes—even homes within the same category. As expected, considerable variation is also evidenced in electricity and gas consumption among months for each home. In addition, for both sets of graphs some homes have utility consumption that is abnormally high or off-trend. These homes, which could be termed outliers, are addressed in more detail below. Because utility cost is closely tied to utility consumption (Figures J-1 to J-16 in Appendix J and Figures K-1 to K-16 in Appendix K), graphs of month-to-month electricity and gas costs (not included) can reasonably be expected to demonstrate the same patterns.

Computing Total and Average Utility Consumption and Cost

The individual monthly records for each household were collated to compute monthly averages and totals (accounting for the varying days per billing cycle) for the amounts of gas and electricity use, gas and electricity costs, and combined utility cost. These values were subsequently merged with the survey responses of the respective households.

Additional Data Screening

Three SheaHomes owners who provided permission to access their utility data were owners of homes designated as early. These homes were constructed before solar water heating was incorporated as standard. Relative to energy use and consumption, these homes are not comparable to other SheaHomes, so their utility data records and the associated values of average monthly consumption and cost were omitted.

Further, analysis of 12-month totals reveals a high degree of variation in electricity consumption and gas consumption among all the homes, a result suggested by the time-series plots of month-to-month consumption contained in Appendixes L and M. This finding indicated the need for a more detailed investigation. To facilitate additional study, side-by-side box plots[5] of 12-month total electricity consumption were constructed that depict the distribution of values for the PV homes, SEE homes, and comparison homes. Similar side-by-side box plots of 12-month total gas consumption were also constructed. These two sets of box plots are shown in Figures 8 and 9. Both sets of box plots indicate the presence of statistical outliers; some outliers are rather extreme.

For electricity consumption, five homes (one PV, three SEE, and one comparison) are indicated as outliers. For gas consumption, seven homes are indicated as outliers (two PV, three SEE , and two comparison).

Extensive investigation of the outlier homes revealed no consistent explanation in terms of equipment or appliances, larger families or different family compositions, or other readily identifiable causes, so the decision was made to exclude these homes. Two homes are indicated as outliers for both electricity and gas consumption, which brings the total number of outlier homes to 10. The utility records of these 10 homes were eliminated to ensure data consistency in the subsequent analysis and discussion of combined utility cost. As a result of this additional data screening, the utility data set was reduced to records from 109 homes (37 PV homes, or 33.9%; 44 SEE homes, or 40.4%; and 28 comparison homes, or 25.7%).

Analysis of Utility Consumption

Several statistical techniques were used to analyze utility consumption. Descriptive statistics were first computed. These statistics were calculated for all homes combined and for various categories of homes. Independent sample t-tests were then used to compare means and to determine whether there were statistically significant differences between home categories. In some cases, χ^2 tests of independence were used to compare home categories with respect to home and household characteristics.

---

[5]A box plot is a graphical portrayal of the distribution of data values. The box plot displays the location of the minimum and maximum values, along with the 25th, 50th, and 75th percentiles. The 50th percentile is equivalent to the median. The box, or rectangle, portion of the display represents the interquartile range (IQR), which encompasses the central 50% of the values or the distance between the 25th and 75th percentiles. The lines that extend below and above the box are sometimes called the whiskers, which extend to the minimum and maximum values or to hinge points in the distribution. The lower and upper hinge points are defined by (1) Q_1-1.5*IQR, where Q_1 is the first quartile (25th percentile), and (2) Q_3 + 1.5*IQR, where Q_3 is the third quartile (75th percentile), respectively. Values beyond the hinge points are considered to be statistical outliers and are so indicated as circles or stars, with stars being the most extreme.

Descriptive Statistics on Utility Consumption

Descriptive statistics on the six utility consumption measures were computed for the various categories of homes; and the values are reported in the tables contained in Appendix N (Descriptive Statistics, 12-Month Utility Consumption and Cost Data). Each table contains the mean, median, minimum value, maximum value, standard deviation, and coefficient of variation[6] for the variable(s) of interest that pertains to utility consumption or cost. All computations were made with the 12-month data set after early and outlier homes were omitted.

Utility Consumption for All Homes Combined

Table N-1 in Appendix N presents the descriptive statistics on total 12-month electricity (kWh) and gas (therms) consumption for the households included in the utility analysis. Descriptive statistics on average monthly electricity (kWh) and gas (therms) consumption are also presented. Figures P-1 and P-18 in Appendix P (Histograms of 12-Month Utility Data, All Homes Combined) depict the frequency distributions of average monthly electricity (kWh) and gas (therms), respectively, for all homes combined.

---

[6] The coefficient of variation is a unitless quantity, reported as a percentage, that expresses variation in the data relative to the mean (i.e., the ratio of the standard deviation to the mean multiplied by 100). Data sets that are tightly clustered around the mean have small coefficients of variation that approach 0, which suggests a high degree of precision. Data sets with values widely spread around the mean have coefficients of variation that are large, which suggests low precision. Because it is expressed only in terms of percentage, the coefficient of variation is a particularly useful measure for comparing data sets with means and standard deviations that are both different.

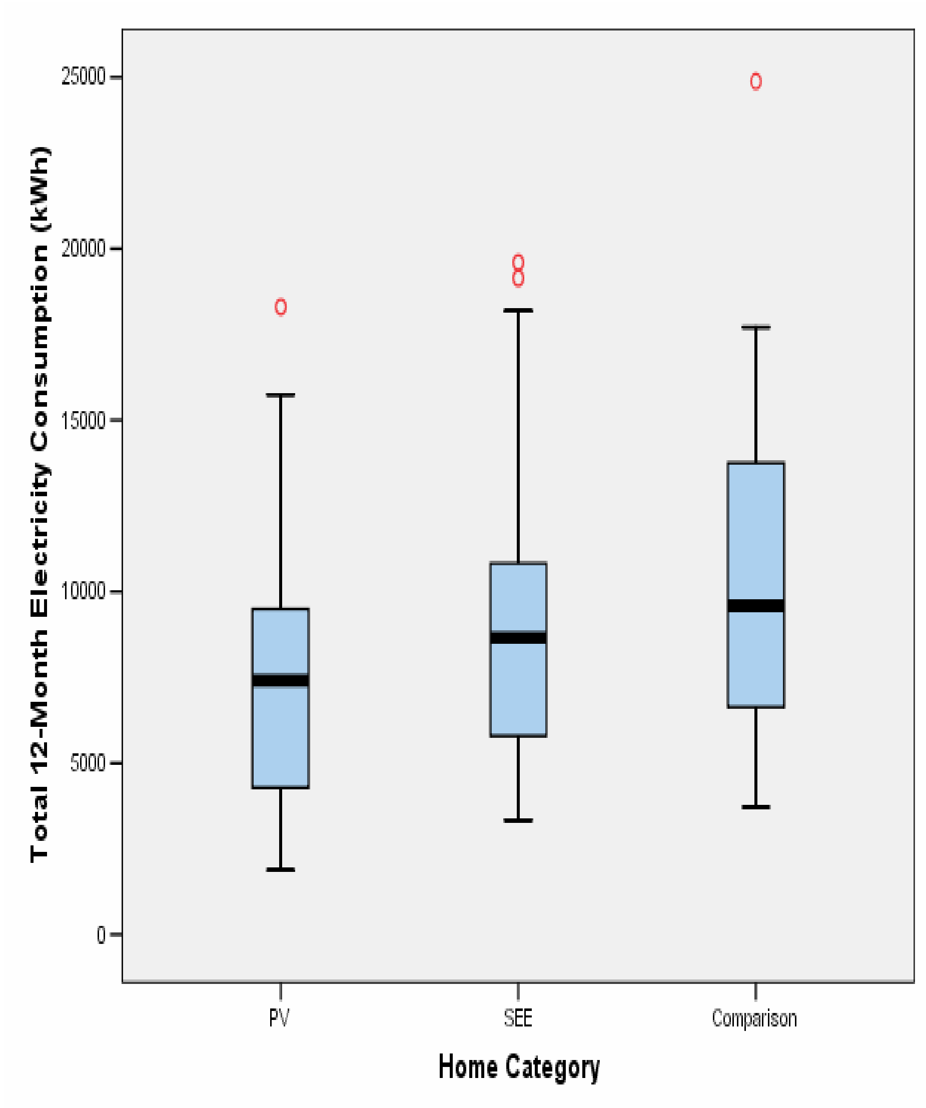


Figure 8. Side-by-Side Box Plots of Total 12-Month Electricity Consumption for Three Categories of Homes: PV Homes (n=40), SEE Homes (n=51), and Comparison Homes (n=31)[7]

[7] A total of five outliers are indicated (the symbols are overlapping for two outlier SEE homes)

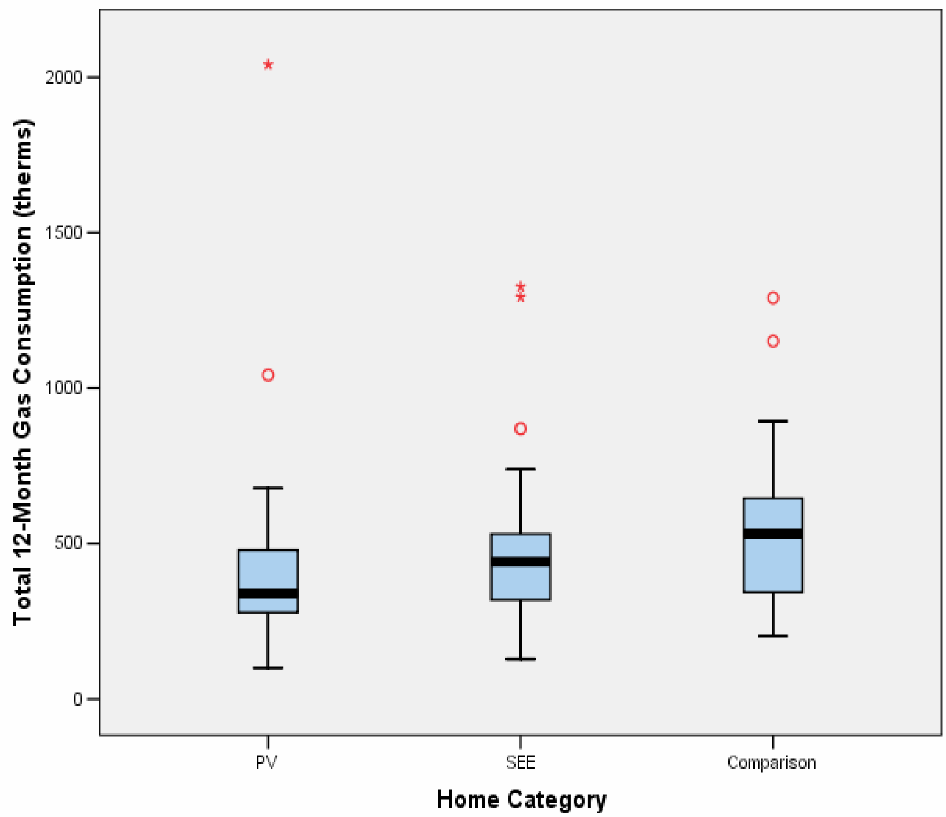


Figure 9. Side-by-Side Box Plots of Total 12-Month Gas Consumption for Three Categories of Homes: PV Homes (n=40), SEE Homes (n=51), and Comparison Homes (n=31)[8]

Table N-2 in Appendix N presents corresponding descriptive statistics on average monthly electricity (kWh) and gas (therms) per square foot. The respective frequency distributions are shown in Figures P-2 and P-8 in Appendix P. These values represent average amounts of electricity or gas used by a household adjusted for home size. As indicated in Tables N-1 and N-2, total 12-month consumption, average monthly consumption, and average monthly consumption per square foot for the homes encompassed in this study are quite variable, as indicated by the coefficients of variation, all of which exceed 35% for both electricity and gas.

[8] Seven outliers are indicated.

Comparing Utility Consumption for SheaHomes and Comparison Homes

Table N-3 presents the comparative descriptive statistics on electricity and gas consumption for SheaHomes and comparison homes. For SheaHomes, total 12-month electricity consumption ranges from 267 to 16,741 kWh, with a mean of 7,425.8 kWh. The average monthly electricity consumption in the SheaHomes ranges from 22.3 to 1,399.8 kWh, with a mean of 619.9 kWh. For comparison homes, total 12-month electricity consumption ranges from 3,716 to 17,707 kWh, with a mean of 9,502.8 kWh. The average monthly electricity consumption in these homes ranges from 309.4 to 1,475.9 kWh, with a mean of 792.6 kWh. Figure Q-1 (a, b) in Appendix Q shows the frequency distributions of total and average monthly electricity consumption for SheaHomes and comparison homes.

Table 75 reports the results of t-tests that statistically compare the mean total 12-month electricity consumption and mean average monthly electricity consumption for SheaHomes and comparison homes. The results given in Table 75 confirm that the differences in mean total 12-month electricity consumption and the mean average monthly electricity consumption for the SheaHomes and comparison homes are statistically significant (t= –2.662, p=009; t= –2.652, p=.009; respectively). On average, SheaHomes households consume less electricity on both an annualized and average monthly basis than do comparison homes.

Similar results are observed when average monthly electricity consumption is adjusted for square footage. As reported in Table 75 (also see Table N-4 in Appendix N), the mean average monthly electricity consumption per square foot for SheaHomes is .200 kWh versus .282 for comparison homes, and this difference is also statistically significant (t= –3.321, p=.002).

The variance, and hence the standard deviation, of total 12-month electricity consumption and average monthly electricity consumption is not significantly different for SheaHomes and comparison homes (F=2.258, p=.136; and F=2.248, p=.137; respectively). However, the variance in average monthly electricity consumption per square foot is significantly lower for SheaHomes than for comparison homes (F=5.477, p=.021). This suggests less fluctuation, or higher stability, when average monthly electricity consumption is adjusted for square footage. On the whole, though, there is substantial variation in all three electricity consumption measures among SheaHomes and comparison homes, as indicated by the relatively high coefficients of variation reported in Table N-3 in Appendix N.

Table 75. Comparison of Mean Utility Consumption Measures for SheaHomes and Comparison Homes

Utility Consumption Measure	Mean for SheaHomes Homes (n=81*)	Mean for Comparison Homes (n=28*)	t-statistic	p-value
Total 12-month electricity consumption (kWh)	7,425.8	9,502.8	–2.662	*.009*
Average monthly electricity consumption (kWh)	619.9	792.6	–2.652	*.009*
Average monthly electricity consumption per square foot (kWh)	.200	.282	–3.321	*.002*
Total 12-month gas consumption (therms)	391.9	497.3	–2.687	*.011*
Average monthly gas consumption (therms)	32.8	41.6	–2.684	*.011*
Average monthly gas consumption per square foot (therms)	.011	.015	–3.618	*.001*

*Early and outlier homes are omitted.

On average, SheaHomes also consume significantly less gas in terms of both total 12-month consumption and average monthly consumption than comparison homes. Total 12-month gas consumption for SheaHomes ranges from 100 to 739 therms, with a mean of 391.9 therms (Table N-3 in Appendix N). Average monthly gas consumption for these homes ranges from 8.3 to 61.9 therms, with a mean of 32.8 therms. When adjusted by square footage, average monthly gas consumption ranges from approximately 0 to .02 therms, with a mean of .011 therms (Table N-4 in Appendix). For comparison homes, total 12-month gas consumption ranges from 202 to 893 therms, with a mean of 497.3 therms; average monthly gas consumption ranges from 16.9 to 74.7 therms, with a mean of 41.6 therms; and average monthly gas consumption per square foot ranges from .01 to .03 therms, with a mean of .015 therms. As indicated in Table 75, the difference in the mean values for each of these measures for SheaHomes and comparison homes is statistically significant; the mean values in each case are lower for SheaHomes. Figure Q-7 (a, b) in Appendix Q shows the frequency distributions of total and average monthly gas consumption for SheaHomes and comparison homes.

The variance, and hence the standard deviation, of total 12-month gas consumption, average monthly gas consumption, and average monthly gas consumption per square foot also are significantly lower for SheaHomes than for comparison homes. This suggests significantly lower fluctuation, or higher stability, in these measures ($F=4.293$, $p=.041$; $F=4.279$, $p=.041$; and $F=9.996$, $p=.002$; respectively). Again, however, there is substantial variation in all three gas consumption measures among both SheaHomes and comparison homes, as indicated by the relatively high coefficients of variation reported in Table N-3 in Appendix N.

The statistical conclusions drawn from the foregoing analysis are based on an implicit assumption that the primary difference in the two groups of homes is the home design itself along with all contributing factors (e.g., the builder's implementation of the design) that may be confounded with the design. Clearly, among homes represented in this analysis, SheaHomes appear to consume less energy, on average, than comparison homes. Teasing out the effects of all the factors that contribute to this result is difficult, particularly those that are related to occupant behavior. Nonetheless, such an exercise is important in determining the extent to which the households in the two groups are comparable.

One obvious consideration is the difference in square footage of SheaHomes and comparison homes. Because the collection of homes for which utility data are available is not identical to the collection of homes from which survey responses were obtained, the square footage of this subset of homes in the 12-month utility data analysis must be calculated. The mean square footage of these SheaHomes is 3,084.6 ft^2, whereas the mean square footage of these comparison homes is 2,810.2 ft^2, and the difference is statistically significant ($t=4.102$, $p<.001$). Hence, in this subset, the SheaHomes are significantly larger (by about 275 ft^2, on average) than the comparison homes. The mean square footages of PV and SEE homes (both constructed by the same builder) are not significantly different ($t=-1.036$, $p=.303$). Table 76 contains the associated descriptive statistics.

Table 76. Descriptive Statistics on Square Footages for Various Categories of Homes*

Home Category	n	Minimum	Mean	Maximum	Standard Deviation
SheaHomes	81	2,222	3,084.6	3,678	289.4
PV homes	37	2,222	3,048.2	3,678	300.9
PV homes with 1.2-kW PV systems	31	2,222	3,032.1	3,678	291.2
PV homes with 2.4-kW PV systems	6	2,584	3,131.8	3,678	364.6
SEE homes	44	2,584	3,115.1	3,678	279.2
Comparison homes	28	2,486	2,810.2	3,502	347.5

*Early and outlier homes are omitted.

The larger mean square footage for the SheaHomes does not appear to have adversely affected mean household energy consumption (on either an average monthly or a 12-month total basis). As noted above, *mean consumption for both electricity and gas is still lower for these households than for comparison households that, on average, have fewer square feet*.

This observation is further underscored in Figures 10–13, which depict the relationship between average total 12-month electricity consumption ($), excluding taxes and miscellaneous charges, and average home square footage.[9] The correlation[10] between these two variables is not particularly strong for any of the three home categories, and it is particularly low for PV homes (the correlation is higher when only those PV homes with 1.2-kW systems are considered). Similar relationships (not shown here) are exhibited in scatter diagrams of average home square footage and the average values of other utility consumption measures. This observation suggests that—contrary to what might have been expected—*utility consumption does not necessarily increase with home square footage*. The question remains as to whether increasing home square footage in combination with other factors leads to higher utility consumption.

Two other factors to consider are household composition and the number of occupants in each household (household size). Table 77 shows the comparative percentages of SheaHomes and comparison homes that are occupied by adults only and by adults plus children. Of the SheaHomes, 35% are occupied by adults alone, whereas 65% are occupied by adults and children. Of the comparison homes, 22% are occupied by adults alone, whereas 78% are occupied by adults and children. These distributions of percentages are not significantly different (χ^2=1.614, p=.204), which suggests that *household composition for the two groups of homes is essentially equivalent*.

Table 77. Comparative Percentages of SheaHomes and Comparison Homes Occupied by Adults Only and by Adults plus Children*

Development	Adults Only	Adults plus Children	Total
SheaHomes	35% (n=28)	65% (n=51)	100% (n=79)
Comparison homes	22% (n=6)	78% (n=21)	100% (n=27)
Total	32% (n=34)	68% (n=72)	100% (n=106)

*This analysis is limited to homes for which actual utility data are available. Early and outlier homes are omitted. Information about household size is not available on three of the homes (two from SheaHomes and one from comparison homes).

[9]Because these graphs depict averages, each data point represents a different number of homes.

[10]Here, the different numbers of homes that contribute to each average is ignored for purposes of computing the correlation coefficient, r.

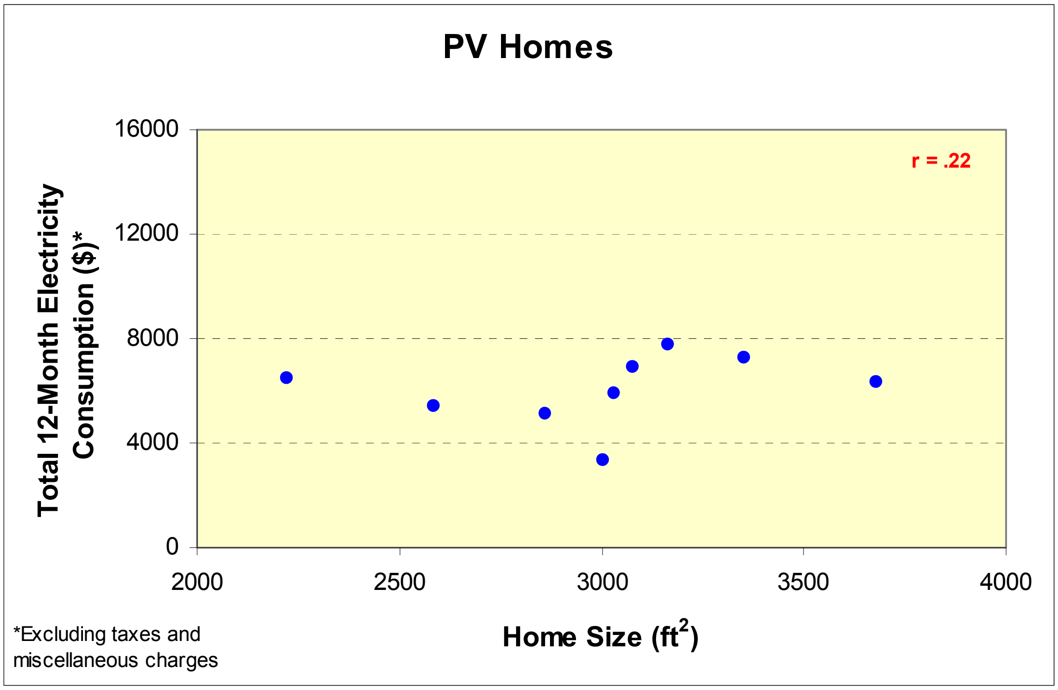


Figure 10. Scatter Diagram of Average Total 12-Month Electricity Consumption ($) versus Average Square Footage for PV Homes (n=37).[11]

[11]The number of homes associated with each data point varies. For example, there may be more 3000-ft^2 homes than 2500-ft^2 homes.

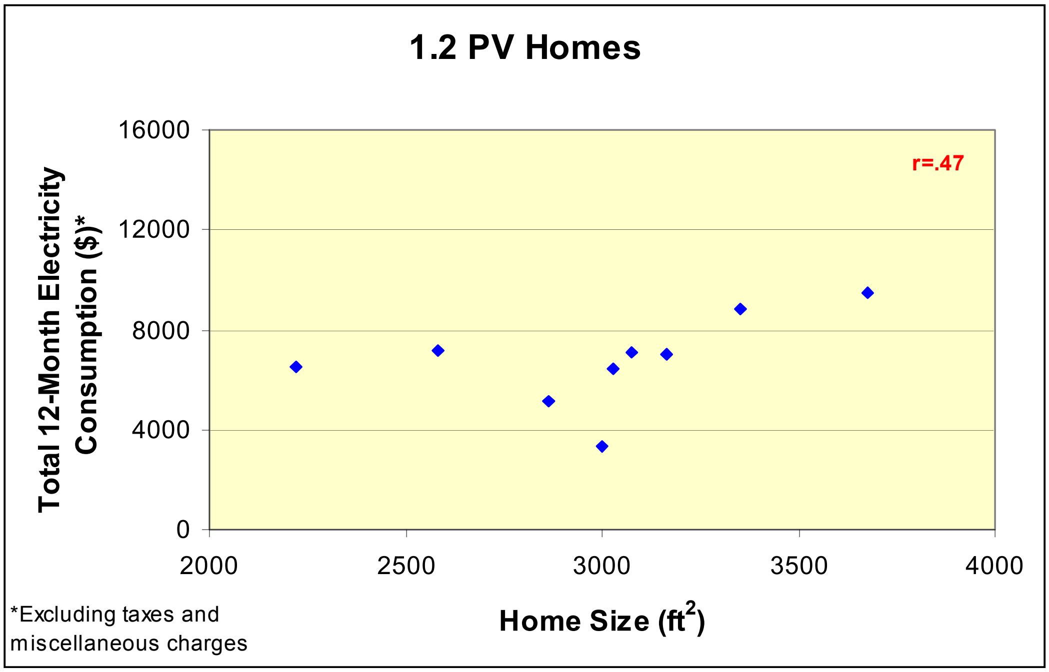


Figure 11. Scatter Diagram of Average Total 12-Month Electricity Consumption ($) versus Average Square Footage for PV Homes with 1.2-kW Systems (n=31).[12]

[12]The number of homes associated with each data point varies. For example, there may be more 3000-ft^2 homes than 2500-ft^2 homes.

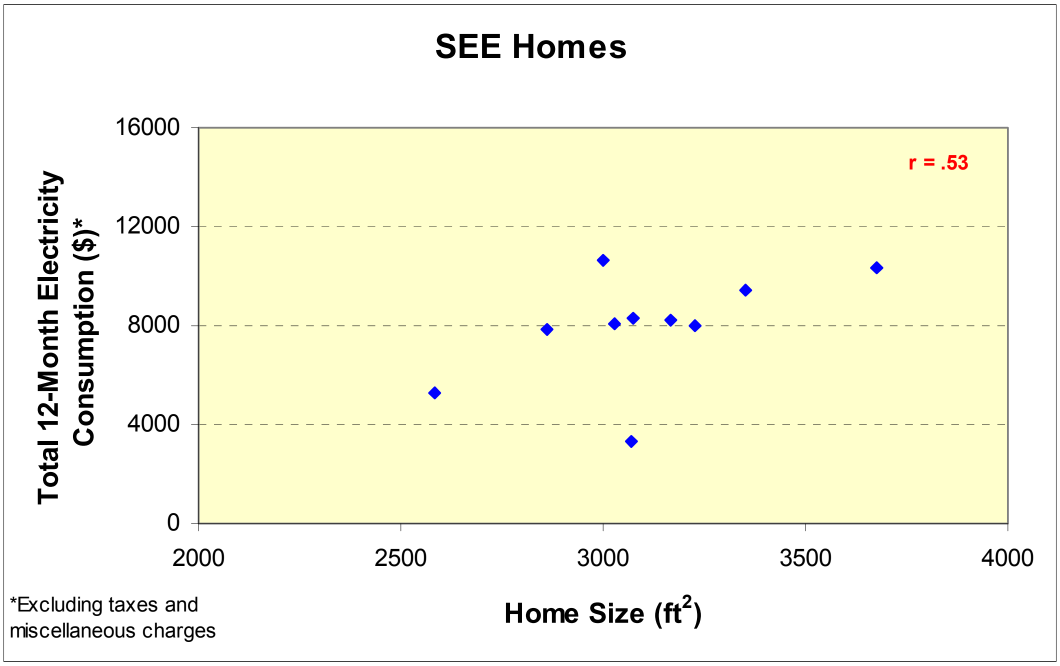


Figure 12. Scatter Diagram of Average Total 12-Month Electricity Consumption ($) versus Average Square Footage for SEE Homes (n=44).[13]

[13]The number of homes associated with each data point varies. For example, there may be more 3000-square-foot homes than 2500-square-foot homes.

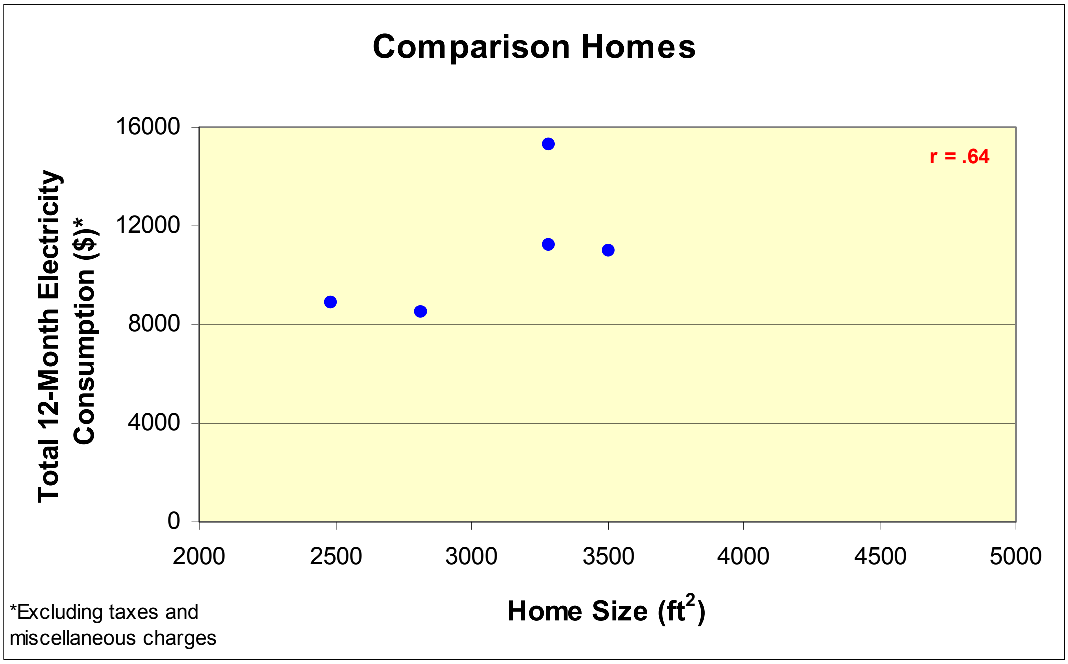


Figure 13. Scatter Diagram of Average Total 12-Month Electricity Consumption ($) versus Average Home Size (ft^2) for Comparison Homes (n=28)[14]

[14]The number of homes associated with each data point varies. For example, there may be more 3000-ft^2 homes than 2500-ft^2 homes.

Table 78 shows the comparative percentages of SheaHomes and comparison homes that are occupied by three or fewer individuals and by four or more individuals. Among the SheaHomes, 55% are occupied by three or fewer persons, and 45% are occupied by four or more persons—a relatively even split. Among the comparison homes, 33% are occupied by three or fewer persons; 67% are occupied by four or more persons—a 2-to-1 ratio.

Table 78. Comparative Percentages of SheaHomes and Comparison Homes Occupied by Three or Fewer Individuals and by Four or More Individuals*

Development	Three or Fewer	Four or More	Totals
SheaHomes	55% (n=44)	45% (n=46)	100% (n=80)
Comparison homes	33% (n=9)	67% (n=18)	100% (n=27)
Total	49% (n=53)	51% (n=54)	100% (n=107)

*This analysis is limited to homes for which actual utility data are available. Early and outlier homes are omitted. Information on number of occupants is missing for two homes (one each from SheaHomes and comparison homes).

Although the higher percentage of comparison homes with four or more occupants is noteworthy in that it offers a potential explanation for the higher mean utility consumption by these households, the difference in the distribution of percentages indicated in Table 78 is not quite statistically significant (χ^2=3.791, p=.052). Records from a greater number of comparison homes would be needed to determine if household size (number of occupants) is significantly larger for those homes. Indeed, considering together all the homes for which actual utility data are available, there is a nearly even split between the number occupied by three or fewer individuals and the number occupied by four or more individuals. This again suggests that *household size may not be a discriminating factor*. Figure 14 gives an expanded view of the comparative distributions of household size for the SheaHomes and comparison homes in terms of a side-by-side percentage bar chart.[15]

Energy-consuming equipment—particularly home recreational amenities such as pools and hot tubs—is also of interest when comparing the two groups of homes.[16] Table 79 shows the percentages of SheaHomes and comparison homes that have either a pool or hot tub, or both, and those that have neither. Of the SheaHomes, 26.3% have a pool or hot tub, or both; 73.8% have neither. On the other hand, 57.7% of the comparison homes have a pool or hot tub, or both; 42.3% have neither. Note that comparison homes did not come with pools or hot tubs standard. Figure 15 provides an expanded presentation of the ownership distribution for SheaHomes and comparison homes in terms of a side-by-side percentage bar chart. *Clearly, a higher percentage of SheaHomes have no pool or hot tub, and this difference in the distribution of percentages is*

[15]Utility consumption and cost per person is an interesting concept that is not pursued here.

[16]Solar hot water and solar PV are not considered at this point because no comparison homes have these features. Nonetheless, all SheaHomes (except early homes) have solar hot water systems, and some have solar PV systems. None of the comparison homes have solar hot water or solar PV systems. Consequently, these features may constitute the single most important reason why mean utility consumption is lower for SheaHomes.

statistically significant (χ^2=8.65, p=.003). Such a strong difference may partially explain the higher mean utility consumption in comparison homes, and this possibility is considered in more detail below.

Table 79. Comparative Percentages of SheaHomes and Comparison Homes with a Pool and/or Hot Tub or with Neither

Development	Neither	Pool and/or Hot Tub	Total
SheaHomes*	73.8% (n=59)	26.3% (n=21)	100% (n=80)
Comparison homes*	42.3% (n=11)	57.7% (n=15)	100% (n=26)
Total	66.0% (n=70)	34.0% (n=36)	100% (n=106)

*Early and outlier homes are omitted. Information about pools and hot tubs is missing for three homes (one from SheaHomes and two from comparison homes).

Table 80 summarizes the results of statistical comparisons of the percentage of ownership of various other energy-related equipment and appliances among SheaHomes and comparison homes. The percentage distribution is significantly different for only two items: (1) two refrigerators and (2) hot water flow regulators. *A significantly lower percentage of the comparison homes have two refrigerators, and a significantly higher percentage of these homes have hot water flow regulators.* Both results might ordinarily be expected to contribute to lower utility consumption; but this is apparently not the case (at least the effect is not immediately apparent) because mean utility consumption in terms of both the 12-month total and the average monthly amount is higher for comparison homes than for SheaHomes (see Table 75). The two groups of homes are considered to be essentially equivalent on the basis of the other equipment listed in Table 80.

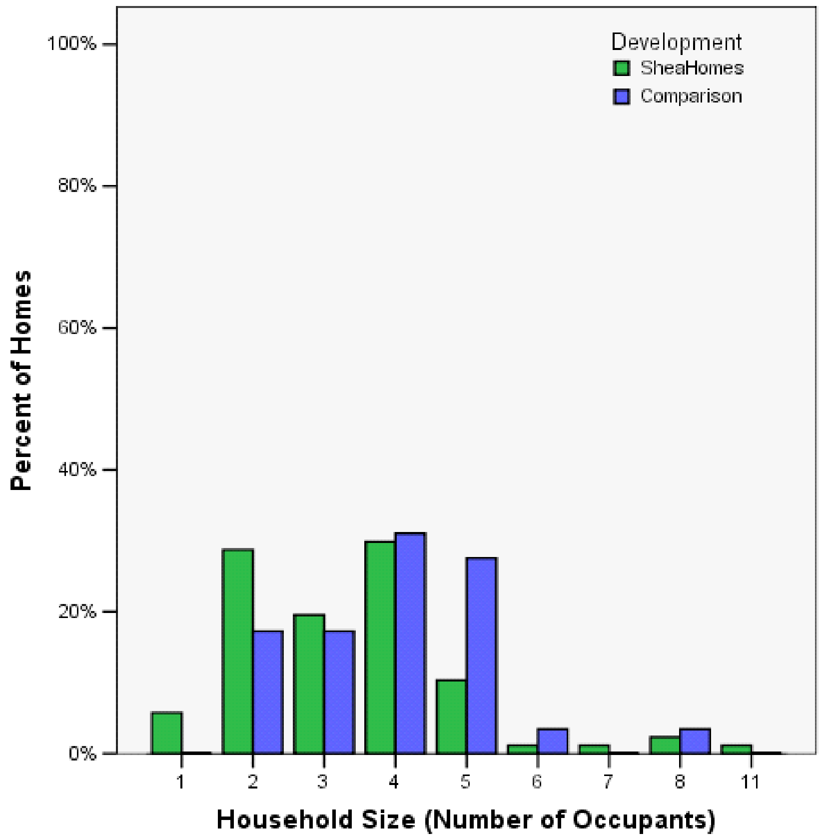


Figure 14. Side-by-Side Percentage Bar Chart Showing the Comparative Distributions of Household Size for SheaHomes (n=80) and Comparison Homes (n=27)[17]

[17] Information on household size is missing for two homes (one each from SheaHomes and comparison homes).

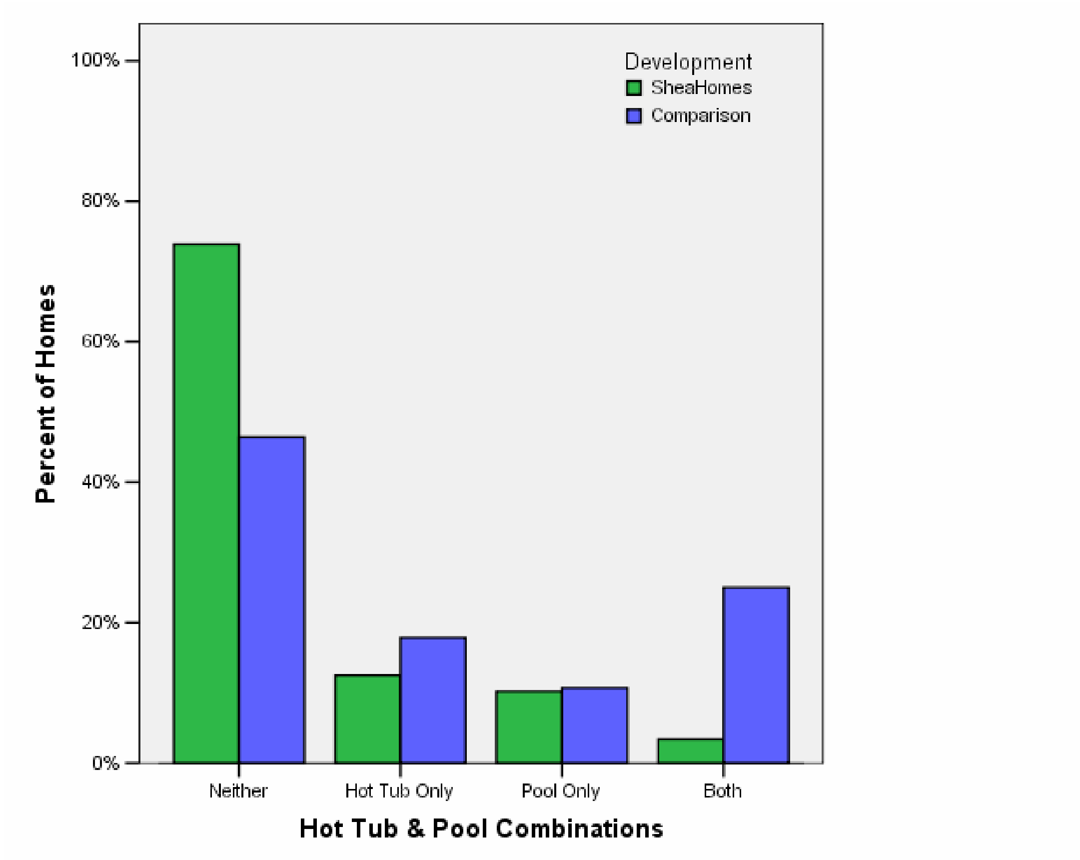


Figure 15. Side-by-Side Bar Chart Depicting the Percentages of Shea Homes (n=80) and Comparison Homes (n=26) with Hot Tubs and/or Pools[18]

[18]Information concerning pool and hot tub ownership is not available for three homes (one from SheaHomes and two from comparison homes).

Table 80. Statistical Comparisons of the Percentage of Ownership of Various Other Energy-Related Equipment among SheaHomes and Comparison Homes

Home Feature	SheaHomes* Ownership	Comparison* Homes Ownership	χ^2	p-value
Ceiling fans	63.8% (n=51)	61.5% (n=16)	.041	.839
Dual zone heating/cooling	62.5% (n=50)	57.7% (n=15)	.191	.662
Dimmer switches for lights	57.5% (n=46)	57.7% (n=15)	.000	.986
Two refrigerators	45.0% (n=36)	23.1% (n=6)	3.942	*.047*
Compact fluorescent light bulbs (CFLs)	43.8% (n=35)	53.8% (n=14)	.805	.370
Hot water flow regulator	10.0% (n=8)	30.8% (n=8)	6.605	*.010*
Standalone freezer	8.8% (n=7)	15.4% (n=4)	.929	.335

*In each comparison, the total number of SheaHomes is 80 and the total number of comparison homes is 26. Information is not available for three homes (one from SheaHomes and two from comparison homes). Early and outlier homes are omitted.

Comparing Electricity and Gas Consumption for PV and SEE Homes

An important question for this study is the extent to which solar PV systems affect actual utility consumption. This question can be directly addressed when PV and SEE homes are compared. Of the 81 SheaHomes on which actual utility data are available, 37 (45.7%) have solar PV systems and 44 (54.3%) do not. The PV and SEE homes are in the same development and were constructed by the same builder with identical energy-efficiency features. Additionally, all homes in both categories are equipped with solar water heating. Further, there is no significant difference between the PV and SEE homes with respect to square footage (t= –1.036, p=.303), household size or composition (χ^2=.690, p=.406; and χ^2=.086, p=.770; respectively), ownership of pools or hot tubs, or both (χ^2=.627, p=.429), or ownership of any of the other equipment and appliances noted in Table 80.[19]

Table N-5 in Appendix N presents descriptive statistics on total 12-month electricity and gas consumption and on average monthly electricity and gas consumption for PV homes and SEE homes. Table N-6 in Appendix N reports descriptive statistics on average monthly electricity and gas consumption per square foot for these same groups of homes.

Figure R-1 (a, b) in Appendix R show the distributions of total and average monthly electricity consumption for PV and SEE homes. For the PV homes, total 12-month electricity consumption ranges from 267 to 12,868 kWh, with a mean of 6,368.9 kWh. Average monthly electricity consumption for these homes ranges from 22.3 to 1073.4 kWh, with a mean of 531.7 kWh. On a square-footage basis, average monthly electricity consumption ranges from .009 to .415 kWh,

[19] At least four different floor plans were constructed by SheaHomes. All four floor plans are represented among the PV and SEE home categories.

with a mean of .174 kWh. For the SEE homes, total 12-month electricity consumption ranges from 3,333 to 1,6741 kWh, with a mean of 8,314.7 kWh; average monthly electricity consumption ranges from 277.7 to 1,399.8 kWh, with a mean of 694 kWh. On a square-footage basis, average monthly electricity consumption for homes without solar PV ranges from .090 to .489 kWh, with a mean of .222 kWh. *These values suggest that, on average, electricity consumption is lower in the PV homes.*

With respect to gas consumption, the findings are somewhat different. Figure R-7 (a, b) in Appendix R shows the distributions of total and average monthly gas consumption for PV and SEE homes. For PV homes, total 12-month gas consumption ranges from 100 to 678 therms, with a mean of 366 therms; and average monthly gas consumption ranges from 8.3 to 56.6 therms, with a mean of 30.7 therms (see Table N-5 in Appendix N). Average monthly gas consumption per square foot ranges from approximately 0 to .02 therms, with a mean of .01 therms. For SEE homes, total 12-month gas consumption ranges from 128 to 739 therms, with a mean of 413.7 therms; and average monthly gas consumption ranges from 10.7 to 61.9 therms, with a mean of 34.6 therms. Average monthly gas consumption per square foot for SEE homes ranges from .011 to .020 therms, with a mean of .011 therms. *These values suggest that, on average, gas consumption is approximately equivalent in PV and SEE homes, all of which have solar water heating and energy-efficiency measures.*

For both electricity and gas, the variances of total 12-month consumption, average monthly consumption, and average monthly consumption per square foot are statistically equivalent for PV homes and SEE homes. Nonetheless, there is substantial fluctuation in these values for both groups of homes, as indicated by the relatively high coefficients of variation reported in Tables N-5 and N-6 in Appendix N, all of which exceed 30%. In particular, the coefficients of variation for total 12-month electricity consumption, average monthly electricity consumption, and average monthly electricity consumption per square foot all exceed 50% for PV homes. This finding suggests that, for whatever reason, electricity consumption in these homes is fairly inconsistent, even though on average it is relatively low.[20]

Table 81 presents the results of formal statistical comparisons of the means of three electricity consumption measures for both electricity and gas for PV and SEE homes. As suggested above, the PV homes have significantly lower electricity consumption, on average, than the SEE homes, in terms of each of three utility consumption measures: (1) 12-month total electricity consumption, (2) average monthly energy consumption, and (3) average monthly energy consumption per square foot ($t=-2.713$, $p=.008$; $t=-2.711$, $p=.008$; and $t=-2.497$, $p=.015$; respectively). There is no significant difference, on average, in gas consumption between PV and SEE homes with and without solar PV systems with respect to any of the three utility consumption measures ($t=-1.549$, $p=.125$; $t=-1.541$, $p=.127$; and $t=-1.130$, $p=.171$; respectively). These results are consistent with the expectation that solar PV systems reduce the need to extract electricity from the grid, but have no significant impact on gas consumption.

[20]One possible explanation for the variability in electricity use, documented in line graphs in Appendix L, is that, at various times, PV systems were down for maintenance or inverter repair (Marks 2006; Nelson 2006). Further analysis of PV system downtime would be needed to clarify this possibility. Results in Chapter 21 on modeling could also be affected by such occurrences.

