Final Report: Occupied Home Evaluation Results

Deliverable Number 16.D.2

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Task 16.D.2 Final Report: Occupied Home Evaluation Results

Project Overview

Executive Summary

Using Building America's new 2008 reporting criteria, this occupied homes evaluation addresses Gate 3 Project Closeout and Final Lessons Learned for the Building America community Premier Gardens. As there have been multiple "Final Lessons Learned" reports, this report will focus on the marketability of benefits created by the Premier Gardens community demonstrated through analysis of gas and electric consumption data and 15-minute interval peak electricity data along with other non-energy information sources. This report builds on previous Premier Gardens post occupancy Gate 3 analysis as it addresses the statistical significance of energy savings and discusses multiple stakeholder benefits of Zero Energy Community construction as it relates to future Building America communities.

In 2004, Premier Garden's near-Zero Energy Homes (ZEHs) and Cresleigh Rosewood's non-ZEHs were built side-by-side, providing BIRA the opportunity to evaluate two large scale communities of occupied single-family homes. The non-ZEHs surpass California's building code, designed to save 30% on summer cooling energy, while the near-ZEHs represent Building America Near-ZEHs. With at least one year of electric and gas use data for each community, totaling almost 200 homes, BIRA compares the benefits of near-ZEHs to non-ZEHs finding a 44% reduction in whole house energy use. Beyond this, BIRA uses inferential statistics to identify statistically significant gas and electricity consumption savings at Premier relative to Cresleigh that can be generalized to the population beyond the sample both by units of energy per home, and per square foot.

Additionally, BIRA investigates and identifies the benefits of near-ZEHs for homebuilders, homebuyers, the Sacramento Municipal Utility District (SMUD), and other stakeholders to understand the collective benefits near-ZEHs offer.

BIRA evaluated the actual energy performance of Premier near-ZEHs against estimates using the simulation tools and best assumptions that were available at the time of construction. Equipped with updated information, models were revised to more closely simulate as-built and customer use information. BIRA found that electricity use was within 2% of expectations, while actual gas use was over estimated by 20% using Micropas and Building America benchmark assumptions for appliance, lighting, and miscellaneous energy use.

This Occupied Home Evaluation Report serves as both an empirical overview of the Premier Gardens project, but also a look forward leveraging the lessons learned and success of Premier Gardens. With the collective benefits better understood for all stakeholders, the Premier Gardens experience can serve as a platform for the next level of Zero Energy Home technical and commercial success.

Task Description

Working with lead builders and developers, BIRA shall evaluate production-scale performance benefits from advanced systems in a minimum of 50 occupied Building America and standard practice homes. The report shall include

• results of energy performance measurements comparing average annual energy savings and peak demand reductions of the Building America homes relative to the standard practice homes..

• an evaluation of builder benefits from the Building America Homes relative to the standard practice homes

• an evaluation of homeowner benefits from the Building America homes relative to the standard practice homes.

• an evaluation of other decision maker benefits from the Building America homes relative to the standard practice homes.

Introduction

Given the large sample of near Zero Energy Homes and control homes combined with the amount of data collected, Premier Gardens and Cresleigh Rosewood offers a unique opportunity to evaluate the large scale impacts of Near Zero Energy Homes. BIRA and the Sacramento Municipal Utility District (SMUD) have evaluated these homes from many perspectives.

In 2006, BIRA authored a Building America Program (BAP) report including similar criteria and asking for the same elements of analysis regarding the Premier Gardens community. This report, 12.E.2, studied the Premier Gardens and Cresleigh Rosewood occupied homes case study accumulating all the pre-existing data and analysis as well as identifying the benefits of Zero Energy Homes for multiple stakeholders. This report was conclusive for the stakeholder benefits at Premier Gardens, and is summarized in an ASES Solar 2007 paper titled, "Premier Gardens and Cresleigh Rosewood: A Zero Energy Community Case Study." Additionally, BIRA used the same concept to identify the benefits of green zero energy construction for jurisdictions, builders, homeowners, utilities, and all levels of government. This paper identified the quantifiable benefits of large scale Zero Energy Home communities and suggested that marketing these benefits to all stakeholders improves the financial picture of ZEH construction fostering greater absorption into the marketplace. This paper was also presented at ASES Solar 2007 and titled, "Putting It all Together: Aggregating Benefits, Selling to Stakeholders- The Benefits of Zero Energy Homes Reach Far Beyond the Homeowner." All three of these papers can be found at www.BIRA.ws.

Given the depth of research and analysis involved in last year's report and the resulting conference papers, this report will focus on an alternate subject. However, the stakeholder benefits of Zero Energy Homes are important to communicating and implementing Zero Energy construction practices, thus identifying, quantifying, and demonstrating these benefits will continue to be a research focus of the BIRA team. Included as Appendix III is an abstract submitted to the 2008 ACEEE Summer Study on Energy Efficiency in Buildings continuing on the stakeholder values concept and suggesting a model for marketing these ZEH benefits to stakeholders outside homeowners.

The Premier Gardens case study utility data and analysis has been instrumental in creating and shaping utility and state programs aimed at institutionalizing high levels of energy efficiency and solar energy in production housing. The energy savings, peak electricity savings, faster sales, and low cost of Zero Energy community development as demonstrated through BIRA and its partners' analysis promoted implementation of several programs including California's New Solar Home Partnership and SMUD's Solar Smart program. The basic argument being used toward the creation of these programs and subsequent incentives is the benefits achieved at Premier Gardens can be expected at future projects if they followed Building America best practices. To do this for utility bill savings and peak electricity reductions inferential statistical analysis must be performed to assert that results at Premier Gardens could be expected with a high level of certainty in other communities. One main focus of this report is to understand and evaluate the statistical significance of the Premier Gardens energy savings and how that could be practically significant to future projects.

The BIRA team worked with partner California State University (CSU) Chico Statistician and Professor Dan Toy Ph.D. to analyze and evaluate the Premier Gardens and Cresleigh Rosewood data. Dr. Toy analyzed the monthly electricity use data, 15-minute electricity use data, gas use data, and predicted values vs. actual using Statistica, an advanced statistical analysis tool. Challenges emerged that limited BIRA's ability to fully report statistical results of the Premier Gardens homes. But, BIRA and CSU have laid a ground work for future studies and learned how advanced statistical analysis tools can be used to better understand the statistical validity of data reporting on Building America home perform.

Over the past year, NREL has created a methodology for evaluating Final Project Closeout Evaluations in its "Building America Program Community Evaluation Guidebook." The protocols require very large samples of homes to be statistically significant and would be cost prohibitive unless utility partners readily provide data and other support for these evaluations. With SMUD's leadership role and support in this evaluation, the value of statistically analyzing the Premier Gardens case study has tremendous value in better understanding the performance of BAP homes, evaluating simulation tools, and disseminating research results to industry stakeholders. To date, all of BIRA and the Sacramento Municipal Utility District's data analysis has been done in the absence of statistics. Having statistically significant results would further bolster the validity of the Premier Gardens case study. What is learned from this analysis may be transferred to other occupied home evaluations. Even though it is cost-prohibitive for BAP to evaluate every BAP community or even one community in each climate zone at each joule milestone, any community scale evaluation that is cost effective can be of significant value to the overall program.

The Premier Gardens results have been used to verify energy savings for consumers and builders, identify and verify peak electricity power savings for utilities, verify accuracy of building energy simulation tools, and demonstrate the practicality and value of Near Zero Energy Home construction. Additional case studies like Premier Gardens will further make the case for more Zero Energy Home construction if statistically significant.

Background

In 2004 and 2005, Premier Homes and Cresleigh Homes undertook a business agreement to divide the development of a plot of land in Rancho Cordova, CA. Rancho Cordova is located on the east edge of Sacramento, as shown below.

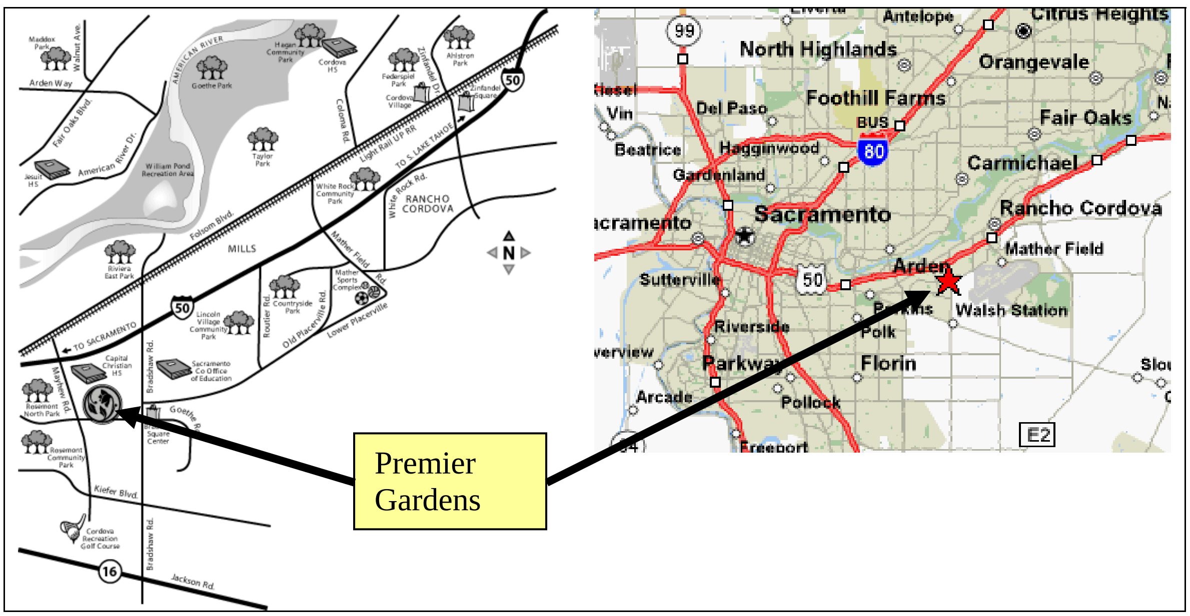

Figure 1: Premier Gardens & Cresleigh Rosewood
Located in Rancho Cordova on the East Edge of Sacramento, CA.

The resulting community consists of 95 Premier homes on the west side of the property, and 98 Cresleigh homes on the east. Many of the homes are right next to each other, as shown in Figure 2.

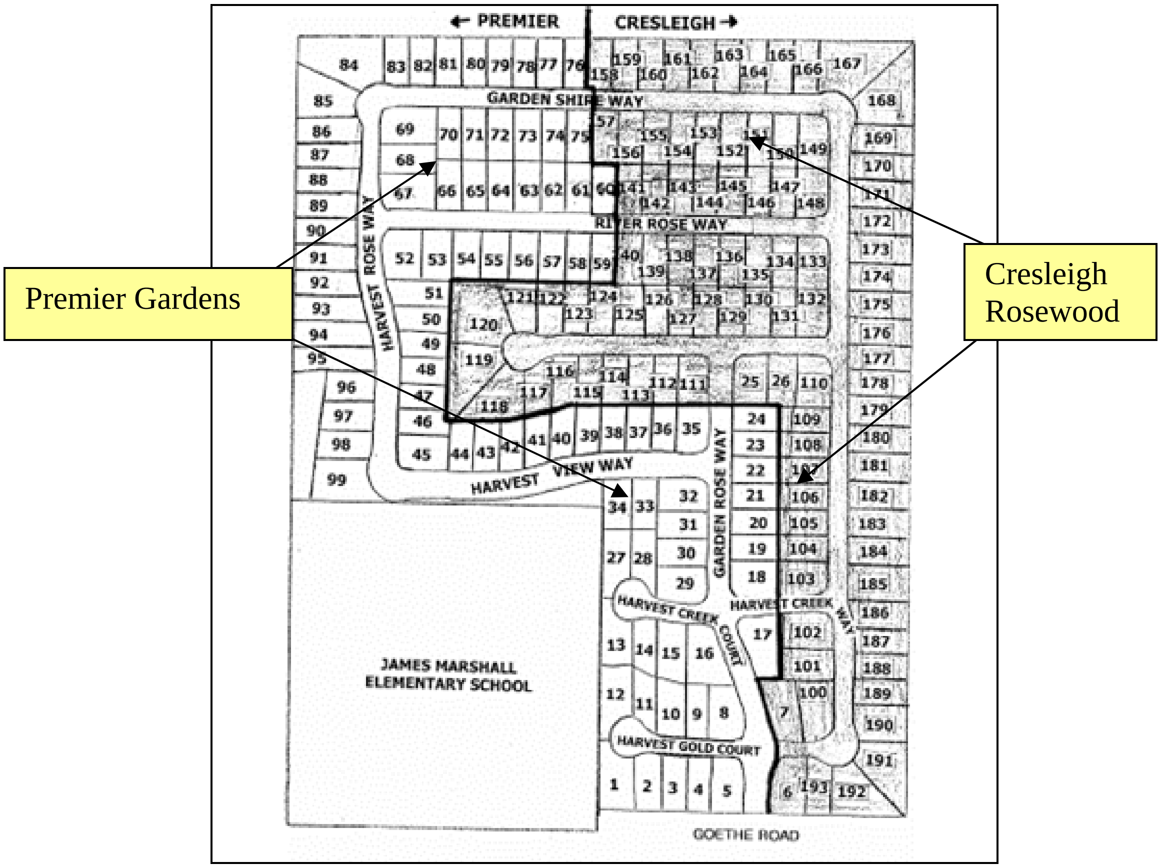

Figure 2: Premier Gardens and Cresleigh Rosewood Side-By-Side

Figure 3: The Entrances to the Two Adjacent Developments

Detailed Description of Homes

The homes built in both of these developments are approximately the same size. The energy features are different in several notable ways. Premier Homes, working with support and encouragement from SMUD and BIRA, developed the first full-scale Near Zero Energy Community in the Sacramento area on their half of the development. On the other half, Cresleigh built homes participating in the SMUD Advantage Program intended to reduce summer cooling by 30% and meeting the California Title 24 requirements in effect at the time of construction. The Premier Garden's homes are significantly more energy-efficient and include a 2.0 kW AC photovoltaic (PV) system on each house. The table below compares the as-built energy features of the two developments.

Community	Premier Gardens	Cresleigh Rosewood
Energy Program	ComfortWise	SMUD Advantage
Square Footage of Each House Plan	2,248 1,846 1,625 1,503 1,285	2,384 2,024 2,000 1,850 1,720 1,610
PV	2kW AC GE	None
AC	14 SEER	10 SEER
Heating	92% AFUE	80% AFUE
Water Heating	Tankless 0.82EF	40 Gallon 0.60EF
Ceiling	R-38	R-30
Walls	R-13 + 1in foam w/Stucco	
Windows	Vinyl Low E	
Lighting	Fluorescent	Incandescent
Ducts	Sealed, Tested, Buried	Sealed, Tested

Table 1: Comparisons of Premier Gardens and Cresleigh Rosewood.

Energy Analysis

Methodology and Notes

SMUD has been an active partner in both collecting and analyzing data. Without their support this analysis would not be possible. SMUD went even further and installed additional meters on a total of 36 homes, 18 in each development to record electric consumption and PV production every 15 minutes. This has enabled analyses of the benefits of the Near ZEH development in terms of savings to the utility and community at large during periods of peak electrical demand.

Also, Pacific Gas & Electric (PG&E) has shared limited natural gas data for all the homes in both communities. This has enabled BIRA to examine the whole energy picture, which is of great value. In the future, BIRA hopes to gather gas data for other BAP/BIRA projects.

If not otherwise stated, the Cresleigh homes will be labeled as "Non-ZEH, or C" and the Premier Gardens' homes as "Near-ZEH, or PG."

This case study is beneficial for many reasons, one of which is the similar size of the homes across the communities. Although similar, there is a notable difference in the average home's square footage between Premier and Cresleigh. The table below displays that the average Cresleigh Home is 10.5% larger.

Premier Plans by Sq Ft	# of Homes Built Per Plan	Total Square Feet/Plan
1285	13	16705
1503	20	30060
1625	13	21125
1848	18	33264
2248	31	69688
Premier Average Square Footage		1798
Cresleigh Plans by Sq Ft	**# of Homes Built Per Plan**	**Total Square Feet/Plan**
1610	12	19320
1720	15	25800
1850	16	29600
2000	19	38000
2042	11	22462
2384	25	59600
Cresleigh Average Square Footage		1988
Cresleigh Homes are 10.5% larger on Average		

Table 2: Average Square Footage of Homes

When interpreting each home's specific energy consumption for space heating and cooling the average square footage for all the homes is unimportant. However, when each community's energy use is aggregated and averaged per home, the energy use corresponds to the above averages. This factor or multiplier is not used in the analysis but is worth considering in understanding the energy usage across the communities.

Micropas is the main tool used to simulate heating, cooling, and domestic hot water energy use. For estimating all other loads, California's Title 24 and Building America's benchmark were used, depending on the situation. California or Title 24 load assumptions regarding lighting, appliances, and miscellaneous energy use come from both the BA benchmark and 1997 PG&E published data. All simulated results included in this analysis are labeled accordingly. In the early analyses the expected savings of the Near ZEH homes compared to homes built to code minimums were 35% for energy efficiency alone and 66% with PV and energy efficiency. As each of the five Premier plans was modeled separately, BIRA weighted each plan's simulated energy use based on the percent distribution in the community, as was done to calculate average square footage. In the Energy Analysis portion of this report, the predicted energy use for Premier Gardens is compared to actual consumption using monitored data. The differences are explored, assumptions about energy features revised to represent as-built features, and differences evaluated to understand why predictions were accurate or not.

When BIRA and SMUD first began analyzing the energy use in this project only a portion of the homes were occupied. Below is a look at the number of occupied homes by month.

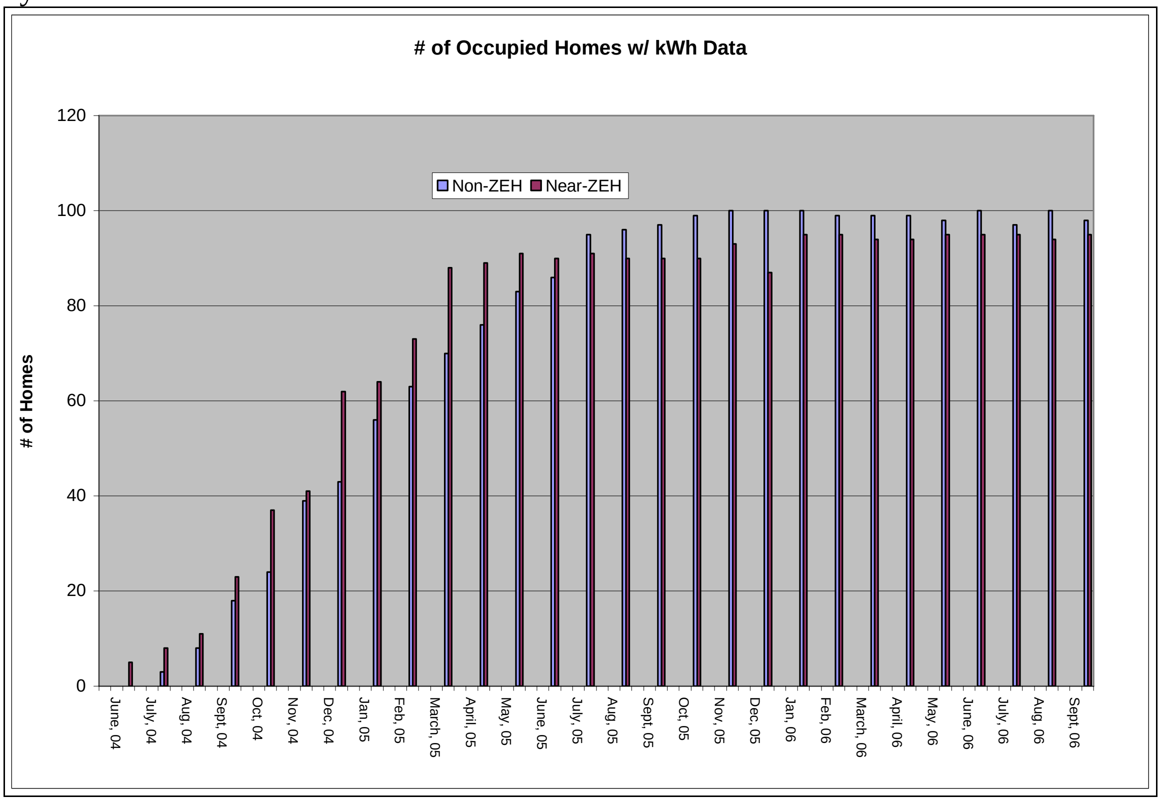

Figure 4: Number of Occupied Homes in each community by Date

Now that BIRA has access to more monthly electrical data, this report will only analyze data beginning when the majority of the homes were occupied, March 2005.

Descriptive statistics showing the differences in energy consumption of the Cresleigh (C) and Premier Gardens (PG) homes shows a substantial energy savings due to both the greater efficiency of the PG homes as well as the impact of PV on the PG dwellings. However, descriptive statistics do not explain if these findings are indicative of what would be expected if BIRA wants to extrapolate the results beyond this sample of homes. The extrapolation of findings from a sample to a population is called inference, and to test the inferential impact of these results requires testing of the results using inferential statistics. In essence, the statistical analysis of the energy consumption results from these two neighborhoods provides a systematic way to determine if the differences in the energy use of the two groups of homes is enough to offset the differences in energy use within each group of homes. Therefore, the t-tests that follow look at the ratio of the energy use variability between groups of homes divided by the variability within each group. This ratio is measured by a value called a t – statistic. If the variability between groups of homes is substantially greater than the variability within the group, then the results are statistically significant. The importance of this is that now the results can be generalized to a population of homes rather than the results being only relevant to the sample of homes in the study. Since the generalization of results is the key to any experiment, it is critically important to test the homes in the PG and C experiment to insure that what was found is not unique to just this set of homes.

Comparing Energy Consumption Across Communities

A significant challenge in analyzing a home's energy consumption, and then attempting to make inferences about the homes features and performance, is the behavioral variability of occupants. Behavior across similar homes can completely outweigh the impact of energy features. For instance, in June 2005, one Premier Gardens resident spent $140 for electricity while a neighbor received a negative bill. The average during June 2005 across the Premier Gardens community was about $33.

The two components determining statistical differences between a group of homes is the energy use variability within each group (driven by behavior) and the delta between each group (driven by home performance). Whereas the smaller the delta between groups and the more variability within the group makes statistically significant results more difficult to produce.

Electricity Use

Before interpreting the electricity consumption, it is important to understand the differences between the Near-ZEHs and the Non-ZEHs. In addition to the differences in energy features identified in Table 1 above , the most notable difference is the PV systems on the Near-ZEHs. This difference can easily be seen in the following graphs. As indicated in Table 1, the Near-ZEHs have a higher R-value ceiling insulation, higher SEER-rated A/C with TXV, florescent vs. incandescent lighting, and buried ducts. The Near-ZEHs also more efficient furnaces and tankless water heaters which contribute to savings in natural gas in combination with other energy features just listed.

Mean Electrical Energy

The statistical analysis will begin by looking at the average monthly electricity use for each community from March 2005 to September 2006. This represents 19 months, and two summers.

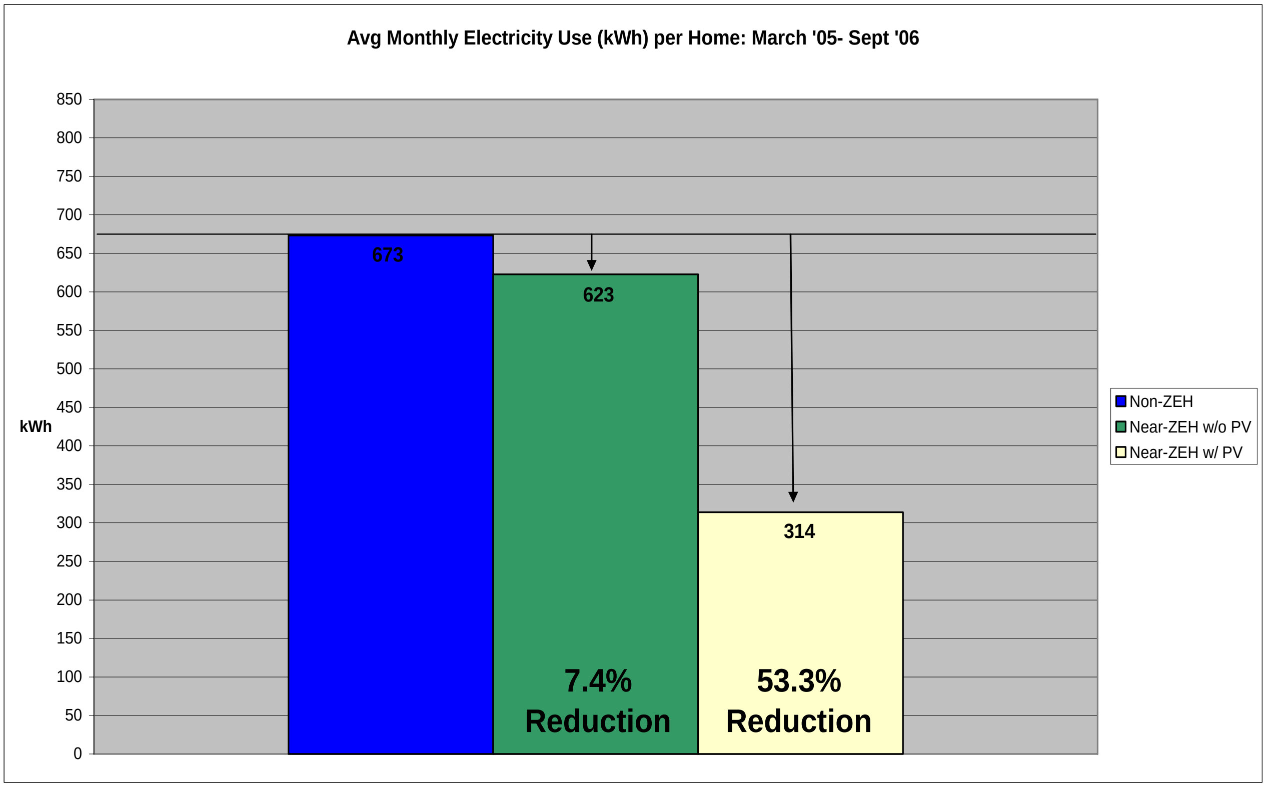

Figure 5: Avg Monthly Electricity Use (kWh) per home: March '05- Sept. '06

Before the PV electricity consumption is factored in, the electricity use across the communities is very similar, especially considering that the Cresleigh homes' are 10.5% larger. The actual difference is the Near-ZEHs homes use 7.4% less than Non-ZEHs. Although early analyses suggested the possibility of larger savings before PV production is factored in, given Cresleigh homes meet one of the nation's most stringent energy codes, Title 24, and were built to reduce cooling bills by 30%, and the wide range in how families in these communities live in their homes, the 7.4% is not too surprising.

Utility Consumption Measure for period from March 2005 to September 2006	**Mean for Cresleigh Homes (n = 70)**	**Mean for Premier Gardens Homes (n = 88)**	**t - statistic**	**P value**
Average kWh consumption – before PV	673.4	622.9	1.22	0.220

Table 3: Utility Consumption Measure for period from March 2005 to September 2006, no PV

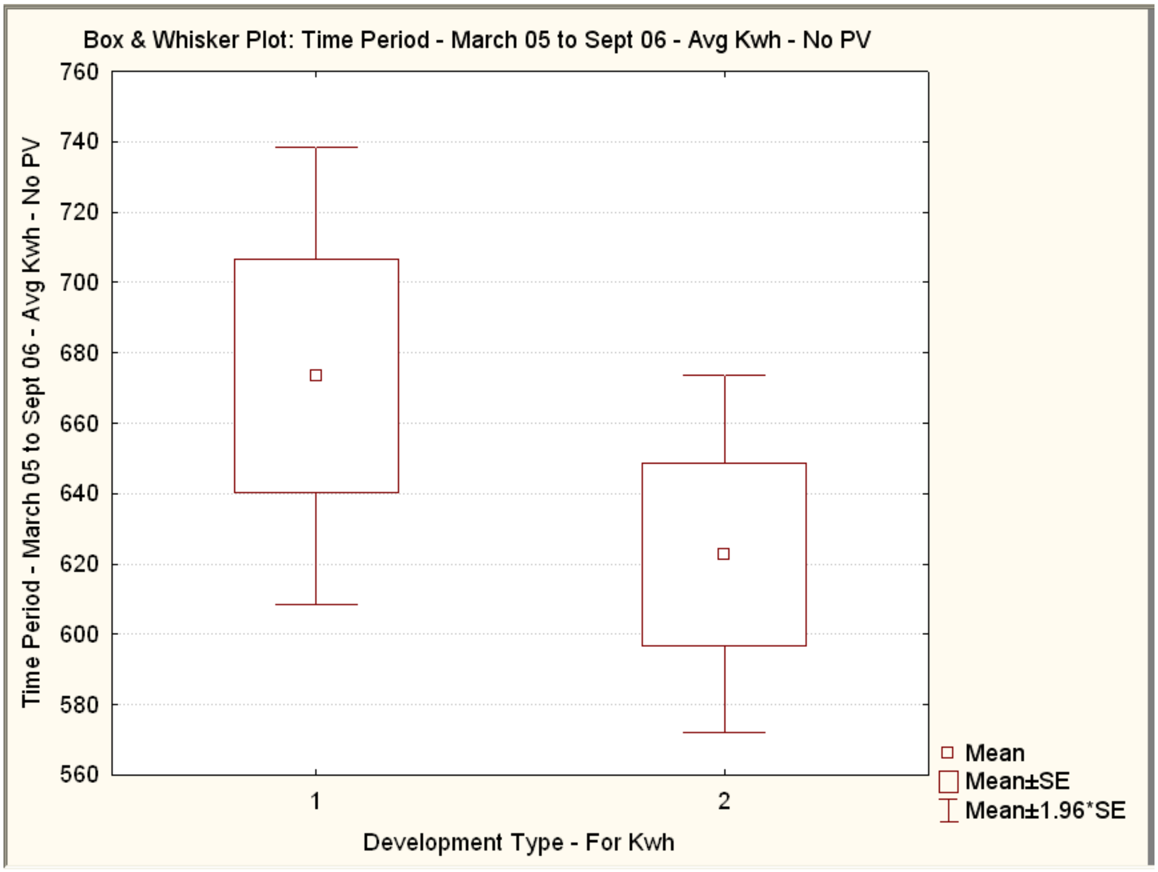

Figure 6: Box and Whisker Plot: Time Period – March 05 to Sept 06 – Avg kWh – No PV

The box and whisker plot[1] above shows the variability and overlap of these two communities average monthly electricity consumption before PV. This first comparison looks at the Near-ZEH community's electricity consumption before PV compared to the Non-ZEH community. This test does not find the difference between the two communities based on energy efficiency only to be statistically significant. This is expected given the small differences between the homes electric bills and the wide range of consumption levels within both communities when PV factors are not considered. In the box plot presented above, "1" represents the results for the C homes and "2" represents the results for the PG homes. The test is an "independent sample t-test" that looks at the equivalence of means on a single variable (kWh in this case) from two different groups (C vs. PG homes in our example). The independent sample t-test aims to see if the results in the sample are representative of the "population" of these types of homes.

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1 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.

Utility Consumption Measure for period from March 2005 to September 2006 (sq ft)	Mean for Cresleigh Homes (n = 70)	Mean for Premier Gardens Homes (n = 88)	t - statistic	P value
Average KWh per square foot consumption – before PV (normalized for house size)	0.339	0.346	-0.35	0.727

Table 4: Utility Consumption Measure for period from March 2005 to September 2006, no PV (sq ft)

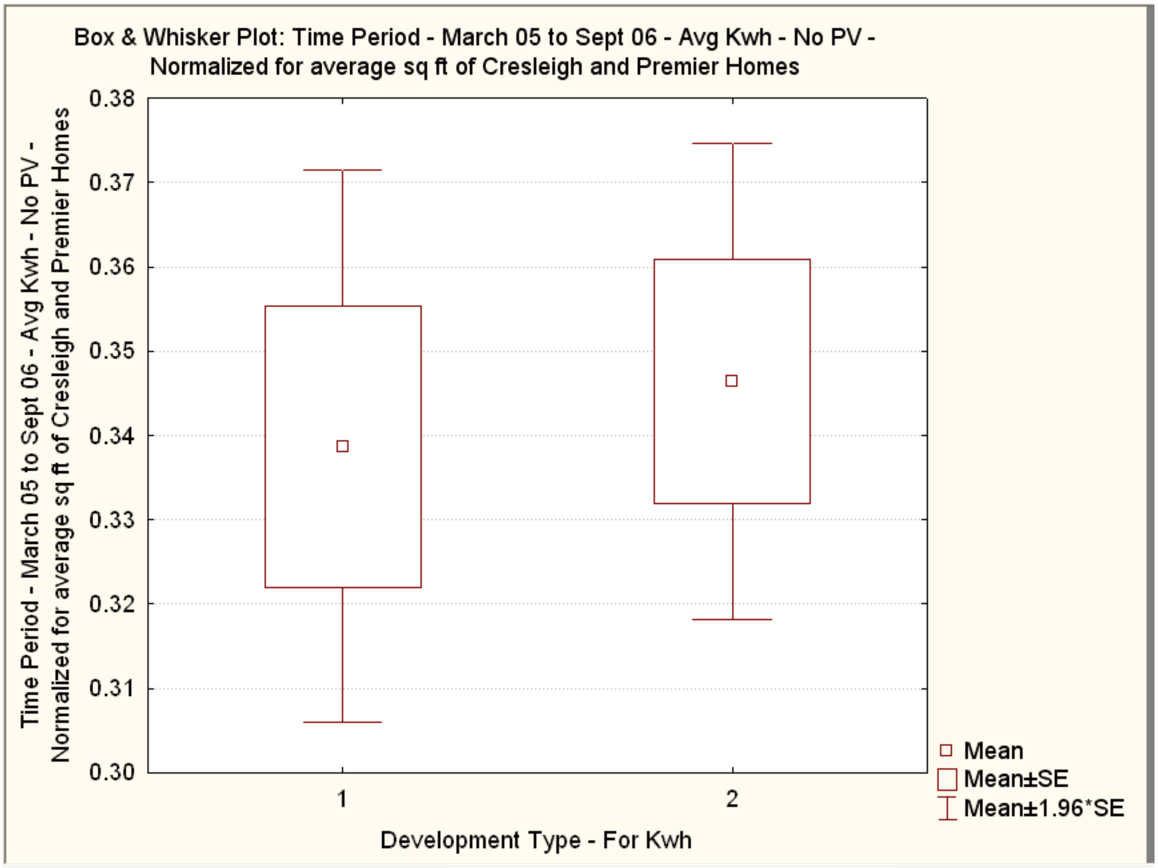


Figure 7: Box and Whisker Plot: Time Period – March 05 to Sept 06 – Avg kWh – No PV (sq ft

This is the same analysis as above, but now using kWh per sq ft rather than overall kWh per home (this provides a better test because the Cresleigh homes are somewhat larger than the Premier homes). The average square feet of the C homes was somewhat greater than the PG homes (1,988 sq ft versus 1,798 sq ft). Again, the results show that there is no statistically significant difference between the Cresleigh and Premier homes when PV is not included.

Utility Consumption Measure for period from March 2005 to September 2006	Mean for Cresleigh Homes (n = 70)	Mean for Premier Gardens Homes (n = 88)	t - statistic	P value
Average KWh consumption – PV generated power included	673.4	313.9	8.64	0.000

Table 5: Utility Consumption Measure for period from March 2005 to September 2006, PV

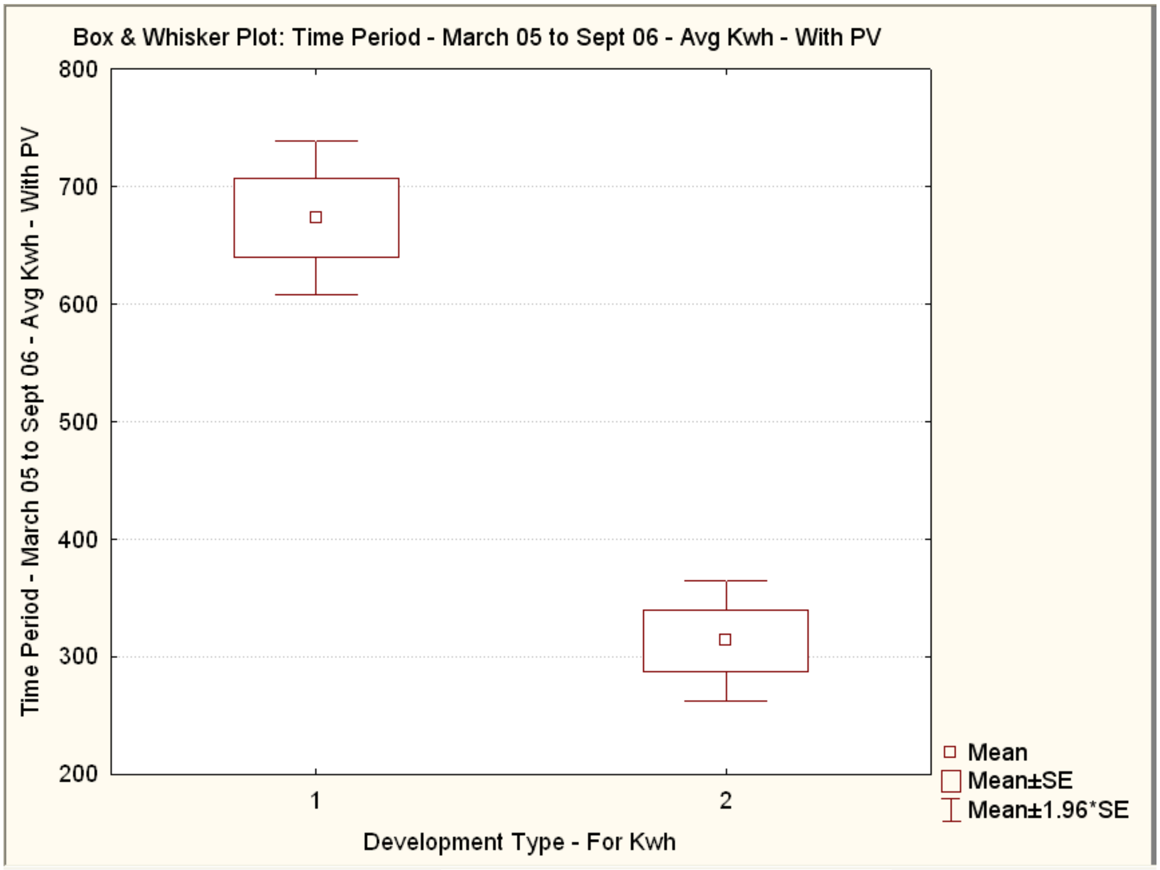


Figure 8: Box and Whisker Plot: Time Period – March 05 to Sept 06 – Avg kWh – PV

This independent sample t-test, taking PV production in the PG homes into account, shows significant results (that is, the mean KWh for Cresleigh homes are significantly greater than the mean KWh for Premier homes). Table 5 shows the results of t-tests on the energy use of C versus PG homes. As Table 5 shows, the results are not only statistically significant (assuming $\alpha = .05$) but also practically significant with the PG homes using 53% less electricity than the C homes. Note that the PG homes were not statistically more energy efficient than the C homes when PV was not included in the energy consumption measures. This test indicates that these results are statistically significant and can be attributed to communities outside of the sample of homes included in this study.