Table 81. Comparison of Mean Utility Consumption Measures for PV and SEE Homes*

Utility Consumption Measure	PV Homes (n=37)	SEE Homes (n=44)	t-statistic	p-value
Total 12-month electricity consumption (kWh)	6,468.9	8,314.7	–2.713	*.008*
Average monthly electricity consumption (kWh)	531.7	694.0	–2.711	*.008*
Average monthly electricity consumption per square foot (kWh)	.174	.222	–2.497	*.015*
Total 12-month gas consumption (therms)	366.0	413.7	–1.549	.125
Average monthly gas consumption (therms)	30.7	34.6	–1.541	.127
Average monthly gas consumption per square foot (therms)	.010	.011	–1.130	.171

*Early and outlier homes are omitted

As described elsewhere in this report, two capacities of PV systems (1.2-kW and 2.4-kW) were available to SheaHomes buyers. However, the statistical comparisons shown in Table 81 do not account for this difference. In general, homes with larger PV systems would be expected to exhibit lower mean electricity consumption than homes with smaller systems, which would make the comparison to SEE homes even more distinct. To test this hypothesis, Table 82 shows the results of formal statistical tests that contrast the mean values of the utility consumption measures for the two sizes of PV systems. Indeed, PV homes with 2.4-kW systems have significantly lower mean values (nearly 50% lower) for all three measures of electricity consumption than homes with 1.2-kW systems. There are no significant differences with regard to gas consumption. Appendix R1 contains comparative histograms of electricity consumption for PV homes with 1.2-kW systems and 2.4-kW systems.

Because substantially more homes have 1.2-kW systems (n=31) than 2.4-kW systems (n=6), additional comparisons of utility consumption should be provided between SEE homes and PV homes with the smaller and larger PV systems. Hence, Table 83 provides the results corresponding to those given in Table 81 when the PV home category is restricted to those with 1.2-kW systems. With this restriction, the differences between the mean values of the three electricity consumption measures for PV and SEE homes are not as large. In fact, the difference in mean total 12-month electricity consumption and the difference in mean average monthly electricity consumption are just barely significant; the difference in mean average monthly electricity consumption per square foot is not statistically significant. *Clearly, the larger (2.4-kW) solar PV systems, in combination with the energy-efficiency package, have a substantial impact on the electricity consumption of PV homes compared with SEE homes*.

Table 82. Comparison of Mean Utility Consumption Measures for PV Homes with 1.2-kW and 2.4-kW Systems*

Utility Consumption Measure	With 1.2-kW PV Systems (n=31)	With 2.4-kW PV Systems (n=6)	t-statistic	p-value
Total 12-month electricity consumption (kWh)	6864.2	3809.5	2.254	*.031*
Average monthly electricity consumption (kWh)	572.9	318.4	2.250	*.031*
Average monthly electricity consumption per square foot (kWh)	.189	.100	2.305	*.022*
Total 12-month gas consumption (therms)	366.8	361.7	.082	.935
Average monthly gas consumption (therms)	30.7	30.3	.086	.932
Average monthly gas consumption per square foot (therms)	.010	.010	.359	.722

*Early and outlier homes are omitted

Table 83. Comparison of Mean Utility Consumption Measures for PV Homes with 1.2-kW Systems and SEE Homes*

Utility Consumption Measure	PV Homes with 1.2-kW Systems (n=31)	SEE Homes (n=44)	t-statistic	p-value
Total 12-month electricity consumption (kWh)	6,864.2	8,314.7	–1.950	.055
Average monthly electricity consumption (kWh)	572.9	694.0	–1.949	.055
Average monthly electricity consumption per square foot (kWh)	.189	.222	–1.682	.097
Total 12-month gas consumption (therms)	366.8	413.7	–1.431	.157
Average monthly gas consumption (therms)	30.7	34.6	–1.422	.159
Average monthly gas consumption per square foot (therms)	.010	.011	–1.166	.248

*Early and outlier homes are omitted

Comparing Electricity and Gas Consumption for SEE and Comparison Homes

Since SheaHomes have lower electricity and gas consumption, on average, than comparison homes (in terms of total 12-month consumption, average monthly consumption, and average monthly consumption per square foot) and PV homes have lower electricity consumption (in terms of the same three measures), on average, than SEE homes, it is of further interest to compare utility consumption in comparison homes and SEE homes. Although these two groups of homes could be conceptually similar and might have essentially equivalent utility consumption, in fact, the SEE homes, as ComfortWise homes, meet a higher standard of energy efficiency than do the comparison homes, which were only built to California's Title 24 efficiency standard.[21] In addition, SEE homes have solar water heating systems. Tables N-7 and N-8 in Appendix N present descriptive statistics on total 12-month consumption, average monthly consumption, and average monthly consumption per square foot for electricity and gas for the comparison and SEE homes.

Table 84 presents the results of formal statistical comparisons of the means of the three electricity consumption measures for both electricity and gas for the two groups of households. On average, the mean total 12-month electricity consumption and mean average monthly electricity consumption are higher for comparison homes than for SEE homes, but the difference is not statistically significant (t= –1.364, p=.177; t= –1.355, p=.180; respectively). However, when adjusted for square footage, the difference *is* significant (t= –2.322, p=.025); that is, the mean average monthly electricity consumption per square foot is significantly lower for SEE homes than for comparison homes. This is particularly noteworthy because comparison homes are significantly smaller than SEE homes (the mean square footage for comparison homes is 2,810.2 and the mean square footage for SEE homes 3,115.1, t=4.104, p<.001).

The observed differences in electricity consumption between SEE and comparison homes may be partly because of differences in the numbers of homes involved, since fewer comparison homes are represented than SEE homes. The observed differences may also result from a significantly higher ownership percentage of pools and hot tubs among comparison homes. Of the 44 SEE homes, only 10 (23%) have pools and/or hot tubs, or both, whereas, of the 26 comparison homes, 15 (59%) have pools and hot tubs (χ^2=8.702, p=.003). Because the comparison homes have significantly less square footage, on average, than do the SEE homes, the ownership of pools and hot tubs may play a more important role in electricity consumption than other variables.

---

[21] The energy-efficiency measures included in the ComfortWise high-performance home are described in Chapter 1 (Introduction and Background). The Title 24 building standards may be reviewed at http://www.energy.ca.gov/title24/ (accessed 9/20/05).

Table 84. Comparison of Mean Utility Consumption Measures for Comparison Homes and SEE Homes*

Utility Consumption Measure	Comparison Homes (n=28)	SEE Homes (n=44)	t-statistic	p-value
Total 12-month electricity consumption (kWh)	9,502.8	8,314.7	–1.364	.177
Average monthly electricity consumption (kWh)	792.6	694.0	–1.355	.180
Average monthly electricity consumption per square foot (kWh)	.282	.222	–2.322	*.025*
Total 12-month gas consumption (therms)	497.3	413.7	–2.015	*.050*
Average monthly gas consumption (therms)	41.6	34.6	–2.012	*.050*
Average monthly gas consumption per square foot (therms)	.015	.011	–3.044	*.004*

*Early and outlier homes are omitted.

There are no other readily apparent differences between these two groups of homes. They are not significantly different in terms of household size or composition (χ^2=2.715, p=.099; χ^2=2.253, p=.133, respectively); and there are no significant differences between them in terms of ownership of the other equipment and appliances noted in Table 80.

The difference in the variance of total 12-month electricity consumption for comparison homes and SEE homes is not statistically significant (F=2.301, p=.134). The difference in the variance of average monthly electricity consumption per square foot for these two categories of homes is also not statistically significant (F=2.280, p=.136). However, when average monthly electricity is computed on a square-footage basis, the difference in the variances of the values for the two groups of homes *is* statistically significant (F=5.859, p=.018). This finding suggests that, in addition to the fact that the mean average monthly electricity consumption per square foot is significantly higher for the comparison homes, there is greater fluctuation, or inconsistency, in this quantity for the comparison homes than for the SEE homes.

The results for gas are entirely different. As indicated in Table 84, total 12-month gas consumption, average monthly gas consumption, and average monthly gas consumption per square foot are all significantly lower, on average, for SEE households than for comparison households (t= –2.015, p=.05; t= –2.012, p=.05; and t= –3.044, p=.004; respectively). Three factors may explain much of this difference: (1) absence of solar hot water systems in comparison homes, (2) inclusion of more energy-efficiency features in the SEE high-performance homes, and (3) a higher percentage of ownership of pools and hot tubs in comparison homes. In many cases, gas is used for heating pools and hot tubs. Appendix M contains line graphs showing the total gas consumption by household since occupancy for comparison homes with pools.

The variances of total 12-month gas consumption, average monthly gas consumption, and average monthly gas consumption per square foot are all significantly higher for comparison homes than for SEE homes ($F=4.203$, $p=.044$; $F=4.203$, $p=.044$; and $F=7.576$, $p=.008$, respectively). In addition to the finding that mean gas consumption is significantly higher for comparison homes, this additional finding suggests greater instability in the gas consumption measures as well. Such instability may again be a result of the higher rates of ownership of pools and hot tubs among comparison homes and the seasonal demands for gas that they create.

Confidence Interval Estimates for Selected Utility Consumption Measures

Because we could not obtain utility data for *all* the SheaHomes and comparison homes, the true mean values of the utility consumption measures cannot be known with certainty. The mean values reported in Tables 82–84 are sample-based values that are associated only with homes for which we could obtain data. In the language of statistics, such values are referred to as point estimates. The households for which data were obtained are assumed to be representative of all the SheaHomes and comparison homes; hence, the point estimates contained in Tables 82–84 are considered to be reliable. However, using an interval approach to estimate the true mean values of utility consumption in all the homes is somewhat more desirable, because there is some sampling uncertainty associated with the point estimates.

Consequently, Table 85 presents 95% confidence interval estimates[22] for the mean values of selected utility consumption measures for the PV, SEE, and comparison homes. These intervals account for the sampling error associated with the individual point estimates that arises because utility data could not be obtained for all homes. Each respective interval is expected to cover the true mean value of the utility consumption measure in question with statistical confidence of 95%. For example, based on data from 37 homes, the interval 5,299.7 kWh to 7,428.0 kWh is expected to cover the true mean of total 12-month electricity consumption for PV homes with 95% confidence. The interval endpoints provide low and high cases on which future planning scenarios can be based. Table 86 provides corresponding confidence intervals for only those PV homes with 1.2-kW systems.

---

[22]The general form of the confidence interval is $\overline{x} \pm t \cdot MSE$, where $\overline{x}$ is the mean, t is a multiplier taken from the t-distribution to guarantee statistical coverage of 95%, and *MSE* is the mean square error. The product $t \cdot MSE$ constitutes the margin of error.

For each of these confidence intervals, the *MSE* is computed using only the data associated with the homes in the specific group or category of interest, and the finite population correction factor is not applied. Different confidence intervals could be computed by using a value of the *MSE* derived from the results of ANOVA, which considers the data from all three groups simultaneously. Although such intervals would not be expected to be substantially wider, they could lead to different interpretations.

Because there are different numbers of homes in the three categories, statistical significance should not necessarily be attributed to the overlapping or non-overlapping confidence intervals for a specific utility consumption measure.

Table 85. 95% Confidence Intervals on the Mean Values of Selected Utility Consumption Measures for Three Home Categories*

Utility Consumption Measure	PV Homes (n=37)		SEE Homes (n=44)		Comparison Homes (n=28)	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Total 12-month electricity consumption (kWh)	5,299.74	7,437.99	7,334.63	9,294.69	7,898.02	11,107.55
Average monthly electricity consumption (kWh)	442.46	620.84	612.12	775.91	658.69	926.45
Total 12-month gas consumption (therms)	319.32	412.68	372.25	455.16	423.37	571.27
Average monthly gas consumption (therms)	26.75	34.56	31.15	38.09	35.42	47.75

*Early and outlier homes are omitted

Table 86. 95% Confidence Intervals on the Mean Values of Selected Utility Consumption Measures for Three Groups of Homes*

Utility Consumption Measure	PV Homes (n=31)		SEE Homes (n=44)		Comparison Homes (n=28)	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Total 12-month electricity consumption (kWh)	5,728.13	8,000.32	7,334.63	9,294.69	7,898.02	11,107.55
Average monthly electricity consumption (kWh)	478.12	667.72	612.12	775.91	658.69	926.45
Total 12-month gas consumption (therms)	313.92	419.76	372.25	455.16	423.37	571.27
Average monthly gas consumption (therms)	26.30	35.15	31.15	38.09	35.42	47.75

*Early and outlier homes are omitted

Impact of Energy-Intensive Household Equipment on Utility Consumption

As previously noted, there are significant differences in the percentages of SheaHomes and comparison homes that have energy-intensive equipment, such as pools and hot tubs. Such equipment would be expected to have an impact on utility consumption. Tables S1- through S-6 in Appendix S (Descriptive Statistics on Total and Average Monthly Electricity Consumption and Total and Average Gas Consumption with and without Selected Equipment, by Categories of

Homes, 12-Month Data) contain descriptive statistics on six utility consumption measures for homes with various combinations of energy-intensive equipment within the three categories of homes (separate descriptive statistics are also included for PV homes having 1.2-kW systems). Figures 16–18 and Figures 19–21 graphically depict this same information. Within each of the three home categories, there are notable differences in the numbers of homes with specific combinations of equipment. In fact, the numbers of homes for several of the equipment combinations are quite small (indeed, within all three home categories some of the equipment combinations are not represented at all); and for this reason, care must be taken when extrapolating the statistics contained in these tables or making percentage comparisons. Nonetheless, the information can be used to establish general trends concerning the incremental impacts on utility consumption of adding energy-intensive equipment to homes. Such impacts are different depending on the home category. Appendix R2 contains comparative histograms of average monthly electricity and gas consumption for homes with and without pools or hot tubs.

For example, one of the most notable observations is the impact of pools and hot tubs (alone, in combination with each other, or in combination with other equipment) on electricity consumption in comparison homes. For these homes, total 12-month electricity consumption (kWh), average monthly electricity consumption (kWh), and average monthly electricity consumption per square foot are all substantially higher than for corresponding homes without this equipment.[23] Higher electricity consumption is also associated with pools and hot tubs in PV homes and SEE homes (electricity is used for pumps), but the increase is not so great; and particularly in the case of PV homes, some evidence suggests that the increase is no larger than for other energy-intensive equipment, such as extra refrigerators and standalone freezers. Interestingly, these same combinations of energy-intensive equipment are also associated with increased gas consumption.

Base-Case Homes

The most important information contained in Tables S-1 through S-6 in Appendix S and Figures 16–18 and Figures 19–21 may be the statistics about utility consumption for homes with no energy-intensive equipment. In fact, for all home categories, those without any energy-intensive equipment constitute the largest subcategory in terms of number of homes. These homes could be considered base-case homes in the sense that the amounts of electricity and gas consumption reported for them are not confounded by energy-intensive equipment.[24] Although there are other factors to consider (e.g., number of occupants), these particular homes provide the most direct comparison of utility consumption between PV, SEE, and comparison homes.

---

[23]No information is available on the sizes and configurations of pools and hot tubs in these homes, which may also affect utility consumption. For purposes of this discussion, all pools are assumed to be equivalent and all hot tubs are assumed to be equivalent.

[24] Base-case homes are defined as homes without pools, hot tubs, standalone freezers, or additional refrigerators. These homes may still have one or more other kinds of energy-intensive equipment.

Figure 16 suggests that base-case comparison homes and base-case SEE homes have roughly the same mean average monthly electricity consumption (7.2% higher for SEE homes); the value for base-case PV homes is considerably lower (separate estimates are presented for base-case PV homes with 1.2-kW systems). Mean average monthly electricity consumption is 77.5% higher in SEE homes than in PV homes (59.9% higher in SEE homes than in PV homes with 1.2-kW systems) and 65.5% higher in comparison homes than in PV homes (49.1% higher in comparison homes than in PV homes with 1.2-kW systems). As indicated by the one-standard-deviation error bars, the variability in average monthly electricity consumption is about the same for all three home categories.

On the other hand, Figure 19 suggests that base-case comparison homes have the highest mean average monthly gas consumption, followed by base-case SEE homes and PV homes, respectively. Mean average monthly gas consumption is 23.1% higher in comparison homes than in SEE homes and 81% higher than in PV homes (83.7% higher than in PV homes with 1.2-kW systems). Furthermore, mean average monthly gas consumption is 47.1% higher in SEE homes than in PV homes (49.2% higher than in PV homes with 1.2-kW systems). The figure also suggests the variability in average monthly gas consumption is highest for base-case comparison homes and lowest for base-case PV homes.

Formal ANOVA applied to these base-case homes indicates that mean average monthly electricity consumption for SEE and comparison homes is not significantly different (589.40 kWh vs 549.59 kWh). The ANOVA results also indicate that base-case PV homes have significantly lower mean average monthly electricity consumption (332.06 kWh) than base-case SEE or comparison homes. However, this is only true when all base-case PV homes are considered together (those with 1.2-kW systems and those with 2.4-kW systems combined). When PV homes are restricted to only those with 1.2-kW systems, the difference in mean average monthly electricity consumption for base-case PV homes and SEE homes is still significantly different (368.61 kWh vs 589.40 kWh), but the difference between base-case PV homes and base-case comparison homes is not (368.61 kWh vs 549.59 kWh) ($p=.073$). This finding seems counterintuitive, but the number of homes is small. As noted above, the mean average monthly electricity consumption for base-case SEE homes is about 7.2% higher than for base-case comparison homes. Apart from sampling variation and disparities in the numbers of homes involved, the reasons for the higher mean average monthly electricity consumption in base-case SEE homes is not completely understood.

All these same results are obtained when ANOVA is applied to electricity consumption computed on a square-footage basis, except that mean average monthly electricity consumption for base-case PV homes (.115 kWh/ft^2; .128 kWh per square foot for PV homes with 1.2-kW systems) is significantly lower than mean average monthly electricity for base-case SEE (.190 kWh/ft^2) and comparison homes (.214 kWh/ft^2), whether or not all PV homes or only those with 1.2-kW systems are considered. Adjusting for home size removes any ambiguity in the comparison of base-case PV homes to base-case homes within the other categories.

Similarly, formal ANOVA applied to base-case homes indicates that mean average monthly gas consumption for SEE and comparison homes is not significantly different (31.970 therms vs

39.362 therms). The ANOVA results also indicate that base-case PV homes have significantly lower mean average monthly gas consumption (21.741 therms; 21.428 therms for PV homes with 1.2-kW systems) than base-case SEE or comparison homes. This is true regardless of whether all base-case PV homes are considered together (both those with 1.2-kW systems and those with 2.4-kW systems combined) or if only those with 1.2-kW systems are considered. All these same results are obtained when ANOVA is applied to gas consumption computed on a square-footage basis (.0075 therms/ft^2 for PV homes, .0074 therms/ft^2 for PV homes with 1.2-kW systems, .0105 therms/ft^2 for SEE homes, and .0154 therms/ft^2 for comparison homes), except that mean average monthly gas consumption for base-case SEE homes is significantly lower than mean average monthly gas consumption for base-case comparison homes. Again, adjusting for home size clarifies the distinction between base-case SEE and comparison homes illustrated in Figure 19.

Based on χ^2 analysis, there is no significant difference among the three categories (PV, SEE, comparison) of base-case homes with respect to any of the demographic variables, such as household size and household composition. This adds credence to the reliability of the findings noted above because utility consumption is not confounded by differences attributable to these variables. Interestingly, while adjusting for home size in the computation of average monthly electricity consumption and average monthly gas consumption appears to clarify the relationship among the three home types somewhat, the size of base-case homes (in terms of square footage) in and of itself is not highly correlated with total or average utility consumption as illustrated in Table 87.[25]

Table 87. Correlation* between Home Size (Square Footage) and Four Utility Consumption Measures for Base-Case PV, SEE, and Comparison Homes

Utility Consumption Measure	PV Homes (n=13)	PV Homes with 1.2-kW Systems (n=11)	SEE Homes (n=19)	Comparison Homes (n=7)
Total 12-month electricity consumption (kWh)	.14	−.01	.45	−.15
Average monthly electricity consumption (kWh)	.14	−.01	.45	−.15
Total 12-month gas consumption (therms)	.23	.08	−.11	−.18
Average monthly gas consumption (therms)	.23	.08	−.11	−.18

*Pearson product moment correlation.

[25]Some of the correlations in Table 87 are negative, suggesting that, as home size (square footage) increases, utility consumption decreases. This somewhat counterintuitive result is largely attributable to the small numbers of homes involved.

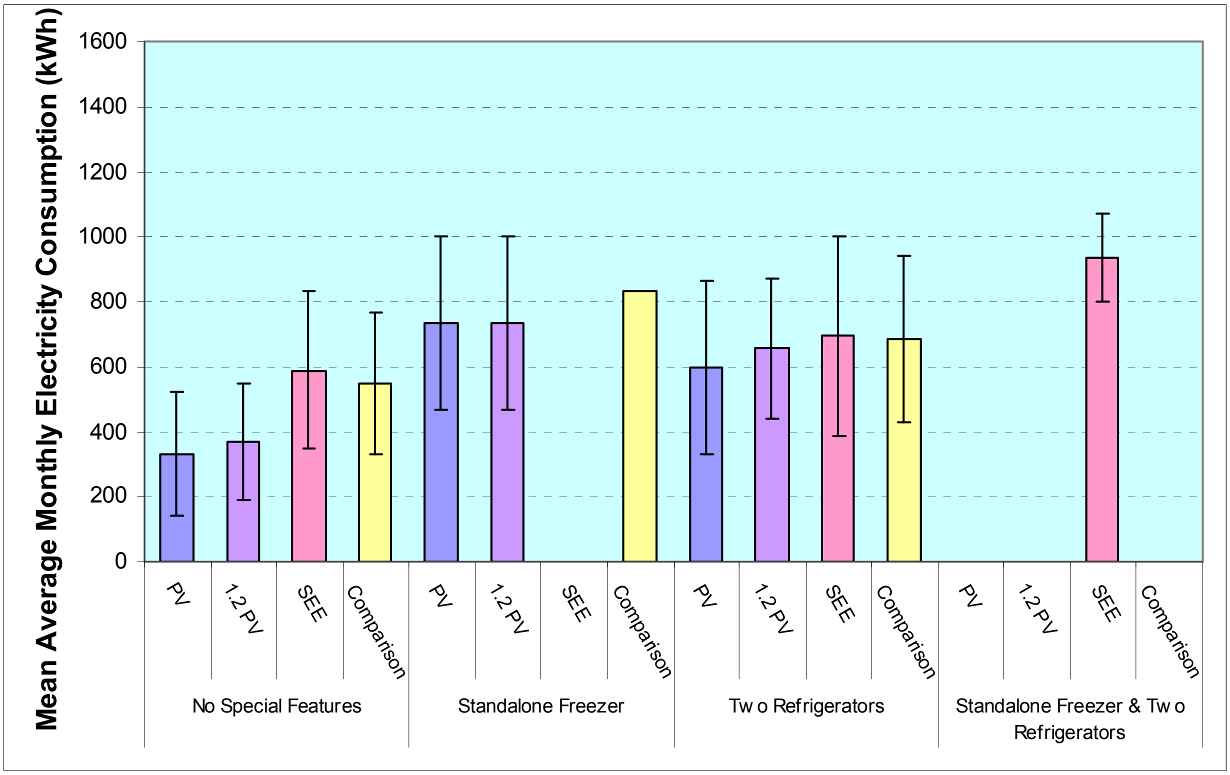


Figure 16. Comparison of Mean Average Electricity Consumption for Four Categories of Homes: No Energy-Intensive Equipment (Base-Case Homes), Standalone Freezer, Two Refrigerators, and Standalone Freezer and Two Refrigerators[26]

[26]Different numbers of homes are associated with each graphed mean. The figure also includes one-standard-deviation error bars. Error bars are absent for means representing only a single home.

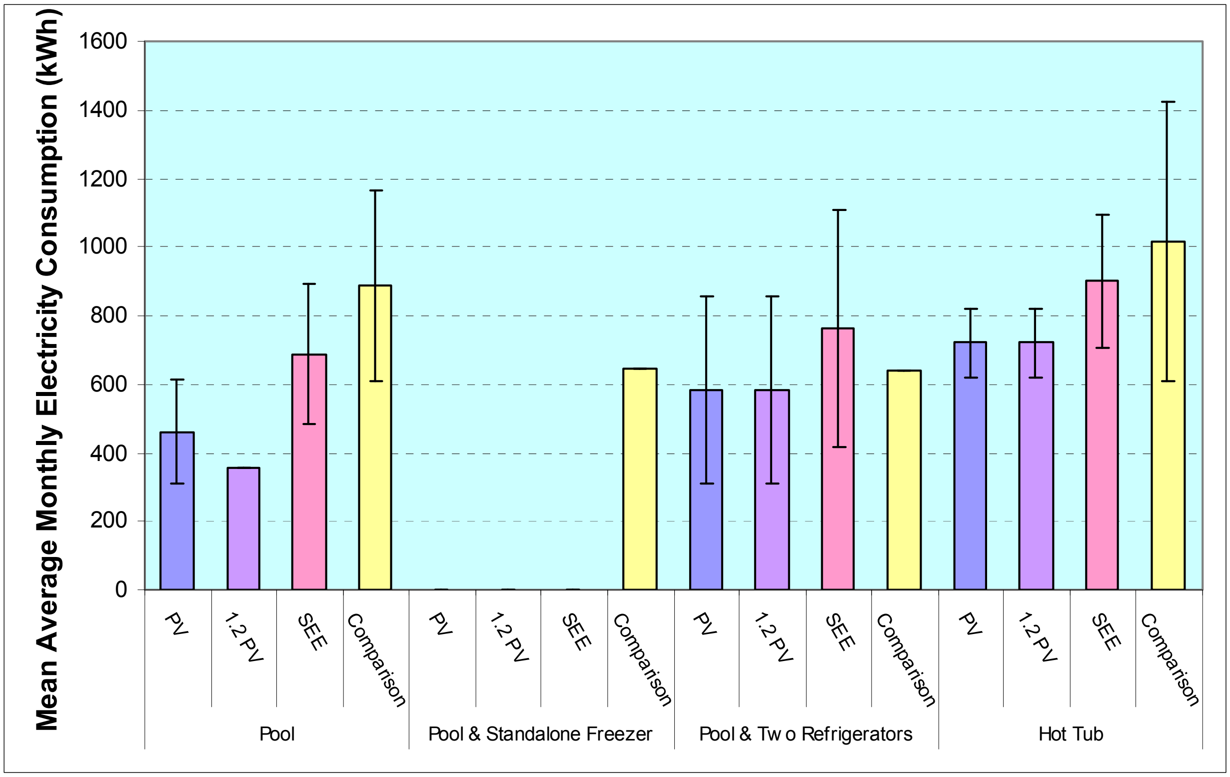


Figure 17. Comparison of Mean Average Electricity Consumption for Four Categories of Homes: Pool, Pool and Standalone Freezer, Pool and Two Refrigerators, and Hot Tub[27]

[27]Different numbers of homes are associated with each graphed mean. The figure also includes one-standard-deviation error bars. Error bars are absent for means representing only a single home.

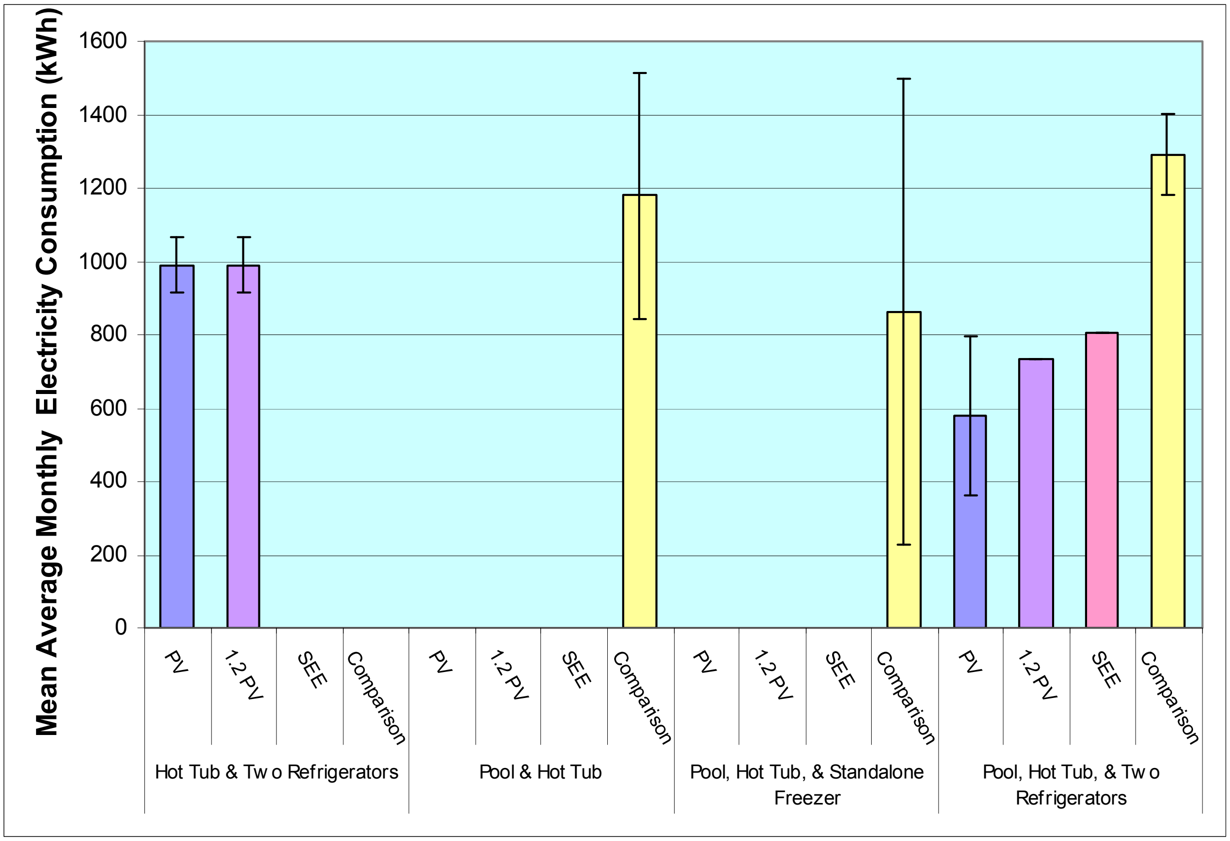


Figure 18. Comparison of Mean Average Electricity Consumption for Four Categories of Homes: Hot Tub and Two Refrigerators; Pool and Hot Tub; Pool, Hot Tub, and Standalone Freezer; and Pool, Hot Tub, and Two Refrigerators[28]

[28]Different numbers of homes are associated with each graphed mean. The figure also includes one-standard-deviation error bars. Error bars are absent for means representing only a single home.

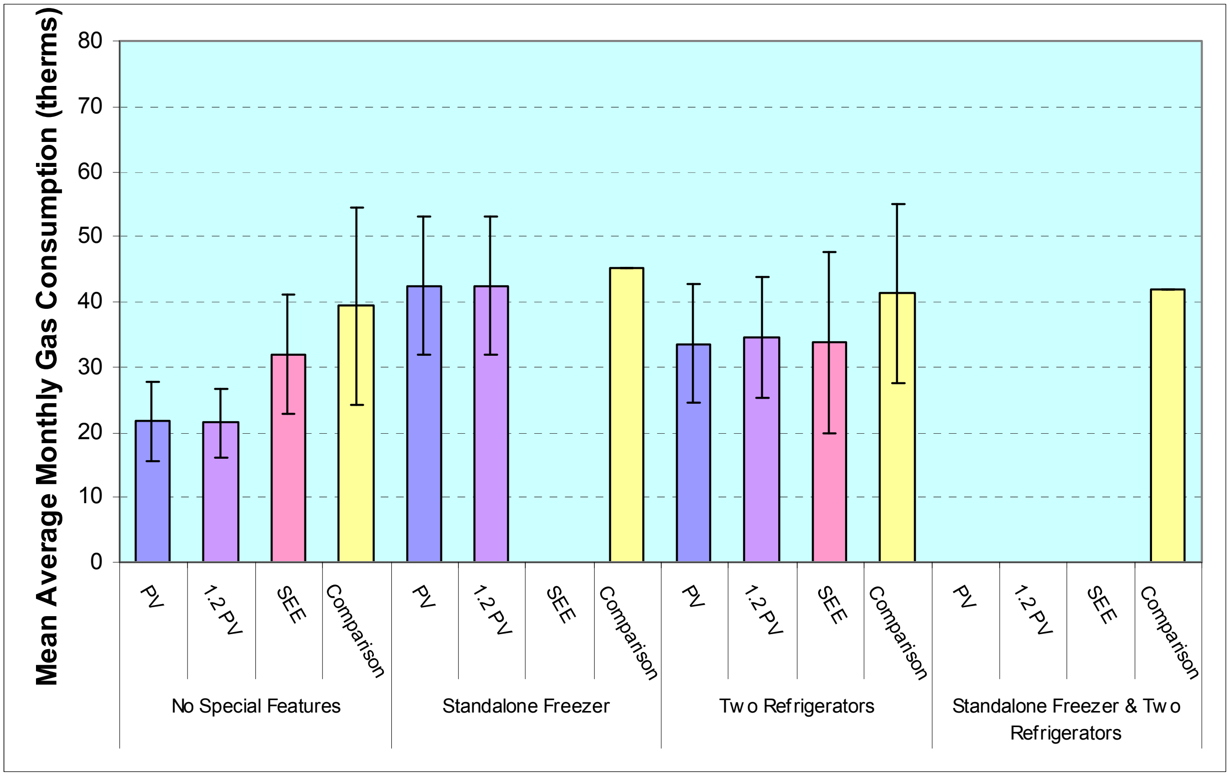


Figure 19. Comparison of Mean Average Gas Consumption (therms) for Four Categories of Homes: No Energy-Intensive Equipment (Base-Case Homes), Standalone Freezer, Two Refrigerators, and Standalone Freezer and Two Refrigerators[29]

[29]Different numbers of homes are associated with each graphed mean. The figure also includes one-standard-deviation error bars. Error bars are absent for means representing only a single home.

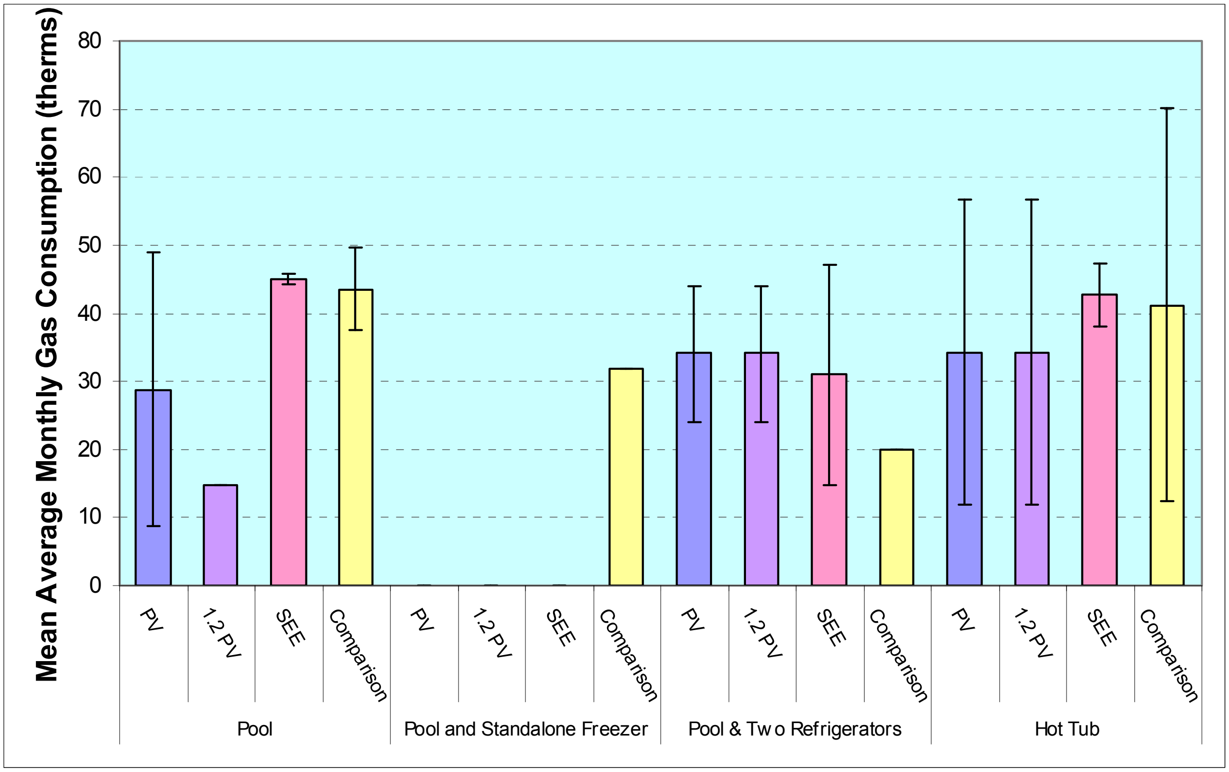


Figure 20. Comparison of Mean Average Gas Consumption (therms) for Four Categories of Homes: Pool, Pool and Standalone Freezer, Pool and Two Refrigerators, and Hot Tub[30]

[30]Different numbers of homes are associated with each graphed mean. The figure also includes one-standard-deviation error bars. Error bars are absent for means representing only a single home.

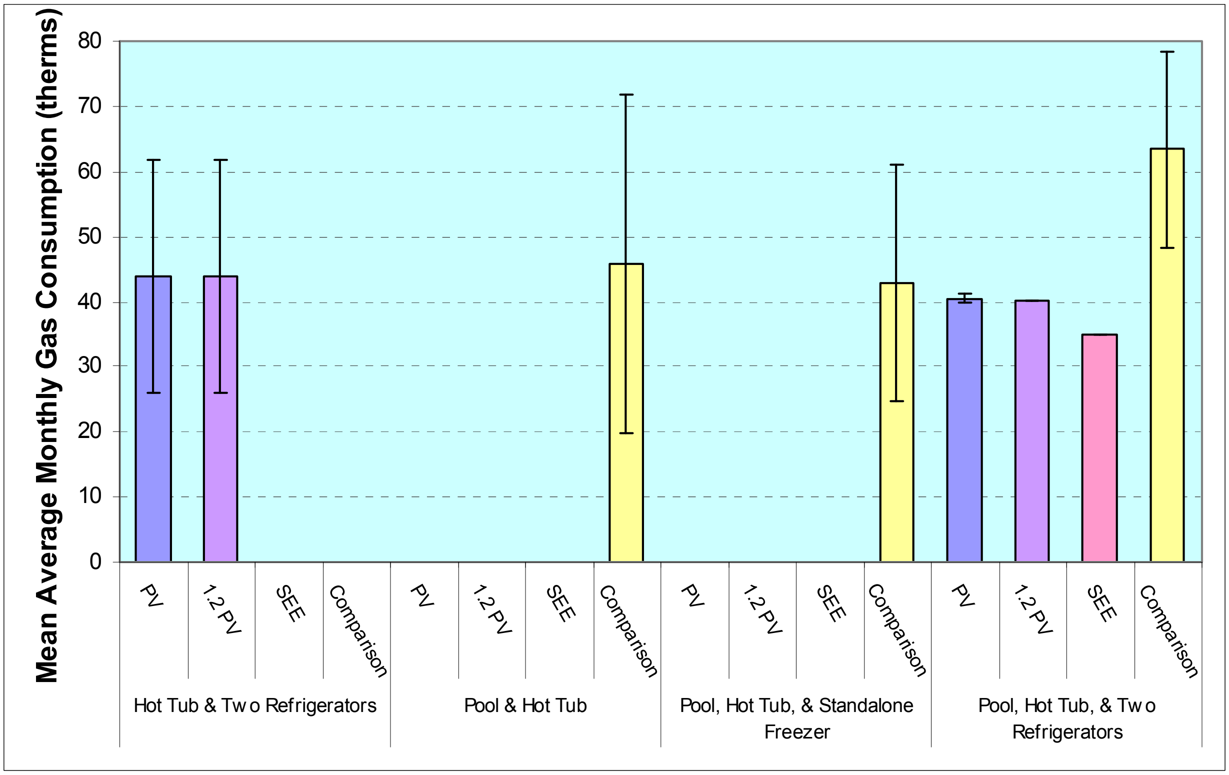


Figure 21. Comparison of Mean Average Gas Consumption (therms) for Four Categories of Homes: Hot Tub and Two Refrigerators; Pool and Hot Tub; Pool, Hot Tub, and Standalone Freezer; and Pool, Hot Tub, and Two Refrigerators[31]

[31]Different numbers of homes are associated with each graphed mean. The figure also includes one-standard-deviation error bars. Error bars are absent for means representing only a single home.

Analysis of Utility Cost

Utility cost data can be analyzed in much the same way as consumption data. Cost is clearly driven by consumption, except that taxes and other miscellaneous charges are added to the utility bill that the consumer pays. Consequently, utility data must be analyzed from two perspectives: (1) the actual cost of the resource consumed (i.e., kWh of electricity and therms of natural gas) and (2) the total utility bill that the consumer pays, which includes all charges above and beyond the cost of the resource.

Descriptive Statistics on Utility Cost

Descriptive statistics on the nine utility cost measures (see p. 3 of this chapter) were computed for various categories of homes, and the values are reported in the tables found in Appendix N. Each table contains the mean, median, minimum value, maximum value, standard deviation, and coefficient of variation of the variable in question. As is the case of electricity and gas consumption, all computations were applied to the 12-month data set after early and outlier homes were omitted.

Utility Cost for All Homes Combined

Table N-9 in Appendix N presents descriptive statistics on total 12-month electricity cost, including and excluding taxes and miscellaneous charges, for the homes encompassed by the study. Descriptive statistics on average monthly electricity cost, including and excluding taxes and miscellaneous charges, are also presented. Figures P-3 and P-4 in Appendix P depict the frequency distributions of average monthly electricity cost, including and excluding taxes and miscellaneous charges, respectively. Similarly, Table N-10 in Appendix N presents descriptive statistics on total 12-month gas cost and average monthly gas cost, including and excluding taxes and miscellaneous charges. Figures P-9 and P-10 in Appendix P depict the frequency distributions of average monthly gas cost, including and excluding taxes and miscellaneous charges, respectively.

Table N-11 in Appendix N presents descriptive statistics on combined utility bill, both on a total 12-month basis and an average monthly basis, with and without taxes and miscellaneous charges. Figures P-15 and P-16 in Appendix P depict the frequency distributions of average monthly combined utility bill, with and without taxes and miscellaneous charges, respectively. Combined utility bill represents the overall utility cost to the consumer of both electricity and gas and may more accurately reflect the energy cost of a home. Combined utility bill also tends to somewhat level out differences in electricity and gas consumption among households, because some households may use large amounts of electricity and very little gas, or conversely, large amounts of gas and more moderate amounts of electricity.

Table N-12 in Appendix N presents corresponding descriptive statistics on average monthly electricity cost, average monthly gas cost, and average monthly combined utility bill, excluding taxes and miscellaneous charges, on a square-footage basis. These values represent the average monthly costs of electricity or gas used by a household adjusted for home size.

Figures P-5 and P-6 in Appendix P show the frequency distributions of average monthly electricity cost, with and without taxes and miscellaneous charges, respectively, on a square-footage basis. Figures P-11 and P-12 in Appendix P depict the corresponding frequency distributions of average monthly gas cost on a square-footage basis. Figures P-17 and P-18 in Appendix P present the respective frequency distributions of average monthly combined utility bill on a square-footage basis.

As indicated in Table N-12, average monthly electricity cost, average monthly gas cost, and average monthly combined utility bill, excluding taxes and miscellaneous charges, for the homes encompassed in this study are quite variable, as indicated by the coefficients of variation, all of which exceed 45%. Visual inspection of the line graphs of month-by-month electricity and gas consumption by individual homes (Appendix L) reveals this variability on a house-by-house basis. In addition, all the frequency histograms are skewed to the right. These two observations suggest that more detailed analysis of the utility cost measures is warranted. However, because average monthly combined utility bill is thought to more accurately reflect overall home energy cost, and because homeowners are more likely to identify with this quantity, all further analysis will be restricted to this single utility cost measure.[32]

Comparing Utility Cost for SheaHomes and Comparison Homes

Table N-15 in Appendix N presents comparative descriptive statistics on average monthly combined utility bill for SheaHomes and comparison homes.[33] Figures Q-15 (a, b) and Q-16 (a, b) in Appendix Q show the distributions of average monthly combined utility bill for these two home categories. For SheaHomes, average monthly combined utility bill, excluding taxes and miscellaneous charges, ranges from $16.59 to $265.08, with a mean of $122.96. When the taxes and miscellaneous charges are added, average monthly combined utility bill ranges from $20.91 to $289.12, with a mean of $134.21. In both cases, the range is quite wide, which is also corroborated by the relatively large values of the standard deviation and coefficient of variation. For comparison homes, average monthly combined utility bill ranges from $63.37 to $288.90, with a mean of $160.25, when taxes and miscellaneous charges are excluded. Including taxes and miscellaneous charges, the range is $69.29 to $307.63, with a mean of $173.57. For the comparison homes, the ranges are also quite wide, and the standard deviations and coefficients of variation are also relatively high. Nonetheless, inspection of the means suggests that average monthly combined utility bill is higher for comparison homes than for SheaHomes (30.3% higher, without considering taxes and miscellaneous charges; 29.3% higher including these additional amounts).

---

[32]Further discussion and interpretation of electricity, gas, and combined utility costs using the 12-month data is presented in the Epilogue to this report.