Utility Consumption Measure for period from March 2005 to September 2006	Mean for Cresleigh Homes (n = 70)	Mean for Premier Garden Homes (n = 88)	t - statistic	P value
Average KWh per square foot consumption – PV generated power included (normalized for house size)	0.339	0.175	7.45	0.000

Table 6: Utility Consumption Measure for period from March 2005 to September 2006, PV (sq ft)

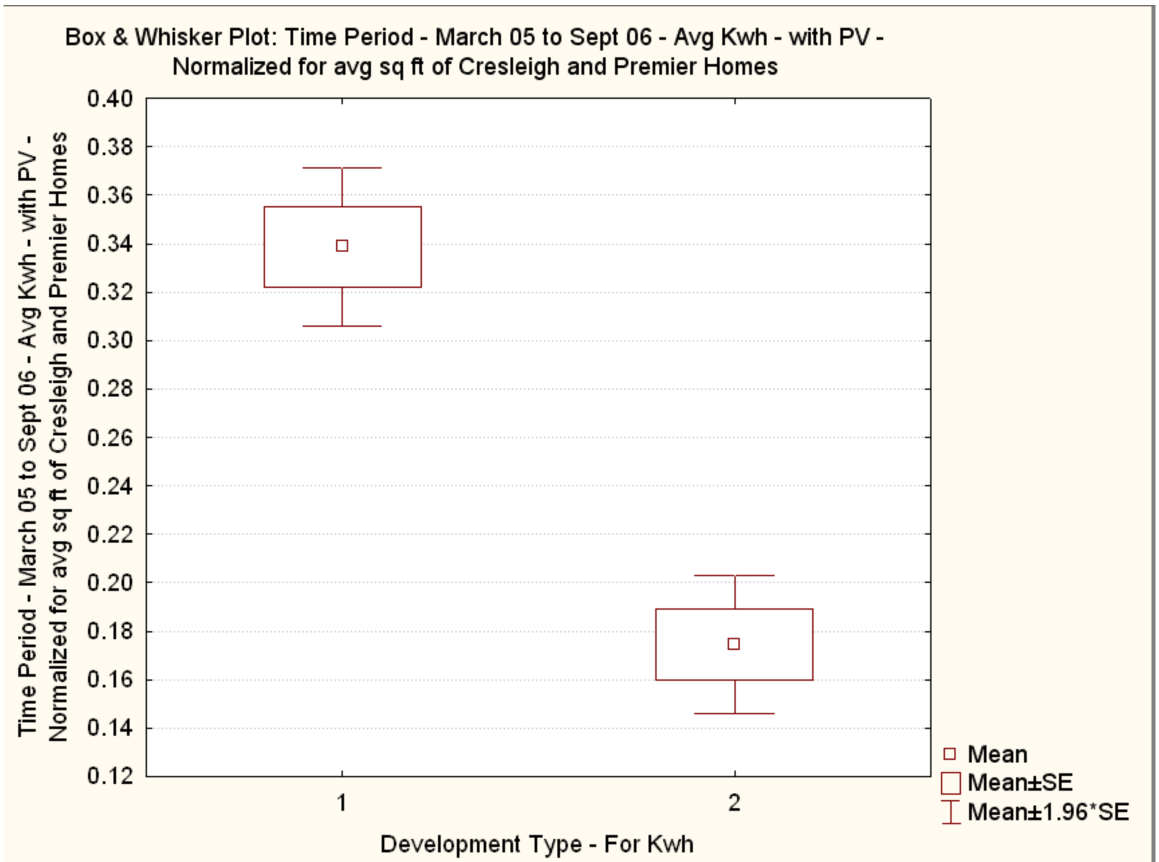


Figure 9: Box and Whisker Plot: Time Period – March 05 to Sept 06 – Avg kWh – PV (sq ft)

This is the sq ft equivalent of Table 5 above. It shows that the Premier homes use significantly less grid electricity than the Cresleigh homes on a square foot basis with PV taken into account.

The below analysis looks at the influence of PV on Premier's electricity consumption as an individual energy feature.

Utility Consumption Measure for period from March 2005 to September 2006	Mean for Premier Homes Without PV Included (n = 88)	Mean for Premier Garden Homes With PV Included (n = 88)	t - statistic	P value
Average KWh consumption	622.9	313.9	74.22	0.000

Table 7: Utility Consumption Measure for period from March 2005 to September 2006, PV vs. No PV

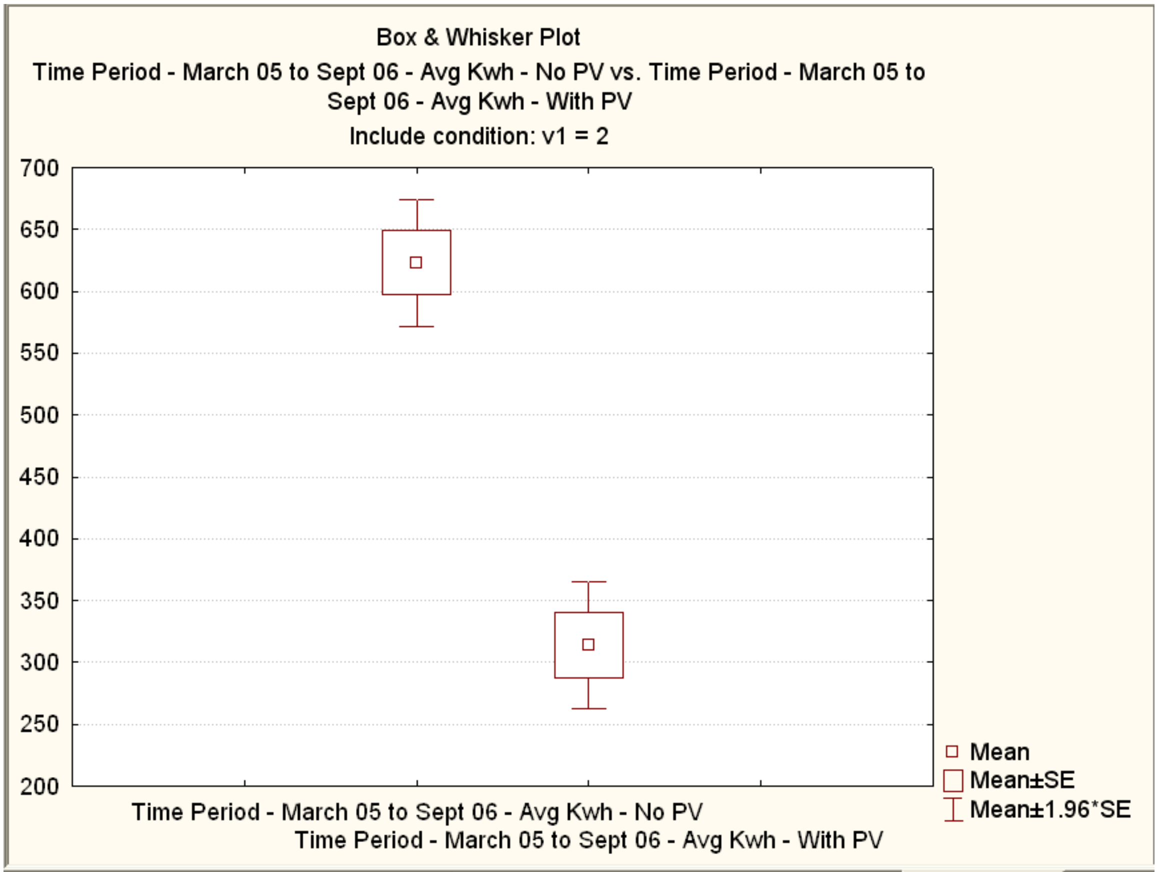


Figure 10: Box and Whisker Plot: Time Period – March 05 to Sept 06 – Avg kWh – PV vs. No PV

The above box & whisker plot represents a test called a dependent sample t-test and it is used to compare means on two different variables for a single group (the group is Premier Gardens homes and the two variables are KWh without PV and KWh with PV). The results show that PV has a significant impact on lowering KWh use.

Table 7 shows the impact of adding PV to the PG homes. The inclusion of PV reduces net energy consumption by 49% and the results are statistically significant (with α = .05).

Summary Table

Utility Consumption Measure for period from March 2005 to September 2006	Mean for Cresleigh Homes (n = 70	Mean for Premier Gardens Homes (n = 88)	t - statistic	P value
Average Kwh consumption – no PV generated power included	673.4	622.9	1.22	0.220
Average Kwh per square foot consumption – no PV generated power included (normalized for house size)	0.339	0.346	-0.35	0.727
Average Kwh consumption – PV generated power included	673.4	313.9	8.64	0.000
Average Kwh per square foot consumption – PV generated power included (normalized for house size)	0.339	0.175	7.45	0.000

Table 8: Utility Consumption Measure for period from March 2005 to September 2006- All

July 2007

Looking at July 2007 electricity use data at both communities, Premier Gardens residents pay less than half compared to their neighbors at Cresleigh as overall kWh savings seemingly persist. This graph also clearly depicts the wide range in electrical consumption within both communities.

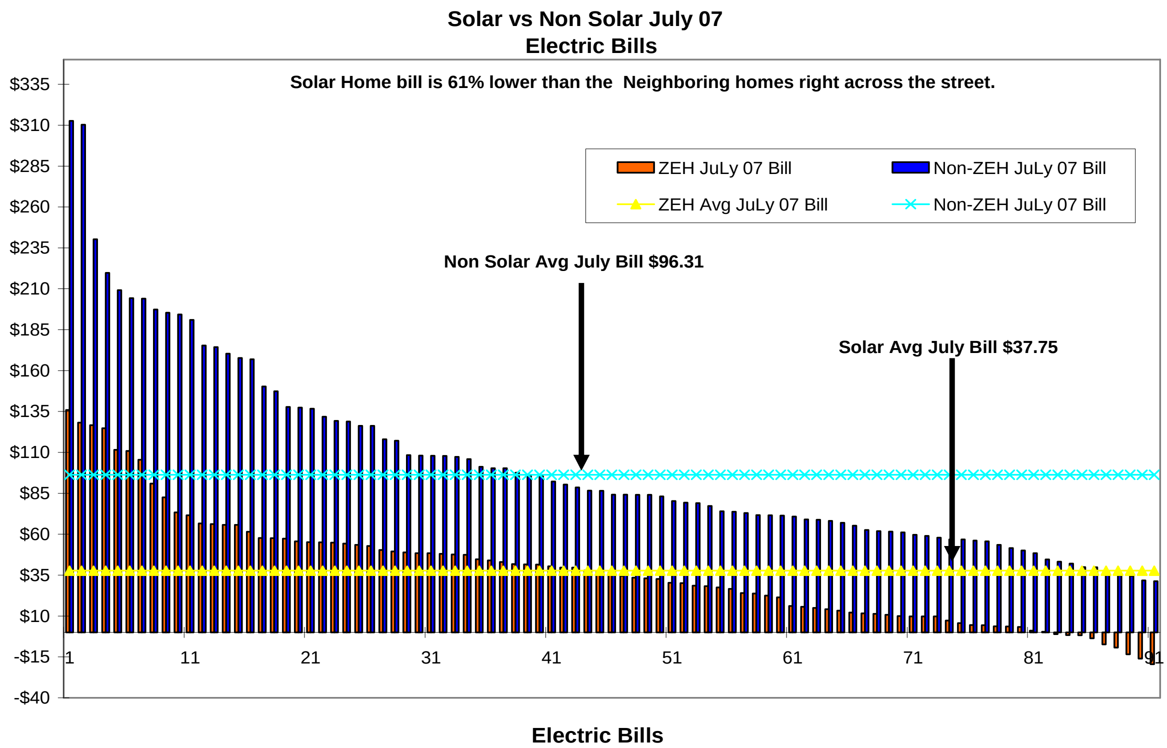


Figure 11: July 2007 Bills for Premier and Cresleigh Residents

Gas Use

Gas Savings for Premier Garden's homes are derived from their buried ducts, higher efficiency furnace, improved ceiling insulation, tankless water heater and air tightness of both ducts and the homes. Note that the PG homes were all tested and inspected regarding their energy features, quality of installation of insulation and tested for whole house and duct air tightness.

Figure 12 shows the total annual gas usage for all the homes in both communities. The near-ZEH homes consistently use less gas than their non-ZEH counterparts across the street. With so many homes of varying sizes, Figure 12 illustrates the apparent benefit of the added near-ZEH features.

Figure 13 illustrates the average 2005 gas usage for each community. This further illustrates the overall benefit of energy efficiency measures between both communities. Figure 13 indicates that in 2005, the near-ZEH community used an average of 324 therms, a savings of 29% over the 455 therms used by the non-ZEH community.

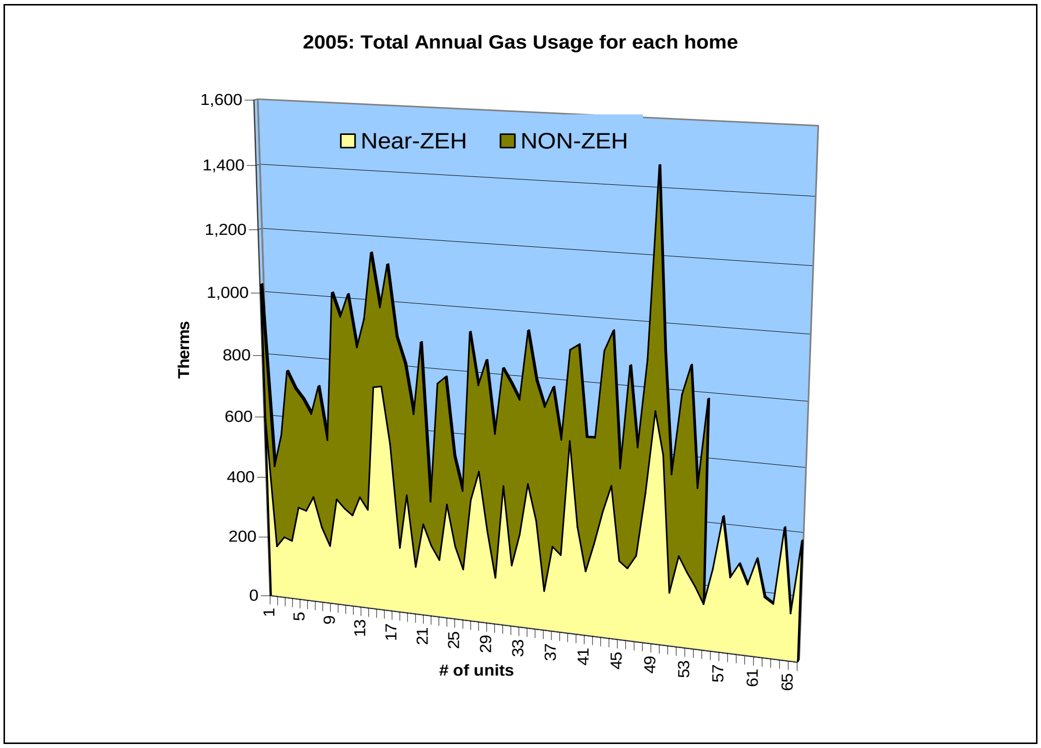


Figure 12: Total Annual Gas Usage for 2005 for Each Home

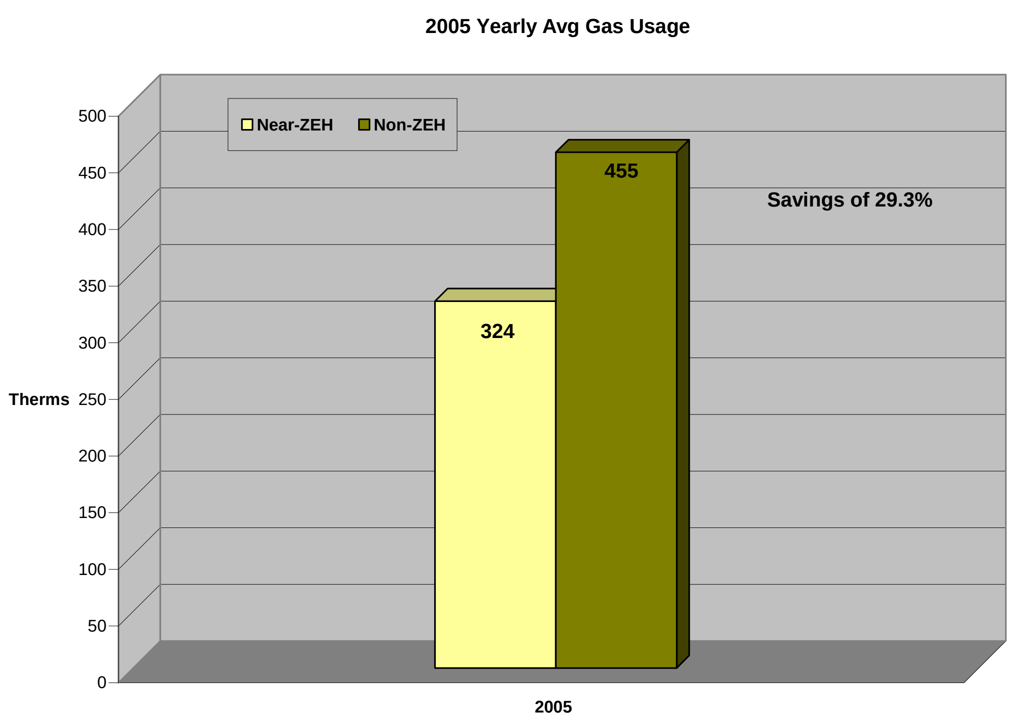


Figure 13: Average Gas Usage by Month, by Community

Natural Gas Consumption Measure for period from January to December, 2005	**Mean for Cresleigh Homes (n = 55)**	**Mean for Premier Gardens Homes (n = 69)**	**t - statistic**	**P value**
Average natural gas consumption in therms	455	324	5.11	0.000

Table 9: Gas Consumption Measure for period from Jan to December 2005

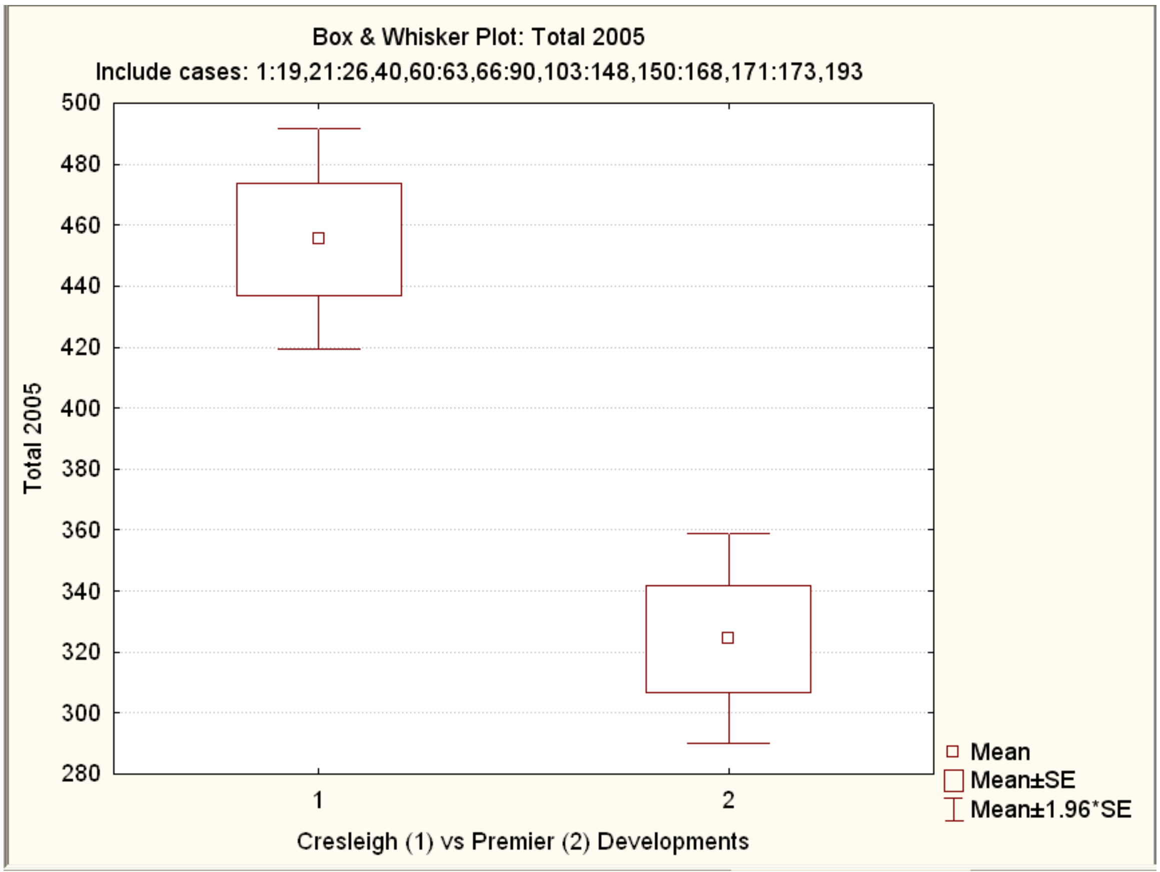


Figure 14: Box and Whisker Plot: Time Period – Dec to Jan 2005 – Avg Therms

This analysis is an independent sample t-test looking at the total gas use of PG vs. C homes for 2005, which is the only gas use period provided by PG&E for these communities It shows that the Cresleigh homes have significantly higher gas use (in therms) compared to the Premier homes. Natural gas usage of the homes was also statistically tested. Again, the PG homes proved superior to the C homes as shown in Table 9 . The results are also shown for the “per square foot” gas usage. The PG homes are 21.4% more efficient in gas usage than their C counterparts on a per square foot basis.

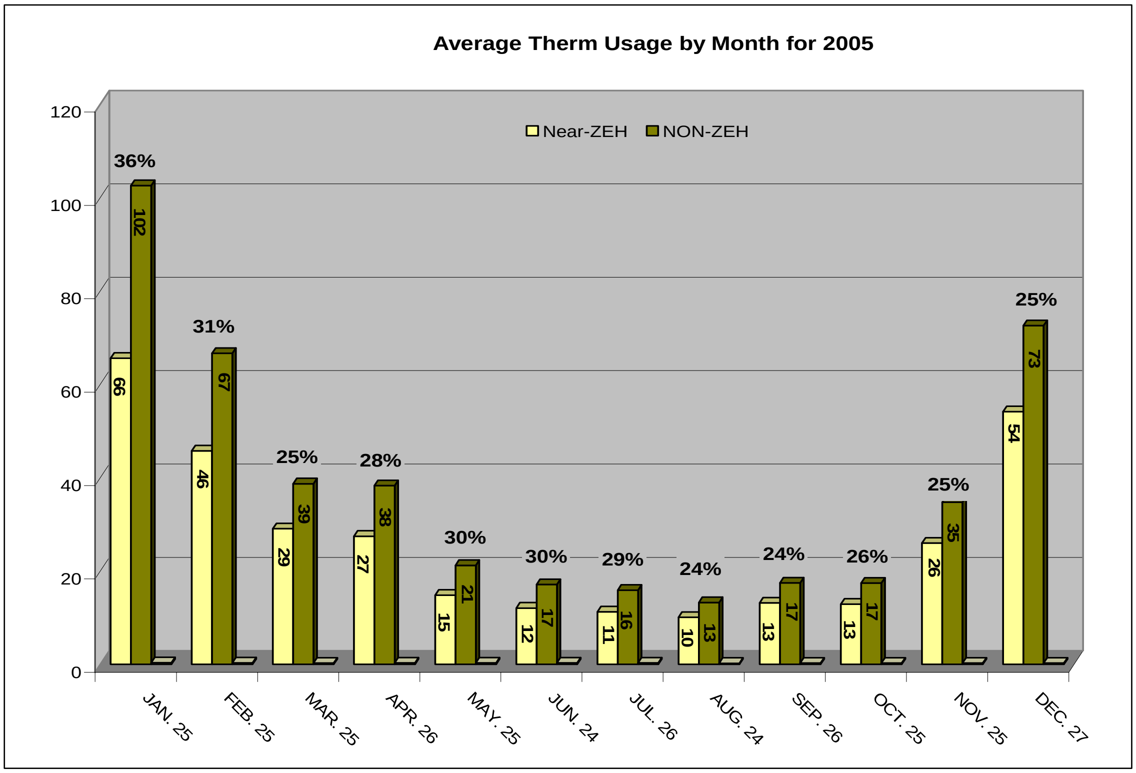


Figure 15: Actual Average Gas Usage by Community

Figure 15 shows the actual average gas usage for both communities by month.

Natural Gas Consumption Measure for period from January to December, 2005	Mean for Cresleigh Homes (n = 55)	Mean for Premier Gardens Homes (n = 69)	t - statistic	P value
Average natural gas consumption in therms per square foot	0.229	0.180	3.55	0.001

Table 10: Gas Consumption Measure for period from Jan to December 2005 (sq ft)

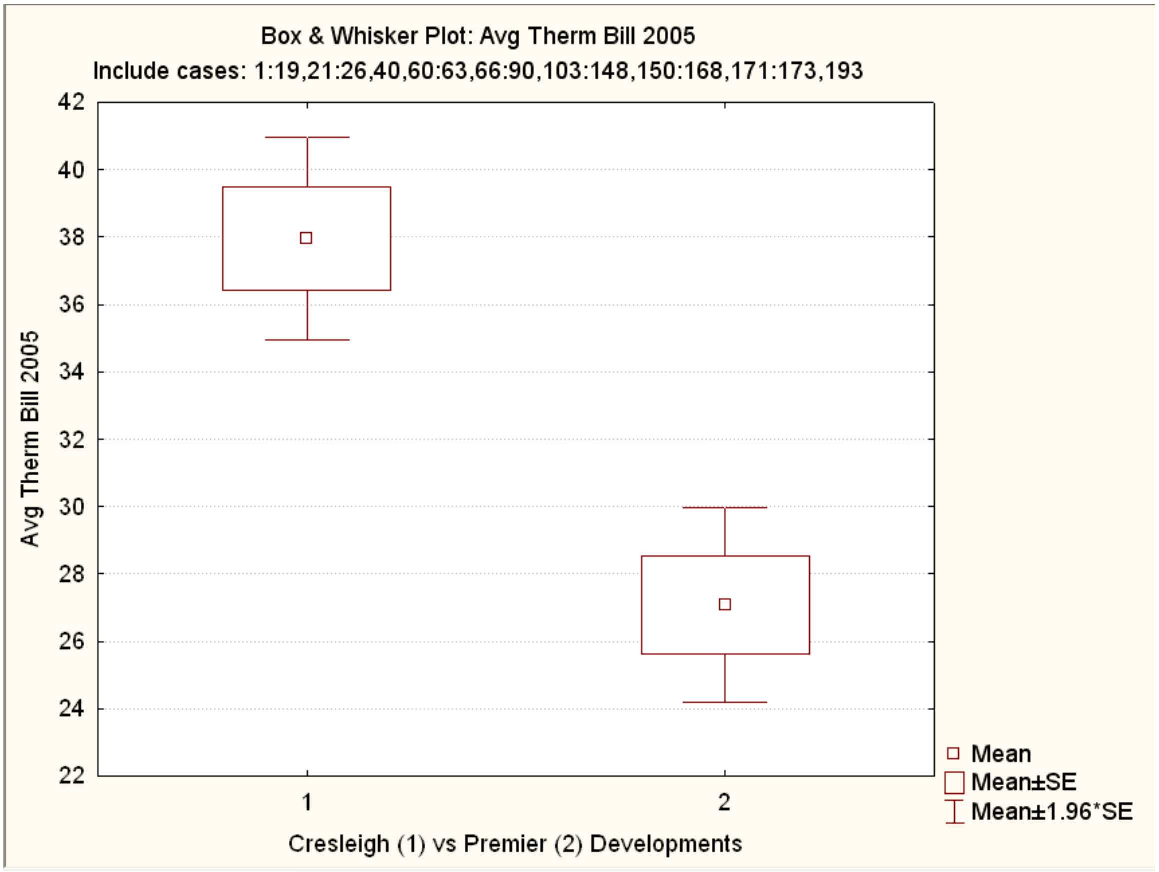


Figure 16: Box and Whisker Plot: Time Period – Dec to Jan 2005 – Avg Therms (by month)

This box & whisker plot shows that same information as the previous analysis, but this is in terms of average monthly gas use per home.

Total Energy Savings

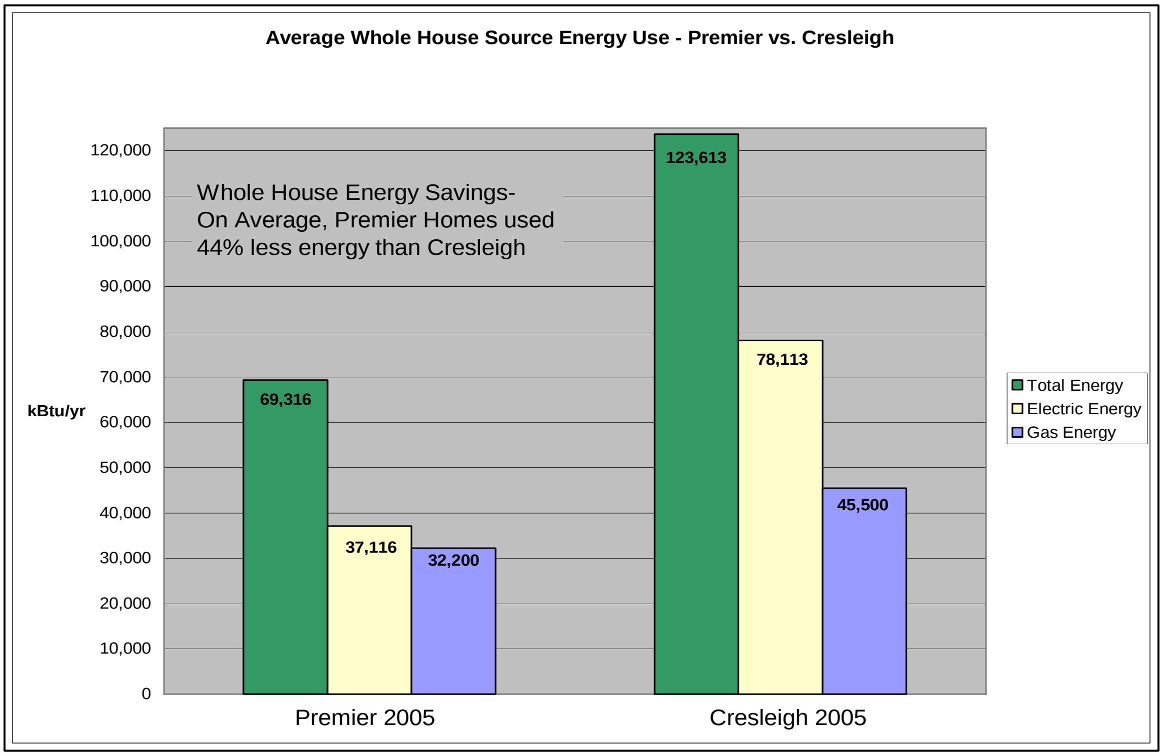


Figure 17: Average Whole House Source Energy Use- Premier vs. Cresleigh

On average, Premier Homes used 44% less source energy than their neighbors in Cresleigh Homes. As displayed in Figure 17, Premier used similar amounts of source gas and electric energy, while Cresleigh used 42% more source electric energy than gas, largely because Premier homes have electric solar generation.

When compared to an energy-efficient SMUD Advantage Home built by Cresleigh, Premier's near-ZEH still used 44% less source energy. It is safe to say that these homes are performing well given that this study is based on actual utility bills representing actual consumption in occupied homes over a three year period. Next BIRA will examine the actual energy use versus simulated use for the Near-ZEHs.

Simulated vs. Actual Energy Use

Now that BIRA has at least one year of electricity and gas data for the Near-ZEH homes it will be valuable to compare these actual results to the predicted values. Through this, BIRA will evaluate both the simulation tools and the assumptions inherent within.

Electricity: Actual vs. Simulated

Below are the results from the Near-ZEHs including actual and simulated results using both California and the Building America benchmark assumptions.

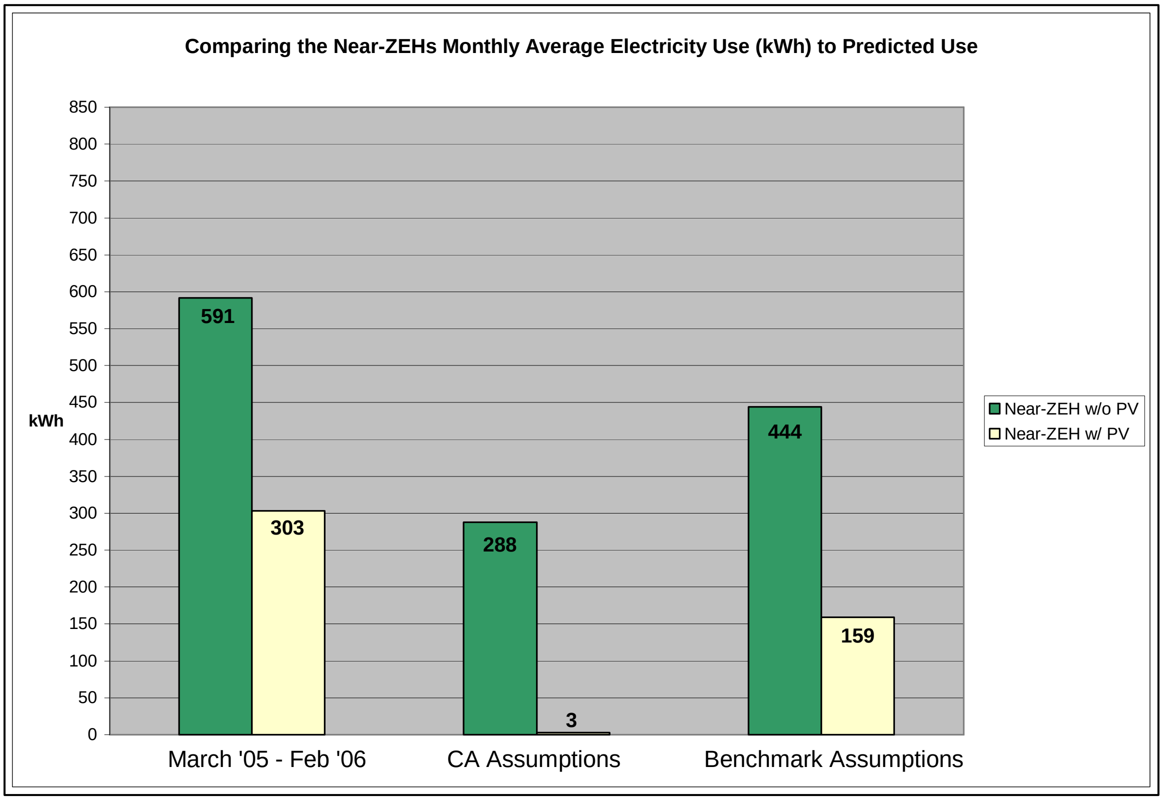


Figure 18: Comparing the Near-ZEHs Monthly Average Electricity Use (kWh) to Predicted Use

As seen in Figure 18, the actual consumption was considerably higher than expected. There are several explanations for this. Note that the CA Assumptions in this Figure represent California assumptions, which are a combination of PG&E and benchmark data.

One very positive feature of this analysis is that the assumptions made for PV kWh production were accurate. Based on GE solar data, BIRA estimated that on average the PVs would produce 285 kWhs a month. Compared to the actual 288 kWhs that were produced, the difference between actual and estimated is only 1%.

Determining why Electricity Consumption was Higher than Expected

Some insight can be gained through a survey of these two adjacent communities conducted by SMUD. In this survey, SMUD found that the majority of occupants of both developments have electric cloths dryers. In addition, many, if not most of the kitchens are all-electric (the standard offering), rather than gas, as originally modeled. Another difference that SMUD found that contributes to this unexpected electricity use is thermostat set points for cooling. In the computer analyses 78 degrees was used. In SMUD's survey most were considerably lower than 78 degrees. The highest temperature used for the cooling set point was 77 degrees with 75 degrees typical. Furthermore, the prediction assumes that the homeowner uses their setback thermostats to raise the set point five degrees at night, whereas the homeowners reported that they set their thermostats and left them alone.