[33]Table N-15 also contains descriptive statistics on total 12-month combined utility bill, with and without taxes and miscellaneous charges, but these statistics are not discussed further. In addition, Tables N-13 and N-14 present the corresponding descriptive statistics on total 12-month cost and average monthly cost, with and without taxes and miscellaneous charges, for electricity and gas, respectively. These tables are presented for the sake of completeness and are also not discussed here.

A t-test was used to statistically compare the average monthly combined utility bill (with and without taxes and miscellaneous charges) for SheaHomes and comparison homes. The results, given in Table 88, confirm that the difference in mean average monthly combined utility bill for SheaHomes and comparison homes is statistically significant (t= –2.966, p=.004; t= –2.874, p=005; respectively). On a mean basis, SheaHomes have lower average monthly combined utility bills than do comparison homes, regardless of whether taxes and miscellaneous charges are taken into consideration.

Similar results are observed when average combined monthly utility bill is considered on a square-footage adjusted basis. As reported in Table 88 and Table N-16[34] in Appendix N, the mean average combined monthly utility bill per square foot, excluding taxes and miscellaneous charges, for SheaHomes is $0.040 versus $0.057 (a difference of 42.5%) for comparison homes, and this difference is also statistically significant (t= –3.548, p=.001). When taxes and miscellaneous charges are included, the difference in means is also significant (t= –3.464, p=.001). The associated distributions are shown in Figures Q-17 (a, b) and Q18 (a, b) in Appendix Q.

The variance, and hence the standard deviation, of average monthly combined utility bill is not significantly different for SheaHomes and comparison homes (F=3.675, p=.058; and F=3.165, p=.078; respectively). However, the variance in average monthly combined utility bill per square foot is significantly lower for SheaHomes than for comparison homes, with or without taxes and miscellaneous charges (F=8.085, p=.005), which suggests less fluctuation, or higher stability, on this square-footage adjusted basis. On the whole, though, there is considerable variation among households in both communities as indicated by the relatively high coefficients of variation reported in Tables N-15 and N-16 in Appendix N.

As expected, these results track those presented earlier for electricity and gas consumption for SheaHomes and comparison homes. On average, both electricity and gas consumption is lower for SheaHomes than for comparison homes, translating to a lower average monthly utility costs, whether or not taxes and miscellaneous charges are considered. This is also true when an adjustment for home size (square footage) is made (recall that SheaHomes in this data set are significantly larger than comparison homes).

[34]Table N-16 also contains descriptive statistics on average monthly cost for electricity and gas, excluding taxes and miscellaneous charges, which are not discussed here.

Table 88. Comparison of Mean Average Monthly Combined Utility Bill for SheaHomes* and Comparison Homes

Utility Cost Measure	SheaHomes (n=81)	Comparison Homes (n=28)	t-statistic	p-value
Average monthly combined utility bill (excluding taxes and miscellaneous charges)	$122.96	$160.25	–2.874	*.005*
Average monthly combined utility bill per square foot (excluding taxes and miscellaneous charges)	$0.040	$0.057	–3.548	*.001*
Average monthly combined utility bill (including taxes and miscellaneous charges)	$134.21	$173.57	–2.966	*.004*
Average monthly combined utility bill, per square foot (including taxes and miscellaneous charges)	$0.043	$0.062	–3.464	*.001*

*Early and outlier homes are omitted.

Comparing Utility Cost for PV and SEE Homes

Table N-19[35] in Appendix N presents descriptive statistics on average monthly combined utility bill for PV and SEE homes. Table N-20[36] in Appendix N reports descriptive statistics on average monthly combined utility bill on a square-footage basis. The associated distributions are shown in Figures R-15 (a, b) and R-16 (a, b) in Appendix R.

For the PV homes, average monthly combined utility bill, excluding taxes and miscellaneous charges, ranges from $16.59 to $219.24, with a mean of $106.53. On a square-footage basis, the range is $0.006 to $0.079, with a mean of $0.035. When taxes and miscellaneous charges are included, average monthly combined utility bill for these homes ranges from $20.91 to $238.49, with a mean of $166.25. In both cases, the range is quite wide, which is again corroborated by the relatively large values of the standard deviation and coefficient of variation.

For SEE homes, average monthly combined utility bill, excluding taxes and miscellaneous charges, ranges from $56.23 to $265.08, with a mean of $136.77. On a square-footage basis, the range is $0.018 to $0.093, with a mean of $0.044. When taxes and miscellaneous charges are factored in, average monthly combined utility bill for these homes ranges from $61.32 to $289.12, with a mean of $149.32. For the PV homes, the ranges are also quite wide (both with and without taxes and miscellaneous charges), and the standard deviations and coefficients of variation are also relatively high. Despite the high variation, inspection of the means suggests that average

[35]Table N-19 also contains descriptive statistics on total 12-month combined utility bill, with and without taxes and miscellaneous charges, which are not discussed here. In addition, Tables N-17 and N-18 present the corresponding descriptive statistics on total 12-month cost and average monthly cost, with and without taxes and miscellaneous charges, for electricity and gas, respectively. Again, these tables are presented for the sake of completeness and are not discussed here.

[36]Table N-20 also contains descriptive statistics on average monthly cost for electricity and gas, excluding taxes and miscellaneous charges, which are not discussed here.

monthly combined utility bill is higher, on average for SEE homes than for PV homes (28.1% higher, without considering taxes and miscellaneous charges; 28.4% higher including these additional amounts).

Table 89 presents the results of formal statistical comparisons of average monthly combined utility bill for PV homes and SEE homes. As suggested above, on a mean comparison basis, the PV homes have significantly lower average monthly combined utility bills than SEE homes, both with and without taxes and miscellaneous charges (t= –2.652, p=.01; t= –2.635, p=.01; respectively). Similarly, on a square-footage basis, the PV homes have a significantly lower mean average combined monthly utility bill than the SEE homes, both with and without taxes and miscellaneous charges (t= –2.458, p=.016; t= –2.444, p=.017; respectively).

Table 89. Comparison of Mean Average Monthly Combined Utility Bill for PV Homes and SEE Homes*

Utility Cost Measure	PV Homes (n=37)	SEE Homes (n=44)	t-statistic	p-value
Average monthly combined utility bill (excluding taxes and miscellaneous charges)	$106.53	$136.77	–2.635	*.010*
Average monthly combined utility bill, per square foot (excluding taxes and miscellaneous charges)	$0.035	$.044	–2.444	*.017*
Average monthly combined utility bill (including taxes and miscellaneous charges)	$116.25	$149.32	–2.652	*.010*
Average monthly combined utility bill, per square foot (including taxes and miscellaneous charges)	$.038	$.048	–2.458	*.016*

*Early and outlier homes are omitted.

Table 81 shows that, for all three utility consumption measures, PV homes exhibit significantly lower electricity consumption, on average, than do SEE homes; there is no significant difference, on average, for three utility consumption measures with regard to gas. As expected, the significantly higher average monthly combined utility bills for SEE homes closely track the average monthly electricity consumption.

As suggested above, average combined monthly utility bill is still quite variable, whether or not taxes and miscellaneous charges are taken into account, and whether an adjustment on the basis of square footage is considered. When taxes and miscellaneous charges are excluded, the variance, and hence the standard deviation, of average monthly combined utility bill is not significantly different for PV homes and SEE homes (F=0.121, p=.729). Considering these additional amounts, the variance of average monthly combined utility bill is also not significantly different (F=0.109, p=.742) for the two home categories. Similarly, on a square-footage basis, the variance of average monthly combined utility bill is not significantly different for the two home categories, with or without taxes and miscellaneous charges (F=.001, p=.975; F≈0, p=.985; respectively).

On the whole, there is considerable variation in average monthly combined utility bill among all SheaHomes as indicated by the relatively high coefficients of variation reported in Tables N-19 and N-20 in Appendix N. Such instability in utility cost is driven, in turn, by the relatively high variation in gas and electricity consumption among all these homes.

Table 90 contains the results of statistical comparisons of mean average monthly combined utility bill for PV homes with 1.2-kW systems and those with 2.4-kW systems (also see the related histograms of utility cost in Appendix R1). The mean values for the four utility cost measures are lower for PV homes with 2.4-kW systems than for those with 1.2-kW systems and mimic the results shown for utility consumption in Table 82. For example, average monthly combined utility bill, excluding taxes and miscellaneous charges, is 35.2% lower for PV homes with 2.4-kW systems than for homes with 1.2-kW systems. However, these differences are not statistically significant, except almost so when average monthly combined utility bill is computed on a square-footage basis. The fact that the differences are not statistically significant may be attributable to two different situations: (1) as shown in Table 82, the contribution of the cost of gas to the combined utility bill is not significantly different in these homes and (2) the number of PV homes with 2.4-kW systems is much smaller than the number of PV homes with 1.2-kW systems. Also note that the mean square footage of the PV homes with 1.2-kW systems and 2.4-kW systems is not significantly different, a result that also undoubtedly plays a role.

Table 90. Comparison of Mean Average Monthly Combined Utility Bill for PV Homes with 1.2-kW and 2.4-kW PV Systems*

Utility Cost Measure	PV Homes with 1.2-kW Systems (n=31)	PV Homes with 2.4-kW Systems (n=6)	t-statistic	p-value
Average monthly combined utility bill (excluding taxes and miscellaneous charges)	$112.98	$73.23	1.828	.076
Average monthly combined utility bill, per square foot (excluding taxes and miscellaneous charges)	$0.037	$.023	2.020	.051
Average monthly combined utility bill (including taxes and miscellaneous charges)	$123.19	$80.36	1.813	.078
Average monthly combined utility bill, per square foot (including taxes and miscellaneous charges)	$0.041	$.025	2.002	.053

*Early and outlier homes are omitted

Since there are substantially more homes with 1.2-kW systems than with 2.4-kW systems, it is important to compare utility cost for PV and SEE homes when the PV homes with 2.4-kW systems are omitted. Table 91 provides the results that correspond to those given in Table 89 when the PV home category is restricted in this way. The mean average monthly combined utility bill for PV homes with 1.2-kW systems is significantly lower (but just barely so) than for SEE homes, whether or not taxes and miscellaneous charges are included. The difference in the means is not statistically different, however, when average monthly combined utility bill is computed on a square-footage basis, which again suggests that home size is not a major contributing factor.

With reference to the results shown in Table 89, the 2.4-kW systems clearly affect the comparison of utility cost between PV homes and SEE homes. *Although the difference in mean average monthly combined utility bill is significantly lower for PV homes than for SEE homes, the difference is not nearly so substantial when the PV homes with 2.4-kW systems are excluded from consideration.*

Table 91. Comparison of Mean Average Monthly Combined Utility Bill for PV Homes with 1.2-kW PV Systems and SEE Homes*

Utility Cost Measure	PV Homes with 1.2-kW Systems (n=31)	SEE Homes (n=44)	t-statistic	p-value
Average monthly combined utility bill (excluding taxes and miscellaneous charges)	$112.98	$136.77	–1.973	.052
Average monthly combined utility bill, per square foot (excluding taxes and miscellaneous charges)	$.037	$.044	–1.729	.088
Average monthly combined utility bill (including taxes and miscellaneous charges)	$123.19	$149.32	–1.991	*.050*
Average monthly combined utility bill, per square foot (including taxes and miscellaneous charges)	$.041	$.048	–1.745	.085

*Early and outlier homes are omitted.

Comparing Utility Cost for Comparison and SEE Homes

Table 92 presents the results of formal statistical comparisons of mean average monthly combined utility bill, with and without taxes and miscellaneous charges, for comparison and SEE households. Figures Q-15b and Q-16b in Appendix Q and Figures R-15b and R16b in Appendix R show the corresponding distributions. *There is no significant difference in mean average monthly combined utility bill between comparison and SEE homes, with or without taxes and miscellaneous charges* (t= –1.564, p=.122; t= –1.650, p=.103; respectively). The mean costs are higher for comparison homes, but not by statistically significant amounts (16.2% and 17.2%, with and without taxes and miscellaneous charges, respectively). However, when adjusted for square footage, the respective differences are significant (t= –2.516, p=.016; t= –2.593, p=.013; respectively). The mean average monthly combined utility bill per square foot for comparison homes is significantly higher than for SEE homes (29.2% and 29.5% higher, with and without taxes and miscellaneous charges, respectively). As noted previously, the SEE homes in this data set are significantly larger than the comparison homes.

On average, electricity consumption is not significantly different for comparison and SEE homes, except on a square-footage basis (SheaHomes have significantly lower electricity consumption, on average, on a square-footage basis). Also, on average, SEE homes have significantly lower gas consumption on all three utility consumption measures. Consequently, these findings about utility cost closely track those reported earlier for electricity and gas consumption, particularly on a square-footage basis.

Table 92. Comparison of Mean Average Monthly Combined Utility Bill for Comparison and SEE Homes*

Utility Cost Measure	Comparison Homes (n=28)	SEE Homes (n=44)	t-statistic	p-value
Average monthly combined utility bill (excluding taxes and miscellaneous charges)	$160.25	$136.77	–1.650	.103
Average monthly combined utility bill, per square foot (excluding taxes and miscellaneous charges)	$.057	$.044	–2.593	*.013*
Average monthly combined utility bill, (including taxes and miscellaneous charges)	$173.57	$149.32	–1.564	.122
Average monthly combined utility bill, per square foot (including taxes and miscellaneous charges)	$.062	$.048	–2.516	*.016*

*Early and outlier homes are omitted

The difference in the variance of average monthly combined utility bill for comparison and SEE homes is statistically significant only when square footage is taken into account. On a square-footage basis, the variance and, hence, the standard deviation of average monthly combined utility bill is significantly higher for comparison homes than for SEE homes, with and without taxes and miscellaneous charges (F=7.527, p=.008; F=6.828, p=.011; respectively). This finding suggests that there is greater fluctuation, or inconsistency, in utility cost for comparison homes than for SEE homes.

Confidence Interval Estimates for Selected Utility Cost Measures

Table 93 presents 95% confidence interval estimates[37] for the mean values of selected utility cost measures for the PV, SEE, and comparison homes. These intervals account for the sampling error associated with the individual point estimates of utility cost that arises because we could not obtain data from all the households. Each respective interval is expected to cover the true mean value of the utility cost measure in question with statistical confidence of 95%. For example, based on data from 37 homes, the interval $98.03 to $134.46 is expected to cover the true mean of average monthly combined utility bill (including taxes and miscellaneous charges) for all PV homes with 95% confidence. The interval endpoints provide low and high cases on which future planning scenarios can be based. Table 94 provides the corresponding comparison of 95% confidence intervals when PV homes are restricted to those with 1.2-kW systems.

[37] Again, each confidence interval is constructed with a margin of error that is derived from the data associated with the specific category of homes in question. Different confidence intervals could be constructed by using a margin of error obtained via ANOVA, which considers the data from all three categories of homes simultaneously.

Table 93. 95% Confidence Intervals on the Mean Values of Selected Utility Cost Measures for PV, SEE, and Comparison Homes*

Utility Consumption Measure	PV Homes (n=37)		SEE Homes (n=44)		Comparison Homes (n=28)	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Average monthly electricity cost (excluding taxes and miscellaneous charges)	$62.83	$91.17	$89.29	$117.13	$97.07	$142.27
Average monthly electricity cost per square foot (excluding taxes and miscellaneous charges)	$.021	$.030	$.029	$.037	$.035	$.050
Average monthly combined utility bill (excluding taxes and miscellaneous charges)	$89.76	$123.31	$120.85	$152.69	$133.91	$186.58
Average monthly combined utility bill per square foot (excluding taxes and miscellaneous charges)	$.029	$.040	$.039	$.049	$.048	$.066
Average monthly electricity cost (including taxes and miscellaneous charges)	$69.31	$100.23	$98.37	$128.75	$105.54	$155.15
Average monthly electricity cost per square foot (including taxes and miscellaneous charges)	$.023	$.032	$.032	$.041	$.038	$.055
Average monthly combined utility bill (including taxes and miscellaneous charges)	$98.03	$134.46	$132.00	$166.65	$144.83	$202.30
Average monthly combined utility bill per square foot (including taxes and miscellaneous charges)	$.032	$.044	$.042	$.053	$.052	$.072

*Early and outlier homes are omitted.

Table 94. 95% Confidence Intervals on the Mean Values of Selected Utility Cost Measures for PV (with 1.2-kW Systems), SEE, and Comparison Homes*

Utility Consumption Measure	PV Homes with 1.2-kW PV Systems (n=31)		SEE Homes (n=44)		Comparison Homes (n=28)	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Average monthly electricity cost (excluding taxes and miscellaneous charges)	$68.02	$98.66	$89.29	$117.13	$97.07	$142.27
Average monthly electricity cost per square foot (excluding taxes and miscellaneous charges)	$.022	$.032	$.029	$.037	$.035	$.050
Average monthly combined utility bill (excluding taxes and miscellaneous charges)	$89.76	$123.31	$120.85	$152.69	$133.91	$186.58
Average monthly combined utility bill per square foot (excluding taxes and miscellaneous charges)	$.029	$.040	$.039	$.049	$.048	$.066
Average monthly electricity cost (including taxes and miscellaneous charges)	$74.83	$108.38	$98.37	$128.75	$105.54	$155.15
Average monthly electricity cost per square foot (including taxes and miscellaneous charges)	$.025	$.036	$.032	$.041	$.038	$.055
Average monthly combined utility bill (including taxes and miscellaneous charges)	$98.03	$134.46	$132.00	$166.65	$144.83	$202.30
Average monthly combined utility bill per square foot (including taxes and miscellaneous charges)	$.032	$.044	$.042	$.053	$.052	$.072

*Early and outlier homes are omitted.

Impact of Energy-Intensive Equipment on Utility Cost

As in the case of utility consumption, various combinations of energy-intensive equipment in homes would be expected to have an impact on utility cost. Tables U-1 through U-12 in Appendix U (Descriptive Statistics on Average Monthly Electricity Cost, Average Monthly Gas Cost, and Average Monthly Utility Bills with and without Selected Equipment, by Categories of Homes, 12-Month Data) contain descriptive statistics on several utility cost measures for homes with various combinations of energy-intensive equipment within the three categories of homes (separate descriptive statistics are also included for PV homes with 1.2-kW systems). Figures 22–24 and Figures 25–27 graphically depict this same information for one utility cost measure, mean average monthly combined utility bill, with and without taxes and miscellaneous charges, respectively. Again, within each home category, there are notable differences in the numbers of homes having specific combinations of equipment and, for some of the equipment combinations, few or no homes are represented. As previously noted, care must be taken when extrapolating the statistics contained in these tables or making percentage comparisons. However, this information might be used to establish trends concerning the incremental impacts on utility cost of adding energy-intensive equipment to homes. Such impacts vary depending on the home category.

Pools and hot tubs (alone, in combination with each other, or in combination with other equipment) have a notable impact on utility cost, whether or not taxes and miscellaneous charges are considered.[38] This is particularly true for comparison homes. For these homes, the mean average combined utility bill, with or without taxes and miscellaneous charges, is substantially higher than for corresponding homes without this equipment. Higher utility cost is also associated with pools and hot tubs in SEE homes and, to a lesser extent, in PV homes. In PV homes, standalone freezers lead to about the same increase in mean average monthly combined utility bill (with or without taxes and miscellaneous charges) as hot tubs, whereas the impact of two refrigerators is not as great. The combined effect of multiple items is difficult to resolve because of the small numbers of households involved.

Base-Case Homes

The most important information contained in Tables S-1 to S-12 in Appendix S, Figures 22–24, and Figures 25–27 may be the statistics about utility cost for homes with no energy-intensive equipment. These are, again, referred to as base-case homes because the utility costs reported for them are not confounded by energy-intensive equipment. As previously noted, there are other factors to consider (e.g., number of occupants); but these particular homes provide the most direct comparison of utility cost between PV, SEE, and comparison homes.

Figures 22 and 25 suggest that base-case comparison homes and base-case SEE homes have about the same mean average monthly combined utility bill, but the amount for base-case PV homes is considerably lower (again, separate estimates are presented for base-case PV homes with 1.2-kW systems). Including taxes and miscellaneous charges, mean average monthly

[38]However, information obtained in the qualitative phase of this study suggests that, due to cost, some homeowners do not heat their pools/hot tubs except on special occasions or unless they are having guests.

combined utility bill is 76.3% higher in base-case SEE homes than in base-case PV homes (64.7% higher in base-case SEE homes than in base-case PV homes with 1.2-kW systems) and 76.5% higher in comparison homes than in base-case PV homes (64.9% higher in comparison homes than in base-case PV homes with 1.2-kW systems). Excluding taxes and miscellaneous charges, the results are similar: the mean average monthly combined utility bill is 76.3% higher in base-case SEE homes than in base-case PV homes (64.3% higher in base-case SEE homes than in base-case PV homes with 1.2-kW systems) and 77.5% higher in comparison homes than in base-case PV homes (65.4% higher in comparison homes than in PV homes with 1.2-kW systems). As indicated by the one-standard-deviation error bars, the variability in mean average monthly combined utility bill is also somewhat lower for base-case PV homes (and 1.2-kW PV homes) than for base-case SEE and base-case comparison homes.

Formal ANOVA applied to these base-case homes confirms that PV homes have significantly lower mean average combined monthly utility bills than SEE or comparison homes. This is true when all PV homes or only those with 1.2-kW systems are considered, whether or not taxes and miscellaneous charges are included (excluding taxes and miscellaneous charges, \$66.20 for PV homes, \$71.04 for PV homes with 1.2-kW systems, \$116.72 for SEE homes, and \$117.52 for comparison homes; including taxes and miscellaneous charges, \$72.46 for PV homes, \$77.56 for PV homes with 1.2-kW systems, \$127.75 for SEE homes, and \$127.92 for comparison homes). Furthermore, the ANOVA results indicate that the *mean average combined monthly utility bills are essentially equivalent for SEE and comparison homes.* Finally, these same results are obtained when ANOVA is applied to average combined monthly utility bill computed on a square-footage basis, with or without taxes and miscellaneous charges (excluding taxes and miscellaneous charges, \$0.023/ft^2 for PV homes, \$0.037 ft^2 for PV homes with 1.2-kW systems, \$0.038 ft^2 for SEE homes, and \$0.046 ft^2 for comparison homes; including taxes and miscellaneous charges, \$0.025 ft^2 for PV homes, \$0.041 ft^2 for PV homes with 1.2-kW systems, \$0.041 ft^2 for SEE homes, and \$0.050 ft^2 for comparison homes).

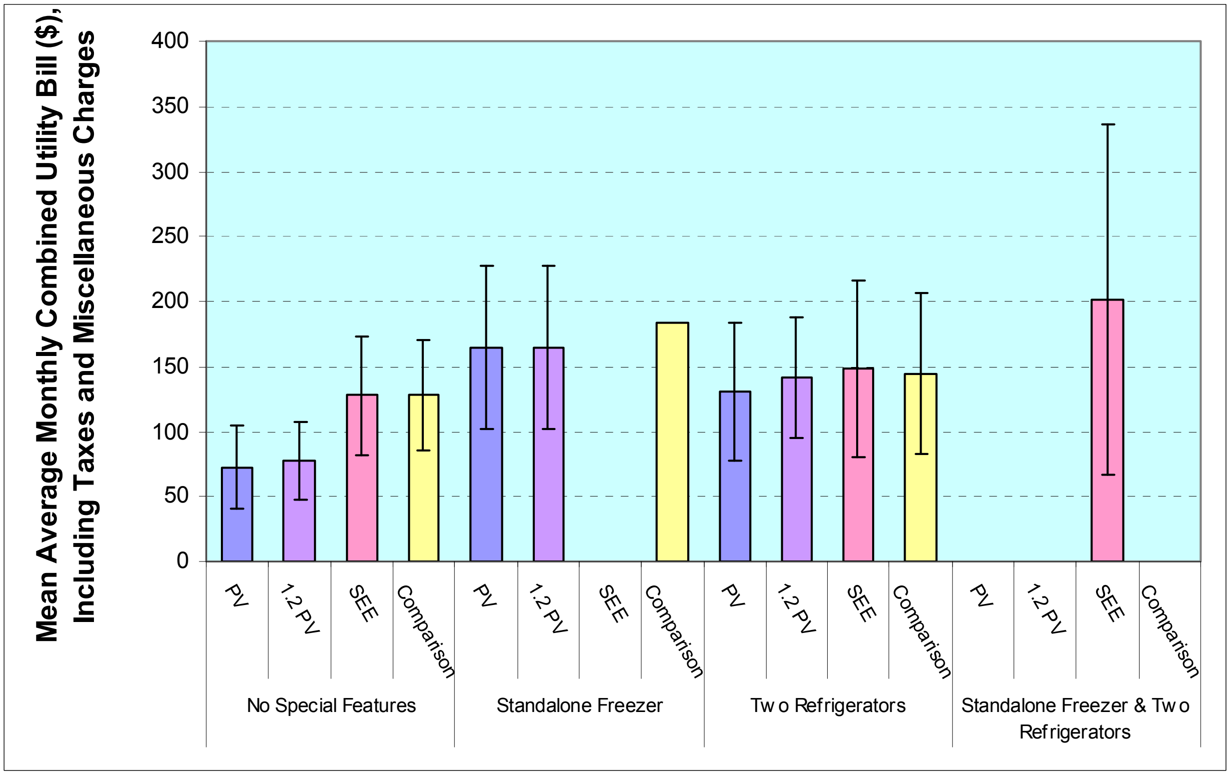


Figure 22. Comparison of Mean Average Monthly Combined Utility Bill, Including Taxes and Miscellaneous Charges, for Four Categories of Homes: No Energy-Intensive Equipment, Standalone Freezer, Two Refrigerators, and Standalone Freezer, and Two Refrigerators[39]

[39]Different numbers of homes are associated with each graphed mean. The figure also includes one-standard-deviation error bars. Error bars are absent for means representing only a single home.

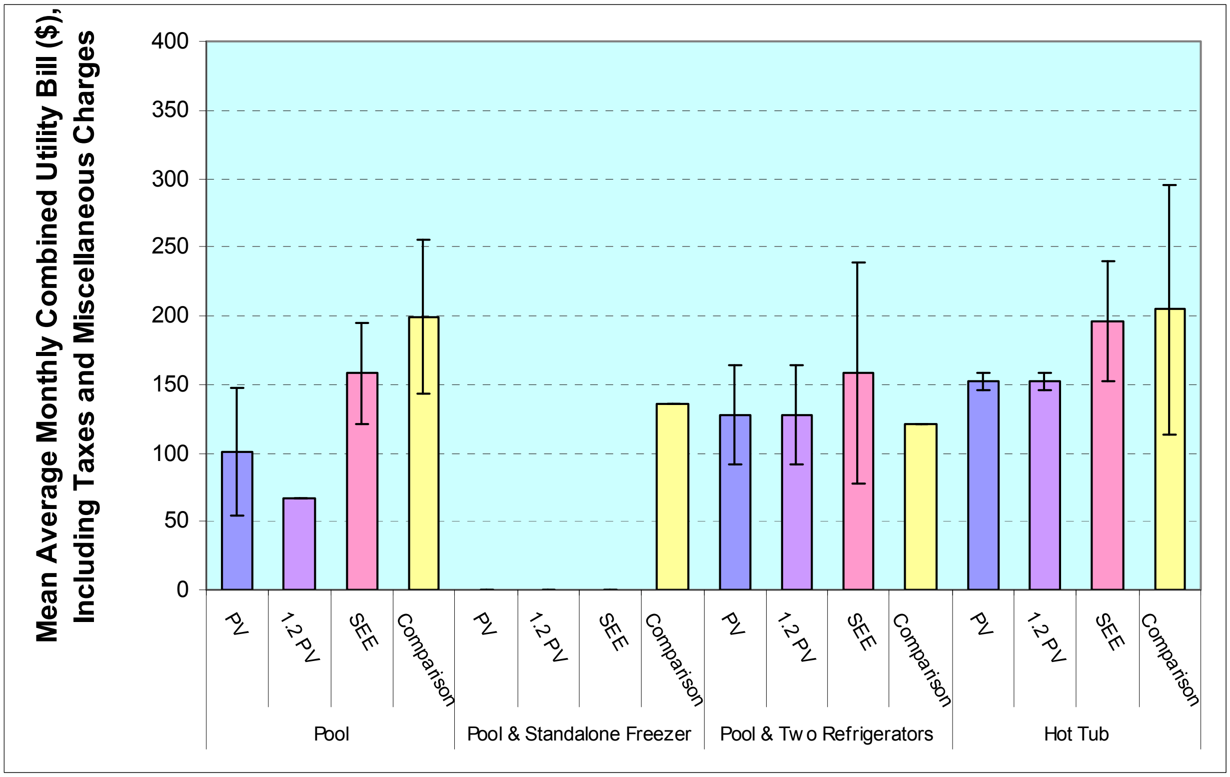


Figure 23. Comparison of Mean Average Monthly Combined Utility Bill, Including Taxes and Miscellaneous Charges, for Four Categories of Homes: Pool, Pool and Standalone Freezer, Pool and Two Refrigerators, and Hot Tub[40]

[40]Different numbers of homes are associated with each graphed mean. The figure also includes one-standard-deviation error bars. Error bars are absent for means representing only a single home.

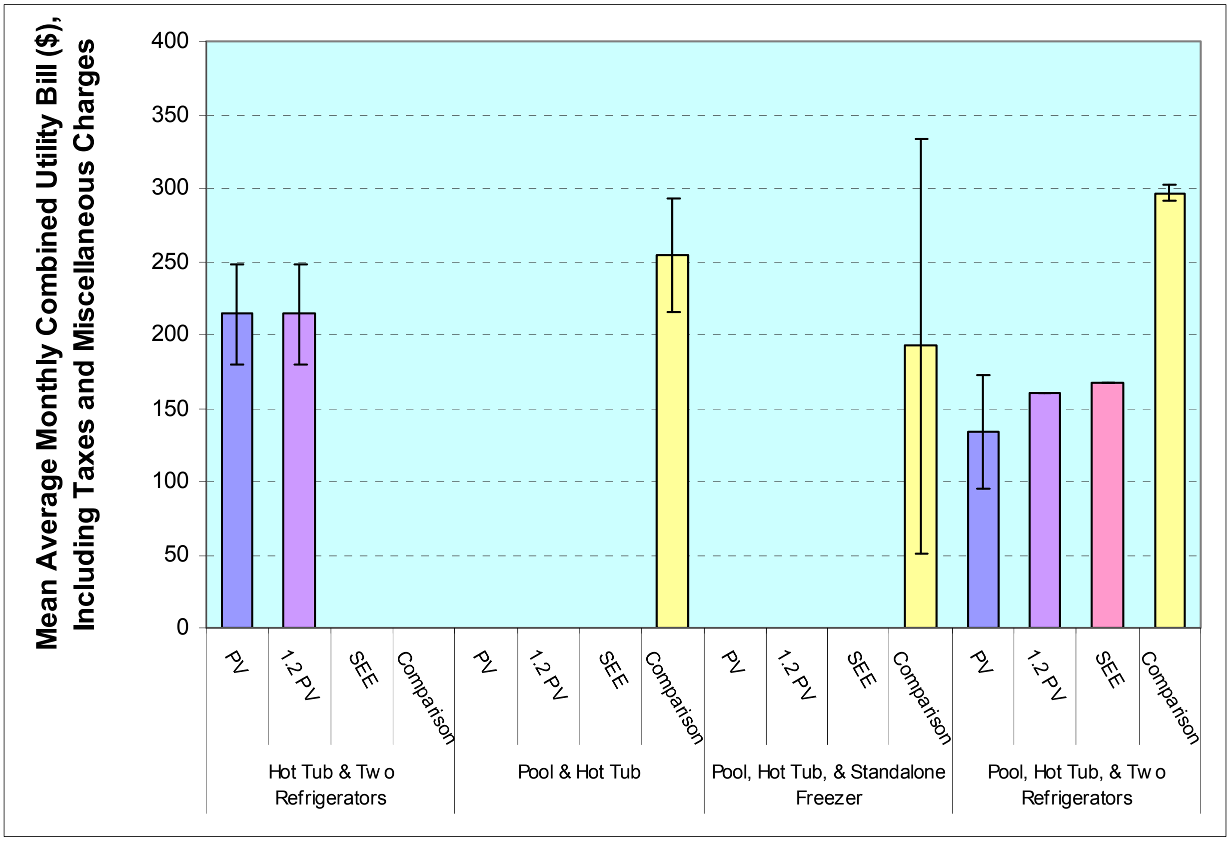


Figure 24. Comparison of Mean Average Monthly Combined Utility Bill, Including Taxes and Miscellaneous Charges, for Four Categories of Homes: Hot Tub and Two Refrigerators; Pool and Hot Tub; Pool, Hot Tub, and Standalone Freezer; and Pool, Hot Tub, and Two Refrigerators[41]

[41]Different numbers of homes are associated with each graphed mean. The figure also includes one-standard-deviation error bars. Error bars are absent for means representing only a single home.

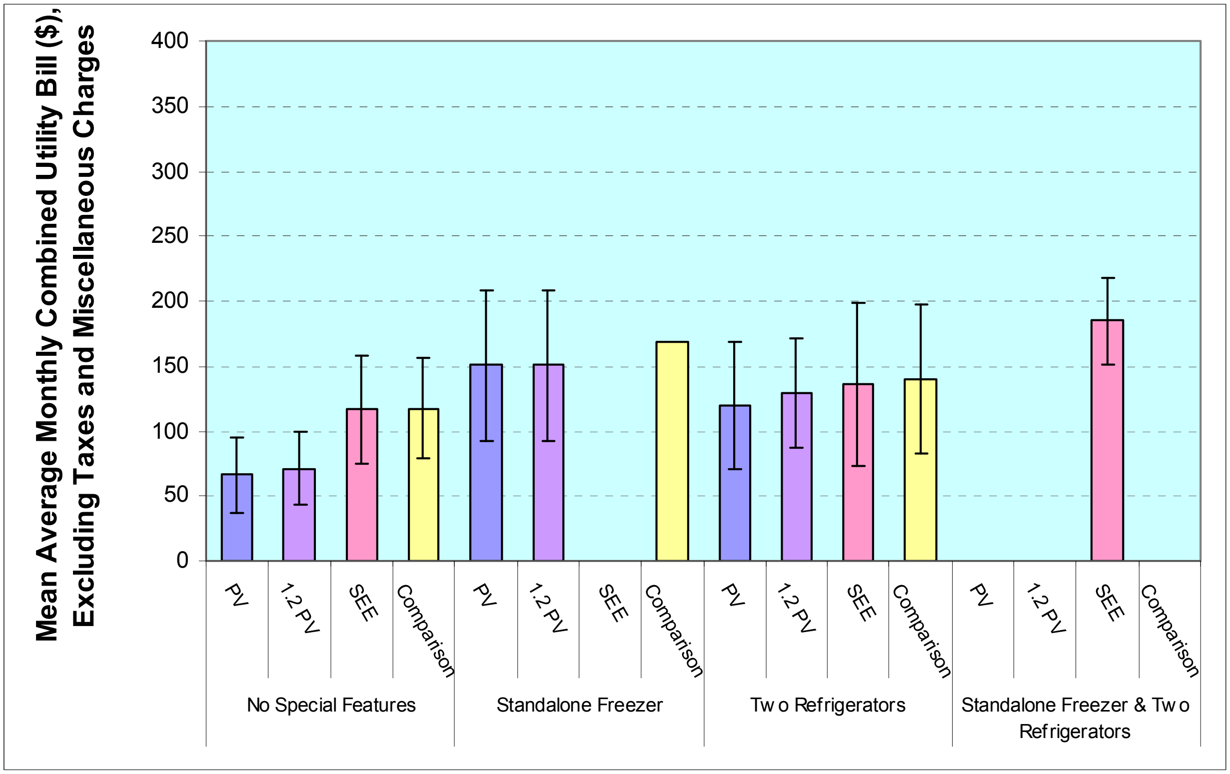


Figure 25. Comparison of Mean Average Monthly Combined Utility Bill, Excluding Taxes and Miscellaneous Charges, for Four Categories of Homes: No Energy-Intensive Equipment, Standalone Freezer, Two Refrigerators, and Standalone Freezer and Two Refrigerators[42]

[42]Different numbers of homes are associated with each graphed mean. The figure also includes one-standard-deviation error bars. Error bars are absent for means representing only a single home.

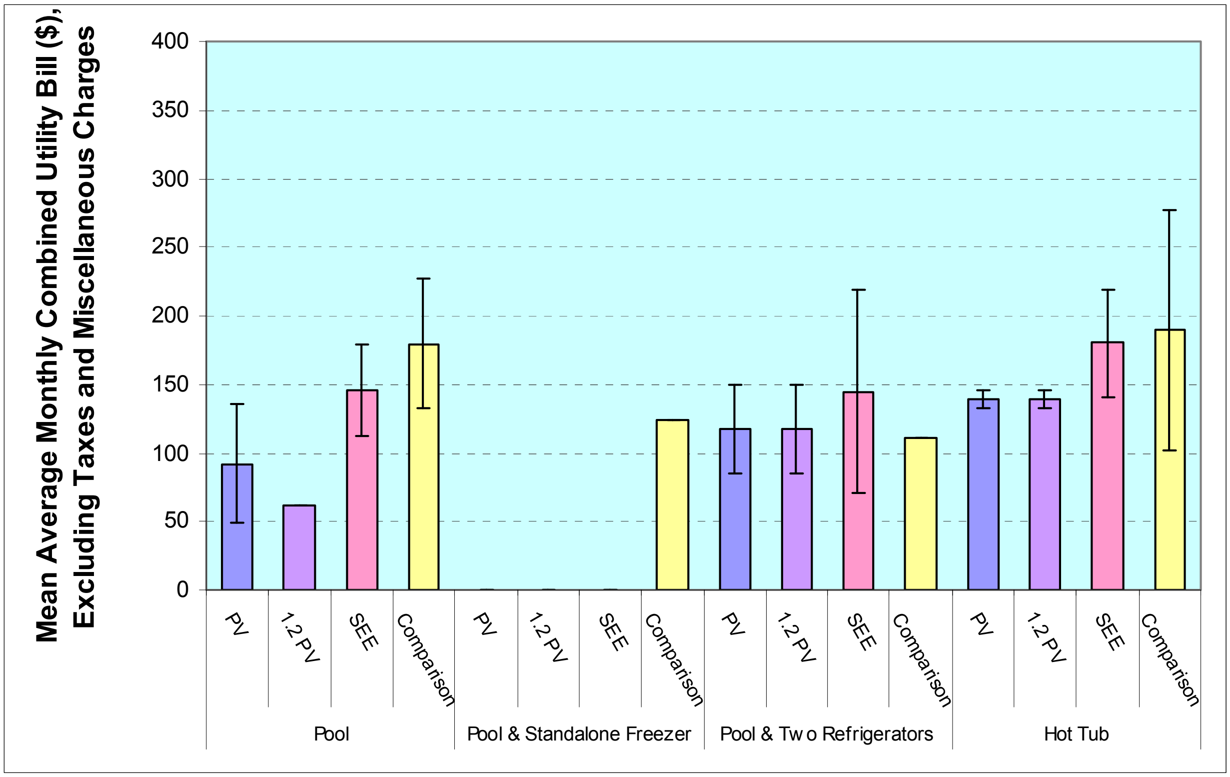


Figure 26. Comparison of Mean Average Monthly Combined Utility Bill, Excluding Taxes and Miscellaneous Charges, for Four Categories of Homes: Pool, Pool and Standalone Freezer, Pool and Two Refrigerators, and Hot Tub[43]

[43]Different numbers of homes are associated with each graphed mean. The figure also includes one-standard-deviation error bars. Error bars are absent for means representing only a single home.

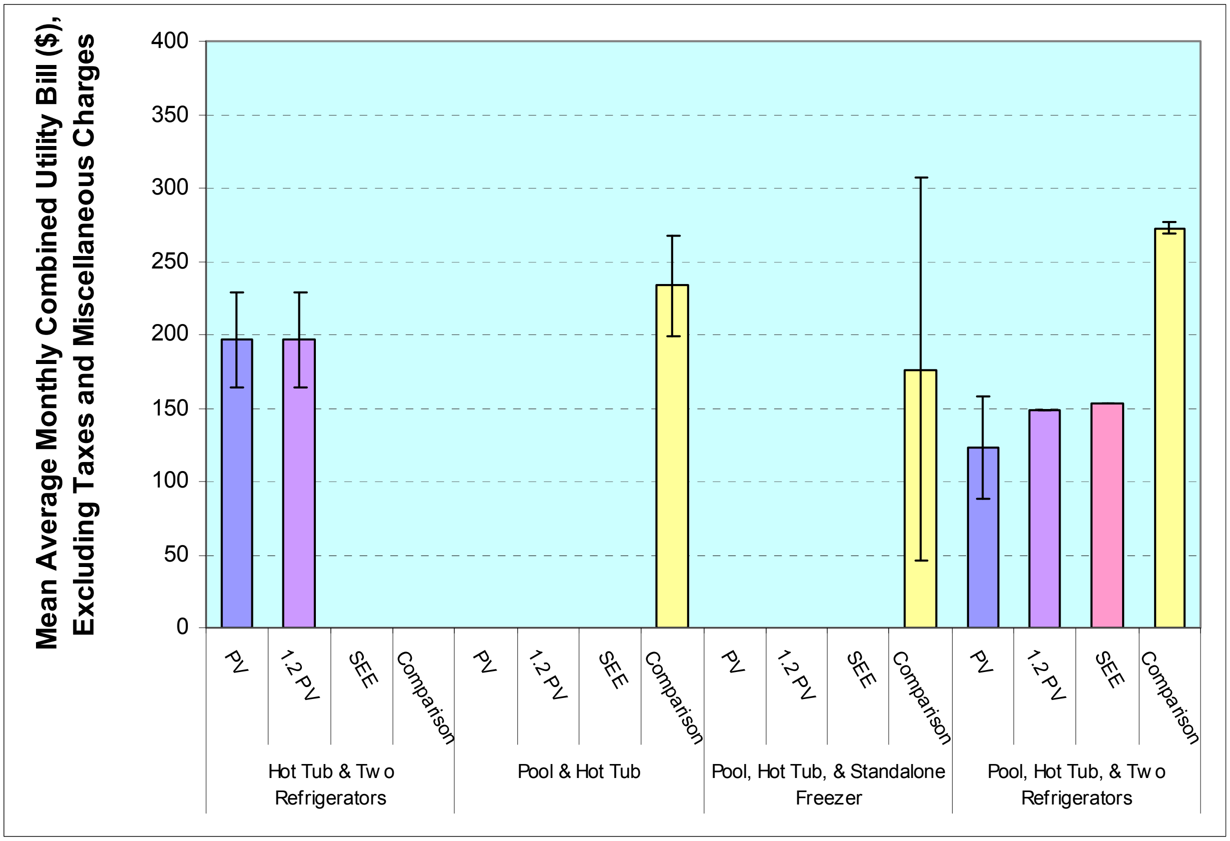


Figure 27. Comparison of Mean Average Monthly Combined Utility Bill, Excluding Taxes and Miscellaneous Charges, for Four Categories of Homes: Hot Tub and Two Refrigerators; Pool and Hot Tub; Pool, Hot Tub, and Standalone Freezer; and Pool, Hot Tub, and Two Refrigerators[44]

[44]Different numbers of homes are associated with each graphed mean. The figure also includes one-standard-deviation error bars. Error bars are absent for means representing only a single home.

Summary and Discussion

This chapter compares actual utility consumption and cost for three specific categories of homes: homes with solar PV systems constructed by SheaHomes, energy-efficient homes constructed by SheaHomes (these do not have solar PV systems), and homes in a nearby comparison community constructed by another builder. Differences in utility consumption and cost between comparison homes and all SheaHomes combined are also evaluated.

Utility consumption and cost were found to be highly variable quantities for all the homes and households encompassed by the study. The variability derives from month-to-month seasonal variation, as well as differences among homes and households within the same home category. Month-to-month seasonal variation is to be expected. Differences among households that may be attributable to occupant behavior or the addition of energy-intensive equipment or amenities are less easily explained. Hence, the chapter investigates the effects of household demographics and several home characteristics on utility consumption and cost and compares and contrasts the results for homes and households included in the various home categories.

The results of the analyses reported here suggest that SheaHomes households (PV and SEE homes combined) consume less electricity and gas on average than comparison households. Several measures of electricity and gas consumption were analyzed and led to essentially the same conclusion. In addition, the average monthly amounts of electricity and gas consumed by SheaHomes households were found to be more stable (less variable) than the amounts consumed by comparison homes, particularly when adjusted for home size. Similarly, SheaHomes households incur lower utility cost, stated in terms of average monthly combined utility bill (with or without taxes and miscellaneous charges), than comparison households. The variability in the amounts for SheaHomes households is about the same as for comparison households (unless square footage is taken into account, in which case it is lower for SheaHomes).

The utility consumption and cost advantages realized by the SheaHomes households seem even more remarkable because the SheaHomes (in the utility data set) are larger than the corresponding comparison homes. The larger size of the SheaHomes apparently has little or no impact on utility consumption and cost relative to the comparison homes. As noted throughout the analyses reported in this chapter, home size (square footage) has an inconsistent and generally limited effect on utility consumption and cost.

Furthermore, there are no statistically significant differences between SheaHomes and comparison households relative to household composition or size (number of occupants). Again, this makes the findings about utility consumption and cost even more meaningful because it suggests the advantages achieved by SheaHomes are not specifically the results of fewer occupants or a different household makeup. On the other hand, a significantly higher percentage of comparison households have pools and hot tubs than SheaHomes households, which suggests that the presence of energy-intensive equipment and amenities is an important consideration (see the discussion below).

The preceding observations are further informed by considering the distinctions in utility consumption and cost between the PV and SEE homes constructed by SheaHomes, and between SEE homes and comparison homes. Summary findings are presented below:

- Mean average electricity consumption is significantly lower in PV homes with 2.4-kW systems than in PV homes with 1.2-kW systems, while mean average gas consumption is essentially equivalent in the two types of homes. Clearly, the size or capacity of the PV system has a notable impact on electricity consumption, but because gas consumption is not affected, the impact on overall utility cost is not so clear cut. However, in this study the number of homes with the larger systems is quite small, and so it was not possible to investigate utility consumption and cost in these homes from all possible perspectives. (See the Epilogue to this report for further discussion.)

- When PV homes with both sizes of systems are considered together, the mean average monthly electricity consumption for such homes is significantly lower than for SEE homes, and the variability in average electricity consumption among PV homes and SEE homes is about the same. Mean average monthly gas consumption is also about the same. These findings translate into lower overall utility cost for PV homes; that is, the mean average monthly combined utility bill for PV homes is significantly lower than for SEE homes, whether or not taxes and miscellaneous charges are considered.

- When only PV homes with 1.2-kW systems are considered, the results are somewhat different. Mean average monthly electricity consumption is lower for PV homes than for SEE homes, but the difference nears statistical significance (p=0.55); plus there is no significant difference in average monthly gas consumption. In terms of overall cost, mean average monthly combined utility bill is lower for PV homes than for SEE homes, whether or not taxes and miscellaneous charges are considered, and the difference is just barely significant; however, on a square-footage basis, the average monthly combined utility bill for these PV homes is not significantly different than the average monthly combined utility bill for SEE homes, whether or not taxes and miscellaneous charges are considered.

Another advantage enjoyed by PV homeowners is that when the net electricity consumed was lower than 300 kWh before March 2004, which was the breakpoint in SDG&E's tiered rate structure, the amount they paid for every kilowatt-hour they use is lower than for those whose net electricity is higher than the breakpoint. The latter pay more per kilowatt-hour for *all* the electricity they use.[45]

As an example of how energy efficiency and solar PV systems could affect electricity costs over time, the 2006 residential summer rates for electricity, which are based on a daily baseline allowance, are as follows (Anders 2006):

---

[45]The monthly threshold changed to $500 in March 2004, according to the SDG&E web site.

Table 94a. SDG&E's Residential Summer Rates for Electricity

Electricity Rate Categories	Cents per kWh
Daily baseline energy allowance	12.867
101%–130% of baseline	14.884
131%–200% of baseline	25.664
201%–300% of baseline	26.571
Over 300% of baseline	28.154

SDG&E provided energy consumption data on a monthly basis; therefore, it was not possible to compute the effect of the SheaHomes' energy efficiency, solar water heating, and PV package on compliance with daily electricity allowances.

These findings are somewhat surprising. As expected, an overall savings in utility cost is achieved in PV homes relative to SEE homes. Such savings are realized solely on the basis of a reduction in electricity consumption since gas consumption is essentially equivalent in the two types of homes. The amount of the reduction is especially noteworthy in PV homes with the larger capacity systems (2.4-kW systems) (see Epilogue).

Mean average gas consumption is significantly lower in SEE homes than in comparison homes. Average gas consumption is also less variable for SEE homes than for comparison homes, indicating greater stability. On the other hand, the difference in mean average electricity consumption in SEE and comparison homes is not statistically significant unless it is computed on an average square footage basis. Furthermore, in terms of overall cost, mean average monthly combined utility bill is not significantly different for SEE and comparison homes, whether or not taxes and miscellaneous charges are consider, except when it is computed on a square footage basis.

These findings suggest there is little difference between SEE homes and comparison homes on the basis of utility consumption and cost, unless home size (square footage) is taken into account. Since the comparison homes are smaller, on average, than the SEE homes, comparison homes might be expected to have lower utility consumption and cost (assuming they had the same energy efficiency features). However, the opposite situation is true. The utility requirements for SEE homes are the same, on average, as those for much smaller homes that do not have the same energy efficiency features.

The presence of various energy-intensive appliances and amenities has an adverse impact on utility consumption in all home categories. Pools and/or hot tubs have a particularly detrimental effect, but other equipment combinations also contribute to higher utility consumption. Because the effects of various equipment tend to interact with, or compound, each other, and because the numbers of homes with distinct equipment combinations are small, formulating precise estimates of the contributions of these equipment combinations to utility consumption and cost is difficult.

However, it is possible, and perhaps even more desirable, to contrast utility consumption and cost in PV, SEE, and comparison homes that do not have any such equipment (base-case homes). In fact, when only base-case homes are considered, PV homes have significantly lower average monthly electricity consumption and significantly lower average monthly gas consumption irrespective of the capacity of the PV system, when computed on a square footage basis. While some ambiguity about average electricity consumption remains when home size, or square footage, is not considered, there is no ambiguity when utility consumption gets translated to cost. Mean average monthly combined utility bill is significantly lower in base-case PV homes than in SEE homes, irrespective of the capacity of the PV system, with and without the adjustment for home size (square footage). This is an important finding because it strongly validates the PV concept.

Comparing utility consumption in base-case SEE and comparison homes suggests the two types of homes are not significantly different in terms of average monthly electricity consumption, and that they are significantly different in terms of average monthly gas consumption only when home size (square footage) is taken into account. When the consumption amounts are translated into cost, mean average monthly combined utility bill is not significantly different for SEE and comparison homes, whether or not home size (square footage) is taken into consideration, and whether or not taxes and miscellaneous charges are included. This suggests that SEE and comparison homebuyers who do not complement their homes with energy-intensive equipment or amenities may not experience much difference in utility consumption and cost, on average.

Based on all these findings, the building/construction/marketing concept initiated by SheaHomes in its two Scripps Highlands developments appears to have been validated. Overall, utility consumption and cost is lower, on average, for SheaHomes than for comparison homes. However, much of this difference is attributable to PV homes, specifically those with the larger capacity PV systems (2.4-kW systems). While they have many obvious benefits, the SEE homes do not necessarily have lower utility consumption and cost, on average, relative to the comparison homes. This is particularly apparent when base-case homes (those without additional energy-intensive equipment or amenities) are considered. These observations about SEE homes do not necessarily support the concept envisioned by SheaHomes relative to comparison homes. Additional study involving larger numbers of homes is needed, however, to substantiate the findings.

Chapter 21
Modeling of Utility Consumption and Cost

Introduction

For planning and marketing purposes, developers and builders have a keen interest in being able to precisely and accurately forecast energy consumption and costs in the new homes they construct and sell. Likewise, consumers are interested in the energy requirements of the new homes they purchase. The availability of reliable estimates of energy cost and consumption can greatly improve the confidence of builders and buyers and enhance overall marketability. Such estimates are perhaps even more critical to the market, and to consumer demand, when new or alternative energy systems and technology are incorporated into housing.

Estimates, projections, or forecasts of residential energy consumption and costs can be obtained in a number of ways. However, they are often developed from models (equations) that involve various inputs that, in combination with one another, are believed to have important impacts.

Chapter Highlights

- Models that predict utility consumption and cost can be useful for builders and consumers.
- In this study, different predictive models were constructed for PV homes, SEE homes, and comparison homes using regression analysis because there is a small number of homes with a wide range of energy-intensive equipment and amenities.
- All the models are dominated by variables that represent the presence of energy-intensive equipment and amenities, such as pools, hot tubs, and two refrigerators. Yet the models are clearly affected by homeowner beliefs, attitudes, and perception. The most reliable models include these variables.
- The predictive models are better for the PV and comparison homes (R^2 of .7 or higher) than they are for the SEE homes.
- Models of electricity consumption have better predictive power than models of gas consumption. These difference are mirrored in the electricity and gas cost models.
- Models are better for homes with 1.2-kW PV systems than for all homes with PV systems because homes with 2.4-kW systems have lower, more variable electricity use and cost.

This chapter presents the results of statistical modeling of actual utility consumption and costs[1] for three groups of homes encompassed by the present study: PV homes, SEE homes, and comparison homes. Table 72 in Chapter 20 (Comparative Analysis of Utility Consumption and Cost) provides descriptions of the home categories. A total of 109 homes are represented: 37 PV homes, 44 SEE homes, and 28 comparison homes. Thirty-one of the PV homes have 1.2-kW systems, and the remaining six have 2.4-kW systems.

---

[1]In this context, *utility* consumption and cost are used synonymously with *energy* consumption and cost.

The empirical models and modeling results presented here were developed by applying statistical methods to the available utility consumption and cost data. Other modeling approaches—specifically, those of an engineering nature—could have been taken but were not pursued in this study.

The consumption and cost data that were used in this modeling effort—called the utility data set—are identical to those described in Chapter 20 after editing and screening. The procedures by which the data were originally obtained and subsequently screened are reported in Chapter 20.

Also as noted in Chapter 20, the actual utility consumption and cost data available for study exhibit considerable variation. Homes vary within and between categories. Such variation can present analytical challenges to the empirical modeling process.

Three types of variables were identified as potential explanatory model inputs: (1) physical characteristics of the home (such as square footage and the presence or absence of a pool); (2) household demographic characteristics (such as total number of occupants, age of head of household, and the presence or absence of children); and (3) energy-related occupant behaviors and attitudes (such as adjusting thermostats and turning off lights and computers).[2] Among these three types, home and household characteristics are fairly distinguishable and factual records or observations about them are generally easy to obtain. Occupant behaviors and attitudes are much more intangible, and therefore, more difficult to measure and analyze. Data on the variables used in this analysis were obtained from various sources that are described in Chapter 3 (Study Methods and Data Resources).

Again, the effects of climate are automatically controlled. The boundaries of the SheaHomes communities (which encompass PV and SEE homes) and the comparison community are within a few blocks of each other, and there are effectively no weather or climate differences. Further, the utility data for SheaHomes and comparison homes encompass the same 12-month period (see the discussion in Chapter 20, which eliminates the possibility of variation caused by seasonality or timing of the data collection process. Hence, the modeling results reported here include no further adjustment for climate or seasonality.

Modeling Approach

Stepwise multiple regression analysis, a well-known statistical approach, was selected as the most direct means of modeling utility consumption and cost. Based on the analysis of the empirical consumption and cost data presented in Chapter 20, separate regression models needed to be developed for PV, SEE, and comparison homes rather than constructing a single, overall model using the approach sometimes referred to as “dummy variables” or “indicator variables.”

---

[2]As previously noted, several variables that contribute to home energy consumption were not measured in this study, such as number of rooms; the number, size, location, and glazing of windows; the orientation of the home; the orientation of solar thermal and PV panels; and so on (for example, Christensen and Barker 2001).

Preliminary modeling investigations that used the "dummy variables" approach indicated there would be insufficient data to establish meaningful results.[3,4]

Because of the difference in consumption units, electricity and gas consumption were modeled separately. Two dependent, or response, variables were considered: average monthly consumption and average monthly consumption per square foot.[5] Hence, separate regression models of average monthly electricity consumption, average monthly electricity consumption per square foot, average monthly gas consumption, and average monthly gas consumption per square foot were constructed for PV, SEE, and comparison homes. Further, separate models were constructed for PV homes and for 1.2 PV homes.[6]

Because cost may ultimately be of greater interest to builders and consumers, it was decided to investigate utility cost on the basis of the following expanded set of response variables[7]:

- Average monthly electricity cost, with and without taxes and miscellaneous charges
- Average monthly electricity cost per square foot, with and without taxes and miscellaneous charges
- Average monthly gas cost, with and without taxes and miscellaneous charges
- Average monthly gas cost per square foot, with and without taxes and miscellaneous charges
- Average monthly combined utility bill, with and without taxes and miscellaneous charges
- Average monthly combined utility bill per square foot, with and without taxes and miscellaneous charges

Consequently, a separate model using each of these utility cost measures as the response variable was constructed for PV, SEE, and comparison homes. Again, separate models were constructed for PV homes and for 1.2 PV homes.

---

[3]The sufficiency of the data is impaired by the different numbers of homes within the three categories and associated inequities in the numbers of observations associated with various home and homeowner categories or classifications, as well as varying degrees of homeowner nonresponse to survey questions, moderate to high variation in the consumption and cost data, and other factors.

[4]A disadvantage of not using the "dummy variables" approach is that it precludes estimation of the *common* effect that a particular variable would have on all types of homes being considered. For example, a hot tub might increase gas consumption by some specified amount, on average, in all kinds of homes; but, because of other factors, the total increase in one type of home might be more than in another. Without using the "dummy variables" approach, the average amount by which a hot tub increases gas consumption regardless of home type cannot be determined.

[5]Other measures of utility (electricity and gas) consumption could have been considered. See Chapter 20 for a description of these measures.

[6]1.2 PV homes are PV homes with 1.2-kW PV systems. There are insufficient data to construct similar models for PV homes with 2.4-kW systems.

[7]These measures of utility cost were also previously described in Chapter 20.

Preliminary Considerations

We undertook several preliminary analyses and investigations before we proceeded to the model development phase. This work validated some underlying assumptions and provided better focus for the overall modeling effort. The modeling effort is also informed by additional results presented in Chapter 20.

Verifying the Consumption-Cost Relationship

In general, utility consumption and cost are expected to be directly related. However, this relationship must be empirically confirmed at the outset so the modeling efforts are not impaired by a faulty assumption that could adversely affect the selection of explanatory variables.

When there is a strong linear relationship between consumption and cost, the variables or features that drive electricity and gas consumption probably also drive their associated costs. In this situation, modeling consumption alone (without the additional effort of modeling cost) may be sufficient. Appendix V contains a number of figures that indicate the data contained in the utility data set exhibit this expected relationship. Figure 28 is illustrative. Here, the relationship between average monthly electricity consumption and average monthly electricity cost, excluding taxes and miscellaneous charges, for PV homes is nearly a straight line indicating a one-to-one relationship between the two quantities. The slight upward curvature reflects the tiered rate structure in effect during the study period.[8]

Relationship between Electricity and Gas Consumption

An additional preliminary question is if the same variables can be used to model both electricity and gas consumption. The degree to which electricity and gas consumption track each other in the study homes over time is an important clue. This question can first be addressed by reviewing Figures L-1 to L-10 in Appendix L and M-1 to M-10 in Appendix M described in Chapter 20. These graphs show the *month-to-month total consumption* (July 2003–June 2004) of electricity and gas for homes encompassed by the study. In some homes, electricity and gas consumption are strongly and positively correlated (as electricity consumption increases, so does gas consumption); in others, electricity and gas consumption are strongly and negatively correlated (as electricity consumption increases, gas consumption decreases). However, in many homes the association is relatively weak, which suggests that a consistent, strong relationship between electricity and gas consumption is absent over time. In fact, the correlation exceeds .5 in only 39 (35.8%) of all the homes represented in the utility data set, and the overall correlation (data from

---

[8] www.sdge.com/tariff/com-elec/DR-LI.pdf, "Residential Customer Rate Information Schedule" (accessed 4-20-06) and www2.sdge.com/tariff/com-gas/GR.pdf, "Residential Customer Gas Rate Information Schedule" (accessed 4-20-06).

all homes combined) is only .029.[9] Consequently, electricity and gas consumption do not necessarily increase or decrease in concert with each other; however, differences in home size, number of occupants, the presence or absence of a pool, and other variables have not yet been taken into account.

Figures 29–32 depict the relationship between *average monthly electricity consumption* and *average monthly gas consumption* for PV, 1.2 PV, SEE, and comparison homes. Figure 33 shows the relationship for all the homes in SheaHomes communities, and Figure 34 depicts the overall relationship for all homes combined. The computation of average monthly electricity and gas consumption smooths out the ups and downs of consumption over time, such as those depicted in the figures contained in Appendixes L and N. Nevertheless, Figures 29–34 also suggest that, even on an average monthly basis, electricity and gas consumption are not strongly related in the homes encompassed by this investigation. Again, these figures do not reflect any adjustments for the effects of specific factors known to affect utility consumption.

Table 95 presents the actual numerical values of the correlation[10] between average monthly electricity consumption and average monthly gas consumption, both with and without an adjustment for square footage, for the respective home categories. In each case the correlation is positive, but relatively modest to low (values range from .43 to .58).

These modest to low correlations suggest that, for all home types represented in Figures 29–34, the variables or features that drive electricity consumption are somewhat different from those that drive gas consumption. This finding indicates that the optimum models of electricity and gas consumption will not necessarily contain the same components, or if they do, that such components will not necessarily have the same importance.

---

[9]Correlation ranges from 0 (total absence of relationship) to 1 (perfect relationship, or total alignment) in either the positive or negative direction. Hence, a correlation of .5 would be the minimum value to associate with a moderate correlation. Values below .5 (either positive or negative) suggest the relationship is weak to nonexistent.

[10]Pearson product moment correlation.

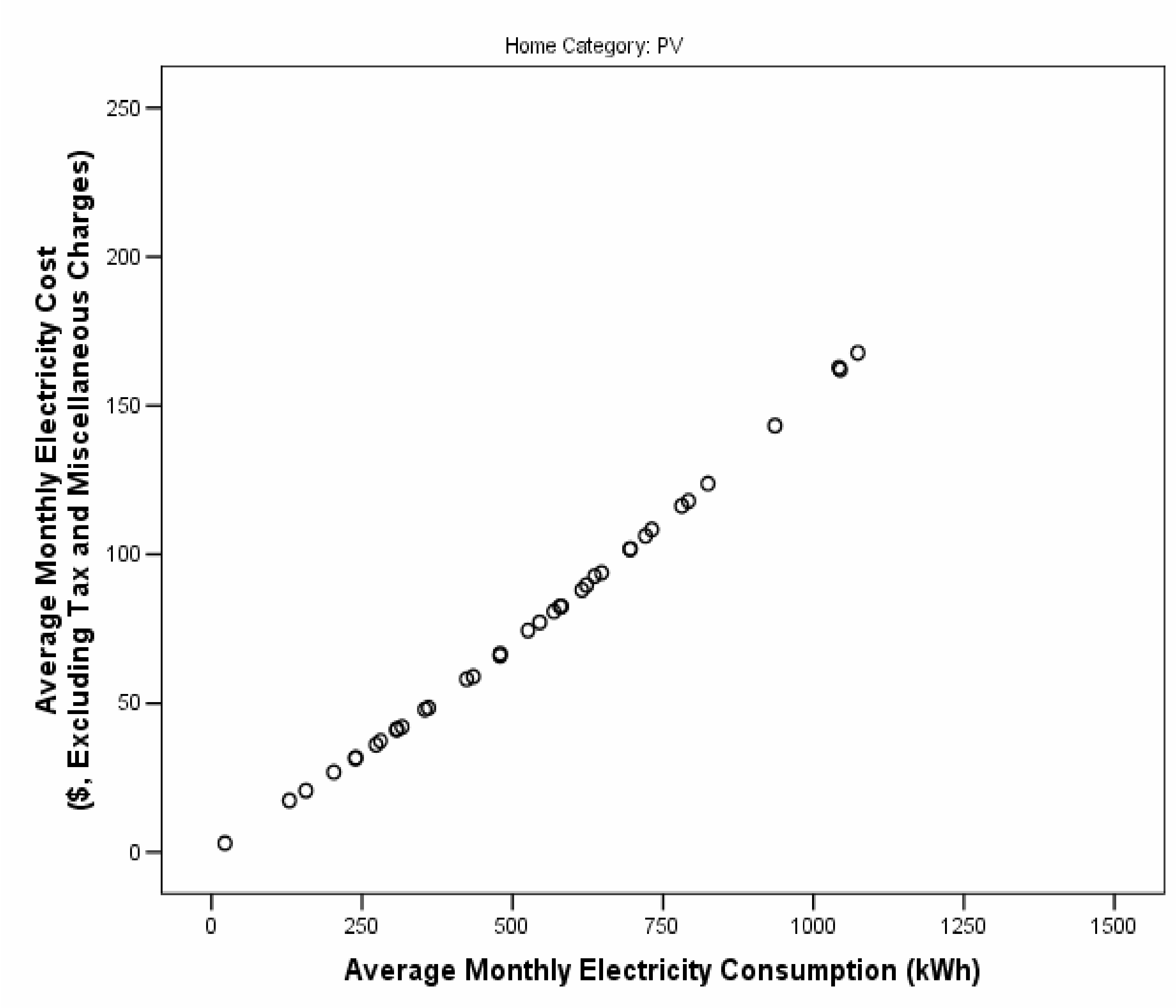


Figure 28. Scatter Diagram of Average Monthly Electricity Consumption (kWh) versus Average Monthly Electricity Cost ($), Excluding Taxes and Miscellaneous Charges, for PV Homes (n=37)

Further, the correlation values reported in Table 95 are not necessarily improved when home size, or square footage, is taken into account. This suggests that adjusting for the effects of home size, a variable that initially might be considered to be an important contributor to utility consumption, may not necessarily lead to improved understanding of consumption patterns by itself, or that the improvement may be limited. This limitation of square footage in predicting energy consumption was discussed in Chapter 20.

Table 95. Correlation* between Average Monthly Electricity and Gas Consumption, with and without Adjustment for Square Footage, for Various Categories of Homes

Home Category	Electricity versus Gas	Electricity versus Gas (ft^2)
PV Homes (n=37)	.558	.545
PV Homes with 1.2-kW Systems (n=31)	.577	.549
SEE Homes (n=44)	.467	.427
SheaHomes (n=81)	.530	.501
Comparison Homes (n=28)	.503	.505
All Homes Combined (n=109)	.553	.569

*Pearson production moment correlation.

Identification of Prospective Explanatory Variables

The various sources of data encompassed by the study yielded information on a large number of variables that could potentially help explain utility consumption and cost in the homes. As noted previously, some of these variables are demographic in nature, some represent physical characteristics of the homes, some reflect the presence of energy-intensive equipment and amenities, and still others pertain to the attitudes, perceptions, opinions, and behaviors of homeowners.[11] An assessment of all these variables led to a subjective determination about each one concerning its potential to directly affect utility consumption. As a result of this assessment, the number of prospective explanatory variables was reduced to 44. Table 96 lists these 44 variables grouped into three categories: household/demographic characteristics; physical home characteristics/features; and homeowner attitudes, behaviors, or perceptions.

[11]Items pertaining to the attitudes, perception, opinions, and behaviors of homeowners represent questions contained in the homeowner questionnaires (see Appendixes A, B, C, and D).

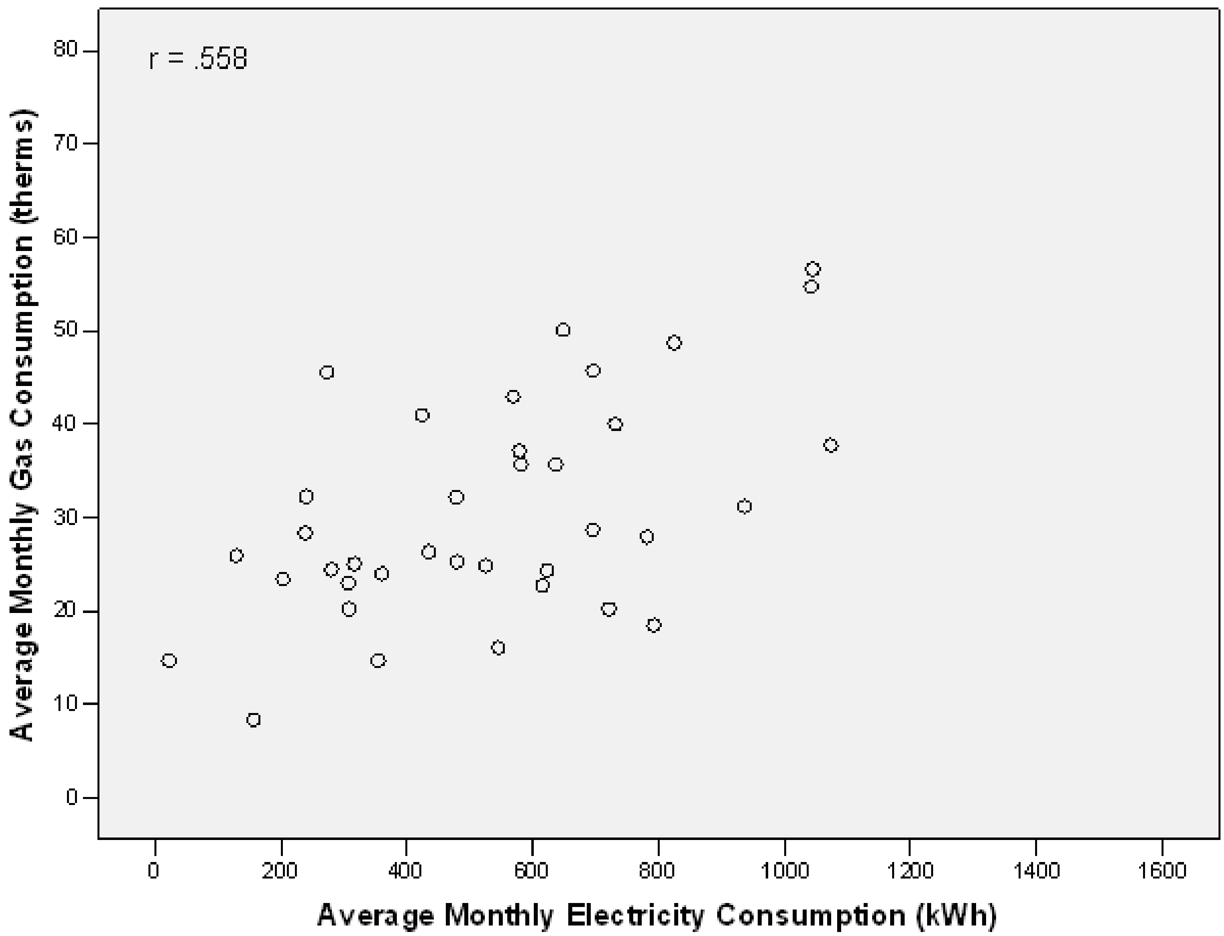


Figure 29. Scatter Diagram Depicting the Relationship between Average Monthly Electricity Consumption and Average Monthly Gas Consumption for PV Homes (n=37)

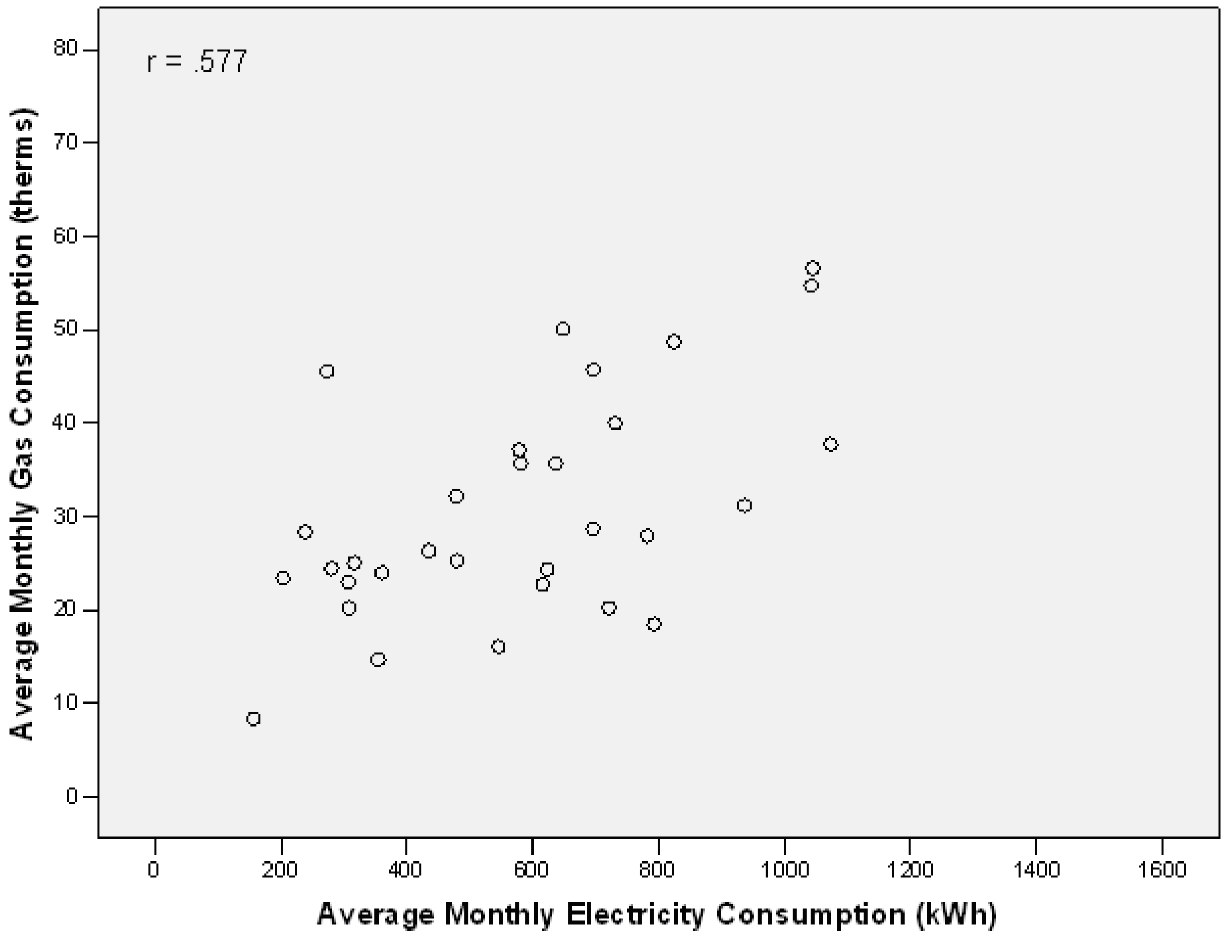


Figure 30. Scatter Diagram Depicting the Relationship between Average Monthly Electricity Consumption and Average Monthly Gas Consumption for PV Homes with 1.2-kW Systems (n=31)

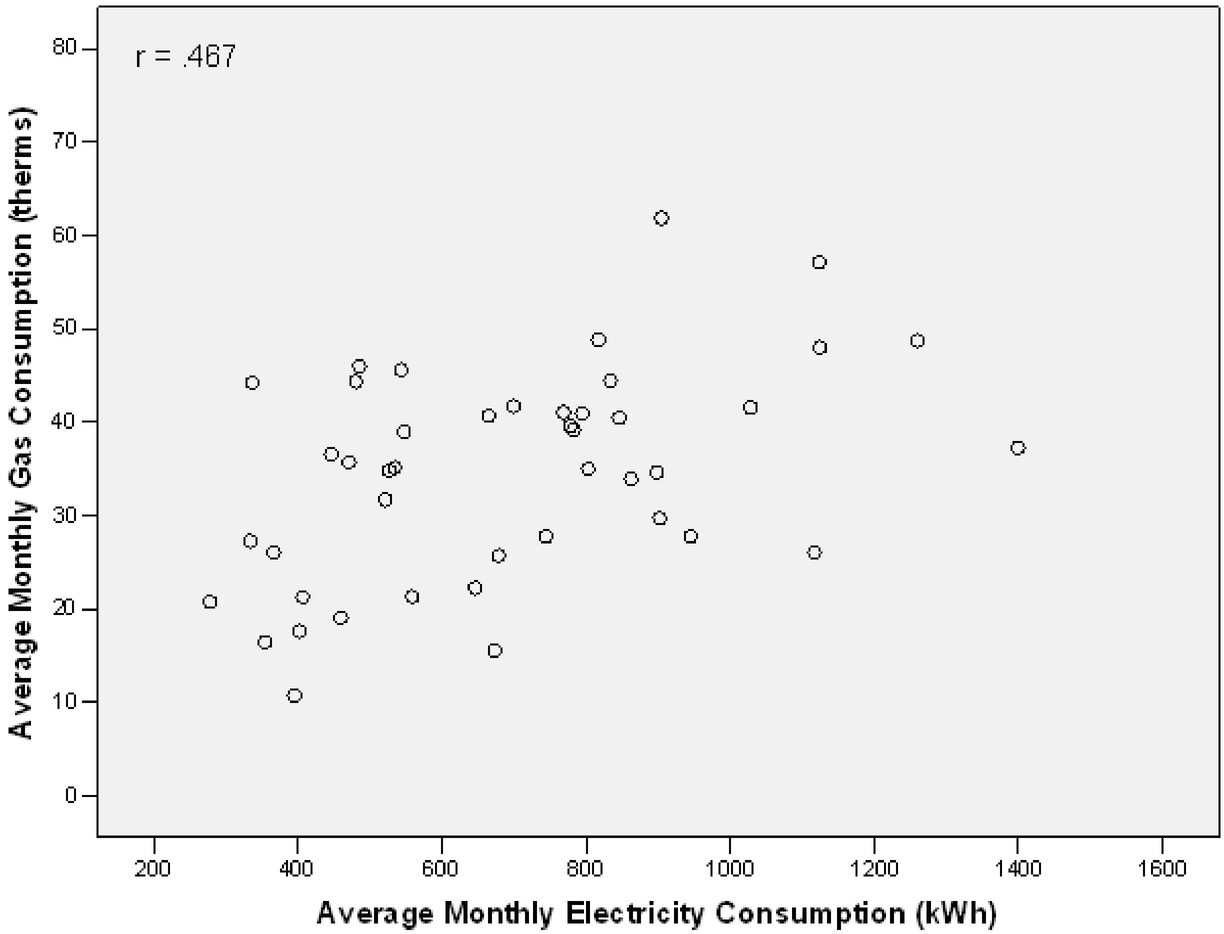


Figure 31. Scatter Diagram Depicting the Relationship between Average Monthly Electricity Consumption and Average Monthly Gas Consumption for SEE Homes (n=44)

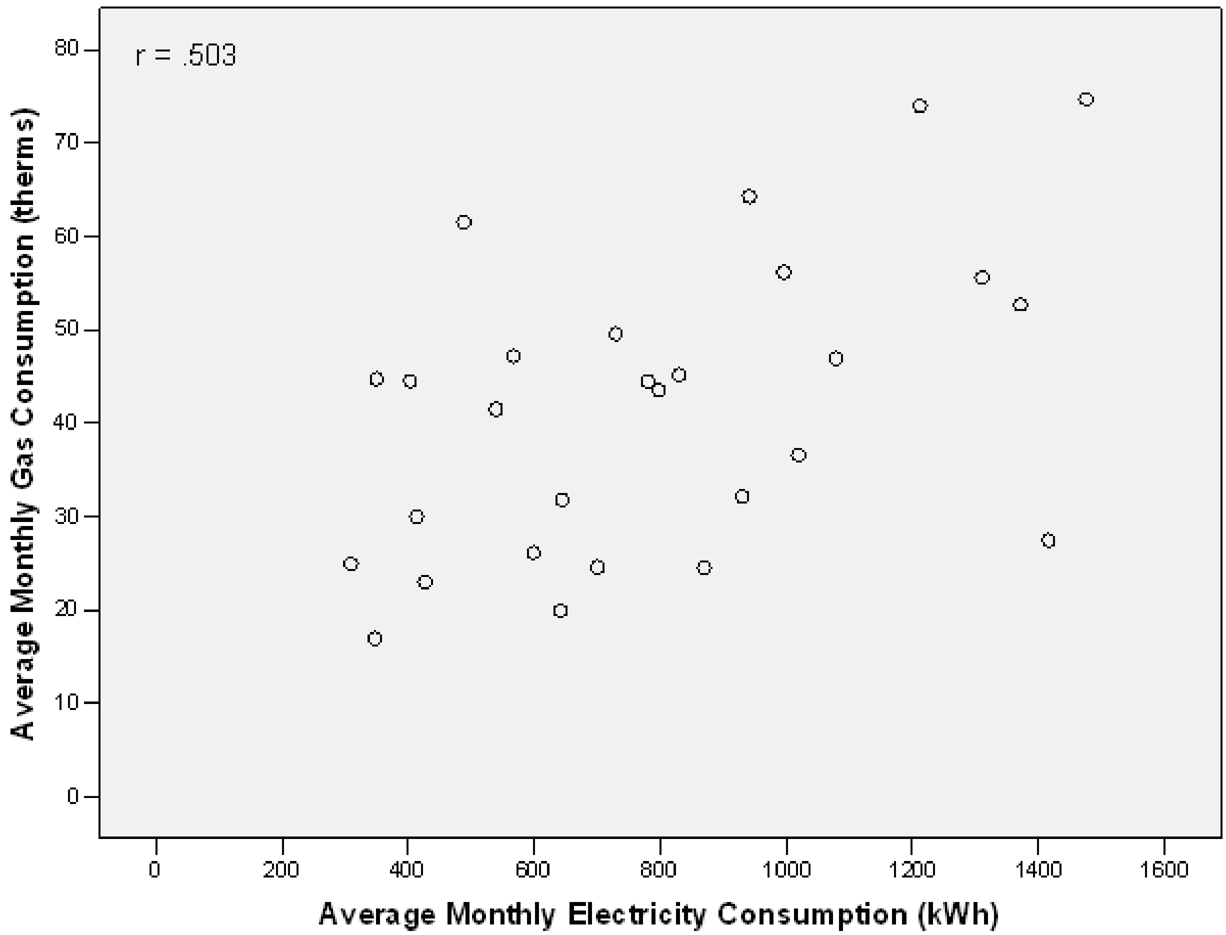


Figure 32. Scatter Diagram Depicting the Relationship between Average Monthly Electricity Consumption and Average Monthly Gas Consumption for Comparison Homes (n=28)

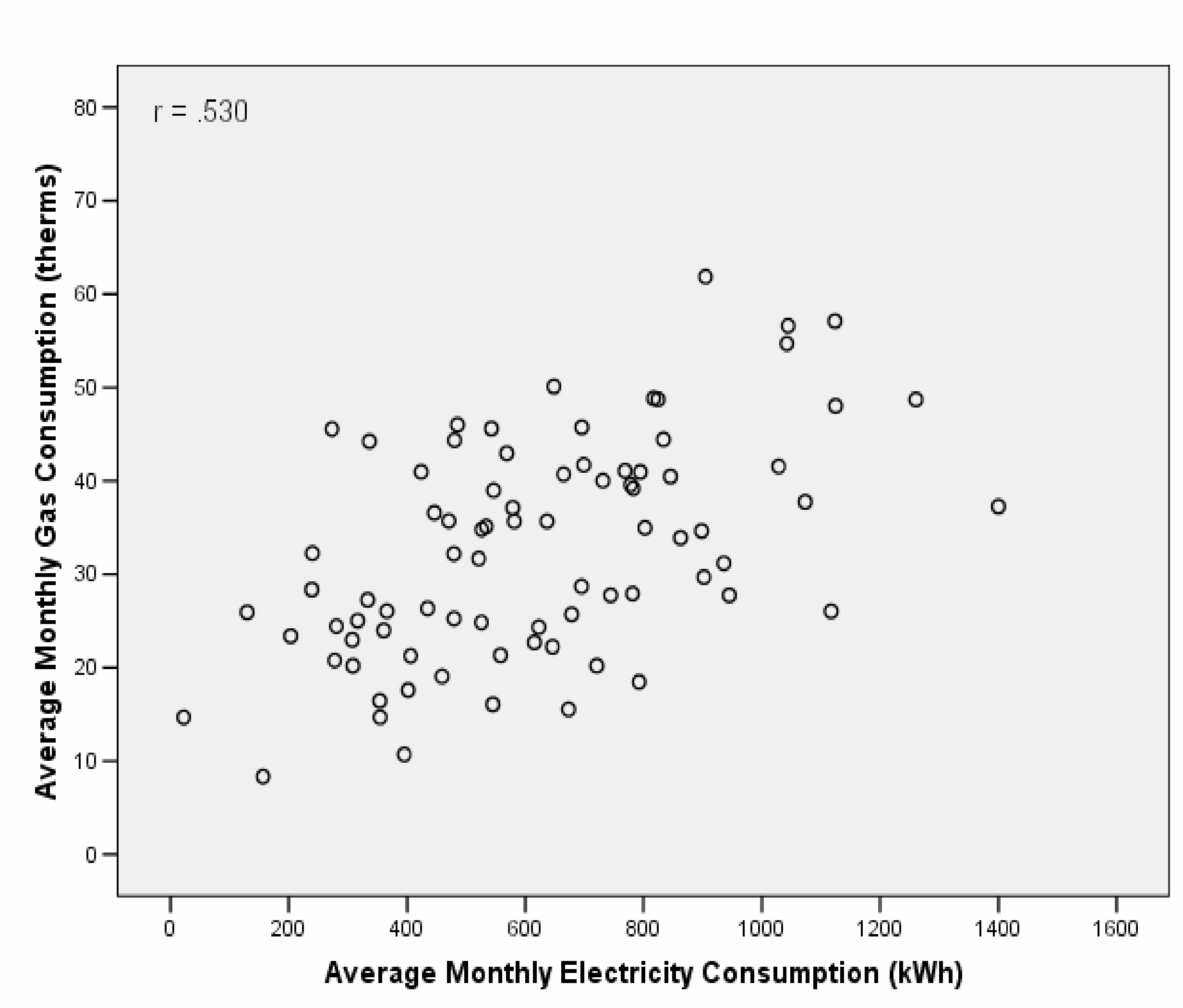


Figure 33. Scatter Diagram Depicting the Relationship between Average Monthly Electricity Consumption and Average Monthly Gas Consumption for SheaHomes (n=81)

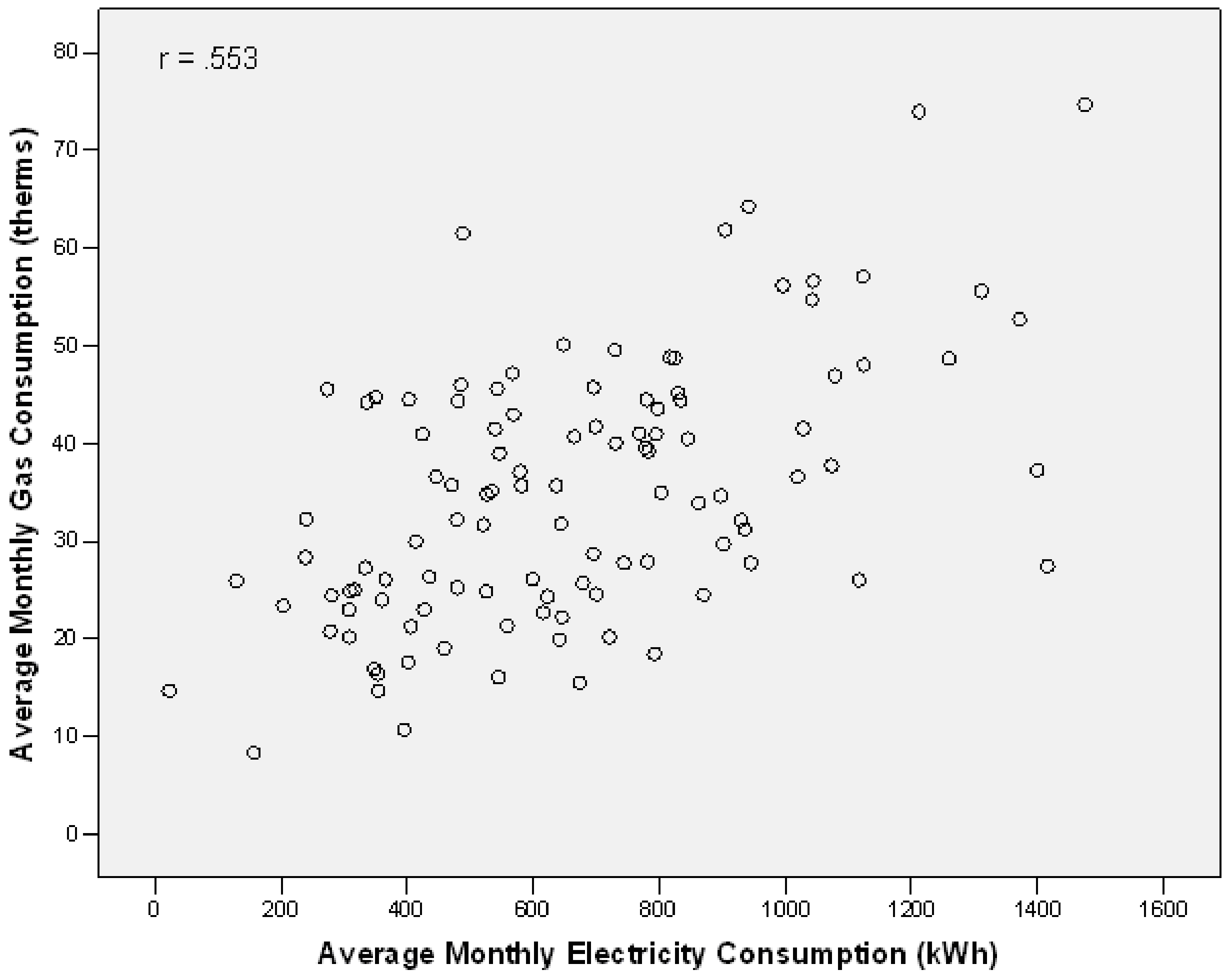


Figure 34. Scatter Diagram Depicting the Relationship between Average Monthly Electricity Consumption and Average Monthly Gas Consumption for All Homes Combined (n=109)

Preliminary Correlation Analysis

Correlation analysis was used as an initial screening approach to investigate the relationship between the variables listed in Table 96 and average monthly electricity and gas consumption. The corresponding correlations between the variables listed in Table 96 and average monthly electricity and gas *cost* were not computed and analyzed because Figure 28 suggests this step would be redundant.

The complete list of all possible pairwise correlations is quite lengthy, and many of the correlations are low and uninformative. Hence, for the sake of brevity, only selected correlations are reported here.