In the focus groups conducted by RAND researching the buying decisions and customer satisfaction of the home owners in these two communities, it was determined that 50% of the participants representing the Near-ZEH group have a second refrigerator in their home and 80% of the Non-ZEHs have a second refrigerator. The second refrigerators are most likely older less efficient models further exacerbating the problem.

Given these findings, BIRA revisited the simulated results. Remembering that each home is modeled individually, BIRA added electric ranges to 80% of the homes, electric dryers to 70% of the homes, and a second refrigerator to 50% of the homes.

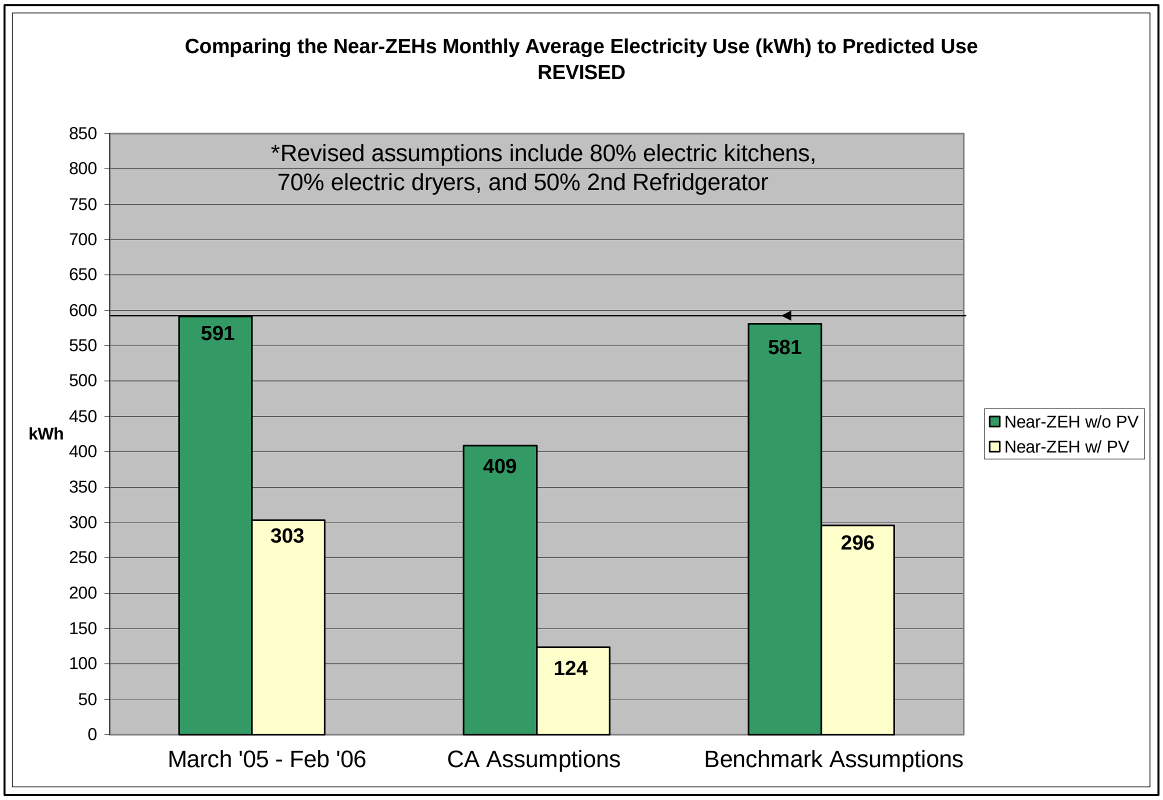


Figure 19: Comparing the Near-ZEHs Monthly Average Electricity Use (kWh) to Predicted Use REVISED

When assumptions were revised, the benchmark simulated energy performance is very close to the energy performance indicated in the actual utility bill data. The California assumptions, which are a combination of PG&E and benchmark data, are still considerably lower than the actual results.

The one element left out of Figure 19, is the lower cooling thermostat set points and failures to set temperature back at night, which would further raise each simulated result.

Gas: Actual vs. Simulated

Figure 20 represents the actual average yearly gas use of the near-ZEHs compared to both California and benchmark assumptions.

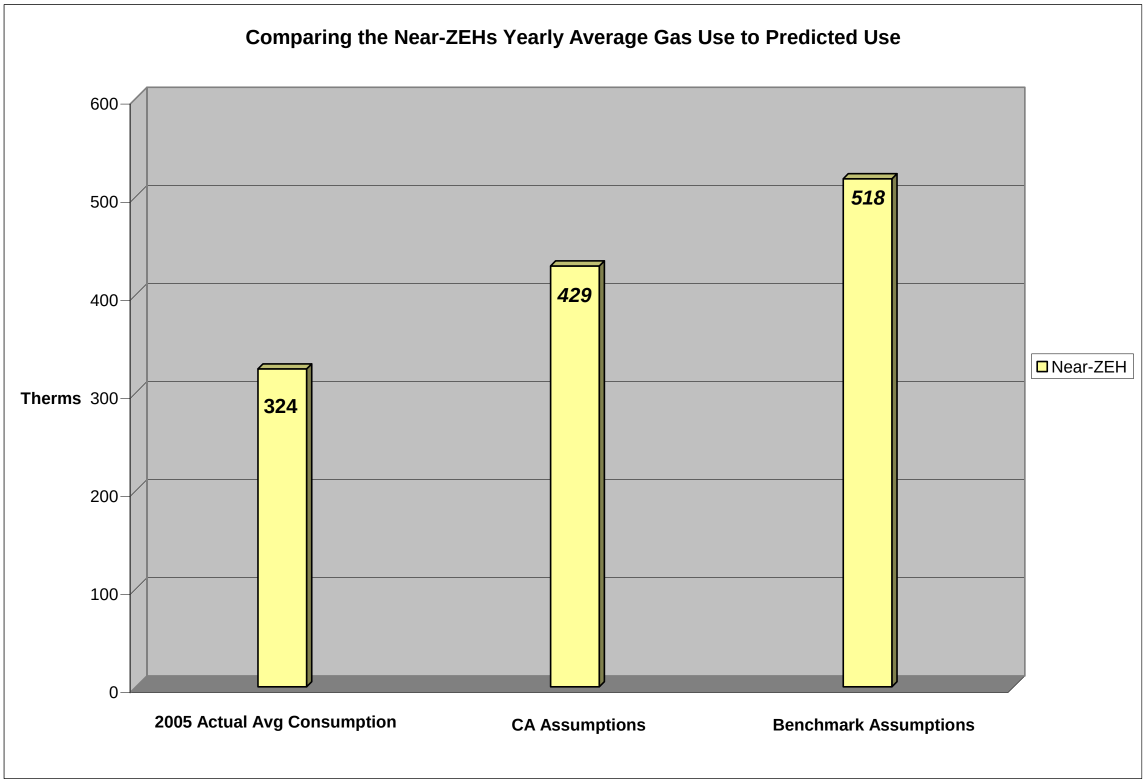


Figure 20: Comparing the Near-ZEHs Yearly Average Gas Use to Predicted Use

The gas use simulations over estimated in the same way that electricity use estimates were underestimated. The revised assumptions draw both estimates closer to the energy performance indicated in the actual utility bills. Across all Near-ZEH plans, the BA Benchmark predicts an average of 72 therms of gas for clothes drying, and 78 therms for cooking. California assumptions for the same are 35 and 44 therms, respectively. The total increase across both uses is 71 therms. This contributes significantly to the total 89 additional therms the benchmark predicted above California.

The below figure represents the revised models to include reduced gas cooking and clothes drying from 100% penetration to 20% and 30% respectively. The second refrigerators do not affect this category.

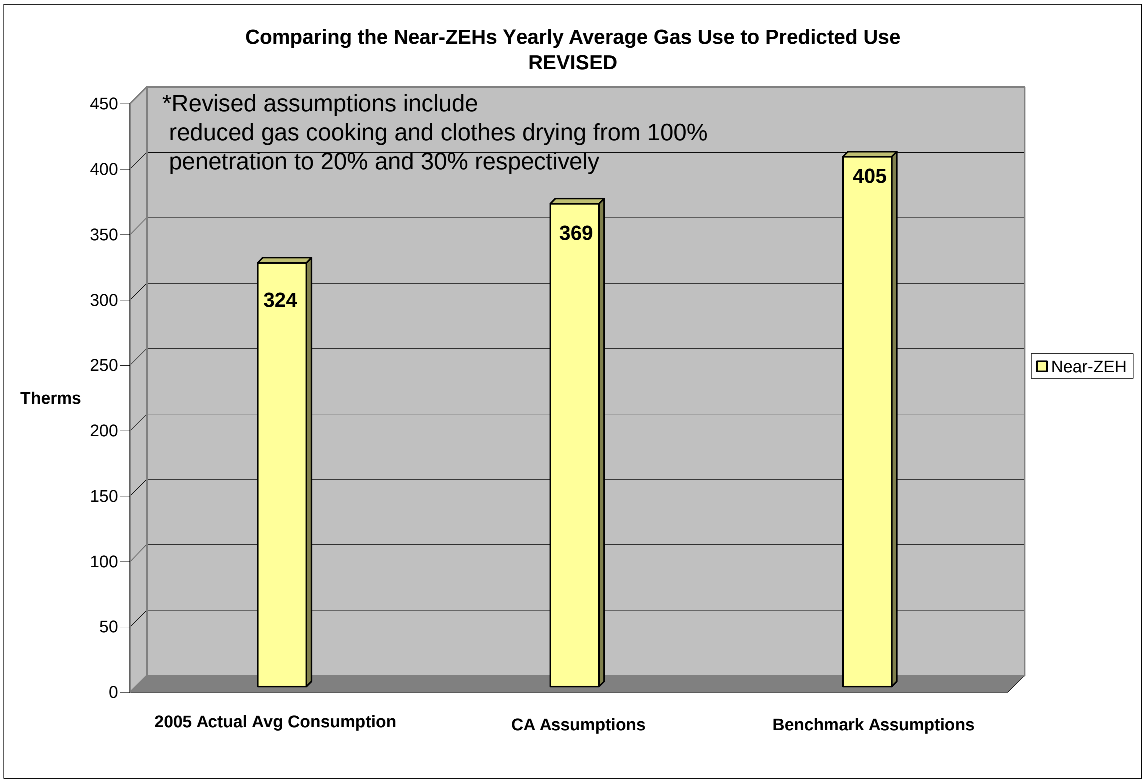


Figure 21: Comparing the Near-ZEHs Yearly Average Gas Use to Predicted Use REVISED

Although both simulated models grew closer to actual gas usage, the actual consumption is still 13% lower than California assumptions estimated and 20% lower than the benchmark. In looking at the benchmark predictions vs. actual consumption, the predicted values are significantly different than actual.

Natural Gas Consumption Measure for Period from January to December, 2005	**Predicted Mean for Premier Homes**	**Mean for Premier Garden Homes (n = 69)**	**t - statistic**	**P value**
Average natural gas consumption in therms	405	324	4.60	0.000

Table 11: Gas Consumption Measure for period from Jan to December 2005 (Premier only)

This is another single sample t-test comparing predicted and actual gas use of the Premier Gardens' homes. It shows that there is a statistically different amount of gas used by the homes compared to the predicted value, as the predicted value is significantly larger than the actual value. The predictions understated the gas efficiency of the homes by 20% which was statistically significant. It is noteworthy that the homes actually performed far better than the expectations based on the simulation models.

Predicted Gas Use Significantly Higher than Actual

One possible reason for this could be a milder winter. Below are the monthly average temperatures as modeled by Micropas and actual 2005 temperatures. Micropas uses TMY2 weather data, which is an average for the last 30 years. As can be seen below in Table 12, the 2005 winter seasons were 4% warmer than the model where every month was warmer.

2005 Weather Compared to Modeled Weather			
Month	TMY2	Actual	% Difference
Jan	45.0	46.0	102%
Feb	50.0	53.0	106%
Mar	53.0	55.0	104%
Apr	57.0	57.0	100%
May	64.0	65.0	102%
Jun	70.0	69.0	99%
Jul	72.0	80.0	111%
Aug	72.0	77.0	107%
Sep	68.0	69.0	101%
Oct	62.0	63.0	102%
Nov	53.0	55.0	104%
Dec	46.0	49.0	107%
The 2005 Winter Seasons Were 4% Warmer than Modeled			

Table 12: 2005 Weather Compared to Modeled Weather

Even with the warmer winter, the assumptions still seem high. However, BIRA does not have any other potential mitigating factors for this. It might be behavior, or perhaps the models and assumptions are incorrect.

Benchmark vs. California Assumptions

The benchmark is 20% higher than the actual average gas use by the near-ZEHs. Even with variability, it may be prudent to investigate the assumptions the benchmark uses for gas consumption.

The Whole Energy Story: Actual vs. Simulated

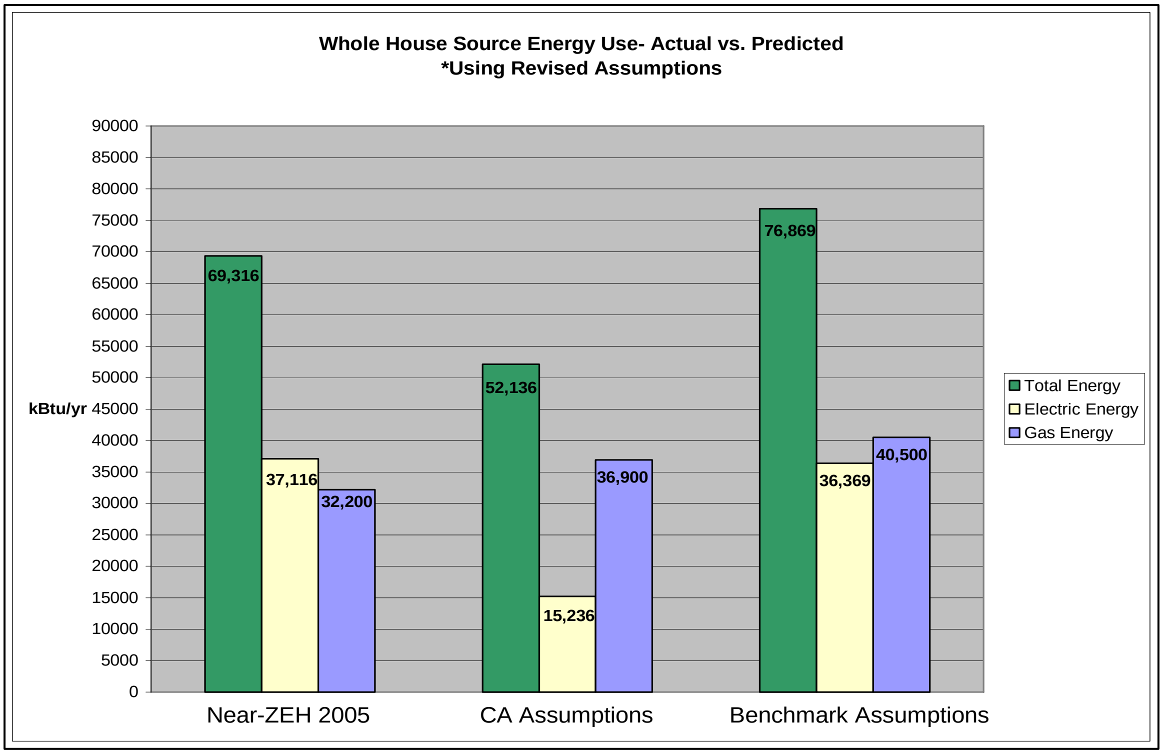


Figure 22: Whole House Source Energy Use- Actual vs. Predicted *Using Revised Assumptions

Whereas the benchmark assumptions were closer to reality for electricity, the California assumptions proved to be closer for gas.

Peak Analysis

System peak demand is a serious concern for SMUD, many other California utilities, and utilities across the country. To study the impacts that near-ZEHs have on peak, SMUD designed a monitoring experiment using the Premier Gardens and Cresleigh Rosewood communities. The methodology for the monitoring experiments can be found in Appendix II.

As seen in the figure below, the average home's kW draw follows a similar curve to SMUD's system draw.

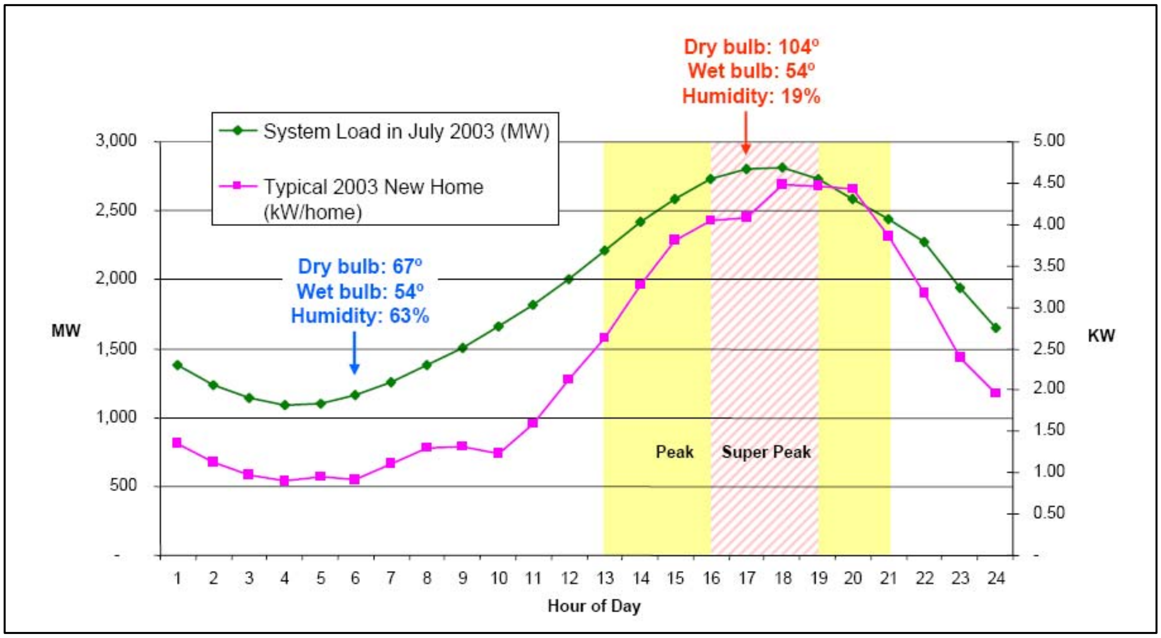


Figure 23: SMUD System Load in July 2003 vs. Typical 2003 New Home (courtesy of SMUD)

The initial monitoring results have been very positive, and have prompted further evaluation and emphasis for near-ZEHs due to peak benefits. The heat storm experienced July 2005 is still the best opportunity we have to monitor the homes' influence on peak.