Tables 97–100 contain the empirical correlations between average monthly electricity consumption (with and without an adjustment for square footage) and several potential explanatory variables for PV, 1.2 PV, SEE, and comparison homes, respectively. These tables also contain the correlations between these same variables and average monthly gas consumption (with and without an adjustment for home size in terms of square footage). Each table represents only those variables in Table 96 for which the correlation with at least one of these utility consumption measures[12] exceeds .3 (in absolute value).[13]

Although .3 is recognized to be a low correlation value and suggests a relatively weak statistical relationship, it does represent a somewhat useful cutoff point for presentation purposes. Note that, in Tables 97–100, the correlation is as large as .55 in only three instances. This finding suggests that no individual item or variable is an adequate descriptor of electricity or gas consumption by itself, and that a multivariable approach is needed to modeling is needed.

Tables 97–100 also indicate that different variables are correlated with average monthly electricity consumption (with or without an adjustment for square footage) than with average monthly gas consumption (with or without an adjustment for square footage). This finding corroborates the situation portrayed in Figures 31–34. For the homes in this study, electricity and gas consumption are apparently driven by somewhat different usage circumstances, home characteristics, and occupant behaviors.

Furthermore, Tables 97–100 indicate that the variables that correlate with average monthly electricity consumption are not necessarily the same as those that correlate with average monthly electricity consumption *per square foot*, and that the variables that correlate with average monthly gas consumption are not necessarily the same as those that correlate with average monthly gas consumption *per square foot*. For many variables listed in these tables, the correlation with average monthly electricity or gas consumption is higher than the corresponding correlation between average monthly electricity or gas consumption per square foot, regardless of the home category. This finding again suggests that square footage may not be a particularly important factor, by itself, when modeling utility consumption in these homes.

---

[12]Average monthly electricity consumption, average monthly electricity consumption per square foot, average monthly gas consumption, or average monthly gas consumption per square foot.

[13]Spearman rank correlation was used to compute the correlation coefficient between the utility consumption measures and variables whose values are recorded on the ordinal (discrete) scale; Pearson product moment correlation was used to compute the correlation coefficient between the utility consumption measures and variables whose values are continuous.

Table 96. Features, Characteristics, and Items Considered as Prospective Explanatory Variables, by Category

Household/Demographic Characteristics	Physical Home Characteristics/Features*	Homeowner Attitudes, Behaviors, or Perceptions
• Household size (number of occupants) • Household composition (adults versus children) • Age of head of household • Gender of head of household • Educational level of head of household • Household income before taxes • Marital status of head of household	• Size of home (square footage) • Own pool • Own hot tub • Own dual-zone heating/air-conditioning system • Own hot water flow regulator • Own two refrigerators • Own standalone freezer • Own ceiling fans • Own dimmer switches for lights • Own compact fluorescent light bulbs • Size of PV system	• In summer, set thermostat to 75° or higher • In winter, set thermostat to 70° or lower • When away, modify thermostat settings • Turn off computers when not in use • Use air conditioning less than in previous home • More energy conscious than before • Tend to be thrifty • When away, turn off lights • Regularly recycle paper, plastic, or cans • Conserve water • Practice xeriscaping • More energy conscious than before • Use less air conditioning than in previous home • Drive fuel-efficient vehicles • Threats to the environment are exaggerated • Individuals need to take responsibility for the environment • Household energy consumption is not a major contributor to environmental problems • Individuals should work to preserve the environment for future generations • Federal regulations provide adequate protection for the environment • Concern for the electricity crisis in California • Like to be as independent as possible • Like to experiment with new ways of doing things • Seen as leader in social, work, or volunteer settings • Buy environmentally friendly products even if they cost more • Willing to modify lifestyle to help the environment • Intrigued with new technology

*Ownership of solar water heating systems is omitted because no homes from the comparison community have these systems. Size of PV water system is applicable only to homes with this feature.

Finally, Tables 97–100 suggest that average monthly electricity and gas consumption (with and without an adjustment for square footage) are correlated with different variables in PV homes than in SEE and comparison homes, and that the total number of variables exceeding the subjective correlation threshold of .3 is different for the three home categories. Only five variables that exceed the .3 correlation threshold are identified in Table 97 for PV homes, whereas 13 variables exceeding the .3 correlation threshold are identified in Table 99 (SEE homes) and 15 variables are identified in Table 100 (comparison homes). In addition, no single variable is common to all three groups of homes (i.e., no variable is common to all three tables). However, two variables (pool ownership and income) are common to the tables for PV homes and comparison homes (Tables 97 and 100); and seven variables (household size, household composition, square footage, willing to modify lifestyle to help environment, turn off computers when not in use, conserve water, use air conditioning less than in previous home) are common to the tables for SEE homes and comparison homes (Tables 99 and 100).

These last results principally indicate the distinctions and commonalities among PV, SEE, and comparison homes. The information presented in these tables tends to underscore the belief that the three groups of homes/households are different in many ways with respect to utility consumption and cost. This finding has an important impact on model development.

As suggested earlier, the results of the correlation analysis indicate that no individual variable identified in Table 96 could likely serve as the sole descriptor of electricity or gas consumption (and cost) in PV, SEE, or comparison homes. Also, because the correlations are empirical and can be directly affected by small numbers of observations, some of them may seem illogical at first glance. Nonetheless, subsets of the variables might be identified that can be used in conjunction with one another to establish reasonable models of utility consumption. In any such endeavor, care must be taken to account for intercorrelations among all the variables, some of which may not be readily apparent. Some combinations of variables may need to be disregarded because they essentially carry the same information content (i.e., multicollinearity). Furthermore, some variables associated with higher correlations in Tables 97–100 may become less important in the presence of intercorrelation. The use of stepwise multiple regression analysis helps identify the most important combinations of variables and unravel their associated relationships.

In summary, the correlation analysis provides a first impression of the relationship between average monthly electricity and gas consumption and the variables listed in Table 96. These results are used to inform the modeling building process which, as indicated below, is highly iterative in nature.

Development of Models

Model development is an iterative process. Even with a powerful tool like stepwise multiple regression analysis, the procedure sometimes requires considerable trial and error to find an optimal solution. Modeling also involves the application of sound scientific judgment. The models reported here resulted from numerous iterations and represent the current state of knowledge about the available data.

As previously indicated, different models were developed for average monthly electricity consumption, average monthly electricity consumption per square foot, average monthly gas consumption, and average monthly gas consumption per square foot for PV, 1.2 PV, SEE, and comparison homes.

Table 97. Variables that Are Most Highly Correlated[1] with Average Monthly Electricity and Gas Consumption (with and without an Adjustment for Square Footage) for PV Homes

Variable	Correlation with:			
	Average Monthly Electricity Consumption	**Average Monthly Electricity Consumption (ft^2)**	**Average Monthly Gas Consumption**	**Average Monthly Gas Consumption (ft^2)**
Two refrigerators[2]	.377	.355	.463	.441
Pool[2]	.402	.359	.301	.237
In summer, set thermostat to 75° or higher[3]	−.214	.200	−.362	−.365
Gender of head of household respondent[4]	−.297	−.314	−.189	−.151
Annual household income before taxes	.308	.225	.183	.117

[1]Only variables for which the Spearman rank correlation or Pearson product moment correlation exceeds .3 (in absolute value) for at least one of the utility consumption measures are included. The value of n is different for each cell.
[2]Presence=1; absence=0
[3]Recorded on a 1-5 scale, where 1=strongly disagree and 5=strongly agree
[4]Male=1; female=2

Table 98. Variables that Are Most Highly Correlated[1] with Average Monthly Electricity and Gas Consumption (with and without the Square Footage Adjustment) for 1.2 PV Homes

Variable	Correlation with:			
	Average Monthly Electricity Consumption	Average Monthly Electricity Consumption (ft^2)	Average Monthly Gas Consumption	Average Monthly Gas Consumption (ft^2)
Two refrigerators[2]	.442	.413	.522	.515
Ceiling fans[2]	−.008	.000	−.241	−.309
Stand-alone freezer[2]	.146	.110	.317	.281
Pool[2]	.471	.422	.275	.226
Regularly recycle paper, plastic, or cans[3]	−.230	−.215	−.341	−.326
In summer, set thermostat to 75° or higher[3]	−.163	−.141	−.371	−.348
Turn off computers[3]	−.137	−.182	−.306	−.315
Gender of head of household[4]	−.401	−.417	−.201	−.185
Annual household income before taxes	.384	.279	.145	.065

[1]Only variables for which the Spearman rank correlation or Pearson product moment correlation exceeds .3 (in absolute value) for at least one of the utility consumption measures are included. The value of n is different for each cell.
[2]Presence=1; absence=0
[3]Recorded on a 1-5 scale, where 1=strongly disagree and 5=strongly agree
[4]Male=1; female=2

Table 99. Variables that Are Most Highly Correlated[1] with Average Monthly Electricity and Gas Consumption (with and without the Square Footage Adjustment) for SEE Homes

Variable	Correlation with: Average Monthly Electricity Consumption	Average Monthly Electricity Consumption (ft^2)	Average Monthly Gas Consumption	Average Monthly Gas Consumption (ft^2)
Ceiling fans[2]	.323	.361	.081	.150
Stand-alone freezer[2]	.336	.342	.168	.131
Dimmer switches for lights[2]	.298	.309	.323	.360
Hot water flow regulator[2]	.136	.104	.344	.360
Turn off computers when not in use[3]	−.512	−.500	−.168	−.112
Conserve water[3]	−.321	−.391	−.204	−.209
Use air conditioning less than in previous home[3]	−.482	−.468	−.358	−.300
Intrigued with new technology[3]	.407	.422	.116	.129
Like to be as independent as possible[3]	.412	.451	.352	.395
Household size	.436	.436	.034	−.019
Household composition	.433	.387	.184	.123
Willing to modify lifestyle to help environment[3]	.351	.353	.434	.351
Federal regulations provide adequate protection for the environment[3]	−.377	−.353	−.153	−.174

[1]Only variables for which the Spearman rank correlation or Pearson product moment correlation exceeds .3 (in absolute value) for at least one of the utility consumption measures are included. The value of n is different for each cell.
[2]Presence=1; absence=0
[3]Recorded on a 1-5 scale, where 1=strongly disagree and 5=strongly agree

Table 100. Variables that Are Most Highly Correlated[1] with Average Monthly Electricity and Gas Consumption (with and without the Square Footage Adjustment) for Comparison Homes

Variable	Correlation with:			
	Average Monthly Electricity Consumption	Average Monthly Electricity Consumption (ft^2)	Average Monthly Gas Consumption	Average Monthly Gas Consumption (ft^2)
Compact fluorescent lights[2]	.031	.134	−.329	−.247
Hot tub[2]	.442	.422	.226	.093
Pool[2]	.569	.527	.285	.211
Tend to be thrifty[3]	−.365	−.369	−.408	−.381
Turn off computers when not in use[3]	−.297	−.263	−.390	−.320
Conserve water[3]	.014	−.006	−.274	−.309
More energy conscious than before[3]	−.499	−.484	−.359	−.268
Use air conditioning less than in previous home[3]	−.330	−.325	−.172	−.096
Drive fuel-efficient vehicles[3]	−.453	−.391	−.390	−.165
Household size	.343	.333	.535	.484
Household composition	.149	.137	.377	.366
Annual household income before taxes	.420	.394	.503	.477
Like to experiment with new ways of doing things[3]	−.371	−.391	−.018	−.018
Willing to modify lifestyle to help environment[3]	−.336	−.398	−.037	−.168
Threats to the environment are exaggerated[3]	.618	.645	.524	.437
Household energy consumption is not a major contributor to environmental problems[3]	.311	.299	.293	.269

[1]Only variables for which the Spearman rank correlation or Pearson product moment correlation exceeds .3 (in absolute value) for at least one of the utility consumption measures are included. The value of n is different for each cell.
[2]Presence=1; absence=0
[3]Recorded on a 1-5 scale, where 1=strongly disagree and 5=strongly agree

Similarly, different models were developed for each of the following utility cost measures:

- Average monthly electricity cost (including and excluding taxes and miscellaneous charges)
- Average monthly utility cost per square foot (including and excluding taxes and miscellaneous charges
- Average monthly gas cost (including and excluding taxes and miscellaneous charges)
- Average monthly gas cost per square foot (including and excluding taxes and miscellaneous charges)
- Average combined monthly utility bill (including and excluding taxes and miscellaneous charges)
- Average combined monthly utility bill per square foot (including and excluding taxes and miscellaneous charges).

Version 13 of the Statistical Package for the Social Sciences (SPSS) served as the primary computational tool, although various other software programs (including Microsoft Excel and the Statistical Analysis System, or SAS) were used in the modeling work. The results reported are largely based on the stepwise multiple regression routines available in SPSS. As noted in Chapter 20, the PRISM system was not used to make any further adjustments to the data because the design of the study already controls for weather and climate differences.

The multiple regression approach to model development is a highly iterative process, requiring the evaluation of numerous combinations of explanatory variables. For the present work, the method of maximizing the coefficient of determination, R^2, was used to obtain an optimum combination of variables, all of which are statistically significant. To begin the process, all the variables in Table 96 are included in the model, and those that are not found to be statistically significant, or that are deemed to have illogical coefficients, are omitted. A new model is then constructed from the reduced set, and again those variables that are not found to be statistically significant, or that are determined to have illogical coefficients, are omitted. This process is iterated until no more terms are eliminated. The final model consists of the set of statistically significant variables for which R^2 is maximum.

Models of Utility Consumption

Tables 101–104 present the summary results of the regression analysis for average monthly electricity consumption, average monthly electricity consumption per square foot, average monthly gas consumption, and average monthly gas consumption per square foot, respectively. Each table contains information indicating the best model[14] (explanatory variables, coefficients, and associated goodness-of-fit statistics) for PV, 1.2 PV, SEE, and comparison homes. For example, in Table 101, the best model of average monthly electricity consumption (Y) for PV homes is

---

[14]In this context, the best model is the one with the highest value of R^2, the multiple correlation coefficient. The values of R^2 range from 0 to 1. If R^2=1 the model completely explains the data (or it is said to fit the data perfectly).

$Y = 741.85 + 322.40X_1 - 104.37X_2 + 277.55X_3 + 466.58X_4 - 151.73X_5 + e$, where

X_1=Own pool
X_2=Turn off lights when away
X_3=Own two refrigerators
X_4=Own standalone freezer
X_5=Age of head of household, and,
e= unexplained remainder (error).

This is the specific combination of statistically significant variables for which R^2 is maximum.

The names of the explanatory variables and their associate coefficients are given in the columns labeled "Variables" and "Coefficients." As indicated in the first column of Table 101, R^2 is .693, which suggests that 69.3% of the variation in average monthly electricity consumption is attributable to its relationship with this specific linear combination of explanatory variables, leaving 30.7% of the variation unexplained. In addition, the standard error, SE, is 169.40 kWh, which is another measure of the size of the remaining variation in average monthly utility consumption.[15] Ultimately, the value of SE could be substituted into an appropriate equation for computing the standard error of future values of average monthly electricity consumption (Y) given specific values of X_1–X_5, or for constructing confidence limits on predicted future values.

The sizes of the p-values (see the last column of Table 101) associated with each of X_1–X_5 in the above model confirm that all the explanatory variables are statistically significant (for each variable $p<.05$). Furthermore, the relative importance of the individual explanatory variables can be best evaluated by inspecting the standardized coefficients (fourth column in Table 101), which account for differences in the units or scales associated with all the explanatory variables.[16] In Table 101, the variable "Own two refrigerators" has the largest effect in the overall prediction of average monthly consumption because it has the largest standardized coefficient. The presence of a pool, a standalone freezer, and two refrigerators all tend to increase average monthly electricity consumption (since their coefficients and standardized coefficients are positive), whereas turning off lights and age of head of household have a dampening effect on average monthly electricity consumption. The directionality of the coefficients adheres to the expected patterns.

Table 105 shows additional details of the stepwise multiple regression modeling of average monthly electricity consumption (without a square footage adjustment for home size) for PV homes. The table illustrates the progressive improvement in R^2 and SE as individual terms are added to the model. The "Regression Mean Square" in the fourth column is an estimate of the variance in average monthly consumption explained by the model, whereas "Residual Mean Square" in the fifth column is an estimate of the variance remaining. The standard error, or SE, is the square root of this number. "Residual Degrees of Freedom" in the sixth column is the number

---

[15]In regression terminology, SE is the square root of the error mean square and is sometimes referred to as the "standard error of estimate." For a model that fits the data perfectly, SE=0.

[16]Standardized coefficients have values that range from +1 to -1.

of observations, n, minus the number of terms included in the model. In this particular case, n=33 (i.e., data were available on all the variables for only 33 of the 37 PV homes). For the sake of brevity, these additional details are omitted for all other models described in Tables 101–104. Further explanation of stepwise multiple regression results can be found in Draper and Smith (1998) or Kleinbaum, Kupper, and Muller (1988).

Note that the best model of average monthly electricity consumption for PV homes (Table 101) involves only two of the variables identified in Table 97. This further confirms that univariate correlation analysis is insufficient to characterize the variation in the data.

The models depicted in Tables 101–104 contain relatively few variables. However, it is not to be construed that the remaining variables have no effect. They do have an effect; but the effects are not statistically significant. Additional terms or variables could be added to these models in every case, and the R^2 value would increase by an incrementally small amount. However, there would be little or no improvement in predictive power. For the sake of simplicity and parsimony, such variables should be left out of the model.

Among all the models represented in Tables 101–104, those for average monthly electricity consumption shown in Table 101 have the highest values of R^2, as a group. The model of average monthly electricity consumption for PV homes has an R^2 value of .693; the model for 1.2 PV homes has an R^2 value of .731. The model of average monthly electricity consumption for comparison homes has an even higher R^2 value of .917. Hence, the models of PV, 1.2 PV, and comparison homes are all reasonably good. On the other hand, the model of average monthly electricity consumption for SEE homes has an R^2 value of .525, which is lower than desired. The reason for this lower R^2 value is not entirely understood. Data on some of the key variables may be missing, or additional variables that are key to explaining electricity consumption in SEE homes may be absent because they were beyond the scope of the study.

On the whole, the models for average monthly electricity consumption per square foot are not as good as the corresponding models of average monthly electricity consumption without the square footage adjustment, as indicated by their correspondingly lower values of R^2. The R^2 value associated with the model for PV homes is only .290, whereas the R^2 value for the corresponding model of average monthly electricity consumption without the square footage adjustment is .693. The R^2 value associated with the model of average monthly consumption per square foot for SEE is .493, whereas it is .525 for the corresponding model of average monthly electricity consumption without the square footage adjustment. On the other hand, the values of R^2 for the two models of electricity consumption with and without the square footage adjustment for comparison homes are .929 versus .917, respectively. The comparisons are not direct because the models of electricity consumption with and without the square footage adjustment involve different explanatory variables (see the further discussion on this issue below); however, the computational adjustment for home size clearly has a debilitating effect on modeling capability, except for comparison homes. The true effect of home size or square footage may be confounded with the effects of other factors that operate in tandem. Also, in the San Diego climate regime, and at the specific geographic location of the study homes, space conditioning may be less important to electricity consumption.

All the models that pertain to electricity consumption (Tables 101 and 102) involve six or fewer explanatory variables, and many encompass four or fewer. That more than 40 variables identified in Table 96 can be reduced to this relatively small subset for purposes of modeling average monthly electricity consumption is rather amazing.

Average monthly gas consumption is more difficult to model than average monthly electricity consumption, a conclusion that is again suggested by lower corresponding R^2 values. The value of R^2 associated with the models of average monthly gas consumption is less than .5 for all three categories of homes, both with and without the computational adjustment for home size; again, the home size adjustment has a debilitating effect on modeling capability, except for comparison homes. The R^2 values associated with the models of average monthly gas consumption, both with and without the square footage adjustment, are particularly low for SEE homes. Again, the reason for these lower R^2 values is not completely understood, although plausible explanations are the absences of data on some of the key explanatory variables, or the exclusion of additional variables because they were beyond the scope of the study.

Two overarching observations can be made about the modeling process and results that pertain to utility consumption. First, the best models of utility consumption (e.g., average monthly electricity consumption) for PV, SEE, and comparison homes encompass different sets of explanatory variables. This ultimate outcome was suggested by the results of the preliminary correlation analysis. Different variables apparently drive electricity and gas consumption for PV, SEE, and comparison homes/households.

Although this situation underscores the distinction between the three home categories relative to these important measures, it is somewhat awkward from an interpretive standpoint because it suggests that factors such as hot tubs that are known to contribute to higher utility consumption and cost are unimportant or missing in some scenarios. This seemingly contradictory situation is easily explained by the fact that, in this specific utility data set, there is an unequal number of homes in the three home categories with data on all variables of interest. For example, as noted in Chapter 20, the number of homes with various combinations of energy-intensive equipment is quite disparate across the three categories of homes, and some combinations are missing altogether (see, for example, Table S-1 in Appendix S). In addition, there are varying degrees of nonresponse associated with the variables linked to items taken from the homeowner survey. This is also the reason the “dummy variable” approach to regression cannot be effectively applied to these data, a situation that often arises in observational studies.[17]

Second, although suggested by the preliminary correlation analysis, it was not entirely known beforehand that the four different utility consumption measures—average monthly electricity consumption, average monthly electricity consumption per square foot, average monthly gas consumption, and average monthly gas consumption per square foot—cannot be modeled by the

---

[17]In investigations based on designed experiments or planned studies, the numbers of observations, or sample sizes, for various combinations of variables are more tightly controlled and can be more directly modeled with the “dummy variables” approach. In observational studies, the researcher usually has little control on the number of responses or data values per variable.

same set of explanatory variables. That is, different variables apparently drive gas and electricity consumption. In addition, the best set of descriptors for average monthly electricity consumption is somewhat different from the best set of descriptors for average monthly electricity consumption per square foot, and the best set of descriptors for average monthly gas consumption is somewhat different from the best set of explanatory variables for average monthly gas consumption per square foot. This finding again suggests that the home size adjustment on the basis of square footage is not a major explanatory variable for utility consumption. On the other hand, in the case of SEE homes, if average monthly electricity consumption is taken to be the response variable of interest rather than average monthly electricity consumption per square foot, and home size (square footage) is included as one of the prospective explanatory variables, it *is* determined to be statistically significant, a finding that is somewhat contradictory. Most likely, the effect of home size is confounded with other variables whose effects act in conjunction with one another. Even so, relative to comparison homes, the SEE homes (high performance homes without PV systems) appear to be somewhat unique with regard to utility consumption.

Table 101. Multiple Regression Models of Average Monthly Electricity Consumption for Three Categories of Homes (without Adjustment for Square Footage)

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.693 SE=169.40	Constant	741.85	109.68	–	6.76	<.001
	Own pool	322.40	86.66	.42	3.72	.001
	Turn off lights	−104.37	40.68	−.29	−2.57	.016
	Own two refrigerators	277.55	63.37	.50	4.38	<.001
	Own standalone freezer	466.58	120.24	.49	3.88	.001
	Age of head of household	−151.73	45.14	−.40	−3.36	.002
1.2 PV Homes n=29* R^2=.731 SE=151.91	Constant	553.85	104.49	–	5.30	<.001
	Own two refrigerators	310.40	61.12	.59	5.08	<.001
	Own pool	352.73	83.01	.51	4.25	<.001
	Own standalone freezer	399.49	98.48	.47	4.06	<.001
	Turn off computers	−72.59	21.22	−.41	−3.42	.002
	Gender of head of household	−146.19	66.02	−.26	−2.21	.037
SEE Homes n=37* R^2 =.525 SE=194.91	Constant	−120.46	392.90	–	−.31	.761
	Turn off computers	−103.42	25.10	−.51	−4.12	<.001
	Tend to be thrifty	−87.21	31.95	−.34	−2.73	.010
	Square footage of home	.30	.13	.28	2.34	.025
Comparison Homes n=21* R^2=.917 SE=111.96	Constant	961.51	107.82	–	8.92	<.001
	Own pool	525.82	53.38	.76	9.85	<.001
	Turn off computers	−129.75	18.51	−.61	−7.01	<.001
	Own two refrigerators	342.64	64.39	.47	5.32	<.001
	Turn off lights	−173.84	58.51	−.24	−2.97	.010
	Own dual-zone heating/air-conditioning system	−141.10	50.33	−.21	−2.80	.013

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 102. Multiple Regression Models of Average Monthly Electricity Consumption per Square Foot for Three Categories of Homes

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.290 SE=.081	Constant	.26	.05	–	4.76	<.001
	Own two refrigerators	.07	.03	−.37	2.38	.024
	Size of PV system	−.08	.04	−.35	−2.24	.033
1.2 PV Homes n=29* R^2=.218 SE=.079	Constant	.15	.02	–	7.73	<.001
	Own two refrigerators	.08	.03	.47	2.75	.011
SEE Homes n=37* R^2=.493 SE=.062	Constant	.26	.01	–	20.64	<.001
	Turn off computers	−.04	.01	−.55	−4.36	<.001
	Tend to be thrifty	−.03	.01	−.34	−2.68	.011
Comparison Homes n=21* R^2=.925 SE=.040	Constant	.43	.04	–	9.65	<.001
	Own pool	.18	.02	.71	9.32	<.001
	Turn off computers	−.05	.01	−.61	−6.90	<.001
	Own two refrigerators	.13	.02	.50	5.71	<.001
	Own dual-zone heating/air-conditioning system	−.08	.02	−.33	−4.32	.001
	Gender of head of household	−.06	.02	−.22	−2.87	.012
	Turn off lights	−.06	.02	−.21	−2.58	.022

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 103. Multiple Regression Models of Average Monthly Gas Consumption for Three Categories of Homes (without Adjustment for Square Footage)

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.434 SE=9.534	Constant	27.53	2.74	–	10.05	<.001
	In summer, set thermostat 75° or higher	−3.46	1.33	−.34	−2.40	.023
	Own two refrigerators	11.38	3.50	.47	3.25	.003
	Own standalone freezer	17.27	6.01	.42	2.87	.008
1.2 PV Homes n=29* R^2=.494 SE=9.234	Constant	21.46	2.66	–	8.08	<.001
	Own two refrigerators	13.24	3.64	.55	3.64	.001
	Own standalone freezer	21.04	5.96	.53	3.53	.002
	Own pool	9.87	4.62	.31	2.14	.042
SEE Homes n=37* R^2=.168 SE=10.116	Constant	33.79	1.76	–	119.19	<.001
	Own hot water flow regulator	14.126	5.36	.41	2.66	.012
Comparison Homes n=25* R^2=.387 SE=13.335	Constant	−25.25	21.35	–	−1.18	.250
	Household size	17.22	5.72	.50	3.01	.006
	Own pool	12.55	5.56	.38	2.26	.034

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 104. Multiple Regression Models of Average Monthly Gas Consumption per Square Foot for Three Categories of Homes

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.393 SE=.003	Constant	.009	.001	–	10.53	<.001
	In summer, set thermostat 75° or higher	−.001	<.001	−.37	−2.53	.017
	Own two refrigerators	.003	.001	.43	2.88	.007
	Own standalone freezer	.005	.002	.36	2.36	.025
1.2 PV Homes n=29* R^2=.445 SE=.003	Constant	.009	.001	–	9.24	<.001
	Own two refrigerators	.004	.001	.52	3.28	.003
	Own standalone freezer	.005	.002	.41	2.59	.016
	In summer, set thermostat to 75° or higher	−.001	<.001	−.33	−2.18	.039
SEE Homes n=43* R^2=.114 SE=.003	Constant	.011	.001	–	19.71	<.001
	Own hot water flow regulator	.003	.001	.34	2.30	.027
Comparison Homes n=25* R^2=.469 SE=.005	Constant	−.004	.008	–	−.52	.609
	Household size	.006	.002	.44	2.77	.012
	Own dual-zone heating/air-conditioning system	−.005	.002	−.41	−2.58	.017
	Own pool	.004	.002	.36	2.25	.035

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 105. Stepwise Multiple Regression Modeling of Average Monthly Electricity Consumption for PV Homes (without Adjustment for Square Footage), n=33

Model	R^2	Standard Error	Regression Mean Square	Residual Mean Square	Residual Degrees of Freedom	F	p-value
1[a]	.209	253.81	528780.32	64421.46	31	8.21	.007
2[b]	.347	234.52	437927.69	54999.67	30	7.96	.002
3[c]	.471	214.69	396386.41	46092.63	29	8.60	<.001
4[d]	.565	198.12	356708.79	39250.37	28	9.09	<.001
5[e]	.693	169.40	350205.79	28696.91	27	12.20	<.001

[1]Model 1: 477.44 + 353.05 (Own pool)
[2]Model 2: 659.77 + 412.54 (Own pool) – 134.35 (Turn off lights)
[3]Model 3: 576.78 + 369.71 (Own pool) – 130.94 (Turn off lights) + 199.49 (Own two refrigerators)
[4]Model 4: 474.00 + 378.23 (Own pool) – 95.22 (Turn off lights) + 249.40 (Own two refrigerators) + 323.70 (Own standalone freezer)
[5]Model 5: 741.85 + 322.40(Own pool) – 104.37 (Turn off lights) + 277.55 (Own two refrigerators) + 466.58 (Own standalone freezer) – 151.73 (Age of head of household)

Models of Utility Cost

In several senses, modeling utility cost is a more straightforward exercise than modeling utility consumption. Since consumption and cost closely track each other (see Figure 28), once a consumption model has been developed and the explanatory variables identified, that model can immediately be used as the starting point for identifying the most important explanatory variables in the corresponding cost model. Models for electricity and gas costs can also be more directly compared because the disparity in consumption units does not need to be rectified. Furthermore, utility cost models developed on the basis of combined monthly expenditures are somewhat more competent from a statistical standpoint, and the results are somewhat more interpretable. A primary reason for this is that, on a combined or overall cost basis, the differing amounts of electricity and gas consumption, translated into dollars, are pooled into a single number that masks some of the variability. For example, homes that use more gas than electricity are essentially indistinguishable from homes that use more electricity than gas because the total cost amount tends to obscure such distinctions and the associated variations.

Tables 105–109 contain the summary results of using stepwise multiple regression analysis to model average monthly electricity cost, with and without taxes and miscellaneous charges, and average monthly electricity cost *per square foot*, with and without taxes and miscellaneous charges, for PV, SEE, and comparison homes. Separate model results are also shown for 1.2 PV homes. As suggested in Chapter 20, homeowners are more likely to consider their utility bills to consist of total monthly utility costs including taxes and other charges, yet excluding these amounts may more accurately reflect the true costs of energy consumption.

Tables 110–113 report corresponding summary modeling results for average monthly gas cost, with and without taxes and miscellaneous charges, and average monthly gas cost *per square foot*, with and without taxes and miscellaneous charges. Finally, Tables 114–117 present the summary modeling results for average monthly combined utility bill, with and without taxes and miscellaneous charges, and average monthly combined utility bill *per square foot*, with and without taxes and miscellaneous charges for PV, 1.2 PV, SEE, and comparison homes. This last set of results pertaining to combined utility bill is of specific interest here. The modeling results for average monthly electricity and gas cost are included only for completeness and are not discussed further.

Except for SEE homes, the R^2 values associated with all the models reported in Tables 114–117 are moderately high. None of the models involves more than six explanatory variables, and many encompass four or fewer. These findings combined suggest that, except for SEE homes, modeling average monthly combined utility bill is fairly straightforward and the results are reasonably good. Again, the reasons for the poorer R^2 values associated with SEE homes are not completely known, although this finding closely mimics that for average monthly electricity and gas consumption in these homes.

Because of the strong relationship between average monthly consumption and average monthly cost observed in the figures presented in Appendix V, the modeling results for average monthly combined utility bill are expected to somewhat mimic those for average monthly electricity and gas consumption. Indeed, in Table 114, the R^2 values associated with models of average monthly combined utility bill (including taxes and miscellaneous charges) for PV, 1.2 PV, SEE, and comparison homes are close to the corresponding values reported in Table 101 for average monthly electricity consumption (but not for average monthly gas consumption). There is also a fairly high degree of correspondence between the variables that constitute the corresponding models.

The modeling results summarized in Table 115, which pertains to average monthly combined utility bill *excluding* taxes and miscellaneous charges, are almost the same as those shown in Table 114, which pertains to average combined monthly utility bill *including* taxes and miscellaneous charges. The corresponding R^2 values are extremely close; the only practical differences in the models found in the sizes of the coefficients are associated with the individual explanatory variables. Including or excluding taxes and miscellaneous charges apparently makes little or no difference to modeling capability.

Tables 116 and 117 present similar summary modeling results for average monthly combined utility bill *per square foot*, when taxes and miscellaneous charges are included and excluded, respectively. For PV and 1.2 PV homes, the R^2 values associated with the models of average monthly combined utility bill per square foot, with and without taxes and miscellaneous charges, are lower than those associated with the corresponding models of average monthly combined utility bill, with and without taxes and miscellaneous charges, computed without the square footage adjustment. The opposite is true for SEE and comparison homes. This finding once again suggests that, at least for PV homes, adjusting for home size has a deleterious effect on modeling capability. Also, the respective models of average monthly combined utility bill, with and without taxes and miscellaneous charges, comprise different variables than those of average monthly combined utility bill, with and without taxes and miscellaneous charges, computed on a square footage basis.

Further inspection of Tables 114–117 permits an assessment of the relative importance of individual explanatory variables to be made on the basis of the standardized coefficients. For PV homes, owning two refrigerators has the largest impact, followed closely by owning a standalone freezer. Both features lead to an increase in average monthly combined utility bill. For 1.2 PV homes, owning a pool has the largest impact, followed closely by owning two refrigerators. Both lead to an increase in average monthly combined utility bill. For SEE homes, turning off computers has the largest impact leading to a decrease in average monthly combined utility bill. Finally, for comparison homes, owning a pool has the largest impact, resulting in an overall increase in average monthly combined utility bill.

Two additional overarching observations can be made. To the extent that such models can be constructed, the identified explanatory variables largely make good physical and practical sense. None of the models represented in Tables 114–117 contain explanatory variables that are illogical or whose coefficients have signs that are opposite the anticipated direction. This was also the case for the models of average monthly electricity and gas consumption. Also, the best models of utility cost (e.g., average monthly combined utility bill) for PV, SEE, and comparison homes encompass different sets of explanatory variables. Different variables apparently drive electricity and gas costs for PV, SEE, and comparison homes or households. Again, this was also the case for average monthly electricity and gas consumption.

Table 106. Multiple Regression Models of Average Monthly Electricity Cost, Including Taxes and Miscellaneous Charges, for Three Categories of Homes

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.695 SE=$29.254	Constant	120.35	18.94	–	6.35	<.001
	Own pool	57.53	14.97	.43	3.84	.001
	Turn off lights	−19.23	7.03	−.31	−2.74	.011
	Own two refrigerators	47.82	10.94	.49	4.37	<.001
	Own standalone freezer	78.46	20.77	.47	3.88	.001
	Age of head of household	−24.75	7.80	−.38	−3.18	.004
1.2 PV Homes n=29* R^2=.718 SE=$27.500	Constant	75.64	13.47	–	5.61	<.001
	Own two refrigerators	51.50	11.23	.56	4.59	<.001
	Own pool	73.05	14.76	.60	4.95	<.001
	Turn off lights	−15.48	6.99	−.27	−2.21	.037
	Own standalone freezer	57.68	18.95	.38	3.04	.006
	Turn off computers	−0.01	3.85	−.29	−2.34	.028
SEE Homes n=37* R^2=.533 SE=$35.851	Constant	−52.59	72.27	–	−.73	.472
	Turn off computers	−19.04	4.61	−.50	−4.13	<.001
	Tend to be thrifty	−16.08	5.88	−.33	−2.74	.010
	Square footage of home	.06	.02	.31	2.57	.015
Comparison Homes n=21* R^2 =.944 SE=$17.306	Constant	187.80	18.93	–	0.02	<.001
	Own pool	97.40	8.27	.77	11.78	<.001
	Turn off computers	−23.79	2.95	−.62	−8.07	<.001
	Own two refrigerators	61.94	10.05	.47	6.16	<.001
	Turn off lights	−32.57	9.12	−.25	−3.57	.003
	Own dual-zone heating/air-conditioning system	−24.56	7.86	−.20	−3.13	.007
	Gender of head of household	−21.55	8.84	−.16	−2.44	.029

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 107. Multiple Regression Models of Average Electricity Cost, Excluding Taxes and Miscellaneous Charges, for Three Categories of Homes

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.695 SE=$26.836	Constant	109.95	13.77	–	6.33	<.001
	Own pool	52.56	13.73	.43	3.83	.001
	Turn off lights	−17.56	6.45	−.31	−2.73	.011
	Own two refrigerators	43.77	10.04	.49	4.36	<.001
	Own standalone freezer	72.10	19.05	.47	3.79	.001
	Age of head of household	−22.91	7.15	−.38	-3.20	.003
1.2 PV Homes n=29* R^2=.718 SE=$25.131	Constant	68.82	12.31	–	5.59	<.001
	Own two refrigerators	46.99	10.27	.55	4.58	<.001
	Own pool	66.71	13.49	.60	4.95	<.001
	Turn off lights	−14.16	6.39	−.27	−2.22	.037
	Own standalone freezer	52.62	17.32	.38	3.04	.006
	Turn off computers	−8.21	3.52	−.29	−2.34	.029
SEE Homes n=37* R^2=.527 SE=$33.075	Constant	−42.85	66.67	–	−.64	.525
	Turn off computers	−17.42	4.26	−.50	−4.09	<.001
	Tend to be thrifty	−14.84	5.42	−.34	−2.74	.010
	Square footage of home	.05	.02	.30	2.46	.019
Comparison Homes n=21* R^2=.948 SE=$15.233	Constant	171.72	16.66	–	10.31	<.001
	Own pool	87.29	7.28	.75	12.00	<.001
	Turn off computers	−22.84	2.59	−.65	−8.80	<.001
	Own two refrigerators	62.26	8.85	.52	7.04	<.001
	Gender of head of household	−22.19	7.78	−.18	−2.85	.013
	Turn off lights	−27.95	8.03	−.23	−3.48	.004
	Own dual-zone heating/air-conditioning system	−20.83	6.91	−.19	−3.01	.009

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 108. Multiple Regression Models of Average Monthly Electricity Cost per Square Foot, Including Taxes and Miscellaneous Charges, for Three Categories of Homes

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.602 SE=$0.011	Constant	.041	.007	–	5.74	<.001
	Own two refrigerators	.016	.004	.49	3.76	.001
	Own pool	.015	.006	.35	2.69	.012
	Own standalone freezer	.024	.008	.43	3.04	.005
	Age of head of household	−.009	.003	−.40	−2.95	.006
	Turn off lights	−.006	.003	−.30	−2.27	.031
1.2 PV Homes n=29* R2=.214 SE=$0.014	Constant	.024	.003	–	6.80	<.001
	Own two refrigerators	.014	.005	.46	2.71	.011
SEE Homes n=37* R^2=.486 SE=$0.012	Constant	.043	.002	–	18.34	<.001
	Turn off computers	−.006	.001	−.55	−4.32	<.001
	Tend to be thrifty	−.005	.002	−.33	−2.62	.013
Comparison Homes n=21* R^2=.531 SE=$0.016	Constant	.033	.004	–	7.82	<.001
	Own pool	.034	.007	.73	4.64	<.001

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 109. Multiple Regression Models of Average Monthly Electricity Cost per Square Foot, Excluding Taxes and Miscellaneous Charges, for Three Categories of Homes

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.602 SE=$0.010	Constant	.037	.007	–	5.72	<.001
	Own two refrigerators	.014	.004	.48	3.76	.001
	Own pool	.014	.005	.34	2.69	.012
	Own standalone freezer	.022	.007	.44	3.06	.005
	Age of head of household	−.008	.003	−.40	−2.98	.006
	Turn off lights	−.005	.002	−.30	−2.26	.032
1.2 PV Homes n=29* R^2=.214 SE=$0.013	Constant	.022	.003	–	6.77	<.001
	Own two refrigerators	.013	.005	.46	2.71	.011
SEE Homes n=.37* R^2=.485 SE=$0.011	Constant	−.039	.002	–	18.17	<.001
	Turn off computers	−.006	.001	−.54	−4.30	<.001
	Tend to be thrifty	−.005	.002	−.33	−2.63	.013
Comparison Homes n=21* R^2=.528 SE=$0.015	Constant	.031	.004	–	7.93	<.001
	Pool	.031	.007	.73	4.61	<.001

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 110. Multiple Regression Models of Average Monthly Gas Bill, Including Taxes and Miscellaneous Charges, for Three Categories of Homes

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.428 SE=$10.494	Constant	28.22	3.01	–	9.36	<.001
	In summer, set thermostat to 75° or higher	−3.82	1.58	−.34	−2.41	.022
	Own two refrigerators	12.24	3.85	.47	3.18	.003
	Own standalone freezer	18.73	6.62	.41	2.83	.008
1.2 PV Homes n=29* R^2=.492 SE=$10.150	Constant	21.48	2.92	–	7.35	<.001
	Own two refrigerators	14.24	4.00	.54	3.56	.002
	Own standalone freezer	22.92	6.55	.53	3.50	.002
	Own pool	11.34	5.08	.32	2.23	.035
SEE Homes n=37* R^2=.172 SE=$11.027	Constant	34.83	1.92	–	18.14	<.001
	Own hot water flow regulator	15.76	5.84	.42	2.70	.011
Comparison Homes n=25* R^2 =.391 SE=$14.847	Constant	−29.98	23.77	–	−1.26	.221
	Household size	18.75	6.37	.49	2.95	.007
	Own pool	14.86	6.19	.40	2.40	.025

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 111. Multiple Regression Models of Average Gas Utility Bill, Excluding Taxes and Miscellaneous Charges, for Three Categories of Homes

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.427 SE=$9.882	Constant	26.47	2.84	–	9.33	<.001
	In summer, set thermostat to 75° or higher	−3.60	1.49	−.34	-2.42	.022
	Own two refrigerators	11.52	3.62	.47	3.18	.004
	Own standalone freezer	17.61	6.23	.41	2.83	.008
1.2 PV Homes n=29* R^2=.492 SE=$9.556	Constant	20.12	2.75	–	7.32	<.001
	Own two refrigerators	13.40	3.77	.54	3.56	.002
	Own standalone freezer	21.57	6.16	.53	3.50	.002
	Own pool	10.71	4.78	.33	2.24	.034
SEE Homes n=37* R^2=.172 SE=$10.382	Constant	32.69	1.81	–	18.09	<.001
	Own hot water flow regulator	14.82	5.50	.42	2.70	.011
Comparison Homes n=25* R^2=.392 SE=$13.975	Constant	−28.38	22.37	–	−1.27	.218
	Household size	17.67	5.99	.49	2.95	.007
	Own pool	13.99	5.83	.40	2.40	.025

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 112. Multiple Regression Models of Average Monthly Gas Bill per Square Foot, Including Taxes and Miscellaneous Charges, for Three Categories of Homes

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.393 SE=$0.003	Constant	.010	.001	–	9.87	<.001
	In summer, set thermostat to 75° or higher	−.001	.001	−.37	-2.56	.016
	Own two refrigerators	.004	.001	.43	2.85	.008
	Own standalone freezer	.005	.002	.36	2.37	.025
1.2 PV Homes n=29* R^2=.443 SE=$0.003	Constant	.009	.001	–	8.61	<.001
	Own two refrigerators	.004	.001	.51	3.23	.003
	Own standalone freezer	.006	.002	.41	2.59	.016
	In summer, set thermostat to 75° or higher	−.001	.001	−.33	−2.21	.037
SEE Homes n=37* R^2=.126 SE=$0.004	Constant	.011	.001	–	17.91	<.001
	Own hot water flow regulator	.004	.002	.35	2.24	.031
Comparison Homes n=25* R^2=.472 SE=$0.005	Constant	−.005	.009	–	−.61	.546
	Household size	.006	.002	.43	2.70	.013
	Own dual-zone heating/air-conditioning system	−.006	.002	−.41	−2.58	.017
	Own pool	.005	.002	.38	2.38	.027

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 113. Multiple Regression Models of Average Monthly Gas Bill per Square Foot, Excluding Taxes and Miscellaneous Charges, for Three Categories of Homes

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.394 SE=$0.003	Constant	.009	.001	–	9.83	<.001
	In summer, set thermostat to 75° or higher	−.001	<.001	−.37	-2.56	.016
	Own two refrigerators	.003	.001	.43	2.85	.008
	Own standalone freezer	.005	.002	.36	2.36	.025
1.2 PV Homes n=29* R^2=.443 SE=$0.003	Constant	.008	.001	–	8.58	<.001
	Own two refrigerators	.004	.001	.51	3.23	.003
	Own standalone freezer	.005	.002	.41	2.59	.016
	In summer, set thermostat to 75° or higher	−.001	<.001	−.33	−2.21	.036
SEE Homes n=.37* R^2=.125 SE=$0.003	Constant	.001	.001	–	17.86	<.001
	Own hot water flow regulator	.004	.002	.35	2.24	.032
Comparison Homes n=25* R^2=.471 SE=$0.005	Constant	−.005	.008	–	−.62	.541
	Household size	.006	.002	.43	2.70	.013
	Own dual zone heating/air conditioning system	−.005	.002	−.41	−2.58	.018
	Own pool	.005	.002	.38	2.38	.027

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 114. Multiple Regression Models of Average Monthly Combined Utility Bill, Including Taxes and Miscellaneous Charges, for Three Categories of Homes

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.734 SE=$32.378	Constant	155.36	20.96	–	7.41	<.001
	Own pool	68.16	16.56	.43	4.12	<.001
	Turn off lights	−22.45	7.78	−.31	−2.89	.008
	Own two refrigerators	59.91	12.11	.52	4.95	<.001
	Own standalone freezer	100.94	22.98	.51	4.39	<.001
	Age of head of household	−28.85	8.63	−.37	−3.34	.002
1.2 PV Homes n=29* R^2=.761 SE=$30.284	Constant	102.33	14.84	–	6.90	<.001
	Own two refrigerators	64.88	12.37	.58	5.24	<.001
	Own standalone freezer	77.64	20.87	.43	3.72	.001
	Own pool	85.79	16.25	.59	5.28	<.001
	Turn off lights	−18.83	7.70	−.28	−2.45	.022
	Turn off computers	−9.04	4.24	−.24	−2.14	.044
SEE Homes n=37* R^2=.429 SE=$44.068	Constant	162.75	9.08	–	17.92	<.001
	Turn off computers	−24.57	5.53	−.58	−4.44	<.001
	Own hot water flow regulator	59.18	23.34	.33	2.54	.016
Comparison Homes n=21* R^2 =.849 SE=$32.004	Constant	−12.28	56.19	–	−.22	.830
	Own pool	122.24	15.14	.80	8.08	<.001
	Household size	51.85	14.85	.34	3.49	.003
	In winter, set thermostat to 70° or lower	−21.87	6.78	−.33	−3.23	.005
	Own dual-zone heating/air-conditioning system	−43.02	14.56	−.30	−2.96	.009

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 115. Multiple Regression Models of Average Monthly Combined Utility Bill, Excluding Taxes and Miscellaneous Charges, for Three Categories of Homes

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.734 SE=$29.831	Constant	142.82	19.32	–	7.39	<.001
	Own pool	62.61	15.26	.43	4.10	<.001
	Turn off lights	−20.60	7.16	−.31	−2.88	.008
	Own two refrigerators	55.15	11.16	.52	4.94	<.001
	Own standalone freezer	93.25	21.18	.51	4.40	<.001
	Age of head of household	−26.77	7.95	−.37	−3.37	.002
1.2 PV Homes n=29* R^2=.761 SE=$27.803	Constant	93.84	13.62	–	6.89	<.001
	Own two refrigerators	59.58	11.36	.58	5.25	<.001
	Own standalone freezer	71.40	19.16	.43	3.73	.001
	Own pool	78.74	14.92	.59	5.28	<.001
	Turn off lights	−17.32	7.07	−.28	−2.45	.022
	Turn off computers	−8.25	3.89	−.24	−2.12	.045
SEE Homes n=37* R^2=.430 SE=$40.462	Constant	149.01	8.34	-	17.87	<.001
	Turn off computers	−22.54	5.08	−.58	−4.44	<.001
	Own hot water flow regulator	54.85	21.43	−.33	2.56	.015
Comparison Homes n=21* R^2=.851 SE=$29.276	Constant	−18.60	51.40	–	−.36	.722
	Own pool	111.61	13.85	.79	8.06	<.001
	Household size	50.37	13.59	.36	3.71	.002
	In winter, set thermostat to 70° or lower	−21.30	6.20	−.35	−3.44	.003
	Own dual-zone heating/air-conditioning system	−38.73	13.32	−.29	−2.91	.010

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 116. Multiple Regression Models of Average Monthly Combined Utility Bill per Square Foot, Including Taxes and Miscellaneous Charges, for Three Categories of Homes

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes	Constant	.053	.008	–	6.60	<.001
n=33*	Own two refrigerators	.019	.005	.51	4.12	<.001
R^2=.636	Own standalone freezer	.030	.009	.46	3.41	.002
SE=$0.012	Age of head of household	−.010	.003	−.39	−3.01	.006
	Own pool	.018	.006	.35	2.87	.008
	Turn off lights	−.007	.003	−.30	−2.41	.023
1.2 PV Homes	Constant	.037	.006	–	6.01	<.001
n=29*	Own two refrigerators	.019	.005	.52	3.71	.001
R^2=.589	Own standalone freezer	.020	.009	.33	2.26	.033
SE=$0.013	Own pool	.020	.006	.43	.313	.005
	Turn off lights	−.007	.003	−.31	−2.21	.037
SEE Homes	Constant	.055	.003	–	20.73	<.001
n=37*	Turn off computers	−.007	.002	−.51	−4.01	<.001
R^2=.469 SE=$0.013	Tend to be thrifty	−.006	.002	−.35	−2.75	.009
Comparison Homes	Constant	.119	.015	–	8.19	<.001
	Own pool	.042	.006	.73	7.42	<.001
n=21* R^2=.865 SE=$0.012	Own dual-zone heating/air-conditioning system	−.027	.005	−.50	−5.04	<.001
	Educational level of head of household	−.008	.002	−.35	−3.59	.003
	Tend to be thrifty	−.009	.003	−.29	−2.96	.010
	Turn off lights	−.012	.006	−.21	−2.14	.049

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Table 117. Multiple Regression Models of Average Monthly Combined Utility Bill per Square Foot, Excluding Taxes and Miscellaneous Charges, for Three Categories of Homes

Home Category	Variable	Coefficient	Standard Error	Standardized Coefficient	t-statistic	p-value
PV Homes n=33* R^2=.637 SE=$0.011	Constant	.049	.007	–	6.60	<.001
	Own two refrigerators	.018	.004	.51	4.13	<.001
	Own standalone freezer	.028	.008	.47	3.443	.002
	Age of head of household	−.009	.003	−.39	−3.03	.005
	Own pool	.017	.006	.35	2.87	.008
	Turn off lights	−.007	.003	−.30	−2.41	.023
1.2 PV Homes n=29* R^2=.590 SE=$0.012	Constant	.034	.006	–	6.01	<.001
	Own two refrigerators	.017	.005	.52	3.72	.001
	Own standalone freezer	.018	.008	.33	2.27	.032
	Own pool	.019	.006	.43	3.14	.004
	Turn off lights	−.006	.003	−.31	−2.21	.037
SEE Homes n=.37* R^2=.468 SE=$0.012	Constant	−.050	.002	–	20.63	<.001
	Turn off computers	−.006	.002	−.51	−3.99	<.001
	Tend to be thrifty	−.006	.002	−.36	−2.77	.009
Comparison Homes n=21* R^2=.839 SE=$0.011	Constant	.097	.010	–	9.40	<.001
	Own pool	.041	.005	.79	7.67	<.001
	Own dual-zone heating/air-conditioning system	−.025	.005	−.51	−4.77	<.001
	Educational level of head of household	−.009	.002	−.41	−3.92	.001
	In winter, set thermostat to 70° or lower	−.007	.002	−.31	−2.91	.010

*Not all homes/households have values for all variables, so the number of cases encompassed by the analysis is reduced. R^2 is the coefficient of determination, or multiple correlation coefficient. SE is the standard error.