July 2005

July 2005 was one of the hottest months in Sacramento weather history dating back to 1877, providing an excellent opportunity to test the effectiveness of the near-ZEH for reducing peak demand. The average daily high of 98 degrees was about 4 degrees higher than the "normal" daily high, and the daily low temperature of 65 degrees was the highest in Sacramento history. As a result, the average customer used about 13% more electricity in July 2005 when compared to July 2004. More importantly, SMUD set a new system peak demand. A new system peak of 2,959 MW was set at 5 pm on July 15th, and represented a 5% increase from the previous peak of 2,809 MW set on July 22, 2003. SMUD's new peak demand occurred on the fourth 100 degree plus day of a seven day "heat storm" in which new peak demand records were set on three consecutive days, July 13-15, 2005.

Peak Demand data compiled from the Premier Garden's ZEHs and adjacent Non-ZEH homes show that ZEHs can have a significant impact on a home's peak demand. The graphs that follow show average 15-minute interval peak demand from the Premier Garden's ZEHs and adjacent Non-ZEH homes for the month of July and July 15th.

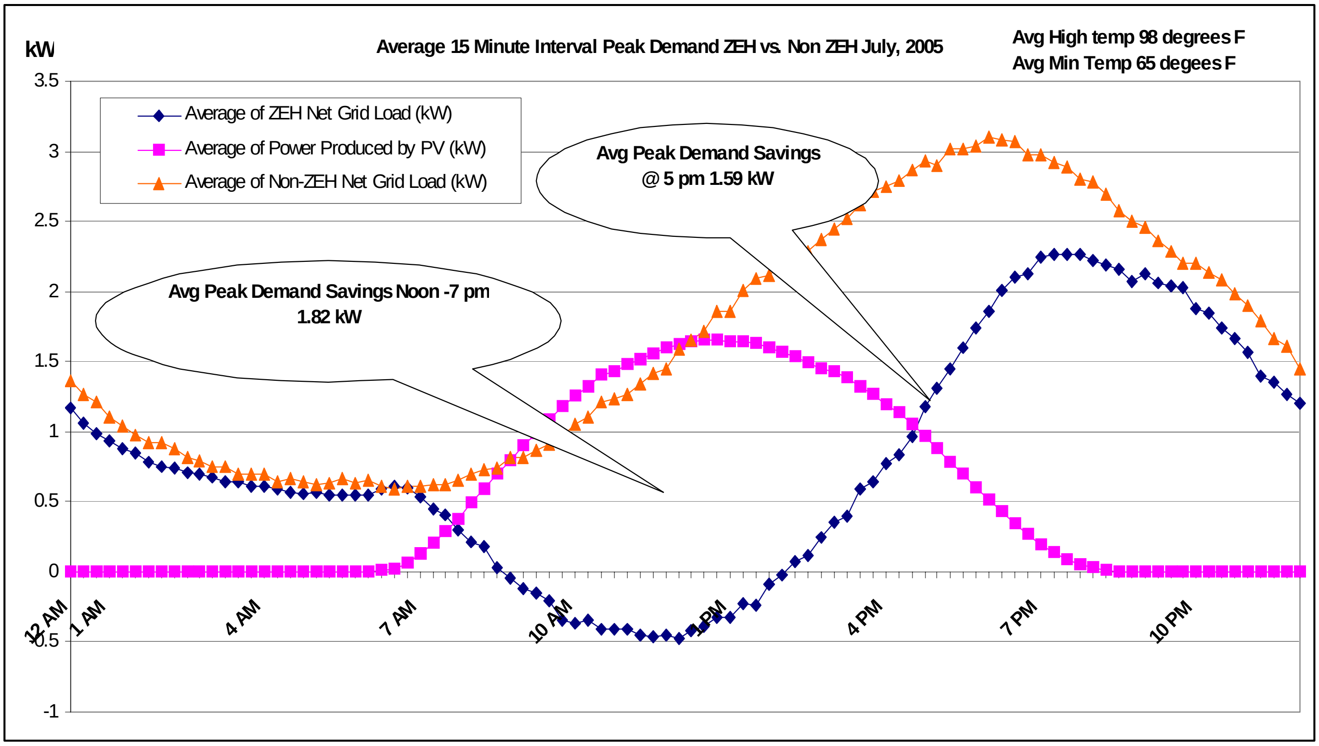


Figure 24: Average 15 minute Interval Peak Demand Near-ZEH vs. Non-ZEH July, 2005

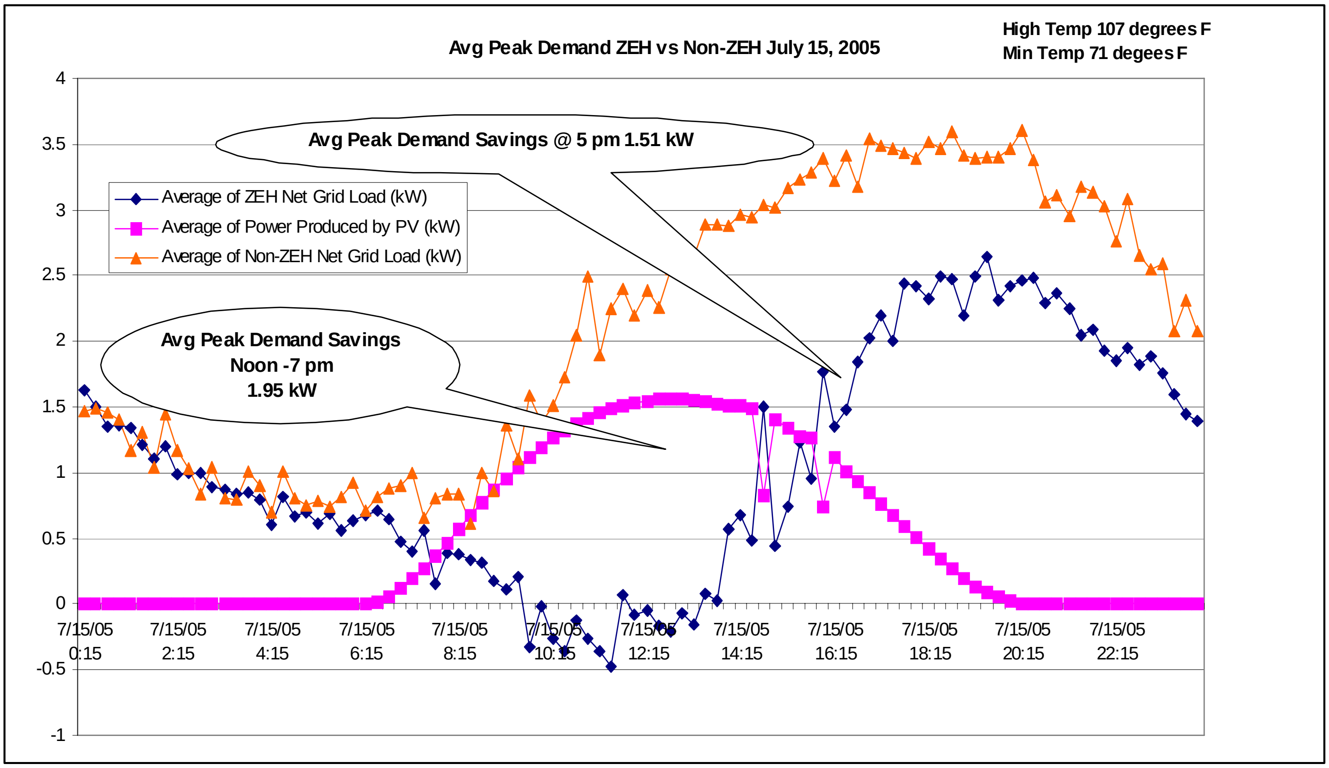


Figure 25: Average Peak Demand Near-ZEH vs. Non-ZEH July 15, 2005

As the graphs show, the near-ZEH peak demand was demonstrably lower than the adjacent, non-ZEH homes. This is especially significant as the non-ZEH homes were SMUD Advantage Homes designed to use at least 30% less cooling energy than homes built to the Title-24 cooling energy standards**.** It is further significant in considering that 11 of the homes in the sample, 28% face east and had no role in reducing peak demand. For the month of July, the ZEHs' peak demand at 5 pm was 59% less than the non-ZEH homes (1.3 vs. 2.9 kW). The ZEH peak demand was 43% lower on the peak day, July 15th.

July 2007

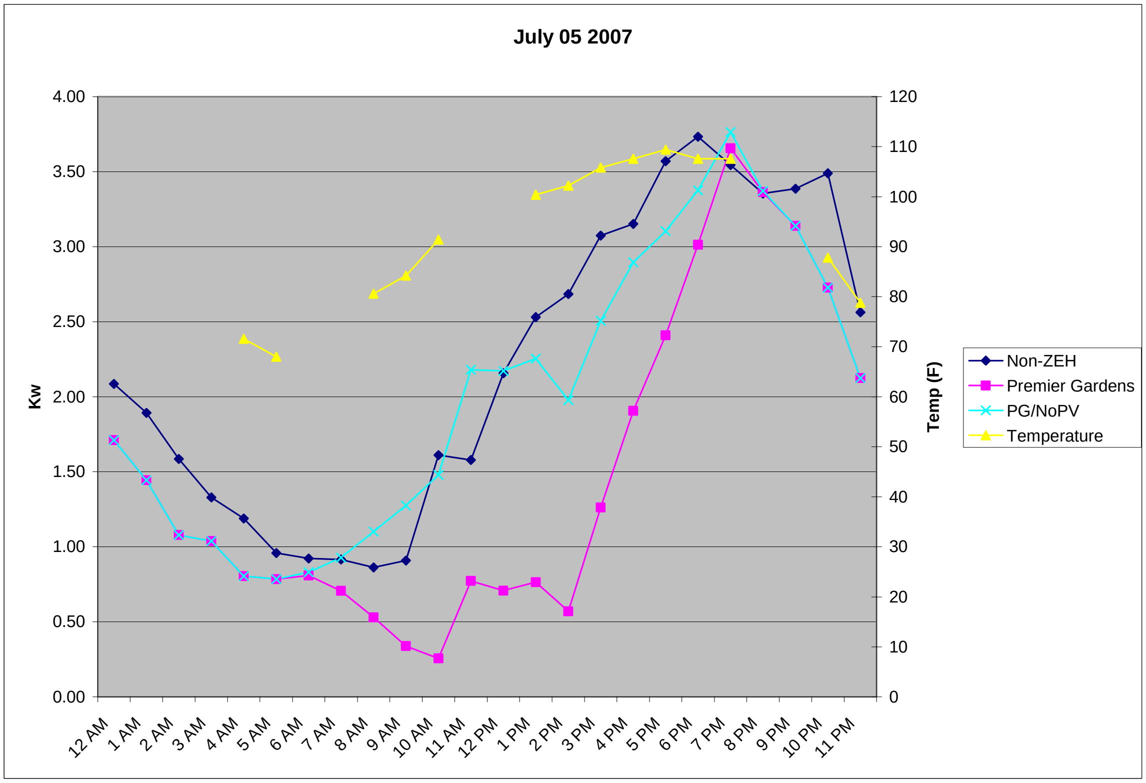


Figure 26: July 5, 2007 Electricity Demand (kW) for both communities with Temperature

This graph represents July 5, 2007 kW consumption at both Cresleigh Rosewood and Premier Gardens' homes before and after the inclusion of PV, graphed with temperature. The high temperature on this day reached 109 degrees Fahrenheit, and came at the end of a heat storm in Sacramento with 3 days of consecutive 100 plus degree days. To determine the most effective days to investigate, BIRA worked with SMUD's Bruce Ceniceros to understand the most important days of peak use for SMUD. Bruce advised BIRA look at the final day of sets of unseasonably hot days, or "heat storms." BIRA selected 10 periods of high interest, as displayed in Appendix V. Given holes in data, along with other factors BIRA chose July 5, 2007 as the best day to evaluate peak demand in the summer of 2007.

The graph displays several interesting points about peak demand at these communities. First, although there are some gaps in weather data, it is easy to see the connection between temperature and peak demand. As stated here and in other places, residential AC is one of the largest contributors to utility peak demand. And second, the Premier homes perform similarly to Cresleigh between 12 – 8pm. This is somewhat surprising compared to past analysis including the graphs directly before the July 5, 2007 plot.

July 3rd and 4th

Given the similar performance of Premier and Cresleigh homes at their peak use around 7pm it is interesting to look at July 3rd and July 4th. These days were not as hot, but still over 100 degrees and were not preceded by multiple hot days.

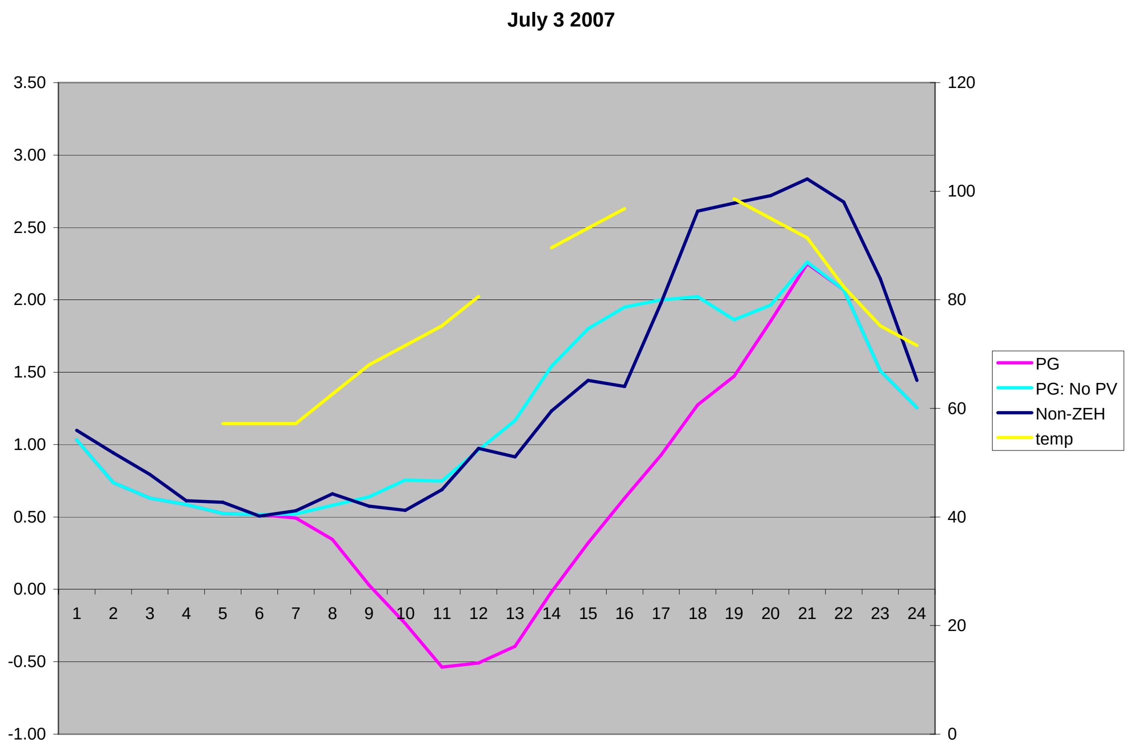


Figure 27: July 3, 2007 Electricity Demand (kW) for both communities with Temperature

As can be seen in Figure 27, the delta between Premier and Cresleigh at 7pm is greater on July 3rd where Premier's peak net load never reaches Cresleigh.

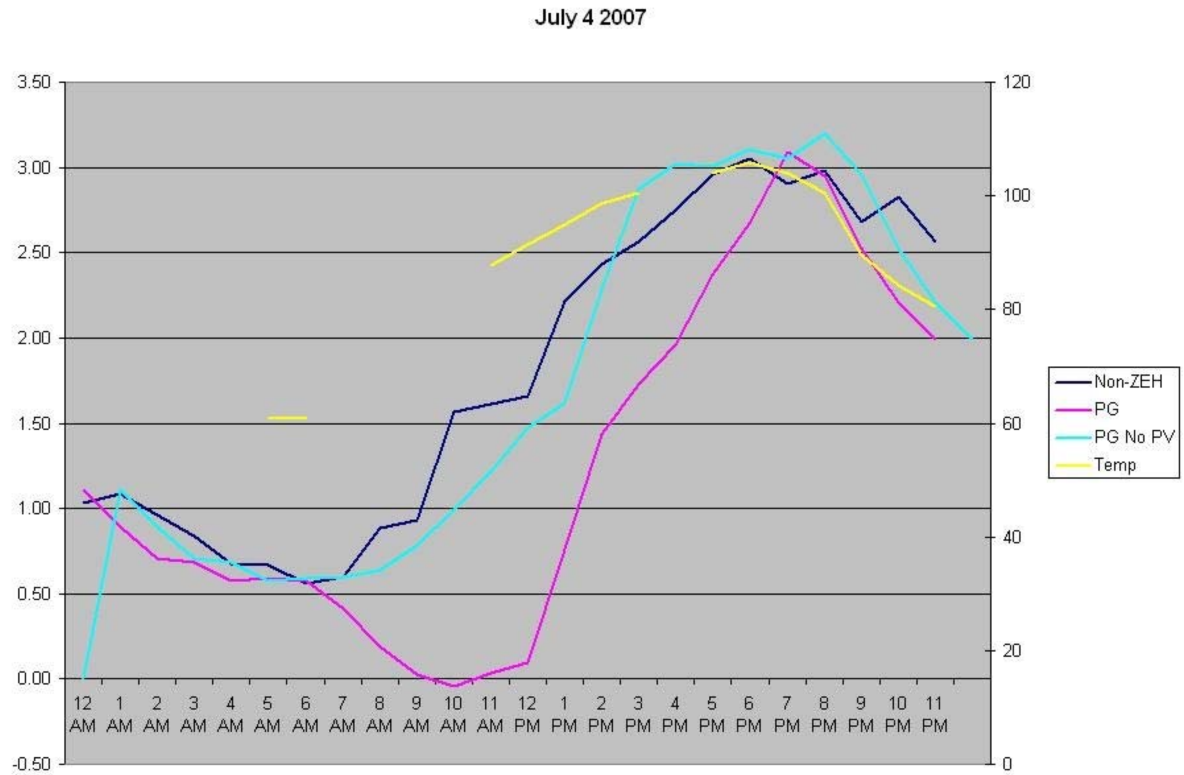


Figure 28: July 4, 2007 Electricity Demand (kW) for both communities with Temperature

On July 4th the loads look closer to July 5th, and Premier reaches above Cresleigh. It is also interesting to note that during this heat storm these communities' peaked near 8pm and still had significant loads into the late evening.

Builder Benefits

Background

Premier Homes builds an average of 70-90 homes a year in the Sacramento region. Prior to the Premier Gardens project, Premier had built only two homes with PV.