Summary and Discussion

This investigation illustrates that statistical models of utility consumption and costs can be constructed for several types of homes that consist of relatively few input variables and have reasonably good explanatory power. As might be expected, most of the models reported here are dominated by variables that represent various energy-intensive equipment, but others tend to represent homeowner demographics, opinions, attitudes, and behaviors associated with energy conservation. In particular, the models of utility consumption and cost associated with SEE homes often include more attitudinal and behavioral inputs than equipment-oriented inputs.

Each section of Tables 101–104 and Tables 106–117 provides the information necessary to write the equation for the respective model, along with the associated goodness-of-fit statistics, for the utility consumption or cost measure in question. The tables contain different models for PV, SEE, and comparison homes. The tables also provide modeling results specifically for homes with 1.2-kW PV systems so distinctions can be made that involve this specific size of PV system (models for PV homes with 2.4-kW systems cannot be developed because of the small number of cases). Each model presented has the largest R^2 that can be obtained using the original collection of prospective explanatory variables listed Table 96, with the caveat that some variables were ultimately omitted from some models because they seemed inappropriate for predicting the quantity of interest or their coefficients were presumed to be in the wrong direction (e.g., ceiling fans lead to an increase in gas consumption). Other terms could be added to every model reported here, but the usefulness and practicality of such terms would be highly suspect.

The explanatory variables encompassed by these models as the “best” ones do not necessarily correspond to those with the highest individual correlations indicated in Tables 97–100, and the variables with the highest correlations in Tables 97–100 do not necessarily have the largest effects in the corresponding models, if, in fact, they appear at all. This result is not surprising, since intercorrelations among variables are to be expected. Clearly, variables that indicate the presence of energy-intensive equipment seem most important across all models.

Regardless of which measure of utility consumption or cost is designated as the response variable, there are notable differences in the models developed for PV, SEE, and comparison homes. There is some, but not extensive, overlap among the sets of explanatory variables for PV, SEE, and comparison homes for either utility consumption or cost.

With regard to electricity consumption, the models associated with PV and comparison homes are moderately good to very good (R^2 values are approximately .7 or higher). The models associated with SEE homes are poorer quality (they have the lowest corresponding values of R^2, on the order of about .5), which suggests that electricity consumption is most difficult to explain for these homes. As noted earlier, this result may be due to inequities in the numbers of responses and data values for individual variables or to the absence of important variables that were beyond the scope of the study. Increased variability in average monthly electricity consumption for SEE homes is not the issue, as indicated by the comparative coefficients of variation shown in the tables of Appendix W.

The models of gas consumption are generally of poorer quality (considerably lower R^2 values and higher SE values on a comparative basis) than the corresponding models of electricity consumption. Average monthly gas consumption apparently cannot be modeled as well as average monthly electricity consumption with the variables identified in Table 96, which suggests that other inputs may be more important. Again, as indicated by the comparative coefficients of variation shown in the tables of Appendix W, average monthly gas consumption is not more variable than average monthly electricity consumption.

These differences among models of electricity and gas consumption for PV, SEE, and comparison homes are mirrored in those for cost. The same patterns of differences among models are present when cost is stated in terms of average monthly combined utility bill. The models of average monthly combined utility bill for PV and comparison homes are fairly good (in terms of R^2 and SE); the models for SEE homes are of poorer quality.

All models of electricity and gas consumption and cost for 1.2 PV homes, as well as those for costs stated in terms of average monthly combined utility bill, are better (higher R^2 and lower SE) than the corresponding models for all PV homes combined. This result is not unexpected because there are substantially fewer 2.4 PV homes in the data set, and the 2.4 PV homes have lower, but more variable, average electricity consumption and cost (see Table W-1 in Appendix W).

The effect of home size on utility cost and consumption is somewhat enigmatic. At the outset of the study, home size, expressed in terms of square footage, was thought to be an important explanatory variable. However, as the results of this modeling work demonstrate, home size is probably not that important, in and of itself; at least not in this set of homes. The impact of home size is likely confounded with one or more additional factors that act sequentially or in parallel to affect utility consumption and cost.

The models reported here are really best used as mathematical expressions with which to portray overall relationships. However, such expressions are not very interesting or practical in and of themselves. The ultimate objective would be to use them to *predict* or *forecast* utility consumption and costs in future home construction. For planning and decision-making purposes, such predictions would be highly useful to builders and new homebuyers. The idea is to substitute into the model equations values of the model inputs associated with prospective homeowners and compute an estimate of utility consumption or cost.

For example, suppose it is proposed to use the best-fit model of average monthly electricity consumption for PV homes to estimate average monthly electricity consumption for a prospective buyer of a new PV home. This model, as previously noted, is given in Table 101 by:

$Y = 741.85 + 322.40X_1 - 104.37X_2 + 277.55X_3 + 466.58X_4 - 151.73X_5 + e$, where

X_1=Own pool
X_2=Turn off lights when away
X_3=Own two refrigerators
X_4=Own standalone freezer
X_5=Age of head of household
e= unexplained remainder (error)

To obtain the requisite prediction, the prospective buyer has to report his/her age as the head of household, state whether or not he/she intends to own a pool, two refrigerators, and a standalone freezer, and indicate his/her level of agreement with a question or survey item about turning off lights.

Though fairly straightforward, this approach can be problematic because the equations encompass input variables for which values may not be readily obtained from prospective homeowners. As noted earlier, factual records and physical measurements, like gender, number of home occupants, and home square footage, can be fairly easily collected. Measurements and responses that represent opinions, attitudes, beliefs, behavioral intentions, and perceptions are somewhat more difficult to procure or replicate, and they can often only be acquired via surveys or focus groups. For more complex models, obtaining the necessary inputs to the equation from all prospective homebuyers—particularly those related to beliefs, opinions, and intended behaviors–may present difficulties.

A related concern has to do with the consistency and compatibility of the input data. The models reported here are developed from a fairly static data set; some of the variables represent homeowner responses to cross-sectional survey questions that were administered at a fixed point in time. Prospective homeowners outside the original survey set would not necessarily have the same conditions and circumstances as those encompassed by this study, nor would they necessarily be expected to respond in the same way. Consequently, caution would need to be exercised to avoid inappropriate extrapolation beyond the range and applicability of the original data.

Models would be better, and more direct, if equations like those reported here could be constructed solely from factual or physical measurements that are easily obtained or replicated. Unfortunately, this seems impossible to do and still obtain high goodness-of-fit. The implication is that utility consumption and cost cannot be adequately modeled or predicted simply on the basis of factual or physical measurements. Homeowner beliefs, attitudes, and perceptions clearly affect utility consumption and cost in tangible (e.g., a purchase decision involving energy-efficient appliances) and intangible ways (such as changes in daily energy behavior), and including such variables is required to develop reliable models with acceptable predictive power. In addition, these models would be applicable only in the climates with the same heating and cooling degree days that San Diego has.

With these caveats in mind, the models of utility consumption and cost reported here for PV and comparison homes clearly can be used to provide reasonably good estimates for future homes of these types. At the very least, they can be used to develop general guidelines and trends for prospective builders and homebuyers. On the other hand, the models associated with SEE homes are really not optimum and probably should not be used for predictive purposes. Their low R^2 values suggest that the resulting predictions would not be very reliable.

Clearly, the ability to derive good models of utility consumption and cost (in the sense of goodness-of-fit) is largely data driven. The end results of all modeling exercises are only as good or as adequate as the available data. Data quality encompasses both the amount of information, in terms of numbers of observations and measurements, and the accuracy or representativeness of the measurements. Identification of all relevant variables, and availability of data on all such variables, are also key. With a larger set of households and an even higher response rate to pertinent homeowner questionnaires,[18] the modeling approaches and strategies described here would probably yield even stronger results in future studies. The ultimate goal would be to develop a straightforward prediction scheme, such as a simple nomograph, to use in estimating utility consumption and cost for prospective homebuyers. Such a device would be particularly helpful in familiarizing prospective buyers of PV homes with the ultimate savings attributable to PV systems as they consider the up-front costs of including such equipment in their new home purchases.

In future work, a number of other analytical approaches could be pursued to further evaluate the model quality. One such approach that might yield valuable insights is to investigate plots of model residuals to determine if any explainable patterns can be detected. Investigation of patterns in the residuals often leads to the identification of other effects that the model does not already address. However, such investigations can be time consuming, particularly when numerous models are involved. In addition, results from the analyses of other utility data sets might be combined to help improve overall model results.

[18]The total number of respondents who agreed to allow their utility data to be obtained was substantially smaller than the total number of study respondents. Also, the performance of multiple regression is sensitive to missing values that often result from item nonresponse. Item nonresponse is the situation in which a respondent selectively responds to survey questions, completing some and omitting others. When using multiple regression, if the response or value for only a single item in a set of items is missing, the entire case is deleted from the analysis.

Chapter 22
Perceived and Actual Utility Bills

Introduction

A key facet of this study involves homeowners' perceptions of their utility bills compared to the actual amounts. This chapter describes important findings about this relationship.

As noted previously, utility data were obtained from SDG&E for 132 study households whose respondents signed a utility release form (URL). In the discussion which follows, data from all these homes are included. Although the homes had received utility service for varying numbers of months, data from every month of service for every home were utilized (except as noted below).[1] The rationale for this approach is that, when asked to estimate their average utility bills, most homeowners, including those surveyed for this study, likely conceptualize a number that encompasses the entire time they have resided in the home, automatically factoring in the variations experienced across months and seasons. Hence, using the actual utility data for the entire period of occupancy is thought to yield amounts that are most comparable to those perceived and estimated by the respondents.

Chapter Highlights

- All homeowners in the study tend to significantly overestimate their actual average monthly utility bills.
- SheaHomes respondents estimate monthly utility bills ranging from $50 to $475, with a mean monthly estimate of $143.
- Comparison respondents estimate monthly utility bills ranging from $4 to $540, with a mean monthly estimate of $184.55.
- PV owners estimate monthly utility bills ranging from $11 to $475, with a mean estimate of $116.
- PV owners estimate significantly lower monthly utility bills than do non-PV owners.
- Comparison of estimated utility bills of non-PV owners and comparison owners result in no significant differences.
- PV owners are more likely to accurately estimate their utility bills than are comparison respondents, who have the least accurate, and highest overestimates, of their utility bills.

To obtain the most direct and reliable comparison possible, it would be necessary to control for the influence of perceptions about utility bills and home size at the respondents' previous residences. Consequently, all respondents were asked to estimate the utility bills and square footage at their previous homes, as well. Fortunately, no significant differences emerged on these variables for households in the SheaHomes and comparison communities, nor for households with and without PV systems in the SheaHomes communities. This finding is important because, on average, homes in the SheaHomes communities are larger than those in the comparison community.

---

[1]By way of comparison, in Chapter 19 (Comparative Analysis of Utility Consumption and Cost), which more specifically addresses actual utility consumption and cost, only data from the period July 2003–June 2004 are used to establish a consistent time frame for comparison. Homes without a full 12 months of service were omitted from the analysis, along with homes determined to be outliers with regard to electricity or gas consumption. The utility data from the homeowners were included here.

Methodology for Computing Actual Average Monthly Utility Bills

To accurately compute the actual average monthly utility bill for each home, additional length-of-service issues had to be addressed. Specifically, it was determined that the number of days per monthly billing cycle varied. Since some households began service in the middle of a month, the number of days in the first billing month was particularly variable, so, for consistency purposes, all records in the data set were omitted for which the number of days per billing cycle was fewer than 28. After applying this filter, the average number of days per billing cycle across all households and billing months was calculated to be 30.5 (also see the discussion in Chapter 20, Comparative Analysis of Utility Consumption and Cost). The individual monthly records for each household were then collated to compute monthly averages (accounting for the differing days per billing cycle and differing months of service) for electricity and gas cost, and for combined utility cost, and these values (weighted averages) were subsequently merged with the survey responses of the respective households.

Prior Utility Bills and Sizes of Homes

Respondents were asked "Approximately what was your household's average total monthly utility bills at your prior residence?" Respondents' answers were reported in dollars per month for a residence of specific size (in square feet). The mean estimated combined monthly utility cost for all responding households was $271.48, with a range of $25 to $300 per month. The mean square footage was 1,786.4, with a range of 1,000 to 4,850 square feet.

SheaHomes owners estimated lower utility bills at their prior residences (mean=$246.09) than did comparison homeowners (mean=$353.63); the difference approaches statistical significance ($t=-1.892$; $p=.062$). The reason for this difference is not altogether clear. The difference in estimated mean square footage for the prior residences between SheaHomes owners (mean=1,814.16 square feet) and comparison homeowners (mean=1,728.94 square feet) is not statistically significant, so the significantly lower average utility bills reported for previous residences by SheaHomes owners is not likely due to home size. Further, there is no significant difference in estimated mean monthly utility bills for prior residences, nor in estimated mean square footage of prior residences, when households in the SheaHomes communities with and without PV systems are compared.

Reported Utility Bills

Because they are billed separately for electricity and natural gas, respondents in SheaHomes communities with PV systems were asked: "Approximately what is your household's average monthly electricity bill now?" and "Approximately what is your household's average monthly natural gas bill now?" Other SheaHomes comparison respondents were asked to state their household's "average monthly utility bill now." These questions result in self-reported data representing point-in-time perceptions of the homeowners and may not accurately reflect actual monthly amounts. Table 118 summarizes these results.

Table 118. Estimates of Monthly Utility Bills Reported by Respondents by Household Category

Household Category	Mean	Standard Deviation
All SheaHomes (n=143)	$143.08	$84.32
SheaHomes with PV systems (n=55)	$116.44	$77.74
SheaHomes without PV systems (n=88)	$159.73	$84.40
Comparison homes (n=44)	$184.55	$100.68

Table 118 shows that the SheaHomes respondents report significantly lower average monthly utility bills than respondents from the comparison community, and that the amounts are less variable. The mean of the average monthly utility bills (gas and electricity combined) reported by SheaHomes respondents is $143.08 with a standard deviation of $84.32 (range of $50 to $475), and the mean of the average monthly utility bills reported by respondents from the comparison community is $184.55 with standard deviation of $100.68 (range of $55 to $540). The difference in the two mean values is statistically significant ($t = -2.721$; $p = .007$). The standard deviation in reported amounts for both groups is quite high. The coefficient of variation of average monthly utility bills reported by SheaHomes respondents is 59%, and the corresponding coefficient of variation of average monthly utility bills reported by respondents from the comparison community is 55%.

If PV owners are omitted from the SheaHomes respondent pool, the results are somewhat different. The mean of the average monthly utility bills reported by the remaining SheaHomes respondents is $159.73 with a standard deviation of $84.40 (range of $50 to $450). The difference in mean values associated with the restricted pool of SheaHomes respondents and the respondents from the comparison community is not statistically significant ($t = -1.492$; $p = .138$). This result suggests that PV systems may have a marked impact on the perceived lowering of average monthly utility bills in these types of homes.

The mean reported monthly gas bill for SheaHomes respondents who are PV owners is $41.30 (range of $6 to $125) and the mean monthly electricity bill is $80.54 (range of $5 to $350). The mean total utility bill (gas and electricity combined) for SheaHomes respondents who are PV owners is $116.44 (range of $11 to $475).[2] When subjected to a t-test, the mean reported monthly utility bill is significantly lower for owners of homes with PV systems than for owners of homes without PV systems in the SheaHomes communities ($t = -3.075$; $p = .003$).

The broad range of reported utility bill values may be the result of differences in respondent perceptions or actual household energy usage attributable to differences in household composition, energy usage behaviors, or appliance installations. It is possible, although unlikely, that a few of the PV systems are not functioning properly or at all.

[2] The mean overall utility bill is not identical to the sum of the mean electricity and mean gas bills because the denominator is different in each case due to missing data in one or the other of the variables.

Table 119 summarizes the percentages of responses with respect to three intervals of average monthly utility cost reported by homeowners from the SheaHomes communities and the comparison community. The three intervals are (1) less than \$100 a month, (2) \$100 to \$199 a month, and (3) greater than or equal to \$200 a month. The percentage of SheaHomes respondents (27%) reporting average monthly utility bills in the lowest cost interval (less than \$100) is more than double the percentage of respondents from the comparison community (13%) who report having average monthly utility bills this low. The difference in percentages among the three intervals for SheaHomes respondents and respondents from the comparison community approaches statistical significance ($\chi 2=5.878$; p=.053).

Table 119. Comparison of the Percentage Distributions of Average Monthly Utility Bills Reported by Homeowners in the SheaHomes and Comparison Communities

Monthly Utility Cost Interval	Percentages of Homeowners in the SheaHomes Communities (n=177)	Percentages of Homeowners in the Comparison Community (n=54)
< \$100 a month	27%	13%
\$100-\$199 a month	37%	35%
≥\$200 a month	36%	52%
Totals	100%	100%

Again, if the PV owners are omitted from the SheaHomes respondent pool, the distribution of percentages among the three intervals for the two respondent groups is not statistically significant ($\chi 2=2.53$; p=.282). However, a higher percentage of SheaHomes respondents report average monthly utility bills in the lowest cost interval than respondents from the comparison community (Table 120); and, as was discussed in Chapter 10 (Homebuyer Satisfaction with the Purchased Home), SheaHomes respondents perceive their homes to be more energy efficient than do respondents from the comparison community.

Clearly, within the SheaHomes communities, owners of homes with PV systems report significantly lower overall monthly utility bills than do owners of homes without PV systems. Table 121 summarizes the percentages of responses with the three intervals of reported average monthly utility cost by PV system owners and non-PV system owners within the SheaHomes communities. The distribution of percentages among the three intervals for the two respondent groups is statistically significant ($\chi 2=7.548$; p=.023).

Table 120. Comparison of the Percentage Distributions of Average Monthly Utility Bills Reported by the Homeowners in the SheaHomes and Comparison Communities (PV Owners Omitted)

Monthly Utility Cost Interval	Percentages of Homeowners in the SheaHomes Communities (n=105)	Percentages of Homeowners in the Comparison Community (n=54)
< $100 a month	19%	13%
$100–$199 a month	42%	35%
≥$200 a month	39%	52%
Totals	100%	100%

Table 121. Comparison of the Percentage Distributions of Average Monthly Utility Bills Reported by Homeowners in the SheaHomes Communities with and without PV Systems

Monthly Utility Cost Interval	Percentages of Homeowners with PV Systems (n=72)	Percentages of Homeowners without PV Systems (n=105)
< $100 a month	38%	19%
$100–$199 a month	31%	42%
≥ $200 a month	32%	39%
Totals	101%*	100%

*Percentage does not add to 100 because of rounding

Relationship between Perceived and Actual Utility Bills

Most homeowners tend to overestimate the size of their combined monthly utility bills compared with the actual amounts obtained from SDG&E. As shown in Table 122, the average combined monthly utility bill reported by 81 homeowners in the SheaHomes communities was $165.44, and the average actual bill for these same households was only $139.11—a difference of $26.33. Based on a paired t-test, the size of the difference is statistically significant (t=5.680; p<.0001).

The corresponding differences in average reported and actual combined monthly utility bills for households in SheaHomes communities with PV systems and those without are both statistically significant, though the overestimation for households with PV systems is slightly less than half as much ($13.01 versus $34.65). Further, 41 owners of homes in SheaHomes communities designated as main reported an average combined monthly utility bill of $190.88 compared to the average actual amount of $157.95—a statistically significant difference of $32.93—whereas six owners of homes designated as ineligible reported an average combined monthly utility of $136.05 versus an average actual amount of $133.38—a difference of only $2.67 that is not statistically significant. The difference for three homes designated as early is much larger, but is not statistically significant.

Table 122. Comparison of Reported Combined Monthly Utility Bills with Actual Monthly Utility Bills by Categories of Households*

Household Category	n	Mean** Reported Monthly Utility Bill	Mean*** Actual Avg. Monthly Utility Bill	Difference	t-test Results****
All households	110	$177.13	$145.65	$31.48	t=5.946; p<.0001
All SheaHomes households	84	$165.44	$139.11	$26.33	t=5.680; p<.0001
PV households	34	$118.55	$105.54	$13.01	t=2.294; p=.029
Non-PV households	50	$194.73	$160.08	$34.65	t=5.358; p<.0001
Ineligible households	6	$136.05	$133.38	$2.67	t=.311; p=.768
Early households	3	$283.67	$204.15	$79.52	t=1.774; p=.218
Main households	41	$190.88	$157.95	$32.93	t=5.075; p<.0001
Comparison households	26	$210.01	$164.03	$45.98	t=2.885; p=.008

*Only households for which there is both a reported (estimated) combined monthly utility bill and an average actual combined monthly utility bill obtained from SDG&E; therefore, the number of households in each category is different in this table than in the previous tables in this chapter
**To facilitate comparison to the mean average monthly utility cost, this is a weighted mean to account for the different number of months of occupancy (partial months excluded). For this reason, as well as the smaller numbers of households, these values are not identical with those reported in Table 118
***The average monthly utility cost for each household is weighted to account for the different numbers of days per service month, and then a weighted mean of these averages for all households is computed to account for the different number of months of occupancy (partial months excluded)
****A weighted paired t-test

Finally, homeowners in 26 comparison households reported an average combined utility bill of $210.01 versus an actual amount of $164.03, for a statistically significant difference of $45.98. Interestingly, except for the three homes in the SheaHomes communities designated as early, the overestimation was highest for homeowners in the comparison community.

Therefore, the ownership of a home with a PV system appears to contribute to less of an overestimation of monthly household utility costs—that is, to a more accurate perception of actual utility costs—than other SheaHomes and comparison home owners have. The least accurate, most overestimated perceptions of utility bills are those of comparison homeowners.

Summary

As anticipated, the respondents' estimates of their current utility bills are highly variable. On average, SheaHomes respondents report significantly lower utility bills than do respondents from the comparison community. However, when homeowners with PV systems are omitted from the analysis, the difference in reported average monthly utility bills between the remainder of the

SheaHomes owners and owners of comparison homes is not statistically significant. Owners of homes with PV systems report significantly lower monthly utility bills, on average, than do owners of SheaHomes without PV systems.

When weighted data are considered, although SheaHomes respondents estimate, on average, their monthly utility bills as $165.44, their actual average monthly utility bills are $139.11. Although comparison respondents, on average, estimate their monthly utility bills as $210.01, their actual average monthly utility bills are $164.03. Although PV owners, on average, estimate their monthly utility bills as $118.55, their actual average monthly utility bills are $105.54.

Comparisons between perceived and actual utility bills show that all homeowners in the study tend to overestimate their actual average monthly utility bills to an extent that is statistically significant. However, ownership of a home with a PV system is associated with a closer-to-accurate perception of actual utility costs than for the other homeowner categories. Homeowners in the comparison community have the least accurate, or highest overestimates, of average monthly utility bills.

Chapter 23
Findings, Conclusions, and Discussion

Introduction

This study was a natural field experiment. It was an empirical and statistical approach to the data and did not involve engineering or economic analysis. The research situation resulting in the findings in this report is unique. We were able to work closely with the SheaHomes staff, and to locate a comparison community adjacent to the high-performance homes that matched the San Angelo and Tiempo homes well. Before the research began, there was a good deal of media attention to and public interest in the high-performance homes project. Even though the SheaHomes owners were fatigued by contacts from reporters and other researchers, they were generous with their time in granting lengthy qualitative interviews and in completing complex questionnaires. The comparison homebuyers were almost equally cooperative and generous with their time. SDG&E staff were also patient and helpful in providing utility data and background information on questions related to utility billing, interconnectivity issues, and net metering. Research at other sites might not be conducted in such an ideal situation.

Because the study's findings are highlighted and summarized in the executive summary and in each chapter, this chapter will not focus on them. Instead, this chapter emphasizes discussion of the meanings and implications of the findings. Offering conclusions on such a substantial study is a daunting task; thus, not every possible conclusion is included here. The focus is on the most important implications that we believe should be highlighted.

The conclusions are discussed in several sections covering topics as follows: who the homebuyers are, their reasons for purchase, and their satisfaction with their homes; PV owners' characteristics, decision-making, satisfaction, information levels, and perceived benefits of PV ownership; aspects of utility consumption and cost including the delivery of high-performance homes on their promise of saving energy costs, the interactive effect between technology and behavior, and modeling utility consumption and cost; and the business aspects of high-performance homes, including their cost relative to other homes, the benefits and costs to the builder, the role of the builder staff, the SheaHomes discontinuance decision, and the value of resold high-performance homes.

Who Are These Homebuyers?

SheaHomes and comparison homebuyers are very much the same. They comprise a homogeneous population of new homebuyers looking for upscale homes in north San Diego. The similarities between these groups as they went through their home search process far outweigh any differences detected. The two categories of homebuyers are similar in their reasons to purchase, designation of energy as a low priority reason for purchase, satisfaction with the sales staff, and satisfaction with their homes' comfort. Respondents are male and female heads-of-household, although 56% are male. They are original owners of the new homes and 90% had previously owned homes. Three-quarters of the respondents are between 25 and 50 years of age, and two-thirds have families. They are highly educated with professional, business, and scientific occupations. A significantly higher percentage of SheaHomes owners than comparison owners have annual incomes that exceed $200,000.

Most of the buyers in the study came from San Diego, so they were already aware of the desirability of the Scripps Highlands location before the developments began. Majorities of the buyers became aware of the developments as they drove through the area. Word-of-mouth was the second most common source of information in learning about the new homes. There was so much interest that SheaHomes held a lottery to give potential buyers a place in line to select their lots and floor plans.

Environmentalism

Although environmentalism and early adopter characteristics are often associated with purchase of innovative "green" products, and high-performance homes could be seen as both innovative and protective of the environment, apparently these motivations do not distinguish the purchasers of high-performance homes from other new homebuyers. Indeed, support for environmental protection is so widespread in the population that we would be unlikely to discern differences among the categories of homebuyers at Scripps Highlands. The one difference found among the environmental variables is that SheaHomes purchasers significantly more frequently link household energy consumption with environmental problems than do comparison home purchasers. As noted, other home features are far more influential in home purchase decisions than are energy and environmental characteristics.

Surprisingly, respondents under 40 years of age exhibit lower support for the environment (and may even be characterized as anti-environmental in their attitudes), whereas those 40–49 years of age are more supportive toward the environment. Those 50+ in age are the most environmentally supportive. A significantly higher percentage of homeowners more than 40 years of age than of younger homeowners indicate they would take actions to preserve and improve the environment; the reason for this is not that older homeowners have higher incomes and could therefore be more financially able to purchase environmental products because statistical tests show that annual income does not vary by age category. So that is not the explanation. Instead, it could be that younger homebuyers are busier raising children and may expect sustainable attributes to be built into their homes

The Purchase Decision Process

Importance of Reasons for Purchase and Home Features in Purchase Decision

When considering 24 important reasons for purchase, responses are virtually identical between the SheaHomes and comparison homeowners. Only two reasons elicit a significantly different response. Comparison respondents rated the desirability of the area as more important to them, and SheaHomes buyers rated reputation of the builder as more important to them. Energy was not a very important factor in the purchase decision for most of these new homebuyers. Concern for the electricity crisis in San Diego was also not an important factor.

When considering 15 home features, almost all were important to the purchase decision of the SheaHomes and comparison buyers. SheaHomes buyers assign higher importance ratings to quality of construction, availability of a three-car garage, and granite counter tops as standard than comparison buyers. Because SheaHomes prides itself on the quality of its homes' construction and positions its homes in the market based on quality, the company's marketing message about quality has apparently reached the home buying market.

From the study's qualitative data, we know that the aesthetics of solar features are not considered problematic by the SheaHomes buyers. However, those who might have been concerned about aesthetics probably would not have purchased the high-performance homes and their views would not be represented in this study.

Barriers to PV Purchase

If PV systems are offered optionally, the most important barriers to the purchase of optional PV systems are that potential buyers perceive the systems as too expensive and that payback would be too long. Main homebuyers who chose not to purchase homes with PV systems also indicate concerns about maintenance and system reliability.

Homebuyer Information Sources

The sales staff of both builder companies provided information on the homes, and the majority of buyers are satisfied with the job the sales staff did. The SheaHomes sales staff was the source of information on the energy features of high-performance homes, and SheaHomes buyers were, on the whole, satisfied with the job they did. The staff was also the single most important source of information on PV systems; 61% of PV owners relied on them for PV information. Other sources, used by far fewer PV homebuyers, include AstroPower, Inc., word-of-mouth, and SDG&E.

Satisfaction

Both categories of homeowners are quite satisfied with their new homes in general, as expected. A significantly higher percentage of SheaHomes owners than of owners of comparison homes (77% versus 67%) indicate they would buy the same house over again. Both categories of homeowners are satisfied with their homes' investment potential, location, size, and layout. A significantly higher percentage of SheaHomes owners than owners of comparison homes is satisfied with lot size, builder reputation, storage space, and quality of construction.

The evidence suggests that SheaHomes owners are more satisfied with their homes than the comparison owners are with theirs. Although this would not be the only factor affecting satisfaction, the comparison homeowners report significantly higher average monthly utility bills than do the SheaHomes owners. Whereas both categories of homeowners find their homes to be comfortable, comparison buyers pay significantly higher utility costs to maintain their comfort levels than do SheaHomes buyers. The homeowners appear to perceive differences in their utility costs: SheaHomes buyers give their homes significantly higher ratings on energy efficiency (a mean score of 7.35 on a 10-point scale) than do comparison buyers (a mean score of 6.31).

After their experiences in living in their new homes, SheaHomes owners, and especially PV owners, indicate they are significantly more knowledgeable about savings on utility bills, tax credits, rebates, interconnectivity issues, and system performance than they were before they moved in.

We believe the findings from the utility analysis (discussed in this conclusions chapter) are directly related to homeowner satisfaction. In response to the homeowner questionnaires, 52% of respondents from SheaHomes with PV systems agree or strongly agree that they are satisfied with the savings on their utility bills, whereas 16% disagree or strongly disagree and 32% are unsure. Of the SheaHomes respondents without PV systems, only 28% agree or strongly agree that they are satisfied, while 25% disagree or strongly disagree and 47% are unsure. Clearly, a higher percentage of PV homeowners are satisfied with the savings on their utility bills than non-PV homeowners, but among both groups, the percentage who are unsure is also quite high. Further, 49% of respondents from SheaHomes with PV systems agree or strongly agree that their gas bills are lower than they would have been without their solar preheating water system, whereas 21% disagree or strongly disagree and 30% are unsure. Fifty-one percent of non-PV SheaHomes owners agree or strongly agree that their utility bills are lower than they would have been without solar preheating water systems, while 17% disagree or strongly disagree and 32% are unsure.

PV Ownership

By and large, those who knowingly selected homes with solar PV systems are very much like all other homebuyers in the SheaHomes and comparison communities. The few differences in the survey responses detected through detailed data analysis apply mostly to the PV owners. The findings suggest that those consciously opting for homes with PV systems tend to be male heads-of-household in their 40s with training as scientists and engineers.

Characteristics of PV Homebuyers

The PV homebuyers are not early adopters of an innovation: they do not have higher education, occupation, or income levels than other homebuyers; they do not display more early-adopter characteristics, such as opinion leadership, than others; and they are not more environmentally oriented than others. These are regular homebuyers buying new upscale homes.

We proposed a new category of high-performance homebuyers that we term the *unwitting adopter*. Although they bought homes with PV systems, these homebuyers were unaware of the fact until after they had been living in their new homes. The existence of unwitting adopters has important implications because it suggests that ordinary homebuyers can and do purchase high-performance homes on the basis of non-energy criteria, which in turn suggests that high-performance homes with PV systems can be sold to ordinary homebuyers without offering PV systems as special options.

The PV Purchase Decision Process

Patterns of response on the importance of reasons for purchase differ by PV ownership. On average, PV owners rate all reasons included in the study as *less* important than do owners of PV-eligible homes who chose not to purchase PV systems, *except* the "Availability of a PV system" and "The package of energy features." These are rated significantly higher by PV owners than by the buyers of PV-eligible homes who chose not to purchase PV systems. These findings lead us to conclude that those who purchased PV homes brought a greater concern about energy to the home purchase decision than did main buyers who chose not to purchase PV homes or comparison buyers. Most homebuyers may not have been very knowledgeable about the energy features when they purchased their homes, but more than three-quarters of the PV owners (77%) feel knowledgeable *after* living in their homes—a significantly higher percentage than non-PV owners (64%).

Homeowner Satisfaction with the Home by PV Ownership

Non-PV owners, on average, assign significantly higher mean satisfaction ratings than PV owners to the location, home size, lot size, layout, and storage space of their homes. PV owners assign higher mean satisfaction ratings to energy features than do non-PV owners, and 77% of them rate themselves satisfied or very satisfied with the package of energy features, compared with 67% of non-PV SheaHomes owners. However, these differences are not statistically significant.

Information Levels of PV Homebuyers

Most of the PV buyers (57%) feel they were not very well informed when they made their decision about PV ownership. Although some information on PV systems was available through a fact sheet, an operating manual on PV systems, web sites, and a video on operations and maintenance, it has not been easy for PV owners to locate and obtain information on their PV systems. Based on our field work, once homes were sold, SheaHomes university did not routinely include energy efficiency, solar water heating, and PV systems in its training curriculum for new homebuyers. Because approximately 10 PV respondents contacted researchers with questions about their systems and how to get information about them, NREL prepared and mailed a letter to SheaHomes PV owners providing information on points of contact for them to pursue, including SheaHomes customer service and AstroPower, Inc.

PV owners seem to have a continued need for technical assistance that could be filled by PV brokers working with new homebuilders. This finding is important because misperceptions about

PV systems could be corrected,[1] levels of satisfaction could be increased, and the beneficial interactive effects between the PV owners and their systems relative to energy efficiency of the home could be reinforced.

Perceived Benefits of PV Ownership

PV owners were presented with 15 statements on potential benefits from owning PV systems; when factor analyzed, these responses result in three factors. The first factor reflects responses for “altruistic” benefits of PV ownership, such as helping to reduce global warming, helping the local economy, benefitting future generations, and helping to improve air quality in the area. This factor closely resembles the first factor of perceived benefits of retrofit grid-tied PV ownership in the study of Colorado homeowners (Farhar and Coburn 2000).

The second factor reflects responses on the financial advantages of PV ownership, such as reduced electricity bills, free electricity once the system is paid for, selling electricity back to the utility company, and increasing the home’s resale value. This factor is quite similar to the second factor of perceived benefits of PV ownership termed “financial advantages” in the Colorado study.

The third dimension reflects responses that appear to focus on the personal satisfaction that can be derived from owning and living with a PV system, such as increased self-sufficiency, being technologically innovative, and feeling good about owning it. Although not identical to the third factor in the Colorado study, this dimension is similar in that the items defining it pertain to personal satisfaction provided by being first on the block with a new PV system and enjoying a new technology.

The fact that these factors emerge from both analyses of two different sets of respondents —owners of new grid-tied PV homes in San Diego and owners of existing homes in Colorado responding to the *idea* of grid-tied PV retrofits—suggests that these perceptions of benefits apply to both new and retrofit markets for PV systems. In the San Diego case, homeowners were responding after experiencing PV systems. In the Colorado case, homeowners were responding only to the *idea* of owning them.

We believe that the energy features, and in particular the PV systems, were icing on the cake for the SheaHomes buyers. These factors seem to describe the flavors of that icing—the aspects that various PV owners appreciate the most: altruistic benefits, financial advantages, and personal satisfaction.

---

[1] One such misperception is that if a PV system is sized at 2.4 kW, it should produce 2.4 kW of electricity. Not so, according to AstroPower, Inc.; technically, the system produces less. Presenting the technical details about why this is so is beyond the scope of this report. But it is an important point bearing on the perception of PV systems by owners who are carefully monitoring what is going on with their systems and homes. It should not be ignored.

Satisfaction with Utility Bills

A significantly higher percentage of PV owners than non-PV SheaHomes owners (not comparison owners) are pleased with utility billing processes and believe that electricity rates have come down. Most of them have bragged to others about their utility bills (67% compared with 26% of non-PV owners bragging about theirs). PV owners, in particular (52%), indicate that their expectations for utility bills have been met, compared with 28% of non-PV owners. Living in PV homes has resulted in significantly lower utility bills, by owners' estimates,[2] than those reported by the rest of the homebuyers. The PV experience has also apparently resulted in an even more positive attitude toward the desirability of energy efficiency and solar features in new housing, and an intention to buy such housing in the future should the PV homeowners move.

Although the analysis suggests that PV owners are somewhat less satisfied than other buyers with the investment potential of their homes, objective analysis of home resale values shows that PV homes more than hold their own in the resale market. The PV owners will very likely become aware of this advantage over time, if they have not already.

The ZEH Experience

The findings reasonably support a conclusion that, once homebuyers experience living in highly energy-efficient homes with solar water heating and PV systems, they become more favorable toward their homes. As noted, buyers of high-performance homes with PV systems are, by and large, like the buyers of other nearby homes of similar qualities and in a similar price range. It is not qualities they brought to the home purchase decision, but rather the *experience of PV ownership* that changes their attitudes and perceptions.

Surprisingly, despite experiencing some difficulties with interconnectivity agreements, PV owners have more positive attitudes toward SDG&E than do SheaHomes non-PV owners. PV owners are significantly more pleased with utility billing processes than are non-PV owners, and they are significantly more likely to believe that electricity rates have come down than are non-PV owners. This appears to be another sound reason for utility companies to actively support net metering for new and retrofit housing.

Conclusions from the Utility Analysis

One of the most unusual and significant aspects of this study is that actual utility data were available for analysis rather than estimates or homeowner perceptions. This information, which consists of records of gas and electricity cost and consumption obtained directly from SDG&E, represents "real world" measurements recorded for homes that encompass a wide range of household types, homeowner lifestyles, and equipment and amenity configurations.

[2]As well as by our analysis of utility bills.

Utility consumption and cost were found to be highly variable quantities for all the homes included in the study. Some of this variation is attributable to normal seasonal cycles, but occupant behavior also plays a role, as do homeowner decisions to improve their homes with energy-intensive equipment and amenities such as pools, hot tubs, and multiple refrigerators. An interesting finding relative to variability comes from visual inspection of the line graphs of electricity and gas consumption of the individual homes in the study. The line graphs on energy consumption of the individual SheaHomes show that the houses built earlier in the project exhibit greater variability in electricity and gas consumption than do the houses built later in the project. This decrease in variability over time suggests that SheaHomes became more effective in implementing the high-performance home designs with more practice. In other words, the builder got better at building the high-performance homes, and this improvement is reflected in the energy consumption data for individual homes.

In addition, it became clear over time that certain PV systems were down for maintenance at various times during the study period. Although we have no data on the exact dates of downtimes, we infer that at least some of the higher months in the electricity consumption of solar PV homes coincide with periods of maintenance.

The Delivery of High-Performance Homes on the Promise of Saving Energy Costs

The original SheaHomes concept has been borne out by the utility analysis. The homes were originally advertised as providing homebuyers with the potential to reduce their utility bills from 30% to 50% over conventionally built homes. At the time San Angelo and Tiempo were planned, ConSol, Inc., estimated that the homes would save 38% of heating, cooling, and water-heating energy beyond the California Title 24 guidelines in effect at that time (Hammon 2004).[3] The 38% energy savings was estimated to convert to 14% of actual cost savings over standard Title 24 houses without solar electric systems. Electricity cost savings attributable to the solar electric system would be in addition to the 14% savings.

Recall that all SheaHomes were more energy efficient than were ENERGY STAR homes, that 296 of them had solar water heating standard, and that 120 of them had PV systems. Among the homes studied, SheaHomes were found to consume less electricity and gas, on average, than comparison homes. Similarly, SheaHomes incur lower utility costs (electricity, gas, and combined utility bill), on average, than comparison households. This finding, in and of itself, essentially validates the SheaHomes construction concept.

Results from comparisons of average monthly combined utility bills (including taxes and miscellaneous charges) among various categories of homes are itemized below:

- When we examine the data for SEE homes (that is, SheaHomes that are highly efficient with solar water preheating systems but without solar PV systems) versus comparison homes, we

[3]These were the older Title 24 guidelines in effect prior to 2005.

find 14% actual average monthly cost savings (including taxes and miscellaneous charges), as had been predicted.

- When we examine the data for SheaHomes versus comparison homes, we find 23% lower combined average monthly utility bills (including taxes and miscellaneous charges) for SheaHomes than for comparison homes.

- When we compare all PV homes (both 1.2-kW and 2.4-kW) to comparison homes, we find a 36% saving in average monthly electricity costs and a 27% saving in average monthly gas cost, and a combined average monthly utility cost saving (including taxes and miscellaneous charges) of 33%.

- The combined average monthly utility bill for homes with 1.2-kW systems is 35% lower than for the comparison homes.

- The combined average monthly electricity cost for homes with 2.4-kW systems is 63% lower than for the comparison homes.

- The combined average monthly total utility bill for homes with 2.4-kW systems is 54% lower than for the comparison homes.

These findings are all statistically significant at p=.05, except for the difference in average monthly combined utility cost between the SEE and comparison homes (p=.122). Thus, the story on energy and cost savings is more complex than was understood when San Angelo and Tiempo were designed and built.

The utility consumption and cost advantages realized in SheaHomes are even more remarkable because SheaHomes (for which actual utility data are available) are larger than comparison homes, and there are no statistically significant differences between the two with regard to household makeup or number of occupants. On the other hand, a significantly higher percentage of the comparison homes include pools and hot tubs.[4] This finding suggests that, as anticipated, homeowner choices about energy-intensive equipment and amenities have an important bearing on actual utility consumption and cost, and that the presence of such features is critical to interpretation of the data.

Energy efficiency and solar features help energy costs in another way. SDG&E calculates energy charges using a daily baseline allowance that varies by climate zone and seasonal time of the year, among other variables. Between May and October 31, the daily baseline allowance for electricity is 11.8 kWh and between November 1 and April 30, it is 11.5 kWh. Similarly, the summer daily baseline allowance for natural gas is 493 therms, and for winter it is 1.546 therms.

---

[4]Fifty-eight percent of comparison homes and 26% of SheaHomes for which there are utility data had pools and/or hot tubs. The comparison homes did not come with pools or hot tubs standard. Of the 44 SEE homes, only 10 (23%) have pools and/or hot tubs, whereas of the 26 comparison homes, 15 (59%) have pools and/or hot tubs.

Electricity costs rise based on the amount of electricity used above the baseline allowance. "The cost per-unit increases as energy use increases."[5]

A closer investigation of the SheaHomes data suggests that most of the utility consumption and cost advantages realized among that group of homes is found in those with PV systems. In particular, SheaHomes with PV systems have significantly lower average monthly electricity consumption and cost than SEE homes,[6] but average monthly gas consumption and cost for the two groups, although 17% lower for PV homes, are statistically equivalent at p=.05. Both categories of SheaHomes (those with PV systems and SEE homes) are highly efficient homes with solar water preheating systems.

Further, the most significant savings among SheaHomes relative to comparison homes are realized in those equipped with the larger, 2.4-kW systems. In fact, although the number of PV homes in the study with 2.4-kW systems is small, the mean savings in average monthly electricity cost is approximately 63% relative to comparison homes, an amount that is consistent with the reductions reported in other studies, and about 57% relative to the high-performance SEE homes. If only the PV homes with 1.2-kW systems are considered, the mean savings in average monthly electricity cost is about 30% relative to comparison homes and about 19% relative to the SEE homes. Because of the rigorous nature of our investigation, we believe our results validate and strengthen our claim that 2.4-kW or larger systems on top of high energy efficiency levels and solar water heating are needed to effect the most significant cost savings.

Additionally we found that average monthly electricity consumption and cost were not significantly different for comparison homes and SEE homes, except when computed on a square-footage basis. On the other hand, we found that the mean differences in average monthly gas consumption and cost for these two groups of homes, though not large, were significant, with the mean amounts for the SEE homes being lower (in the 17%-18% range for both consumption and cost). While the SheaHomes in this particular comparison are not equipped with PV systems that can lower electricity consumption, they do have solar water heating systems that help reduce gas consumption.

Taken together, the results reported in the section on satisfaction discussed earlier in this chapter suggest that most homeowners believe their solar preheating water systems are helpful, but that adding solar preheating water systems alone to highly efficient homes is not enough to effect a level of savings of monthly utility cost that is obvious to them. On the other hand, the effect on cost of the energy package together is much more readily apparent to homeowners because of the savings realized especially on electricity consumption.

[5] www.sdge.com/customer/baseline.shtml (accessed 7/18/06).

[6] SheaHomes without PV systems, excluding early homes (which had no solar water preheating systems) and outliers from the analysis.

At the time solar features were added at San Angelo and Tiempo, the houses were evaluated for suitability for PV. An effort was made to install solar water heating and PV systems on the side and rear roof exposures. An examination of the site maps suggests that the houses with PV systems standard may have had more optimal orientation for solar water heating systems. This is because if the house had a PV system it probably had a south-facing solar water heating system. The percentage difference in monthly gas cost between base-case PV homes and base-case comparison homes is 50% (with the PV home costs lower) almost double the 27% difference when all PV and comparison homes are compared.

Although the results reported above reflect real-world conditions in homes representing a broad spectrum of features, the presence of energy-intensive equipment and amenities confounds the interpretation of the data, as suggested above. Hence, we believe it is necessary to consider additional comparisons of utility consumption and cost in homes that do not include any of these features. Such homes, which are here referred to as base-case homes, would be purchased in their "raw" or "natural" state before any additional equipment or features are installed. Among these homes, we found base-case SheaHomes with energy efficiency, solar water heating, and PV systems had significantly lower average utility bills than either the base-case comparison homes or the base-case SEE homes with energy efficiency and solar water heating. The mean difference in average monthly electricity cost between base-case PV homes and base-case comparison homes is approximately 42%, and for average monthly gas cost it is about 47%. The mean difference in average monthly electricity cost between base-case PV and SEE homes is approximately 47%, and for average monthly gas cost it is about 34%. Although the numbers of homes involved in these comparisons are relatively small, the findings are especially significant because they fundamentally validate the overall benefits of PV added to high-performance homes with solar water heating for the residential market in terms of savings in both electricity and gas costs.

On the other hand, we find the mean difference in average monthly electricity cost is not statistically significant at $p = .05$ for base-case comparison homes and base-case SEE homes, nor is the mean difference in average monthly gas cost. In fact, average monthly electricity cost is slightly higher (about 9%) for the base-case SEE homes than for the base-case comparison homes, whereas average monthly gas cost is about 20% lower for base-case SEE homes with solar water heating than for base-case comparison homes. Again, the number of homes involved is small, but the results are somewhat surprising; perhaps part of the reason for this finding is that the comparison homes were built to the Title 24 building code in effect in 2001. We conclude that buyers of basic high-performance homes (such as the SEE homes) may not experience much difference in their average monthly electricity cost relative to buyers of Title 24 comparison homes, but that they may experience somewhat lower average monthly gas cost. However, in terms of average monthly combined utility bill, base-case SEE homes are not significantly different from base-case comparison homes, indicating the apparent reduction in average monthly gas cost (presumably the result, in part, of the presence of solar water heating systems) is not enough to offset higher average monthly electricity cost in the SEE homes.

Feedback and the Interactive Effect between Technology and Behavior

Considering all these findings and conclusions together, it appears that, relative to more conventional comparison homes, true savings in utility consumption and cost can only consistently be obtained when energy-producing technology (such as PV systems) is in place on top of energy efficiency and water heating technologies. Interestingly, other findings from this study suggest that PV ownership tends to foster increased interest in, and enthusiasm about, the technology, which may translate into energy-saving behaviors. In fact, the presence of a physical feedback device (the digital display) in the PV homes is closely linked to satisfaction with these systems and to an expression of pro-solar-energy beliefs and behaviors. When PV systems are producing more electricity than is being consumed, the electric meter runs backwards, which provides additional feedback and satisfaction to PV owners.

Additional analysis suggests that living with the systems, whether or not there is specific intent to acquire them from the outset, promotes increased familiarity with, and interest in, those systems that ultimately leads to heightened awareness of energy consumption and conservation and changes in energy consumption behaviors. Hence, we conclude that, although the presence of the PV systems is very important, the behavioral interaction of the consumer with the technology based on the digital display—and to some extent the electric meter—provides feedback that produces the most pronounced effect on homeowners. The fact that the base-case SEE owners do not have feedback devices and that their energy consumption and costs, though lower, are not on average, significantly lower at p=.05 than comparison homeowners adds further evidence to the significance of feedback in optimizing energy and cost savings.

Perceived versus Actual Utility Bills

Homeowner estimates of their monthly utility bills are notoriously inaccurate. The study provided a rare opportunity to compare the amounts of monthly utility bills that homeowners estimated they were paying with the amounts they were actually paying, at least for those homeowners who released their utility bills. Because homeowners tend to think about what their utility bills are running per month, this analysis used monthly averages of the total utility costs since the homeowners moved in. We found that SheaHomes respondents report significantly lower average monthly utility bills ($143.08) than do comparison respondents ($184.55), and that their estimates are less variable than those of comparison respondents.

When we compare perceived to actual mean monthly utility bills (limiting the analysis to those whose utility data we have and using weighted means), SheaHomes respondents estimate average monthly utility bills of $165.44, but their actual average monthly bills are significantly lower at $139.11 (p=.000). Similarly, comparison respondents report average monthly utility bills of $210.01, but their actual average monthly bills are significantly lower at $164.03 (p=.008).

Clearly, PV owners report significantly lower average monthly utility bills ($116.44) than do SheaHomes non-PV owners ($159.73) (p=.003). When we compare perceived to actual utility bills (limiting the analysis to those whose utility data we have and using weighted means), PV owners estimate average monthly utility bills of $118.55, but their actual mean monthly utility bills are significantly lower at $105.54 (p=.029). Owners of SheaHomes non-PV homes estimate their mean monthly utility bills at $194.73, but their actual mean monthly utility bills are significantly lower at $160.08 (p=.000).

We conclude that all homeowners tend to overestimate their average monthly utility bills to an extent that is statistically significant. Ownership of homes with PV systems is associated with a more accurate perception of utility costs than other SheaHomes and comparison homeowners have. Comparison homeowners have the highest overestimates of their average monthly utility bills.

Conclusions from the Modeling Work

The primary objective of our modeling exercise was to develop straightforward and logical equations with which to forecast or predict utility consumption and cost in new construction. Such forecasts or predictions would be extremely beneficial to homebuilders as they plan and market new homes and developments, as well as to consumers who are contemplating the purchase of a new home. The ultimate goal of this work would be to provide a straightforward and reliable way to calculate utility consumption and cost under a variety of home/household configurations and lifestyles.

We demonstrate that, at least in the case of PV and comparison homes, utility consumption and cost can be reliably modeled by an equation containing a relatively small number of variables (on the order of three to six). However, even though most of these variables involve the presence of tangible equipment or amenities, some relate to occupant behaviors, attitudes, or perceptions that may be more difficult to pin down. On the whole, the best models of utility consumption and cost that can be constructed involve the interaction or interface of homeowners with various equipment and amenities, and we conclude that consideration of both kinds of variables is necessary to optimally model the utility response in homes.

The utility response in SEE homes is much more difficult to model. These homes/homeowners appear to be a unique category with utility response patterns that are more closely tied to occupant behaviors, attitudes, and perceptions than to the presence of specific energy-intensive equipment and amenities. Such variables are certainly more intangible and are likely interrelated in ways that are not completely known. Both situations can counteract and even defy the development of mathematical equations that reliably explain and predict utility consumption and cost.

The Business Aspects of High-Performance Homes

The builder’s experience and perception of the project were documented through in-depth interviews with the executives and staff, as well as review of the SheaHomes contractor reports and media coverage, and through public records. SheaHomes, in completing its San Angelo and Tiempo developments, accomplished a complex technical and institutional achievement. Besides selling all 306 homes in 31 months, the builder also sold almost half of them with solar PV systems. SheaHomes sold three times as many homes as the comparison builder in the same length of time. In this section, we discuss conclusions about the competitiveness of high-performance homes, the business experience of SheaHomes in offering high-performance homes, the role of the builder staff, the uptake of PV systems, the optimal development of high-performance homes, and the resale value of high-performance homes.

Are High-Performance Homes Competitive on the Market?

The study's findings do not support a widely held belief that new high-performance homes are more expensive than conventional homes on the market. The mean price per square foot of the high-performance homes in this study was significantly lower than the mean price per square foot of the comparison homes, which came with no extra amenities standard.

Benefits and Costs to the Builder

SheaHomes enjoyed economic advantages for building high-performance homes. The company received a 50% subsidy on the cost of the PV systems from the CEC—the first time a residential builder in California had received the subsidy from the state. The company also received a $750 rebate from SDG&E for the installation of solar water preheating systems at each home and enjoyed a 15% tax credit for energy-efficient housing that was more than 15% more efficient than Title 24 housing (the standard in effect in 2001).

SheaHomes also enjoyed several other benefits from completing its Scripps Highlands project, including (1) partnerships with organizations interested in solar energy and energy efficiency, (2) extensive media coverage of its innovative developments, (3) enhanced reputation by becoming an innovator with high-performance home technology, and (4) greater exposure to the home buying market. Other benefits may have also accrued to the company through the contacts the company forged in its work with DOE, NREL, the State of California, and with San Diego city government. These benefits, with time, could translate into economic advantages.

SheaHomes management said that the San Angelo and Tiempo homes sold out a year faster than expected, and attributed the accelerated sales pace to the desirable location. This is interesting because the comparison development had model homes for potential buyers to visit, whereas many of the earlier SheaHomes buyers, when they bought their homes, could see only the undeveloped land, pictures of elevations, and drawings of floor plans. SheaHomes did not build its model homes until late in the sales process. This made the sales process between SheaHomes and comparison homes an uneven playing field in favor of the comparison homes; therefore, it seems remarkable that the two developments sold out in the same length of time. This suggests that, all other things being equal, the high-performance homes would sell more quickly than conventional homes (despite the management view in July 2003).

SheaHomes management also told us that the company did not lose money on the energy efficiency and solar energy attributes of the high-performance homes, but they seemed to indicate that the homes were not that profitable, either. The company did not share proprietary information with the researchers on its expected or actual profits from the San Angelo and Tiempo developments.

SheaHomes staff indicated, however, that they hoped that the City of San Diego would view the Scripps Highlands communities favorably. The company planned to work with the City on a project to provide affordable housing with high-performance features in the San Diego area. This became the Bella Rosa affordable housing development.

The Scripps Highlands experience was something of a double-edged sword for SheaHomes. Several of the benefits also involved costs. These included costs of (1) building high-performance homes, despite rebates; (2) climbing the learning curve, including new language and acronyms; (3) selling and scheduling installation of optional solar PV systems; (4) obtaining the rebates for the PV systems; (5) dealing with interconnectivity issues; (6) dealing with tax implications for customers; and (7) educating visitors and new homebuyers about the homes' innovative energy features. In addition, SheaHomes was concerned about whether high-performance homes could be sold at prices that were competitive with conventional new home prices in the area.

SheaHomes managers also pointed out that they took some informal complaining and grumbling from members of the San Diego homebuilders association for building the Scripps Highlands project. To speculate on this phenomenon, in building San Angelo and Tiempo, SheaHomes took a highly innovative step. It is the normal social process in any social group to sanction members who are perceived as deviating from group norms (in either positive or negative directions). This dynamic is similar to the sanctions that hourly-paid factory workers impose on a "rate-buster."[7] It must be acknowledged that innovative builders stand out from the builder community within which they are embedded, and they could face informal sanctions from other builders. This phenomenon should be offset with higher financial incentives for ZEH builders.

What Was the Uptake of Optional Solar PV?

Ryan Green and the company were interested in knowing what the uptake of homes with PV systems would be. Of the total 306 homes, only 260 were PV-eligible. Of these 260 homes, 120, or 46%, were actually sold with some sort of PV system. Of these 120, 96 were sold with 1.2 PV systems standard. The remainder of the homebuyers chose to purchase either 1.2 PV systems or 2.4 PV systems optionally. In addition, eight of the 96 buyers that purchased homes with PV systems standard chose to upgrade their 1.2 PV systems to 2.4 PV systems. Hence, a total of 32 homebuyers made an optional PV purchase. These 32 home represent 27% of all the homes sold with PV systems or 12% of all PV-eligible homes.

Clearly, homes with PV systems standard can be sold, since not one of these homes remain unsold today. However, the findings presented above paint a picture of only limited market interest in solar PV systems offered as optional features. This picture influenced SheaHomes

---

[7]A "rate-buster" is a worker who works much harder and produces much more than the group norm.

management when it made its decision to discontinue building high-performance homes in other projects it was planning (see Chapters 2 and 4).

Our research suggests several reasons why homebuyers may be reluctant to consider an optional purchase of a PV system. However, we believe the seemingly lackluster sales of optional systems was due more to ineffective marketing than lack of homebuyer interest. In the course of our research, we discovered that only 44% of buyers of PV eligible homes remembered being offered an optional system. Thus, 56% of buyers of PV-eligible homes at Scripps Highlands were apparently not offered such systems. When we examine the data with this knowledge in hand, we observe that, of those who remember being offered optional PV systems, 46% actually purchased them. Extrapolating to all the PV-eligible homes at Scripps Highlands, we estimate that 44% would have purchased the systems had they been offered. Obviously, this is a much higher percentage than the 12% figure reported above. So the market interest in optional PV systems appears to have been much higher than these figures would indicate. They suggest that, had buyers been aware of solar PV options, another 40 to 50 homebuyers at San Angelo and Tiempo would have purchased 1.2-kW systems or would have upgraded to 2.4-kW systems.

The Roles of the SheaHomes Sales and Options Staffs

The question might be asked why 56% of the buyers of PV-eligible homes were not offered the option. Although the lead sales agent was enthusiastic about solar PV, in the end the sales staff were more concerned about finalizing home sales, for which they were rewarded with commissions, and they were less focused on sales of PV systems that were considered "extracurricular" and might complicate the deals. Sales people learned that homebuyers in general are not likely to be well informed about solar PV systems (although a few were sophisticated about energy features), and that educating them would take a fair amount of time. Also, the sales staff was the major source of information for homebuyers, and they, themselves, were not fully informed about the utility cost savings that could be expected from the homes and the PV systems. This is not to fault the sales staff, who are quite effective at what they do, and who are much appreciated by the homebuyers. More needs to be known about the energy and cost savings of high-performance homes and ZEHs, and the sales staff were probably as informed as they could be at the time the Scripps Highlands project was going on.

We also learned through qualitative work that the individuals whose job it was to offer optional features to the buyers were apparently uninformed about the PV systems (including their placement on the roofs and other aspects). Undoubtedly, this prevented some systems from being sold or upgraded because buyers could not get answers to their questions rapidly, and they had hundreds of other decisions to make at the time.

Management Decisions

To continue our discussion, then, upper management at SheaHomes-San Diego realized that only a small percentage of PV-eligible homes were selling with optional PV systems. On the other hand, they were undoubtedly unaware that the majority of the buyers of PV-eligible homes had not been offered the PV option. Thus, SheaHomes management may have decided to discontinue its pursuit of high-performance homes in its upcoming developments based on inaccurate or incomplete information.

Based on this analysis, we conclude that inadequate information on the part of the builder can lead to premature withdrawal from the market. In addition, when the innovation champion (in this case, Ryan Green) leaves the company, such projects will likely flounder. For high-performance homes projects to succeed, their champions must be heirarchically located at or near the top of the company, have the support of the top management team, and provide follow-through to the end of, and possibly even beyond completion of, the projects.

SheaHomes is an industry leader in offering quality upscale energy-efficient solar homes. The company was a participating builder in the Ladera Ranch project. Its reputation still remains, even though SheaHomes is not pursuing ZEH concepts in any of its current developments in the San Diego area. If another San Diego large-production builder aggressively pursues the development of PV homes and establishes a reputation, SheaHomes could eventually lose this specific market advantage that it enjoyed because of Scripps Highlands. However, SheaHomes has kept the door open to future use of ZEHs, although management said the company wants to better understand costs, benefits, and market response before committing to another project.

Optimal Development of High-Performance Homes by Large-Production Builders

From this experience we learned that offering energy efficiency and solar features standard does not interfere with homes sales; in fact, it may have accelerated home sales. We learned that this is *not* a "niche market," as is commonly believed. However, because PV technology is complex, unfamiliar, and costly, buyers have difficulty making decisions about whether to purchase it. When PV systems are offered optionally, customers weigh them against aesthetic features of their homes, such as granite counter tops. Yet PV systems are part of a home's basic equipment and structure, so to many customers the decision felt like comparing apples and oranges.

Also, offering optional PV systems seems to be burdensome for large-production builders because the transaction costs of scheduling system installation are higher than if the installations were routine for each house, and sales staff have to sell the solar PV systems in addition to the home itself. These considerations lead us to believe that PV systems should be offered standard. Including PV in the price of the home streamlines PV purchases, and PV homebuyers will experience lower utility (especially electricity) bills than they would have otherwise. The home price does not necessarily increase noticeably where subsidies are in effect.

Therefore, from a business perspective, future new home developments should feature highly energy-efficient new homes with solar water preheating and tankless water heating, and PV systems standard. PV service providers, broker companies, or installers trained to provide turnkey packages rather than builders, should handle the technical details of PV installation. These include ordering or bulk purchasing the PV systems, providing qualified installers, post-installation inspection, dealing with interconnectivity for net metering, dealing with rebates and tax credits, and handling any callbacks related to PV systems.

In addition, larger PV systems are needed (at least 2.4-kW and preferably larger yet) so that homeowners can clearly perceive the effects of the PV systems on their utility bills. The PV owner perceptions were discussed in an earlier section of this chapter.

The heating and air-conditioning systems in these homes should be highly energy efficient. Dual-zone heating and air-conditioning systems should be provided standard for two-story homes. The new home package would ideally include ENERGY STAR appliances. If appliances are not included, homebuyers should be encouraged to select energy-efficient appliances, for which their utility company could provide rebates.[8] Highly efficient homes with solar water heating and PV systems standard will be more profitable for builders and sales staff, more beneficial for utility load profiles, and more cost-effective for homebuyers.[9]

The Increase in Property Values of High-Performance Homes over Time

High-performance homes not only hold but increase their value at a faster rate than do conventional homes. Both SheaHomes and comparison homes increased markedly in value at resale. Five percent of SheaHomes had been held an average 22.5 months and 13% of comparison homes 28.1 months before resale at some 42 months after the developments were begun in the spring of 2001. Owners of SheaHomes realized a higher percentage of financial gain when compared to the nearby comparison homes, despite the similarities between the two groups of homes in location, original sales price, and square footage. Resale prices for 29 homes analyzed (the first 29 homes sold in the area[10]) show that the increase in value for SheaHomes averaged 55.4% and 44.7% for the comparison homes. The mean gain in sales price for SheaHomes was $306,509 over original price. The most expensive home sold for $1.1 million. The mean gain in sales price for the comparison homes was $264,562 over the original price. The most expensive comparison home sold for $995,000. Comparison homes also apparently turn over sooner than do SheaHomes—that is, two and one-half times the number of comparison homes than of SheaHomes were sold in the 42 months—which could be related to their owners' somewhat lower levels of satisfaction. Although we do not have data in this study on all of the variables that could affect resale value, it seems reasonable to partially attribute the difference to the energy features of the SheaHomes.

Answers to the Advisory Group's Questions

As mentioned in Chapter 2 (Guiding Ideas), the study's advisory group recommended that the research address a specific set of questions. Briefly, the answers to these questions are presented here.

---

[8]Federal tax credits are currently provided tax credits for energy efficiency features, including windows and water heaters.

[9]The caveat that this is not an economic analysis must be repeated here. This refers to a utility bill savings effect that is large enough to get the notice of homeowners, but is not a reference to results of a cost-benefit analysis.

[10]By 2/7/05.

1. *How much did buyers know about the energy features of the homes? How well do the consumers understand them? What messages are the sales staff communicating about the energy features?*

   The buyers were relatively uninformed about the energy features of the homes before they bought them. SheaHomes respondents rate themselves with a mean score of 5.73 on a scale of 1 to 10, and comparison respondents rate themselves at 4.81, on average. Indeed, a handful of buyers actually bought homes with PV systems and did not know it! SheaHomes buyers are, in general, satisfied with the information received from sales staff on energy features, giving average ratings around 7 on a 1 to 10 scale.

2. *What is the role of the home builder "image" and reputation in the sales of the ZEHs?*

   The reputation of the builder was significantly more important in the home purchase decision to SheaHomes than to comparison homebuyers. Its average importance rating was 3.96 on a 1 to 5 scale among SheaHomes purchasers and 3.57 among comparison buyers, a difference that is statistically significant at p=.05.

3. *Do ZEHs have more market value than conventional homes and resale homes? Did energy features bring out people who were originally shopping for resale homes as well as new homes?*

   The SheaHomes at Scripps Highlands originally sold for somewhat less than the comparison homes. The mean price of the SheaHomes was $556,344; the mean price of the comparison homes was $598,028. The most expensive home at SheaHomes sold for $701,184, and the most expensive comparison home sold for $711,887.

   However, the situation is reversed at resale. SheaHomes experienced a mean dollar gain of 55.4% for a mean length of 22.5 months of ownership. Comparison homes experienced a mean dollar gain of 44.7% for a mean length of 28.1 months of ownership. The mean resale prices of the SheaHomes and comparison homes were nearly identical; for SheaHomes the mean resale price was $862,853 and for comparison homes it was $862,590. The most expensive resale home at SheaHomes sold for $1.1 million by February 2005. The most expensive resale comparison home sold for $995,900 by that date. The mean dollar gain per month owned was $14,492 for SheaHomes and $9,301 for comparison homes.
   More than double the percentage of comparison homes than SheaHomes were resold in the first 42 months of ownership. Comparison owners are, on average, less satisfied than are the owners of SheaHomes. Seventy-seven percent of SheaHomes owners say they would be willing to purchase their same homes all over again, compared with 67% of comparison owners; 5% of SheaHomes owners would be unwilling to do so, whereas 15% of comparison owners would be unwilling to purchase their same homes over again.

   Based on the survey data, the energy features did not result in visits by more buyers who were looking at both new and resale homes. In fact, 72% of comparison buyers indicate they visited resale housing, whereas 57% of SheaHomes buyers visited resale housing, a difference that is statistically significant ($\chi2$=3.835; p=.05). The lost lookers study (Collins 2003) suggested that visitors were not necessarily drawn by energy features, and in fact some were *unaware*, even after their visit to Scripps Highlands, that SheaHomes offered special energy features in their homes.

4. *What is the additional value to the customer of these systems? What price could be added to the price of a ZEH over a conventional home?*

   It is, of course, interesting that the high-performance homes sold for *less* than the comparison homes. The data on willingness-to-pay, collected from non-PV and comparison owners (that is, buyers who did not purchase PV homes), suggest a cut-off point of approximately $5,000 for a system that would save 60% to 70% of electricity costs. However, this level of savings would require a larger PV system. SheaHomes buyers who upgraded their PV systems from 1.2-kW to 2.4-kW paid an additional $4,000; those who purchased optional 1.2-kW systems paid $6,000 (later raised to $7,000); those who purchased optional 2.4-kW systems paid $10,000 (later raised to $11,000). Reasons for not purchasing a PV system tend to center around the expense. Subsidies and amortization would be required to permit installation of the larger 2.4-kW to 3-kW systems that would be needed to reduce electricity costs by 60% to 70%.

5. *To what extent are energy performance features important in drawing people to look at the homes? To buy the homes?*

   The energy features—and the media attention they generated—drew significant numbers of people to the SheaHomes Sales Center, but many of these people were not buyers. They were interested in solar energy and how it worked, but they were not actively looking. In fact, some mentioned they were thinking of building their own homes and wanted more information.

   The data from the buyers showed that energy features are far less important in the purchase decision than issues like location, the safety and security of the area, and the quality of the neighborhood. The mean importance rating for the "package of energy features," although lower than most other features listed, is positive at 3.56 on a 1-to-5 scale. The "package of energy features" had a higher mean importance rating than solar water heating (3.49) or availability of PV system (3.34 on a 1-to-5 scale). A majority of SheaHomes buyers (58%) indicate that the package of energy features was important or very important in their purchase decision; 52% indicate that the availability of solar water heating was important or very important in their purchase decision, and 49% indicate that the availability of solar PV was important or very important in their decision.

   The sense of the responses seems to be that the energy features were "icing on the cake" for most of the SheaHomes buyers.

Seventy-seven percent of comparison buyers indicate they visited SheaHomes while they were shopping for their new homes; however, a majority of 57% of comparison buyers indicate they were *unaware* of the homes' energy features.

6. *Should solar features be standard or optional? Are optional upgrades a good idea?*

   As discussed earlier, our research suggests that solar PV systems of at least 2.4-kW should be standard, and optional upgrades are not a good idea because they complicate the transaction.

7. *How are ZEH purchasers different from purchasers of conventional homes in motivation, attitudes, and demographics?*

   In general, purchasers of high-performance homes are upscale, and they are not different from purchasers of upscale conventional homes in motivation, attitudes, and demographics.

8. *Among energy features, which are the most important to homebuyers—efficiency features, solar water heating systems, or solar electric systems? Which feature has the most appeal? Or does an integrated ZEH with all features have the most draw?*

   The package of energy features including the PV system appears to have the most appeal. PV buyers give a mean importance rating relative to their purchase decision of the package of energy features as 3.75 on a 1-to-5 scale and the availability of PV systems as 3.60. These mean scores are significantly higher than those of all main owners, and even more so than those of main owners who were offered PV systems and chose not to purchase them.

9. *Is aesthetics a barrier? Is it positive, negative, or neutral? How important was it in the purchase decision? Does it matter if solar equipment is on the front or back of the house?*

   Neither the qualitative nor the quantitative studies identified aesthetics as a barrier to high-performance ownership. However, because the study is of homeowners who bought these homes, it cannot be concluded that no one objects to the aesthetics of high-performance homes. It seems fair to conclude that the market is large enough that it does not matter if some people object. Plenty of buyers do not object. No one mentioned a problem with the placement of the PV systems, and the solar water preheating systems look like a pleasant skylight.

10. *How important is the feedback device (showing the amount of electricity the house is using and the amount the PV systems is producing)?*

    The feedback device is very useful to PV owners. This device is the link between PV technology and the home's occupants that results in the interaction effects discussed above. The digital display shows owners how and when they are using electricity, permitting them a modicum of control over task scheduling. They use it to monitor if appliances or lights have been left on as they are leaving the house so they can turn them off. They report that they change their behavior because of this device. Without it, PV owners would have no way to monitor their electricity production and consumption in real time. We conclude that the digital display, showing both production and consumption of electricity, is *critical* in optimizing the interaction between ZEH technology and energy-consuming behavior.

11. *How satisfied are customers with their home purchases?*

    Most buyers are satisfied with their new homes, but SheaHomes buyers, and especially PV buyers, are more satisfied than are comparison buyers. Several pieces of evidence in the study support this conclusion.

Summary Remarks

These findings and conclusions are believed to be valuable to builders, policy-makers, utility companies, trade and professional organizations, and the energy-efficiency and solar-energy communities, as well as to marketers, researchers and energy analysts, and homebuyers. Recommendations for some of these groups are discussed in the next chapter.

In conclusion, this study is replete with findings that support the rapid development of high-performance homes with PV systems, near-ZEHs, and ZEHs. Once offered standard, the costs of these homes to the builder appear to be manageable, the product provides differentiation on the market, and ordinary homebuyers want to buy these homes. Once they live in them, homeowners become even more enthusiastic. Policies that support the deployment of ZEHs, such as net-metering legislation, simplified interconnectivity agreements, building codes and standards, utility rebates, and subsidies for solar water heating and PV systems, will be rewarded by rapid diffusion of an idea whose time has come.

Chapter 24
Recommendations and Summary Remarks

This study has produced an extensive and invaluable body of evidence and information that should help guide an array of government and private industry organizations and industries for years to come. The findings increase our understanding about the complex relationships among large-production builders, energy efficiency companies, water-heating companies, the PV industry, utility companies, government organizations, and buyers of high-performance homes. The study can also serve as a model for obtaining similar information concerning builder and consumer acceptance of ZEHs in other areas.

Many recommendations could be formulated based on the extensive findings of this report. The ones included here represent the authors' best judgments on approaches that are likely to foster an upsurge in building ZEHs that effectively save utility-supplied energy and that will enjoy market popularity. These recommendations are organized into several categories to underscore the need for collaborative work and contributions from many parties. Recommendations for the business community, organizations involved in information dissemination and environmental concerns, and government agencies are highlighted, as are suggestions for future research. Each recommendation is presented as a specific action that we think should be taken, along with some associated discussion. Potential audiences for the report are also listed. Some final summary remarks about the study are provided at the end of the chapter.

Part One: Recommendations for the Residential Real Estate Marketplace

In order for ZEHs to proliferate, there has to be a definable market. Consumers have to be interested in the concept, builders must be willing to construct the homes, lenders have to adopt a pro-ZEH financing stance, PV manufacturers must be able to produce enough equipment and at reasonable prices, utility companies have to embrace the idea of residentially-generated electricity, and secondary market mortgage lenders must recognize the value that PV technology brings to the home over time. In the end, the homebuyer wants to obtain a quality product at a reasonable price, and each of the other entities wants to recoup its costs and receive a reasonable return on its investment. With these things in mind, we offer a number of recommendations that we believe would promote a more robust marketplace for ZEHs based on our research findings.

Builders

Builders, themselves, may have the greatest potential impact on the ZEH market. Without builders who are willing to adopt and experiment with the ZEH concept, there is no way for the ZEH market to grow unless the state or federal government becomes the builder. Hence, we offer a number of specific recommendations to encourage builder participation.

Orientation of Homes

Builders should plan developments with primarily east-west streets to maximize opportunities for the optimal placement of solar features on new homes.

Offer PV Systems, Efficiency, and Solar Water Heating as Standard Equipment and Focus on Larger PV Systems

Builders should offer ZEHs with efficiency, solar water heating, and PV systems as standard (rather than optional) equipment on all homes in large-scale developments. All PV systems should be at least 2.4 kW in size and should include digital feedback/readout displays. Transactions costs are too high when homes and PV systems are sold separately, and homebuyers have difficulty determining the value of PV systems as home options when juxtaposed with other optional features. Our research suggests that it is simply more effective from a sales and marketing perspective to use this standard-package approach when offering homes with specific energy packages.

Foster Management Commitment

The top management of home builders must, themselves, be committed to the ZEH concept, and must acknowledge that building ZEHs may require a shift in construction practice and the company's usual operating model. Ideally, all major home builders should establish a ZEH concept team that is responsible for following market trends and consumer preferences, researching the latest technology, pursuing vendor and governmental partnerships, and reporting to top management on a regular basis. Top management should establish communication channels by which ZEH champions can step forward to provide leadership in this area. Top management should also recognize that even a partial switch to building ZEHs will require steadfast decision-making and follow-through for at least five years.

Provide Training and Incentives for Sales Staff

To accurately and completely address questions from potential and actual homebuyers, all sales staff involved in marketing ZEHs need formal training on ZEH features and their impacts. For example, such individuals need to be able to distinguish Title 24 homes, ZEHs, and near-ZEHs if they are to maximize sales. Specifically, the sales staff needs to be able to provide realistic projections of energy savings. In addition, if the decision is to offer PV systems as optional equipment, contrary to our recommendation, sales staff need to be able to provide accurate information about their costs, benefits, and operational aspects. As noted elsewhere, a labeling system would help. To maximize the buy-in from sales staff, we recommend they be offered incentives for completing training courses about ZEHs and premiums on sales commissions for selling them.

Become Trained in the ZEH Building Concept

Builders and their construction staff should become trained in the ZEH building concept so that they can fully understand and appreciate market expectations, construction performance expectations, benefits, and costs. Such training could be offered by homebuilder associations, involving companies with special expertise, such as DOE’s Building America partners. In addition to construction and business details, the builder training should also include information about the new market paradigm for ZEHs.

Contract for Turnkey Packages to Provide PV Management Services

Builders unaccustomed to PV installations in their projects should contract with PV installers to provide turnkey procurement, installation, and management services for the PV systems in their high-performance homes and ZEHs. These companies specialize in PV systems procurement, installation, interconnectivity, and technical assistance. This role is analogous to that of ConSol, Inc., for energy-efficiency packages. Although one of the primary responsibilities of PV brokers is to arrange for the bulk purchase and scheduling of systems installations, such individuals and organizations can fill many other important and necessary roles, including the following:

- Serving as the homebuyers’ ombudsman for ZEH features, answering questions, inspecting systems, arranging for repairs, if necessary, and arranging for interconnectivity between the homeowner and the utility company

- Applying for rebates or other financial incentives to which the builder and homeowners are entitled (e.g., tax credits, rebates, or subsidies)

- Providing a warranty for the entire system, including inverters

- Processing and handling homeowner callbacks regarding PV system problems, educating PV owners, and helping to train sales staff regarding the costs, benefits, and operating expectations of PV systems.

Create More Effective Marketing Messages

Builders must market ZEHs more effectively. Model homes should be available that feature ZEH attributes, and those attributes should be clearly highlighted, labeled, and explained. Strong, appealing marketing materials must be available, and the sales staff need to be able to use these materials to educate potential buyers. Our research suggests that potential ZEH buyers are ordinary new home shoppers who are not likely to be sophisticated about the homes' attributes. Consequently, even if PV systems are standard, the buyers need to be more informed about them.

SheaHomes has a reputation for building quality homes, and it succeeded in selling its homes at Scripps Ranch by offering a quality product. However, many of the visitors to the sales center, as well as many buyers, remained unaware of the energy features of their homes. Consequently, to sell more ZEHs, builders should consider positioning themselves as "green" companies or as companies committed to energy efficiency. Essentially, they need to re-brand themselves to be most successful.

Explore Opportunities to Build Affordable ZEHs

In collaboration with governmental agencies (as suggested above) and non-governmental organizations (NGOs), builders should explore opportunities to build affordable housing with ZEH features. At this point in time, building affordable ZEHs would undoubtedly require subsidization; however, reduced utility bills would clearly benefit lower-income homeowners and renters. Use of ZEH technologies in affordable housing would also help bring down the cost of these technologies as the result of larger-scale manufacturing. Investments in affordable housing would be a much better alternative than subsidizing high utility bills for lower-income families.

Photovoltaics Manufacturers

PV manufacturers should foster large-scale ZEH construction by offering PV panels at discounted prices for bulk purchases. PV manufacturers should also provide training and technical assistance for installers offering turnkey packages, builder sales staffs, real estate agents, and owners of PV systems. Turnkey packages could include obtaining permits, handling interconnectivity agreements, ordering PV and solar water heating systems, installing systems, applying for relevant rebates for the builder, training builder sales staffs and real estate agents, and handling customer education and callbacks. Warranty enforcement should also be part of the package. Alt-aire Energy, Ecobroker, and Powerlight, for example, are developing and offering turnkey services.

Utility Companies

Utility companies have a special role to play in the development of ZEH markets, and, as a result, they can enjoy the unique benefits of a zero-peak community. One direct benefit is the potential for using residentially supplied electricity from PV systems to ease peak-load requirements on hot summer afternoons. Additionally, our research suggests that an increased number of ZEHs will likely result in an improved perception of the utility companies on the part of homeowners leading to better public relations overall. Finally, utility companies have substantial expertise and resources that, when turned toward solving problems related to ZEH deployment, can enhance implementation of the zero-peak community concept.

We recommend that utility companies perfect the interconnectivity process by simplifying it. SDG&E reported that its lawyers were working to create user-friendly forms especially designed for residential PV homeowners to make it easy for them to interconnect. This single step would go a long way to improving relations between ZEH buyers and their utility providers

Utility companies should foster net metering, and should agree to the one-meter concept of net metering. Offsetting any resulting revenue losses, utility financial benefits can come from peak shaving. Another is that PV owners have a more positive view of utility companies than other homeowners, which is a public relations advantage. Finally, utility companies have substantial expertise and resources that, when turned toward solving problems in deploying ZEHs while improving the grid, can be a substantial positive force in increasing the sustainability of electricity supply. Such a role could be rewarded by public utilities commissions, for example.

Utilities should conduct analyses of the benefits that ZEH-produced electricity offers them relative to peak loads and easing strain on the utility grid. Grids need upgrading and repair, and analyses should be conducted to define how integration of ZEHs with the grid can be simultaneously developed with grid renovation projects.

Utilities should take the initiative to educate consumers, builders, and other parties with brochures, videos, fact sheets, and web sites. Every utility should have a ZEH ombudsman to deal with the transition to the ZEH new home market.

Utilities should continue to promote vigorous demand-reduction programs, including rebates on energy-efficient appliances for builders and homeowners.

Solar Water Heating Manufacturers

Manufacturers of solar water heating should seek to participate in the market for turnkey packages for new ZEHs. If, as is hypothesized in this study, new homes with PV systems also provide better orientation for solar water heating systems, the benefits of solar water heating in reducing utility costs for customers will be even higher. Solar water heating, along with features that promote high levels of energy efficiency, should be offered standard with all ZEHs in the future.

Lenders

In this study, we found that the SheaHomes appreciated more on a percentage basis than comparison homes. Consequently we strongly recommend that lenders consider ZEHs to be a particularly lucrative mortgage-lending market because of the likelihood of improved cash flow for the buyers. There exists the potential for some innovative lenders to develop a niche in ZEH financing and successfully differentiate themselves within the broader market. Approaches to ZEH lending could be based on previously established models of energy-efficient mortgages (EEMs).

Secondary Mortgage Markets

Fannie Mae, Freddie Mac, and other secondary mortgage organizations have responsibilities to the public. These organizations should educate lenders and underwriters nationwide on the benefits of lending to ZEH homebuyers.

Real Estate Agents and Agencies

As the ZEH market develops, more and more of these homes will come into the secondary market. In order for them to be properly valued and re-marketed, real estate agents and agencies are going to have to be (1) made aware of their existence and (2) become as familiar with them as the original sales agents. This situation presents an excellent opportunity for a niche in the secondary market to be developed. Agents will undoubtedly be asked questions about taxes, insurance, longevity of the PV systems, and other related issues from prospective buyers who no little or nothing about ZEHs. Hence, we recommend that real estate agents and agencies take the initiative to obtain training about ZEHs and to engage their professional organizations to support such training activities.

Part Two: Information Dissemination Organizations and Environmental Concerns

Public awareness of ZEHs and their benefits will go a long way to promoting more availability. As the public demands access to ZEHs, builders will be forced to provide them, and a natural market will develop. Hence, the dissemination of information about ZEHs is extremely important. However, such information must be appropriate and reliable, and it must be easily accessible in order to have an impact. Not only does the public need information about equipment costs and energy savings, it needs information about the environmental benefits of ZEHs and solar PV technology. DOE should add a prominent ZEH section to both the Buildings and Solar Web sites at eere.gov. In this section, we link recommendations that have to do with information dissemination about ZEHs with those that have to do with environmental awareness.

Information Dissemination Organizations

We strongly encourage journalists and broadcast media to become aware that there is a win-win-win feature story to be reported about the value and desirability of ZEHs for builders, utility companies, the renewables industry, and homeowners. As examples, the *Today Show* of May 26, 2006 featured a segment on the Premier Gardens near-ZEH development in Sacramento, California. *Newsweek* featured a story called, "No More Electric Bills" on August 18, 2005. Such feature stories would help educate the public and the homebuying markets about the potential for ZEHs. Journalists and broadcast media should become aware of the value and desirability of ZEHs for builders, utility companies, the renewables industry, and homeowners. This would help educate the public and the homebuying markets about the potential for ZEHs, thus benefitting builders, homebuyers, utility companies through the zero-peak load to cut residential bills, the environment, the emerging photovoltaics industry, and others.

Environmental Organizations

Voluntary environmental organizations at all levels (local, state, and national) should be actively engaged in the promotion of ZEHs in all communities. Such efforts must be based on sound data and analyses to be credible. They will be most effective if environmental organizations coordinate their work, portraying a consistent picture about the environmental implications of ZEHs. Claims concerning the effects on the environment do not need to be exaggerated—the data substantiate the claims that these homes use less utility-supplied energy and help protect the environment. This is particularly critical in the arena of concern about the "carbon footprint" and global warming. Environmental organizations should actively engage the media to tell the full story about ZEHs.

Nonprofit Initiatives for Clean Energy and "Green" Building Initiatives

States, foundations, and nongovernmental organizations should better acquaint themselves with the potential of ZEHs in their communities. Such initiatives as state "clean energy funds" in 10 states[1] have provided support for PV, including buy-down programs for customer-sited PV (Barbose, Wiser, and Bolinger 2006). These funds can be used to provide higher incentives for builders to adopt PV and high-efficiency homes with solar water heating. They can also be used to cultivate the turnkey approach to PV and solar water heating, installation, builder champions, and to educate and train large production builders. Considerable potential exists for action among state, local and nonprofit partnerships to foster widespread ZEH construction.