There are a few important factors that may have contributed to Premier's success with this project that must be stated to understand the context in which Premier was able to achieve success at Premier Gardens. Given the lessons learned from past ZEH experiences, such as Shea Homes in San Diego, it was strongly recommended by BIRA that Premier build with PV and enhanced energy efficiency as standard. Past experience shows that selling electric solar as an option is difficult, and more costly. Premier agreed, and every home in Premier Gardens was equipped with standard PV systems and enhanced energy efficiency. These systems were installed by a sister company that Premier Homes owned, which may have also aided them during installation.

Premier worked closely with BIRA, ConSol, and SMUD to design, build, and market the homes at Premier Gardens. As a median size builder having little experience with advanced home building, Premier did not have in-house experience or expertise to design and market Zero Energy Homes. ConSol works with production homebuilders and was able to advise Premier throughout the entire process. SMUD provided very important marketing support, and lastly, Premier's senior management was enthusiastic to build Premier Gardens, not only for business reasons but also ideological ones. This desire and commitment to Zero Energy Homes was important for there are always set-backs in home construction, and building ZEHs may compound this.

It is difficult to judge how all these factors contributed to the success of Premier Gardens, or how important they are for other builders.

Expectations vs. Reality

When Premier first decided to build Premier Gardens as a ZEH community, it stated goals for the project. These reasons were highlighted in a previous BAP task, and are as follows:

1. To differentiate themselves from all other builders
2. To promote innovative construction and energy efficiency and be energy conscious and doing good to the community
3. To attract attention, and hopefully provide faster sales
4. To continue to build with photovoltaic (PV) systems, which they have been doing for a few years, working with SMUD
5. To be competitive and have an advantage over Cresleigh Homes in the same development as well as other Sacramento builders
6. To take advantage of incentives from SMUD for building ZEH

7. To sell the ZEH homes with higher resale values
8. To offer ZEH homes as a standard package and make it affordable for entry level homebuyers while other builders only offer ZEH as a move up option.

BIRA revisited these goals with John Ralston, Premier Homes Director of Sales, and a driving force behind the Premier Gardens project. BIRA asked John to address each point on the list and evaluate the success of each. John, with little hesitation, stated that each goal was met and many were exceeded. John said that Premier received more media attention than was ever expected and that sales were remarkable. Although brisk sales would be expected during the 2004-2005 hot housing market, Premier Gardens began construction later and sold out earlier than neighboring Cresleigh Homes. Additionally, the Premier Gardens experience has prompted Premier to build more near-ZEHs, having built over 250 as of October 2006. The one goal that was difficult to access was whether Premier Garden's homes will appreciate faster than Non-ZEHs. As more homes are resold, this question will be answered.

Organizational Benefits

Reputation

By building Premier Gardens and Premier Oaks, in near by Roseville, CA, Premier Homes has developed a reputation as a forward-thinking environmentally and energy wise builder. As suggested by a 4:1 turn-out in favor of Premier Homes over Cresleigh for the RAND study, Premier homeowners may not only be happy with their homes but seem to be interested in sharing the news of their ZEHs. Premier Garden's homeowners seem to be more than willing to talk about their low energy bills and comfortable homes. Almost every Premier Garden's homeowner that Premier and BIRA have spoken with is excited to share their happiness with their homes and energy bills. This willingness to share their story has solidified Premier Homes as a homebuilder that cares about its customers and provides excellent customer service. As a small homebuilder, reputation is very important to John Ralston, and Premier Homes.

Premier Homes has also gained the respect of the homebuilding industry for its innovative designs and marketing success winning an Energy Value Housing Award, administered by the National Association of Home Builders Research Corporation and funded by DOE.

Premier will continue to build their reputation as an industry leading builder continuing to push the limits of quality, price, and energy efficiency.

Direction

The success of Premier Gardens encouraged Premier to become a ZEH builder. Although Premier has not committed to build only Zero Energy Homes, Premier's latest projects have all included solar and energy efficiency. Premier Garden's showed Premier that building ZEHs is not only good for the planet, but also good for the bottom line. Premier has decided that the value of differentiation and reputation offered by building ZEHs is worth the additional cost. Differentiation and reputation are atop John’s list of important attributes for a homebuilder’s success. One of Premier’s main goals is to differentiate themselves from other homebuilders, and the ZEH concept has done that.

Lessons Learned

Through building and marketing Premier Gardens and other solar communities, Premier has learned how to build and market ZEHs more effectively. Premier estimates that when PV is sold as an option it costs 40% more to install than if built standard. Premier has also learned and crafted their marketing message based on what resonates with homebuyers. Both John and his sales personnel work to communicate the benefits of a ZEH to potential homebuyers. This mission is difficult and takes a clear and concise message. Premier Homes is now confident that they can sell cost savings through reduced energy bills as Premier Gardens has offered verifiable evidence.

Morale

Most Premier Homes employees are proud of what they have accomplished and believe that their homes enhance people’s lives. Some Premier employees even own Premier ZEHs. This benefit is difficult to measure but non-the-less important for the people who work at Premier and for the organization as a whole.

Marketing and Sales Benefits

Public Relations

Before construction began, there were numerous articles about Premier Gardens in local newspapers and in home and garden magazines exposing the energy efficiency features. On April 21, 2004, Premier Homes completed three models and had their Grand Opening ceremony. They were interviewed and on the news of three Northern California television stations. Premier Homes felt this was a great success, and the media coverage provided good exposure of both Premier Homes and Premier Gardens to the community. In addition, the whole energy-efficient expert team was there including a guest speaker Robert Rivinius, CEO of the California Building Industry Association, who highly praised Premier Homes for voluntarily building the first ZEH community.
Premier Homes received immeasurable benefits from the PR generated from the Premier Gardens Project. The exposure did not fade, and Premier executives continue to be interviewed and written about in national and regional new sources including Newsweek magazine.

It is difficult to value the news articles, television stories, and other PR but it certainly is valuable to selling homes. The media attention Premier Gardens received saved on advertising, and offered exposure Premier could otherwise not afford.

Interestingly, there is a downside to the national media attention Premier Homes received. As a regional builder, Premier gains little from media observed outside California. John Ralston says that he frequently receives calls from people all over the country asking if Premier can build homes in their area. The answer is no, but it still takes time for Premier employees to respond to all the requests. Although, John wouldn't have it any other way, and appreciates the free publicity, the national media attention is certainly more valuable for a national builder.

Selling a Zero Energy Home

Through speaking with John Ralston and Premier Sales personnel, BIRA has learned how Premier approaches communicating the benefits of a ZEH to homebuyers. Because Premier allows its sales people to create their own marketing message it is hard to understand exactly how they approach it, but there are common threads.

An important benefit of selling a ZEH is the element of differentiation. Most model homes in the Sacramento region look alike. Selling a home with solar makes Premier stand out, and it gets people in the door asking questions. The challenge is having the time and proper message to communicate the benefits of a Premier home. Much of the interest from homebuyers is derived from the opportunity to save money compared to their current utility bills. John Ralston believes the most effective way to communicate this is by showing a potential homebuyer a summer electric bill from a Premier Garden's house. Although it is a small thing, he thinks offering a $40 electric bill is more powerful then offering a 40% reduction in monthly utility bills. This is an important nuance that Premier has learned through selling Zero Energy Homes.

For Premier Gardens, the prices of the homes compared to Cresleigh were comparable. The main difference, minus the homes' layout, was Premier's standard ZEH features, and Cresleigh's standard granite countertops. The task is adequately communicating the value of a ZEH, and what that means for a homeowner.

Moving forward Premier values the ability to confidently communicate energy bill savings based on Premier Garden's results. As the building industry is not among the most trusted, Premier knows having verifiable bill savings from Premier Gardens is an asset for selling future ZEHs.

Differentiation vs. Cost

Currently Premier Homes are selling homes in two ZEH communities. Now that the housing market has cooled, other builders are dropping prices. Premier's margins are not as high as other builders because they competitively price their homes while spending more to integrate ZEH features, and thus cannot lower their prices to align with other builders. This makes it difficult to sell, as homebuyers are spending even less time in model homes. Premier's differentiation is the market is now increasingly valuable. When the housing market was hot in 2004 and 2005 people were buying homes because they were for sale. Now buyers are becoming more discriminating, but Premier must effectively communicate the value of a ZEH, and get past the gimmicks and price cuts that other builders are offering.

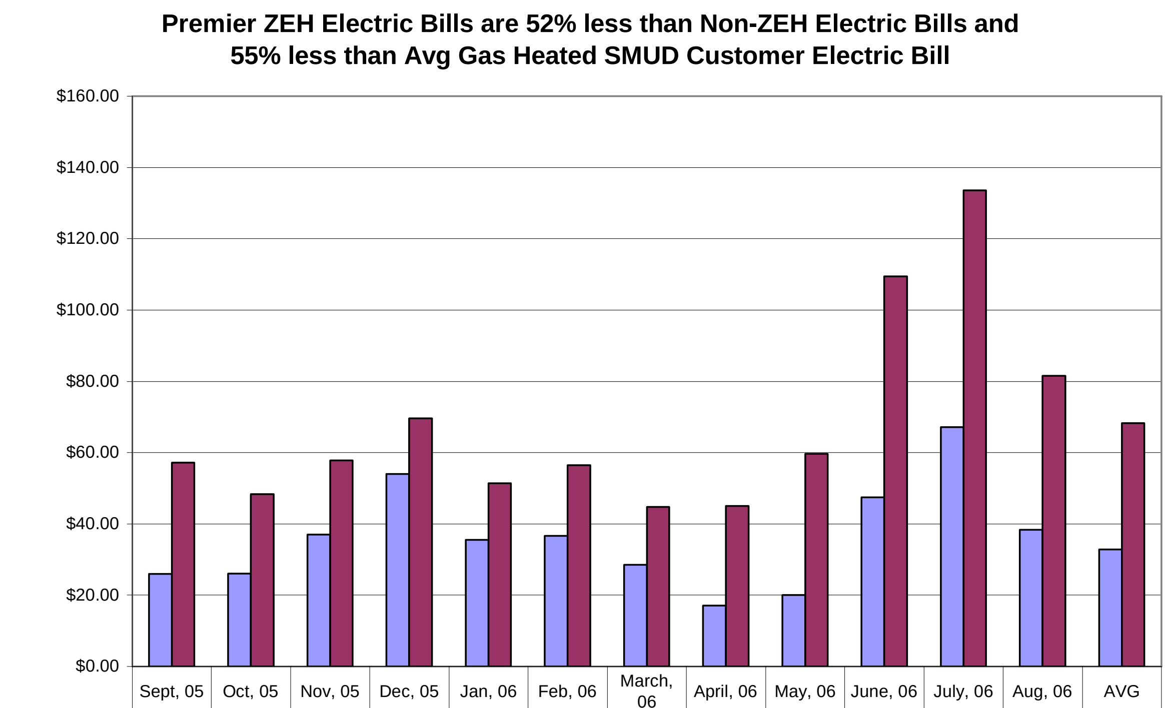
Home Owner Benefits

The benefits of the well-built Premier Zero Energy Homes are numerous. A professionally engineered and tested HVAC system provides better comfort and indoor air quality for occupants. Low-emissivity windows provide added comfort and protect furniture and fabric from fading and wear. Better insulation and testing provide more even temperatures throughout the home and better sound insulation from outside noise. All the ZEH features provide 44% whole house energy savings over a Cresleigh Rosewood home and make the home more affordable.

Energy Bill Savings

Electricity

Premier Garden's homeowners are saving money every month on their electric bills relative to both SMUD residential customers and neighboring Cresleigh homeowners. On average, between September 2005 and August 2006 Premier residents paid 55% less than the average SMUD customer and 52% less than the average Cresleigh resident. This amounts to an average savings per month of $35.40 over Cresleigh homeowners. Also, given SMUD's tiered rate system, which penalizes high electricity use, Premier homeowners almost always remain in the 1st tier, as Cresleigh residents pay higher 2nd and 3rd tier rates during high electricity use months such as the summer cooling season.



	Sept, 05	Oct, 05	Nov, 05	Dec, 05	Jan, 06	Feb, 06	March, 06	April, 06	May, 06	June, 06	July, 06	Aug, 06	AVG
Premier ZEH	$25.90	$26.10	$36.98	$54.04	$35.52	$36.62	$28.48	$17.07	$20.07	$47.42	$67.21	$38.35	$32.89
Non-ZEH	$57.18	$48.31	$57.85	$69.62	$51.46	$56.46	$44.71	$44.95	$59.60	$109.50	$133.55	$81.55	$68.29

Figure 29: Premier Monthly Electric Bills vs. Cresleigh for 12 month period (courtesy of SMUD)

Additionally, Premier residents are able to create negative bills if they conserve energy. Every month there are a handful of Premier residents that experience negative bills creating a credit at the end of the year. In June 2005 more than 10% of Premier residents had negative bills.

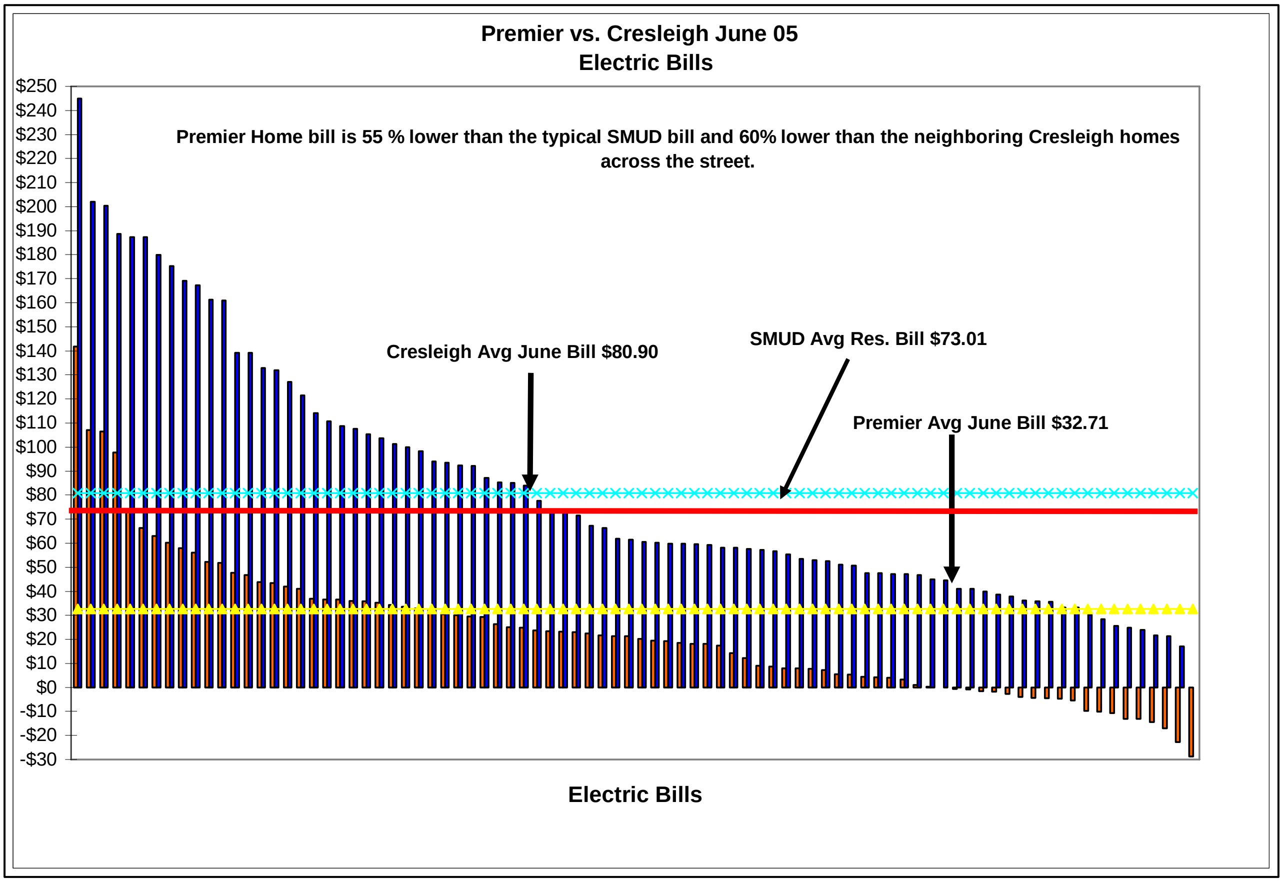


Figure 30: Premier vs. Cresleigh June 2005 Electric Bills (courtesy of SMUD)

Gas

Premier Residents also save on their gas bills. In 2005, Premier residents on average pay 30% less than Cresleigh residents, representing $13.82 savings each month.

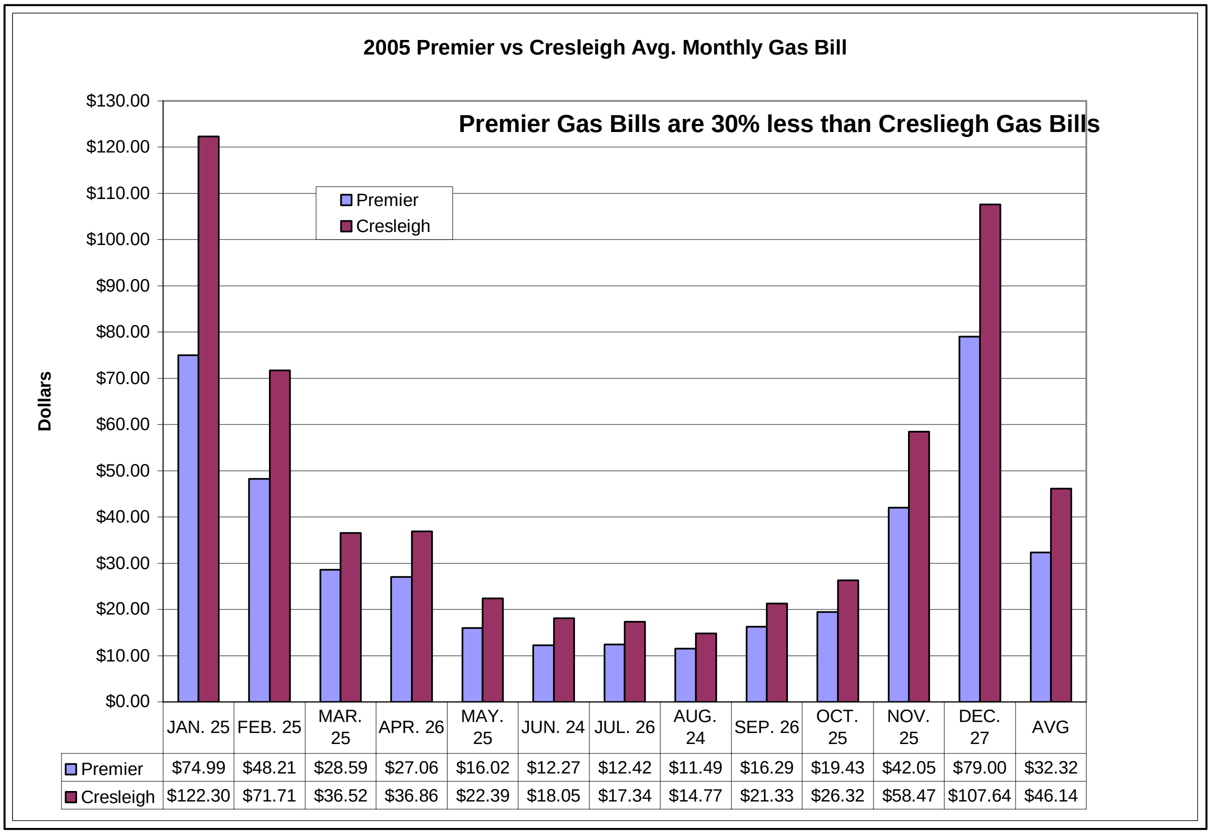


Figure 31: 2005 Premier vs. Cresleigh Avg. Monthly Gas Bills (courtesy of SMUD)

Total Energy Cost Savings

Premier homeowners save money on both gas and electric bills each month. The following table shows their savings over a 12-month period relative to Cresleigh.