[1]California, Connecticut, Illinois, Massachusetts, Minnesota, New Jersey, Oregon, Pennsylvania, Rhode Island, and Wisconsin.

Part Three: Recommendations for Government Agencies

A number of advances in federal, state, and local government programs and policies are needed to insure proliferation of ZEHs. Below we present some specific ways in which government entities can work to promote the development of a robust ZEH market.

Federal Government

Several agencies within the federal government can impact the uptake of ZEHs, including the U.S. Department of Energy (DOE) , the U.S. Environmental Protection Agency (EPA), the U.S. Department of Housing and Urban Development (HUD), and the Federal Energy Management Agency (FEMA).

U.S. Department of Energy (DOE)

DOE has a buildings R&D program and regulatory activities to improve building codes and to assist states in improving the energy efficiency of buildings. It also has a Solar Powers America Initiative. Through its Building America program, DOE should continue R&D to achieve true ZEHs before the current 2020 goal and continue its Building America Program to assist builders in designing, constructing, and monitoring ZEH subdivisions in various climates.

U.S. Environmental Protection Agency (EPA)

Based on its experience with the ENERGY STAR program, EPA should develop labeling for ZEHs so that consumers would know that the claims made for energy savings are realistic and accurate. ZEHs could be labeled similar to the same way that ENERGY STAR commodities are labeled, or they should receive some kind of approval similar to a *Good Housekeeping* Seal of Approval. However, such approval should only be awarded when the homes meet standards that have been established under best practices and meet the approval of appropriate industry and professional groups.

Federal Energy Management Agency (FEMA)

In working on redevelopment of areas devastated by natural disasters, FEMA should cooperate with builders, developers, and other federal agencies to foster sustainable rebuilding using ZEH principles and concepts. Homes that are rebuilt according to quality standards and best ZEH practices will result in significant savings in electricity consumption and costs, and will support the utility grid in traumatized areas, especially where the electricity load for air-conditioning is substantial.

The opportunity is not to reduce the potential hazards, which can only be achieved through better siting decisions, but to take advantage of the opportunity to build new ZEHs as replacement homes. The performance results would be superior to retrofitting older homes. Because homeowners who are victimized by natural disasters would have a difficult time building ZEHs on their own, they would need technical assistance from FEMA, builders, and others.

State and Local Governments

State and local governments can also take some very specific actions to foster the construction of more ZEHs.

As noted elsewhere in the report, our results suggest that SEE and comparison homes, which were built to California's Title 24 building code, have similar utility consumption patterns. Hence, we conclude that California's program is successful in conserving energy. The California initiative to provide utility surcharge funds for a million solar roofs statewide by 2010 appears to be well-advised, especially with California's need to shave peak loads, and may be mimicked in other states with peaking problems.

Additional recommendations for state and local governments follow:

- State legislation for net metering should be enacted to foster the use of the utility grids for residential and commercial PV-produced power to reduce peak loads. The homes at Scripps Highlands have a single meter, which seems to be the most effective approach.

- States with Renewable Portfolio Standards (RPSs) should mandate a set-aside for small scale residential net-metered electricity. A certain percentage of each utility's electricity supplies should come from net metered residential solar electricity by a certain date.

- The process for issuing building permits should be altered to encourage construction of ZEHs. Also, permits for ZEHs should "go to the head of the line" for permitting (as in the Expedite Program in San Diego) since they cut energy use and related emissions by at least 50%.

Part Four: Research Recommendations

Although our study was very extensive, there are still aspects of the ZEH concept that need to be explored. In particular, our ability to answer all the questions we wanted to ask was limited by the number of homes and homeowners available for study. Consequently, we recommend that a more controlled, statistically designed field experiment be conducted that encompasses more homes and a broader spectrum of home types. Provisions should also be made to study homes and homeowners longitudinally. It would be very desirable to observe utility behavior in ZEHs and comparison homes over time with the same occupants. The difficulty in planning such an experiment is that even large-production developments tend to have only a few hundred homes, and homeowner cooperation and response rates are notoriously low, although our study had a 63% response rate. The only way around these real-world limitations is to conduct more carefully designed longitudinal comparative studies with several new ZEH home developments near conventional developments. It would be ideal if the "experimental" and the comparison communities were built adjacent to each other and the utility data analyzed were for identical time periods.

There is a limit to how many variables can be included in a single study. Yet we discovered questions we didn't ask the homeowners that we wish we had. Additional variables would strengthen an investigation similar to the one we conducted. For example, in retrospect we would like to have asked homeowners about their expectations for their utility bills in the their new homes in real dollar terms. In addition, we did not collect data on the floor plans and orientations of the houses, which would be useful, and we should have obtained more details about the number of stories, bedrooms, living areas, and garages, as well as the actual ages of all occupants.

We recommend that a formal study of builders' attitudes toward ZEHs be conducted that would investigate the barriers and opportunities perceived by builders. However, finding the correct people within the company to answer such questions would be difficult; and the responses from the CEO, CFO, site manager, sales manager, options manager, and others would likely be different. Other questions of interest would include: (1) Are there ZEH innovation champions in the builder communities? and (2) What is the attitude and role of homebuilder associations relative to ZEHs?

Our study did not analyze the peak-demand impacts of the SheaHomes Scripps Highlands development. However, it is important to understand the peak-demand impacts of ZEH-induced electricity savings as well as ZEH output to the grid on hot summer afternoons. Relative to ZEH impacts on utility peak-demand, SMUD estimates that, if all new homes built during 2004 had been built to ZEH standards with PV systems oriented west of south, the utility could have realized a significant peak load reduction—up to 20 MW (Keesee 2005). Further analyses to establish these effects are needed.

Mortgage-lender requirements for cash-flow benefits of ZEH ownership relative to qualifying mortgages for ZEH loans also need to be analyzed. This would be similar to an EEM concept, except that it needs to go much further in considering in the economic impacts of electricity and gas cost savings in homes with PV systems of at least 2.4 kW.

Formal economic analyses should be performed on the costs of ZEHs. Variables to be addressed include: subsidies, tax credits, and utility bill savings in real dollar terms, expected length of stay in the households, mortgage payments and their increases (if any) in amortizing the cost of ZEH features, energy cost increases, and consideration of payback questions. Past economic analyses have focused on individual homeowners and addressed the question of whether PV purchase makes sense for individual households. We recommend a shift in the focus of economic analysis toward the costs and benefits of having a thriving ZEH industry to global, national, state, and local economies and the environment.

Further market research is needed on how to brand ZEHs. This research should address the kinds of terminology that should be used to capture public attention about the benefits for individual families purchasing these homes, as well as builders, utility companies, and other associated entities.

Research should explore further whether tankless water heating in combination with solar water preheating systems would be a better alternative to solar preheating water systems with gas-fired storage tanks. Tankless water heating has been successfully used in near-ZEH projects in the Sacramento area. The NAHB Research Center instrumented and monitored the heating, cooling, and water heating energy consumption of five SheaHomes without PV systems at Scripps Highlands (Moore 2003). The report, sponsored by PATH, showed that combining solar water preheating systems with tankless water heating resulted in the greatest energy savings among the various alternatives studied (45% to 77% savings from the base case used in their study).

Analysis of how ZEHs can be made available in affordable housing is needed. Such analysis should address the kinds of programs that would be needed to foster the routine inclusion of ZEH features in affordable housing and apartments, as well as the kinds of incentives that might be needed in rebuilding efforts, such as Katrina redevelopment, to build only sustainable housing.

Part Five: Audiences for the Report

Stakeholder groups know best how they can use the findings from this study to pursue productive and profitable activities. Following is a list of stakeholders for whom we think the report will be most beneficial.

Building Industry

- Large-production builders
- Home builders association
- California Building Industries Institute (BII)
- NAHB
- NAHB Research Center
- HVAC contractors
- Electricians, electricians' unions, International Association of Electrical Inspectors
- Other trade unions

Code Officials

- State building code officials
- Local building code officials
- Professional associations of state and local building code officials

Home Inspectors

- Building inspectors
- American Society of Home Inspectors
- National Association of Certified Home Inspectors

Marketing Companies and Market Research

- Home sales
- PV system sales
- Water heating systems sales
- Related sales
- Market research companies

Environmental Organizations

- Environment California
- Natural Resources Defense Council
- Sierra Club
- Other environmental organizations

Solar Energy Industries Associations

- California Energy Industries Association
- Colorado Solar Energy Industries Association
- Other solar energy industries associations

Professional Associations
- American Solar Energy Society
- American Council for an Energy-Efficient Economy
- Alliance to Save Energy
- Other professional associations

PV Manufacturers, Installers, and Brokers
- PV manufacturers (e.g., Alt-aire Energy, Powerlight, GE, Sharp, and Kyocera Solar, Inc.)
- Other installers and PV manufacturers

Water Heating Industry
- Solar water heating systems manufacturers (e.g., Sun Systems, Inc.)
- Tankless water heating manufacturers

Home Design Professionals
- Architects
- Architectural engineers
- Designers

Utility Companies
- SDG&E
- SMUD
- Other utility companies
- EPRI
- GRI

Federal Power Management Agencies
- WAPA
- BPA
- TVA

Energy Education
- Colorado Energy Science Center
- San Diego State University
- San Diego Regional Energy Office
- Vocational education
- Other educational institutions and organizations

Communicators
- Journalists; science writers
- *Time/Newsweek*, etc.
- Broadcast media (NPR, PBS, CNN, etc.)
- PR firms

Financial Interests

- Home mortgage lenders
- Investors
- Secondary mortgage markets (Fannie Mae, Freddie Mac, etc.)
- EEMs

Home Energy Raters and Energy Efficiency Designers

- RESNET
- ConSol, Inc.
- Energy Star Colorado

Federal Policy-Makers

- DOE Buildings Program; Million Solar Roofs Initiative
- HUD Energy Office
- EPA ENERGY STAR program
- NSF Climate Change Program
- CEQ Council on Environmental Quality
- OSTP Office of Science and Technology Policy
- U.S. military (military housing)

Regional Policy-Makers

- Western Governor's Association energy initiative
- Other regional policy-makers

State Policy-Makers and Associated Organizations

- State legislatures
- National Conference of State Legislatures (NCSL)
- Clean Energy States Alliance
- California Energy Commission
- Colorado Office of Energy Management (e.g.)
- California Governor's Office (million solar roofs initiative)
- Other state energy offices
- California PUC
- National PUC organization
- Other PUCs

Local Policy-Makers

- City of San Diego
- City of Aspen
- City of Boulder
- Other municipalities that are working on energy efficiency and renewable energy programs
- Local energy offices

Analysts/Researchers

- Climate change analysts (carbon footprint)
- Energy analysts/national laboratory and university researchers and research centers
- Environmental analysts
- Environmental sociologists, environmental psychologists, behavioral scientists
- National laboratory staffs

Nongovernmental Organizations

- Habitat for Humanity
- Consumer organizations (e.g., Consumers Union)
- Other NGOs and nonprofits

Other Interested Parties

- Coal, nuclear industries
- BP
- Alternative energy companies and manufacturers
- Lobbyists

Part Six: Final Summary Remarks

The creativity of SheaHomes in pursuing the high-performance homes project at Scripps Highlands has made possible a unique study on the market response and utility performance of these homes and helped to jump-start ZEH developments. The results of the study are encouraging for those who want to stimulate ZEH developments in California, throughout the United States, and abroad. If organizations become dedicated to the widespread building of ZEHs, the residential markets will be there. The degree to which the markets develop, however, depends on the collective and sustained response of all concerned.

This study provides extensive information for the many groups that will be involved in building ZEHs, providing equipment for them, and implementing policies to ensure their widespread acceptance. Effectively employed, this information can serve as the fuel for the engine of change in home building and utility net metering for years to come.

Bibliography

Albrecht, Don, Gordon Bultena, Eric Holberg, and Peter Nowak. 1082. "The New Environmental Paradigm Scale." *Journal of Environmental Education 13*: 39-43.

Anders, Scott. 2002, 2003. San Diego Regional Energy Center. Personal interviews.

Anders, Scott. 2006. Personal communication.

Bohner, Tom. 2002. Sun Systems, Inc. Personal interview.

Buhrmann, Jan and Barbara C. Farhar. 1998. Willingness to Pay for Renewable Energy: A Follow-up Study of Colorado Homeowners Interested in Residential Grid-Tied PV Systems. Boulder: University of Colorado, Bureau of Sociological Research, December, 60 pp.

Christensen, C.B. and G.M. Barker. 2001. Effects of Tilt and Azimuth on Annual Incident Solar Radiation for United States Locations. Kleis, S.J.; Bingham, C.E., eds. Solar Engineering 2001: Proceedings of the International Solar Energy Conference Presented at FORUM 2001, 21-25 April 2001, Washington, DC. New York: The American Society of Mechanical Engineers (ASME) pp. 225-232; NREL Report No. CP-550-32966.

Coburn, Timothy C.; Barbara C. Farhar, and Megan Murphy (2004). Comparative Analysis of Homebuyer Response to New Zero Energy Homes. Breaking Out of the Box: *Proceedings of the 2004 ACEEE Summer Study on Energy Efficiency in Buildings*, 22-27 August 2004, Pacific Grove, California. Washington, DC: ACEEE American Council for an Energy-Efficient Economy; pp. 8/48-8/60; NREL Report No. CP-550-37190.

Cohen, Jacob and Patricia Cohen. 1983. *Applied Multiples Regression/Correlation Analysis for the Behavioral Sciences*. 2nd Ed. Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.

Collins, Nancy. 2003. "Zero Energy-Use Homes Project: Interviews with People Who Visited the SheaHomes Scripps Highlands New Home Development." Oakland: Q^4 Associates.

Del Chiaro, Bernadette. 2006. "Rave Reviews for Solar Homes: A Survey of Homeowners in California." Los Angeles: Environment California Research and Policy Center, 24 pp. March.

Dillman, Don A. 1978. *Mail and Telephone Surveys: The Total Design Method*. New York: Wiley, 325 pp.

Dillon, William R. and Matthew Goldstein. 1984. *Multivariate Analysis: Methods and Applications*. New York: John Wiley & Sons, 587 pp.

Draper, N.R. and H. Smith. 1998. *Applied Regression Analysis*, 3rd ed. New York: John Wiley & Sons, 706 pp.

Dunlap, Riley E. and Kent D. Van Liere. 1978. "The New Environmental Paradigm." *Journal of Environmental Education 9*: 10-19.

Dunlap, Riley E., Kent D. Van Liere, Angela G. Mertig, and Robert Emmett Jones. 2000. "Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale." *Journal of Social Issues 56*: 425-442.

Farhar, Barbara C. 2004. Confidential focused interview with a SheaHomes buyer.

Farhar, Barbara C., Timothy C. Coburn, and Megan Murphy. 2004. "Large-Production Home Builder Experience with Zero Energy Homes." in *Proceedings of the 2004 ACEEE Summer Study on Energy Efficiency in Buildings, Breaking out of the Box,* pp. 8-09 to 8-109. Presentation at Pacific Grove, California, on August 24, 2004. http://www.nrel.gov/docs/fy04osti/35913.pdf

Farhar, Barbara C., Timothy C. Coburn, and Nancy Collins. 2002. "Market Response to New Zero Energy Homes in San Diego, California." In *Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings*. Washington, D.C.: American Council for an Energy-Efficiency Economy, pp. 8.41-8.54.

Farhar, Barbara C. and Colleen Fitzpatrick. 1989. *Effects of Feedback on Residential Electricity Consumption: A Literature Review*. 25 pp.; NREL Report No. TR-254-3386.

Farhar, Barbara C. and Timothy Coburn. 2000. *A Market Assessment of Residential Grid-Tied PV Systems in Colorado*, NREL/TP-550-25283, Golden, CO: National Renewable Energy Laboratory, September, 209 pp. http://www.nrel.gov/doc/fy00osti/25283.pdf

Farhar, Barbara C., Timothy C. Coburn, and Nancy Collins. 2002. "Market Response to New Zero Energy Homes in San Diego, California." In *Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings*. Washington, D.C.: American Council for an Energy-Efficient Economy, pp. 8.41-8.54.

Farhar, Barbara C., Grant Johnson, Jack Clark, Julia Mewes, Ron Rinkle, and Susan Shoulders. 1978. *Technology and Society: Weather Modification in South Dakota*. Boulder: Institute of Behavioral Science, University of Colorado. December. 488 pp.

Farhar-Pilgrim, Barbara and Charles T. Unseld. 1982. *America's Solar Potential: A National Consumer Study*. New York: Praeger Publishers. 438 pp.

Glaser, Barney and Anselm Strauss. 1967. *The Discovery of Grounded Theory: Strategies for Qualitative Research.* Chicago: Aldine Publishing Company.

Green, Ryan. 2002. Personal interview.

Greenberg, Michael. 2005. “Environmental Protection as a U.S. National Government Priority: Analysis of Six annual Public Opinion Surveys, 1999-2004.” *Journal of Environmental Planning and Management 48*: 733-746.

Hammon, Rob. 2005. “The Near-Zero-Energy House.” *Solar Today 19*: 22-25.

Hammon, Rob. 2004. Personal communication.

Hering, Garrett. 2005. “Solarizing the American Dream.” *PHOTON International.* Pp. 80-85.

Holbrook, Dale. 2003. Vice President, SheaHomes, San Diego Division. Personal interview.

Jl, Chang-Ho C. 2004. “Factor Structure of the New Environmental Paradigm Scale: Evidence from an Urban Sample in Southern California.” *Psychological Reports 94*: 125-130.

Keesee, Mike. 2005. “Setting A New Standard: Zero Energy Homes in the U.S.” *reFOCUS.* July/August. Pp. 26-28.

Kempton, Willett and Linda Layne. 1988. “The Consumer’s Energy Information Environment.” *Proceedings of the 1988 ACEEE Summer Study on Energy Efficiency in Buildings 11*: 11.50-11.66. Washington, DC: American Council for an Energy Efficient Economy.

Kinnear, Paul R. and Colin D. Gray. 1997. *SPSS for Windows Made Simple*, 2nd Ed., East Sussex, UK: Psychology Press. 386 pp.

Kleinbaum, David G. and Lawrence L. Kupper. 1978. *Applied Regression Analysis and Other Multivariable Methods.* North Scituate, Massachusetts: Duxbury Press.

Kleinbaum, D. G., L. L. Kupper, and K. E. Muller. 1988. *Applied Regression Analysis and Other Multivariable Methods*, 2nd ed. Boston: PWS-Kent Publishing Company, 718 p.

Leonard-Barton, Dorothy. 1978. *The Diffusion and Adoption of Solar Equipment among California Homeowners: Report on a Pretest Study.* Stanford, California: Institute for Communications Research, Stanford University.

Leonard-Barton, Dorothy and Everett M. Rogers. 1979. “Adoption of Energy conservation among California Homeowners.” White paper. Stanford, California: Stanford University Department of Communications.

Marcus, M. and H. Mine. 1988. *Introduction to Linear Algebra*. New York: Dover, p. 145.

Marks, Addison. 2006. Personal communication.

Merton, Robert. 1990. *The Focused Interview: A Manual of Problems and Procedures*. 2nd Ed., New York: The Free Press.

Moore, Michael. 2003. "Final Report for Field Evaluation of PATH Technologies, SheaHomes, San Diego, California." Washington, D.C. National Association of Home Builders (NAHB) Research Center, for the Partnership for Advancing Technology in Housing (PATH), U.S. Department of Housing and Urban Development. October. 35 pp.

Morrison, Donald F. 1976. *Multivariate Statistical Methods*. 2nd Ed. New York: McGraw-Hill Book Company.

Murr, Andrew. 2005. "No More Electric Bills." *Newsweek*, August 15, p. 43.

Nelson, Les. 2006. Personal communication.

RESNET. 2006. "Adopted 2005 Enhancements of the National Home Energy Rating Standards." Residential Energy Services Network www.natresnet.org/amendments/default.htm.

Rivera, Diane. 2002, 2003, 2004. Marketing Director, SheaHomes, San Diego. Personal interviews.

Rogers, Everett M. 1995. *Diffusion of Innovations*. Fourth Edition. New York: The Free Press, 519 pp.

Rogers, Everett M. and F. Floyd Shoemaker. 1971. *Communication of Innovations*. 2nd Edition. New York: The Free Press.

Roper, Marc. 2002. AstroPower, Inc. Personal interviews.

Roper, Marc. 2006. Personal communication.

Shusterman, Teri. 2001, 2002. Marketing Director, SheaHomes, San Diego. Personal interviews.

Starrs, Thomas J. 1996. "Net Metering: New Opportunities for Home Power." *Renewable Energy Policy Project (REPP) Issue Brief*, No. 2, College Park: University of Maryland, September, 11 pp.

Stokes, Kirk. 2004. Altair Energy, Denver, Colorado. Personal interviews.

Van Liere, Kent. 2003. Personal communication concerning the best items to use in the questionnaires to measure environmental values from the New Environmental Paradigm.

U.S. Department of Energy. n.d. “Building America Research Is Leading the Way to Zero Energy Homes.” Fact Sheet. Washington, D.C.: Office of Energy Efficiency and Renewable Energy, Building Technologies Program.

U.S. Department of Energy Web site for renewable energy and energy efficiency: http://www.eren.doe.gov/solarbuildings

Epilogue

Introduction

Considerable activity by production home builders has moved the concept of near zero-energy homes (ZEHs) closer to reality since this study began in 2001. This epilogue summarizes recent builder activity in near-ZEHs. It also compares findings on electricity bill savings from other solar home projects to results from the current study on the SheaHomes Scripps Highlands development using 12 months of utility billing data for the SheaHomes and comparison home communities.

New Production Solar Home Developments in California

Since this study began, large-production builders other than SheaHomes have initiated new solar home projects in California. According to the 2006 Mortgage Industry National Home Energy Rating Standards (HERS), tomorrow's ZEH is a home that saves 100% of its energy consumption compared to a HERS reference home of the same size (RESNET 2006). The newly adopted "HERS Index" uses a score of "0" for a net zero energy home while a score of "100" equates to the HERS reference home. None of the solar PV homes built in California since the SheaHomes Scripps Highlands development meet the true ZEH standard; however, at least 13 projects in California have been identified that feature homes with solar-electric (solar-PV) systems. Table 123 summarizes these developments. At least six large-production builder companies offer these solar homes: Centex Homes, Clarum Homes, Morrison Homes, Pardee, Premier Homes, SheaHomes, and US Homes. Hundreds of today's ZEHs have been built and thousands have been planned in California communities as of this writing. Today's ZEH cuts utility bills at least 50%.

Clearly, at least a small percentage of production builders in California has recognized a market for new solar homes in California. These "early adopter" builders are climbing the necessary learning curve to build and offer these innovative homes. The homes provide the builders with market differentiation, free advertising through media interest, fast sales, a market edge because of substantially reduced utility bills, and community goodwill (Hammon 2005). The market experience for these homes appears to be positive. For example, Clarum Homes reportedly sold 60% of the 257 solar homes at Vista Montana before its grand opening and sold out completely one year ahead of schedule (Hering 2005). In fact, the builder has decided to build only solar homes in the future (Hammon 2005).

Table 123 shows a relatively modest number of solar homes compared to the estimated 150,000 new housing starts in California during 2005 (Hering 2005). As noted in Table 123, Lennar Communities is involved in the Bickford Ranch development in Placer County. In addition, Lennar is developing a 1,600-home community with 1.2 PV systems at Hunters Point Naval Shipyard in San Francisco.

New technology is helping to spur builder interest in solar homes. Roof-integrated PV systems—such as PV tiles or shingles—blend seamlessly into roofs. These building-integrated PV systems are preferred by homebuilders for aesthetic reasons.

Table 123. Solar Home Developments in California in 2005

Name of Development	Builder and Location	Price Range	Number of Homes; PV System Sizes
Premier Gardens Rancho Cordova	Premier Homes Sacramento	$150,000 to $270,000	99 homes 2.4-kW PV systems
Terramore at Ladera Ranch	SheaHomes Orange County	$900,000 to $1 million starting price	87 homes 2.4-kW PV systems
Vista Santa Barbara	Pardee Homes San Diego	_**	_
Evergreen at Ladera Ranch	Pardee Homes Orange County	_**	77 homes; 29% with 2.4-kW PV systems
Ladera Ranch San Diego	Other builders	_**	122 homes with 1.2-kW and 2.4-kW PV systems***
Grupe Homes	Sacramento	–	–
Vista Montana	Clarum Homes Watsonville	$340,000 to $380,000	257 homes 1.2- to 2.4-kW PV systems
Shorebreeze I, II, III, and IV	Clarum Homes Palo Alto	$595,000 (Phase IV)	39 homes
Hamilton Park	Clarum Homes Menlo Park	_**	47 homes
KD Development San Diego	_**	_**	100-150 homes
Premier Oaks	Premier Homes Roseville	_**	49 homes 2-kW PV systems
Bickford Ranch Hunter's Point	US Homes Lennar Communities Placer County	_**	917 proposed homes
Lakeside Elk Grove	Morrison Homes	_**	120 homes; only 12 with 2-kW PV systems
Centex Homes	Livermore San Ramon	–	–

*Other builders of solar homes mentioned by Hering (2005) are Centex Homes and Standard Pacific Homes
**Information not available
***Hering (2005) reports that GE Energy is supplying 350 systems to Terramore Village at Ladera Ranch in Orange County

Sources: http://environmentcalifornia.org/ accessed 9/1/05;
unpublished case studies by Bruce Baccei, ConSol, Inc., (2005); and Pratsch (2006).

Performance of Near-ZEHs: The Premier Gardens Case

Keesee (2005) reports that Premier Gardens developed by Premier Homes in Sacramento, California, is one of the first "all ZEH" communities.[1] Keesee also claims that these homes have a package of energy-efficiency measures that reduces heating and water heating energy use by more than 15% and cooling energy use by 50%, compared to California's Title-24 building energy standards in a cooling-dominated climate.

Results reported by the Sacramento Municipal Utility District (SMUD) from an analysis of 10 months of utility data comparing the 95 Premier Gardens homes with 95 nearby conventional homes (Keesee 2005) are as follows:[2]

- On average, 16% less electricity was used by the Premier Gardens Homes compared to the comparison homes during the first 10 months of occupancy.[3]
- PV systems supply more than 47% of the electricity in the Premier Gardens Homes.
- Average monthly electricity bills are 54% lower in the Premier Gardens Homes than in the comparison homes.
- Average monthly electricity bills for the Premier Gardens Homes are 50% lower than the average monthly SMUD residential bill.

A corresponding analysis of April 2005 bills conducted by Keesee (2005) showed that the average electricity bills for this one month were 78% lower than the "typical SMUD bill" and 63% lower than the comparison homes' bills. A SMUD analysis of December 2004 bills shows that the Premier Gardens' electricity bills were 42% lower than SMUD's "typical residential customers" for this one month (Hering 2005).

Hammon (2005) also analyzed a comparison of one month of electricity bills in September 2004 for Premier Gardens and comparison homes. He reports that 22 of the Premier Gardens "near-ZEHs" used 60% to 70% less electricity than 17 neighboring homes in the Sacramento area during that month. The size of the PV systems was not reported, but other sources suggest that it was 2 kW (Table 123). Data on the homes' square footage, occupancy, equipment, and other factors that affect energy consumption—and therefore bills—are not reported.

---

[1]Technically, this is not accurate because these homes cannot provide all the energy they use. Data reported in Keesee (2005).

[2]The method was a comparison of simple averages of the electricity bill data from the two communities.

[3]Hammon (2006) later clarified that the 16% decrease in electricity use was the result of energy efficiency measures only; the effects of the PV systems were in addition to the 16%. The Premier Gardens homes all had two electric meters, one for PV generation and one for home net, so that the contributions of energy efficiency and PV could be calculated separately. More analyses have been completed on the Premier Gardens experience and they may be found in the Proceedings of the American Council for an Energy-Efficient Economy 2006 Summer Study, authored by Hammon and others.

Results from the Premier Gardens development were also reported in a *Newsweek* article by Andrew Murr on August 15, 2005, entitled "No More Electric Bills" (page 43). The article features a claim that the average power saving for those living in these homes is 60%. The story describes the energy features of the community, including 2-kW solar modules on the roof, spectrally selective windows, "fluorescent bulbs" (probably referring to compact fluorescent lights), and tankless water heating. The homes are net metered. SMUD's Keesee is quoted as saying that the project "helps us lower usage at peak power times. That lets us avoid building costly plants or buying expensive power at peak usage time."

The article reported that the Premier Gardens' energy features add $18,000 to the purchase price of the home; in other locations these features can add $25,000 or more. California subsidizes approximately 50% of the cost of the solar PV systems.[4]

The current study did not analyze the peak-demand impacts of the SheaHomes Scripps Highlands development. However, it is important to understand the peak-demand impacts of ZEH-induced electricity savings, as well as ZEH output to the grid on hot sunny afternoons. Relative to ZEH impacts on utility peak demand, SMUD analyses show that peak electrical demand has been reduced by as much as 13% in homes that participated in the PV Pioneer retrofit and Solar Advantage Home PV programs. SMUD estimates that, if all new homes built during 2004 had been built to ZEH standards with PV systems oriented west of south, the utility could have realized a significant peak load reduction—up to 20 MW (Keesee 2005). SMUD plans continued analysis of electrical usage, bills, and peak-demand impacts of the ZEH homes over the years ahead to determine the impact of ZEHs on the utility's system peaks.

Percentages of Energy Cost Savings at the SheaHomes Scripps Highlands Relative to Comparison Homes

Tables 124 through 128 present data from the current study on the percentages of savings on bills for electricity and gas for various categories of homes. In all cases, the SheaHomes high-performance homeowners enjoyed lower electricity and gas bills, on average, than did the comparison homeowners for the 12-month period from July 1, 2003, through June 30, 2004.

Table 124. Mean Monthly Gas Costs for PV, SEE, and Comparison Homes

Gas Costs	PV Homes (n=31)	SEE Homes (n=44)	Comparison Homes (n=28)	Total (n=103)
Mean monthly* gas cost including taxes and miscellaneous charges (F=4.970; p=.009)	$31.59	$35.76	$43.22	$36.53
Mean monthly* gas cost excluding taxes and miscellaneous charges (F=4.960; p=.009)	$29.64	$33.56	$40.58	$34.29

*12-month average

[4] As of July 2006, California's subsidy stood at $2.60/W (Nelson 2006).

Table 124 presents data on the average monthly gas costs for PV, SEE, and comparison homes. As Table 124 shows, the ANOVA results in highly significant differences in mean gas cost among the three categories of homes. The mean monthly gas costs for PV homeowners including and excluding taxes and miscellaneous charges are significantly lower than those of comparison homeowners. The mean monthly gas costs for SEE homeowners both including and excluding taxes and miscellaneous charges are also significantly lower than the mean monthly gas costs of comparison homeowners (p=.009). The mean monthly gas costs including and excluding taxes and miscellaneous charges for PV homeowners are not significantly different from those of SEE homeowners.

As Table 125 shows, the mean annual electricity cost was 13% lower for the SEE homes[5] than for the comparison homes when taxes and other charges are included, and the mean monthly electricity cost with all charges was 14% lower. The gas costs were even more advantageous to the SEE owners, fully 17% lower than the gas costs in the comparison community homes, on average. These savings are attributable to the energy-efficiency features of the SEE homes, which save electricity and gas that would otherwise have been used for space conditioning and water heating. All these differences are statistically significant. The savings in gas costs near statistical significance (p=.059).

Table 126 compares data on the same variables for SheaHomes with PV systems[6] and the comparison homes. In this instance, the mean electricity savings are higher, with the SheaHomes PV owners saving, on average, 35% on electricity costs compared to the comparison homeowners. Interestingly, the gas savings of the PV homes are even higher than for the SheaHomes in general, averaging 27%, or 10 points higher than for SheaHomes as a whole. These savings may be attributed to the energy efficiency and solar PV features of the SheaHomes, as well as other factors. The cost savings could result simply from greater consciousness of energy consumption on the part of solar PV residents, the floor plans or orientations of solar PV homes, or other factors.

Table 127 compares data on these variables for SheaHomes with PV systems[7] to SEE homes. The PV homeowners enjoy 25% lower electricity bills, on average, than do the non-PV homes. They also enjoy a 17% cost saving on their gas bills, on average.

Table 128 compares data on the same set of variables for SheaHomes with 1.2-kW PV systems and SheaHomes with 2.4-kW PV systems. The percentage differences in electricity cost are the highest of all the comparisons. All these differences are statistically significant. SheaHomes owners of 2.4-kW solar PV systems save an average of 46% on their annual electricity costs compared with SheaHomes owners of 1.2-kW solar PV systems. Clearly, this finding is a function of PV system size. Further, although the numbers are small, the owners of the larger PV systems average an incremental saving of 2% on their annual gas bills.

---

[5]SEE homes are SheaHomes energy-efficient homes with solar water preheating systems.

[6]Ignoring size of PV system

[7]Ignoring size of PV system

Table 125. Percentage Differences in Electricity and Gas Costs of SEE Homes and Comparison Homes

Electricity Costs	SEE homes (n=44)	Comparison Homes (n=28)	Percentage Difference
Mean annual electricity cost including taxes and miscellaneous charges (t-test n.s.; p=.214)	$1,360.43	$1,562.98	13%
Mean annual electricity cost excluding taxes and miscellaneous charges (t-test n.s.; p=.183)	$1,236.37	$1,434.87	14%
Mean monthly* electricity cost including taxes and miscellaneous charges (t-test n.s.; p=.217)	$ 113.56	$ 130.34	13%
Mean monthly* electricity cost excluding taxes and miscellaneous charges (t-test n.s.; p=.186)	$ 103.21	$ 119.67	14%
Gas Costs			
Mean annual gas cost including taxes and miscellaneous charges (t= –1.940; p=.059**)	$ 427.17	$ 516.61	17%
Mean annual gas cost excluding taxes and miscellaneous charges (t= –1.937; p=.059**)	$ 400.95	$ 485.05	17%
Mean monthly* gas cost including taxes and miscellaneous charges (t= –1.938; p=.059**)	$ 35.76	$ 43.22	17%
Mean monthly* gas cost excluding taxes and miscellaneous charges (t= –1.936; p=.059**)	$ 33.56	$40.58	17%

*12-month average
**These results near significance.

Table 126. Percentage Differences in Electricity and Gas Costs of SheaHomes with PV Systems and Comparison Homes

Electricity Costs	SheaHomes with PV Systems (n=37)	Comparison Homes (n=28)	Percentage Difference
Mean annual electricity cost including taxes and miscellaneous charges (t= –3.196; p=.002)	$1,015.38	$1,562.98	35%
Mean annual electricity cost excluding taxes and miscellaneous charges (t= –3.422; p=.001)	$ 922.32	$1,434.87	36%
Mean monthly* electricity cost including taxes and miscellaneous charges (t= –3.190; p=.003)	$ 84.77	$ 130.34	35%
Mean monthly* electricity cost excluding taxes and miscellaneous charges (t= -3.415; p=.001)	$ 77.00	$ 119.67	36%
Gas Costs			
Mean annual gas cost including taxes and miscellaneous charges (t= –3.105; p=.003)	$ 375.72	$ 516.61	27%
Mean annual gas cost excluding taxes and miscellaneous charges (t= –3.102; p=.003)	$ 352.52	$ 485.05	27%
Mean monthly* gas cost including taxes and miscellaneous charges (t= –3.098; p=.003)	$ 31.48	$ 43.02	27%
Mean monthly* gas cost excluding taxes and miscellaneous charges (t= –3.095; p=.003)	$ 29.53	$ 40.58	27%

*12-month average

A Comparative Analysis

It is useful to discern whether the data from our study of electricity cost savings support the findings of Keesee (2005) and Hammon (2005) that compare Premier Gardens homes with neighboring comparison homes. As noted above, Keesee (2005) reports mean monthly electricity bills that are 54% lower than the bills of comparison homes for the first 10 months of occupancy (number of homes not reported). Also as previously noted, Keesee reports a 63% lower electricity bill for the month of April 2005 compared with the bills of comparison homes. Also Murr (2005) reports a 60% saving on electricity bills, and Hammon (2005) reports 60% to 70% lower electricity bills for the month of September 2004 compared with comparison homes.

Table 127. Percentage Differences in Electricity and Gas Costs of SheaHomes with PV Systems and SEE homes

Electricity Costs	SheaHomes with PV Systems (n=37)	SEE Homes (n=44)	Percentage Difference
Mean annual electricity cost including taxes and miscellaneous charges (t= –2.671; p=.009)	$1,015.38	$1,360.43	25%
Mean annual electricity cost excluding taxes and miscellaneous charges (t= –2.653; p=.010)	$ 922.32	$1,236.37	25%
Mean monthly* electricity cost including taxes and miscellaneous charges (t= –2.669; p=.009)	$ 84.77	$ 113.56	25%
Mean monthly* electricity cost excluding taxes and miscellaneous charges (t= –2.651; p=.010)	$ 77.00	$ 103.21	25%
Gas Costs			
Mean annual gas cost including taxes and miscellaneous charges (t-test n.s.)	$ 375.72	$ 427.17	17%
Mean annual gas cost excluding taxes and miscellaneous charges (t-test n.s.)	$ 352.52	$ 400.95	17%
Mean monthly* gas cost including taxes and miscellaneous charges (t-test n.s.)	$ 31.48	$ 35.76	17%
Mean monthly* gas cost excluding taxes and miscellaneous charges (t-test n.s.)	$ 29.53	$ 33.56	17%

*12-month average

An analogous case that uses our study's data compares electricity bills from the homes with 2.4-kW PV systems with the electricity bills of the comparison homes. The findings should be similar because the PV system size reported for Premier Gardens is 2-kW AC, approximately equivalent to the 2.4-kW PV DC systems in the current study. Table 129 exhibits the costs and percentage differences for electricity and gas bills, as well as for combined utility bills, for the comparison homes and the SheaHomes with 2.4-kW PV systems only. The data span a comparable period of 12 months. As Keesee's and Hammon's studies would predict, *the savings on electricity bills for these small groups of homes average 62% to 64%*, depending on which cost variable is examined.

Taking the analysis further than earlier analyses reported by Keesee and Hammon, Table 128 compares the gas costs and differences as well, showing that, on average, the SheaHomes with 2.4-kW PV systems save 29% more than the comparison homes on their gas bills, in addition to their electricity cost savings.

Table 128. Percentage Differences in Electricity and Gas Costs of SheaHomes with 1.2-kW PV Systems and SheaHomes with 2.4-kW Systems

Electricity Costs	**SheaHomes with 1.2-kW PV Systems (n=31)**	**SheaHomes with 2.4- kW PV Systems (n=6)**	**Percentage Difference**
Mean annual electricity cost including taxes and miscellaneous charges (t=2.140; p=.039)	$1,097.42	$ 591.48	46%
Mean annual electricity cost excluding taxes and miscellaneous charges (t=2.169; p=.037)	$ 998.42	$ 529.13	47%
Mean monthly* electricity cost including taxes and miscellaneous charges (t=2.137; p=.040)	$ 91.60	$ 49.25	46%
Mean monthly* electricity cost excluding taxes and miscellaneous charges (t=2.166; p=.037)	$ 83.34	$ 44.24	47%
Gas Costs			
Mean annual gas cost including taxes and miscellaneous charges (t-test n.s.)	$ 376.98	$ 369.21	2%
Mean annual gas cost excluding taxes and miscellaneous charges (t-test n.s.)	$ 353.73	$ 346.30	2%
Mean monthly* gas cost including taxes and miscellaneous charges (t-test n.s.)	$ 31.59	$ 30.91	2%
Mean monthly* gas cost excluding taxes and miscellaneous charges (t-test n.s.)	$ 29.64	$ 28.99	2%

*12-month average

Indeed, the combined total utility costs for the 12-month period of analysis shows that the SheaHomes with 2.4-kW PV systems save 54% on their *overall combined utility bills* for the 12-month period, on average, compared with the overall combined utility bills for the comparison homes. Thus, the claims made by prior researchers, engineering estimates, and analyses of actual performance of near-ZEHs are borne out by the data in this study.

Our findings are not strictly comparable to those reported from the Premier Gardens studies. For one thing, the analyses in this report measure an annual utility billing cycle rather than one month or 10 months of billing data, which were the foci of previous investigations. In addition, two different sets of homes are involved with different characteristics and located in somewhat different climates. Perhaps their only common characteristics are certain energy features. Also, the Premier Gardens solar PV systems are larger than are most of the 1.2-kW solar PV systems on SheaHomes.

To set the findings discussed above into a broader context, Table 130 presents data on the average monthly combined utility bills for PV, SEE, and comparison homes. As Table 8 shows, the analysis of variance results in highly significant differences in mean combined utility bills among the three categories of homes. The mean combined monthly utility bills for PV homeowners (1.2-kW and 2.4 kW combined) both with and without taxes and miscellaneous charges are significantly lower than those of SEE homeowners, and the latter enjoy significantly lower mean combined monthly utility bills than do comparison owners. These results are particularly pronounced when the costs are analyzed on a square-footage basis. This set of findings provides additional support to the concept of high-performance homes' reducing overall monthly utility bills.

Concluding Remarks

These findings have implications for policy makers. In addition to homebuilders, policy makers are taking notice of the investment and business potential of solar PV homes. Hering (2005) reports that the Million Solar Roofs initiative (now the Solar Powers America Initiative) has set the goal of one million solar roofs by 2017. The recently authorized California Solar Incentive (CSI) program has similar goals, setting more than $3 billion aside over 10 years for construction and retrofit of commercial and residential buildings. The residential new construction share is $350 million.

Thus, the claims made by prior researchers, engineering estimates, and analyses of actual performance of near-ZEHs are borne out by the data in this study reducing average monthly utility costs by at least 50% when 2.4 PV systems are used in highly energy-efficient homes with solar water heating systems.

Table 129. Percentage Differences in Electricity and Gas Costs of Comparison Homes and SheaHomes with 2.4-kW PV Systems

Electricity Costs	Comparison Homes (n=28)	SheaHomes with 2.4-kW PV Systems (n=6)	Percentage Difference
Mean annual electricity cost including taxes and miscellaneous charges	$1,562.89	$ 561.48	64%
Mean annual electricity cost excluding taxes and miscellaneous charges	$1,434.87	$ 529.13	63%
Mean monthly* electricity cost including taxes and miscellaneous charges	$ 130.35	$ 49.45	62%
Mean monthly* electricity cost excluding taxes and miscellaneous charges	$ 119.69	$ 44.24	63%
Total kWh cost, 12 months ($t = -3.054$; $p = .005$)	$1,434.87	$ 529.13	63%
Total electricity bill, 12 months ($t = -2.990$; $p = .005$)	$1,562.89	$ 591.48	62%
Gas Costs			
Mean annual gas cost including taxes and miscellaneous charges	$ 516.61	$ 369.21	29%
Mean annual gas cost excluding taxes and miscellaneous charges	$ 485.05	$ 346.30	29%
Mean monthly* gas cost including taxes and miscellaneous charges	$ 43.22	$ 30.91	29%
Mean monthly* gas cost excluding taxes and miscellaneous charges	$ 40.58	$ 28.99	29%
Total therm cost, 12 months (t-test n.s.; $p = .116$)	$ 485.05	$ 346.30	29%
Total gas bill, 12 months (t-test n.s.; $p = .116$)	$ 516.61	$ 369.21	29%
Combined Utility Costs			
Total combined utility bill including taxes and miscellaneous charges, 12 months ($t = -3.010$; $p = .005$)	$2,079.50	$ 960.69	54%

*12-month average

Table 130. Average Monthly Combined Utility Bills Comparing PV, SEE, and Comparison Homes

Cost Measure	PV Homes (n=37)	SEE Homes (n=44)	Comparison Homes (n=28)	Total (n=109)
Mean monthly* combined utility bill including taxes and miscellaneous charges (F=7.269; p=.001)	$116.25	$149.33	$173.57	$144.32
Mean monthly* combined utility bill excluding taxes and miscellaneous charges (F=7.517; p=.001)	$106.53	$136.77	$160.25	$132.54
Mean monthly* combined utility bill per ft^2 including taxes and miscellaneous charges (F=11.095; p=.000)	$.038	$.048	$.062	$.048
Mean monthly* combined utility bill per ft^2 excluding taxes and miscellaneous charges (F=11.451; p=.000)	$.035	$.044	$.057	$.044

*12-month average

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
December 2006	Technical Report	

4. TITLE AND SUBTITLE
A New Market Paradigm for Zero-Energy Homes: The Comparative San Diego Case Study; Volume 1 and Volume 2 (Appendixes)

5a. CONTRACT NUMBER
DE-AC36-99-GO10337

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
B.C. Farhar and T.C. Coburn

5d. PROJECT NUMBER
NREL/TP-550-38304

5e. TASK NUMBER
ZB033003; BET68007

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

8. PERFORMING ORGANIZATION REPORT NUMBER
NREL/TP-550-38304

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)
NREL

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 Words)*
The housing industry is in flux. Today's landscape differs from the buyer's market in San Diego we have studied for the past five years. Demand for housing varies in different parts of California and the nation, and interest rates are on the upswing. The value of our study does not lie in describing the motivations of today's new homebuyers, but rather it lies in suggesting a conceptually fresh alternative paradigm for the building and marketing of zero-energy homes (ZEHs) based on experience. When this paradigm is used, builders, new homebuyers, and utility companies will benefit. When appropriately applied to business practice and public policy, this new paradigm will help builders create the sustainable communities so necessary for our well-being and that of future generations.

15. SUBJECT TERMS
zero-energy home; zeh; SheaHomes; new homebuyers

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			
Unclassified	Unclassified	Unclassified	UL		**19b. TELEPHONE NUMBER** (*Include area code*)