Energy Bill Savings				
Community	Avg Gas Bill	Avg Electric Bill	Total Energy Bill	Yearly Energy Bill
Premier	$32.32	$32.89	$65.21	$782.52
Cresleigh	$46.14	$68.29	$114.43	$1,373.16
Savings ($)	$13.82	$35.40	$49.22	$590.64
Savings (%)	30%	52%	43%	43%
Premier Residents save 43% on energy bills amounting to $590.64/year				

Table 13: Total Energy Bill Savings Premier vs. Cresleigh

Premier residents save 43% on energy bills over Cresleigh amounting to $43.22 per month, and $590.64 per year. These bill savings make the cost of home ownership cheaper for Premier residents.

Resale Value

It has been said that Zero Energy Homes have higher resale values. According to a National Renewable Energy Laboratory Technical Report, ZEHs built by Shea Homes in San Diego resold for 16.6% more than a comparable community.[2]

BIRA, SMUD, and NREL have been anxious to evaluate the resale value of Premier Gardens' homes compared to Cresleigh to understand the value of energy efficiency and PV in the resale market. The below table begins to address this question by identifying homes that have been resold. However, given the small sample of homes and other variables including the down housing market, BIRA and its real estate partners determined no conclusions could be drawn at this time. As more homes are resold, this question can be answered.

Address	Date of Sale	Price	Price per SQ FT	Community	Sq Ft
3506 Spring Rose Way	8/6/2007	328,500	204	Cresleigh	1,610
9570 Rose Vista	5/1/2007	360,000	223	Cresleigh	1,610
9676 Harvest View Way	12/6/2006	435,000	217.5	Cresleigh	2,000
3421 Spring Rose Way	2/23/2007	437,000	218	Cresleigh	2,000
9507 Harvest View Way	6/29/2007	325,000	252	Premier	1,285
3513 Garden Rose Dr	12/22/2006	325,500	253	Premier	1,285
9602 Harvest View Way	6/5/2007	352,000	216	Premier	1,625
9594 Harvest View Way	6/5/2007	356,000	219	Premier	1,625
9562 Harvest Gold Ct	12/22/2006	398,000	244	Premier	1,625
3509 Garden Rose Dr.	12/6/2006	439,000	195.3	Premier	2,248

Table 14: Homes Resold at Premier and Cresleigh

Environmental Benefits

Of the 95 Premier Garden's homeowners, it is likely that some value the ability to decrease their impact on the environment. Premier's near-ZEHs offered homeowners the choice to buy a home that is less dependent on source energy, and therefore less polluting.

Residential buildings are the largest consumer of energy within the largest sector, buildings, consuming 21.5 percent of all energy produced within the United States in 2002.[3] Likewise, residential buildings contribute 20.6 percent of total carbon dioxide emissions.

According to previous calculations, Premier Garden's homeowners use 44% less energy than Cresleigh homeowners. Therefore, Premier Garden's homes impact on the

[2] "A Comparative Market and Utility Analysis of New High-Performance Homes in San Diego" B.C. Farhar and T.C. Coburn
[3] EIA data

environment is about 44% less than Cresleigh's impact. Considering the impact residential buildings have on the environment, this savings is substantial. Near-ZEH owners can appreciate the positive impact they are having on environmental protection.

Quality of Life

Premier Garden's homeowners are genuinely satisfied with their homes. They find them to be comfortable, affordable, and easy to maintain. All research gathered suggests that Premier Garden's homeowners love their homes. As John Ralston said, we want our homes to enhance people's lives, and from all accounts these homes succeed.

Other Stakeholder Benefits

Building Community

The Premier Garden's project has contributed significantly to the knowledge base for building high performance homes that deliver expected energy saving results. This case study has created evidence that shows building near-ZEHs is both technically and practically possible for production homebuilders. All stakeholders can reference actual energy use data from Premier Gardens to prove that ZEHs work serving multiple stakeholder goals.

Verifiable Results

Premier Gardens serves as a model for production level Zero Energy Homes that deliver verifiable results. This evidence provides a valuable tool for energy consultants, utilities, homebuilders, and other stakeholders to sell the ZEH concept to others. Premier Gardens has proven the ability of near-ZEHs to cut energy bills, energy use, and peak electrical use. These verifiable results likely contributed to the creation of SMUD's Solar Smart program as well as the California Energy Commission's New Solar Homes Partnership.

Growing Evidence shows Zero Energy Homes are marketable

Profit driven production home builders are skeptical that consumers truly value the benefits that a Zero Energy Home provides. But as projects like Premier Gardens prove successful, the evidence is mounting that profitable homebuilders build Zero Energy Homes.

One key element for profitability in homebuilding is turning inventory. Homes are expensive to build, expensive to own, and expensive to sell so each day the homebuilder owns their homes costs them money. Homebuilders like Premier are showing that Zero Energy Homes sell faster. Clarum Homes, of California, also experienced brisk sales compared to industry averages with their Vista Montana project.

More recently, Grupe has been experiencing ZEH success, marketing their GrupeGreen homes in the Sacramento area. The GrupeGreen homes are part of a larger master planned community with multiple other builders. Although, Grupe is the furthest track of homes from the entrance and experiences less customer traffic, they have sold more homes than every other homebuilder.[4]

The evidence is mounting that in hot and cool housing markets the value of ZEH differentiation and value sells homes faster.

Understanding Zero Energy Home Buyers

The RAND study evaluating the decisions made by Cresleigh and Premier buyers begins to explain how and why consumers by Zero Energy Homes. Compared to Cresleigh

[4] As of November 2007

buyers, Premier buyers were younger, earned less household income, were more educated, and visited twice as many homes before buying. Most homebuilders tell BIRA the key to selling ZEHs is education, customers must understand how a ZEH works and the benefits it offers. The fact that Premier buyers did more research would support this claim.

A white paper entitled "Energy in the Home Study" suggests that "If you have a product that is both energy efficient AND green, over two-thirds of the market are going to be interested in it. The appeal of a two-pronged attack is much wider."[5] This could be why GrupeGreen homes are selling so well compared to neighboring communities. This is also supported by an informal study done by ConSol of ZEH sales personnel from 15 communities across California. There were four themes that were repeated by the majority of interviewees: customers want homes that are good for the environment, save money (energy efficiency), customers need more solar education, and predominately men are interested in solar. Two-thirds of the near-ZEH RAND participants were male, supporting that men are interested in solar.

Commonalities across studies:

- Education is key to selling Zero Energy Homes
- Men are interested in PV
- Two-pronged approach most effective (good for the environment + energy efficient, which saves money)

Energy Analysts

The amount of information collected concerning gas and electricity use offered BIRA the opportunity to test the modeling tools and assumptions currently used to evaluate energy use in single-family homes. The large sample of homes equalizes the behavioral differences that exist from one home to the next. This offered a unique ability to compare expected results to actual results. As shown earlier, current models and assumptions worked reasonably well, but there is certainly room for improvement especially for gas use estimations. As additional years of data become available the variability from climate and other environmental factors will work with the large sample to further normalize actual results. The Premier Garden's library of data can be used to judge new tools as well, such as BEopt, to compare its effectiveness not only to other simulation tools but also actual results.

SMUD & Electric Utilities

SMUD Profile

- Electric Utility with 900 square mile service territory serving 1.3 million customers

[5] "Energy in the Home Study" June 2002 Prepared by American LIVES, Inc. Oakland, CA

- Heavily dominated by residential customers (515,000 residential meters, 65,000 commercial customers)
- More than 2,000 employees
- Peak Demand: 3,000 mW
- Load Factor- 40%

The Premier Gardens project has been as successful for SMUD as it has been for Premier Homes. The demonstrated ability of the Near-ZEHs to cut peak electrical demand significantly over Cresleigh's SMUD Advantage Homes delighted SMUD officials. The success at Premier has prompted SMUD to create a Solar Smart program to begin to leverage the peak shaving power of ZEHs.

When speaking with Mike Keesee, Wade Hughes, or Bruce Ceniceros at SMUD, BIRA quickly learned their main object: cut peak demand, more specifically cut residential cooling demand. Wade Hughes said "It's all about A/C."[6]

Mike Keesee wrote, "In the past few years, Sacramento has seen record numbers of new homes built. This boom in new home construction is leading to increased demand for electricity, raising utility bills and taxing local electrical utility systems. Central air conditioning is a standard feature in all new homes built in Sacramento and a major factor in SMUD's peak electrical demand growth. SMUD is participating in the BAP because the District believes ZEH can reduce its peak demand while dramatically reducing new homeowners' utility bills."[7] In a personal interview, Mike Keesee told BIRA that the Premier Garden's project was "precedent setting" and that an important goal was to "shift demand."[8]

Bruce Ceniceros, SMUD's Principal Planner for New Construction Programs, believes SMUD needs to focus more on peak both for grid reliability and to reduce the marginal costs of peak electricity.

SMUD's need to shift peak demand is similar to most electric utilities. As shown in the Energy Analysis section, residential electricity demand follows a similar shape to the overall system load. At peak periods electricity is expensive to produce, buy, and distribute. Large capital investments are needed to provide electricity for very few hours throughout the year. The ability to shift demand, and flatten the utility's load shape can significantly reduce the capital investments and marginal costs of energy creating lower prices for all consumers.

Pacific Gas & Electric

The benefits, or lack there of, for gas retailers is difficult to gage. PG&E provides gas to Premier and Cresleigh customers. By reducing Premier's gas consumption, potential revenues are lost for PG&E. For electricity providers the peak shaving benefits of ZEHs are significant enough to overcome lost revenues from conservation, but the benefits for

[6] Personal Interview with Wade Hughes November 7, 2006.
[7] PREMIER GARDENS – SACRAMENTO'S FIRST ZERO ENERGY HOME COMMUNITY, by Mike Keesee
[8] Personal Interview with Mike Keesee November 2006.

gas providers is relatively unknown. The fact that natural gas is a finite resource means that decreasing demand will ensure future supplies. But the value of this for PG&E is unclear. As PG&E also sells electricity, one positive is the conservation of natural gas will help ensure the gas-powered electricity generators they source electricity from will continue to provide low cost electricity.

The impact of reducing gas consumption in ZEHs on natural gas retailers must be studied further to better understand the benefits ZEHs can provide them.

Conclusions

The Premier Gardens and Cresleigh Rosewood communities both represent well designed homes that exceed one of the best building codes in the country, California's Title 24. Even so, Premier Garden's near-ZEHs use 44% less source energy than Cresleigh while significantly shaving peak electricity demand as well.

The statistical analysis of the utility data provided by SMUD showed significant validity to the overall energy savings of the Near-ZEH community in comparison to the control community when the PV production was included. Occupant behavior does not affect the PV production so minimal variances in PV production influenced by orientation and possible shading did not adversely affect the results. However, the small difference in electrical consumption between the two communities, 7.4%, and the wide variations in electrical consumption resulted in no statistical significance to the energy savings of electrical consumption between the two communities. These conclusions are consistent with the findings of NREL's working group on Post Occupancy Evaluations.

With all the information gathered and analyzed, this project represents an essential case study for designers, builders, and energy analysts interested in building high performance homes with predictable results. The benefits of the Premier Garden's homes are numerous and affect multiple stakeholders. Now that many ZEH benefits have been identified, the task for future near-ZEH projects will be to appropriately communicate and assign value to all affected stakeholders.

As the building industry moves forward, building in higher levels of efficiency, the lessons learned from Premier Gardens will continue to influence the next generation of Zero Energy Homes.

Acknowledgements

Vikki Wood, Bruce Ceniceros, and Mike Keesee at SMUD were instrumental in making data available for this report. Professor Dan Toy Ph.D. worked tirelessly to help BIRA work through our challenges with the statistical elements of this report. The whole BIRA team appreciates his contributions.

Future Work at Premier Gardens

Although the Premier Gardens community has been evaluated seemingly till exhaustion, there is still more worthwhile work to do. When looking at the impact of efficiency before PV on an annual basis BIRA saw no statistically significant difference. However, consumption at a particular time of day was not analyzed. For instance, is the consumption delta larger during peak hours and is the difference pre-PV consumption between Premier and Cresleigh statistically significant? Several non-statistical analyses have suggested energy efficiency was as important to Premier's peak reductions as PV, and others suggested the opposite. This is an important question to answer given the focus on peak in California and the importance program developers place on peak reductions at the CEC, SMUD, and beyond. If BIRA can show a statistically significant difference between Cresleigh's on peak consumption vs. Premier's peak consumption before PV, these results could significantly influence utility related investment in Zero Energy Home construction, thus becoming a driver of overall efficiency in housing.

BIRA experienced some growing pains in evaluating the communities' for statistical validity. A complete dissemination of these challenges and BIRA's approach for solving them can be found in Appendix IV. Given the steep learning curve and lessons learned, it will be considerably easier the next time Professor Toy works with BIRA to evaluate this and other community scale projects. BIRA in partnership with CSU Chico and Professor Toy have laid the groundwork for important analysis both at Premier Gardens and other community scale evaluation projects.

In working with Paul Norton at the National Renewable Energy Laboratory, Dan Toy Ph.D., and Ryan Kerr discovered potential changes that could be made to update and streamline the "Building America Program Community Evaluation Guidebook." This work could be coupled with the lessons learned in statistically analyzing large sets of community scale energy data and be used to create better protocols for design and implementation of effective occupied home evaluations at an affordable cost of the U.S. DOE. There are several important variables that must be present for effective and manageable occupied home evaluations and if present, these variables could promote reasonably affordable future occupied home evaluations. An example of one of these variables would be the participation and partnership with a utility such as SMUD.

Power Meter Research

Given the amount of data available and analysis performed at Premier Gardens, it is a fruitful experimental site for further work. Of primary interest is an ongoing plan aimed at *Evaluating the Effectiveness and Behavioral Response of Real-Time Electricity Feedback Systems in Near Zero Energy Homes*. This work has been made possible by Gate 3 evaluations done at Premier Gardens and will be important for evaluating consumer feedback power meters under Stage 1 evaluation criteria for use in all Building America homes aimed at addressing the rising miscellaneous electricity consumption in Building America homes. This project is discussed in length in Appendix VI.

Appendix I - Energy Analyses Premier Gardens

Energy Analysis and Selection of Energy Features

ConSol reviewed the requirements of meeting the ZEH program. After many discussions and reviews, ConSol finalized and provided the ZEH features to Premier Homes. Premier agreed to build utilizing the energy features and recommended PV system for all of the homes in the Premier Gardens development. ConSol also compared the proposed ZEH homes to the BA benchmark. The spreadsheets on the following pages show energy analyses for each of the floor plans in this project in comparison to the BA benchmark. These energy analyses use the California Energy Commission (CEC) and BESTEST-certified Micropas[9] energy analysis software for building code compliance.
The Building America features are as follows:

1. Wall insulation of R-13 batt with 1 inch foam insulation (1-coat stucco system)
2. Tight envelope with low air infiltration: Specific Leakage Area (SLA) = 3.5 or less (inspection and testing by ConSol's ComfortWise certified inspectors
3. Dual pane vinyl frame with spectrally selective glass
4. Highly energy-efficient furnace of 0.91 AFUE
5. Highly energy-efficient AC of 14 SEER with Thermostatic Expansion Valve (TXV)
6. R-4.2 duct insulation buried in attic insulation, producing R-13 equivalent
7. Tight duct system designed by a licensed mechanical engineer using ACCA manual D
8. Tankless water heater with an Energy Factor (EF) of 0.82
9. R-4 pipe insulation on all major hot water trunks.
10. Gas dryer
11. Fluorescent lighting at all down lights
12. 2.0 kW AC PV system by GE (building integrated panels to blend in with roof tiles)

Plan #	Floor Area	% Energy Savings Compared to BA Benchmark wo/PV	% Energy Savings Compared to BA Benchmark w/PV
1503	1,503	38%	61%
1285	1,285	37%	63%
1625	1,625	37%	59%
1846	1,846	37%	58%
2248	2,248	39%	56%

[9] Micropas is a product of Enercomp, Inc.

Energy Analysis for Each Plan Type

Comparison of Total Energy Use 4 Bedrooms

Plan 1285	**Base Case / BA Benchmark House**			**BA Prototype House** - 40% Energy Savings (Upgraded Features, Fluorescent, Gas Dryer Stub, 2.4 kW PV and Tankless Hot Water)		
	\		Dollars	Energy Use		Dollars
	Therms	kWh	$	Therms	kWh	$
Energy Code Related						
Space Heating	278		$ 208.17	152		$ 114.30
Space Cooling		1,906	$ 162.04		474	$ 40.32
Water Heating	219		$ 164.22	121		$ 91.07
Other Uses						
cooking	78		$ 58.50	78		$ 58.50
clothes washer		123	$ 10.41		123	$ 10.41
dishwasher		240	$ 20.42		240	$ 20.42
electric or gas dryer		974	$ 82.79	84		$ 63.00
refrigerator		669	$ 56.87		669	$ 56.87
Miscellaneous (Appliances + Plug)		2,146	$ 182.41		2,146	$ 182.41
Lighting		1,833	$ 155.81		477	$ 40.55
reduce kWh by solar contribution		n/a	n/a		(3,420)	$ (290.70)
Total use	575	7,891	$ 1,101.63	436	709	387.14
Total Annual Energy Use		138,248	kBtu/yr		50,843	kBtu/yr
Reduction in Energy Use				24%	91%	65%
Total for Column in kBtu/yr	57,452	80,796		43,583	7,260	

Total kBtu/yr for BA Benchmark House	138,248	kBtu/yr
Total kBtu/yr for Prototype House	50,843	kBtu/yr
Percent End Use Energy Savings	**63%**	

Estimated Montly Energy Bill	$ 91.80 /mo	$ 32.26 /mo	
Reduction in Energy Cost		35%	

price of gas/therm	$0.75
price of electricity/kWh	$0.08500

Comparison of Total Energy Use

Plan 1503	**Base Case / BA Benchmark House**			**BA Prototype House** - 40% Energy Savings (Upgraded Features, Fluorescent, Gas Dryer Stub, 2.4 kW PV and Tankless Hot Water)		
	\		Dollars	Energy Use		Dollars
	Therms	kWh	$	Therms	kWh	$
Energy Code Related						
Space Heating	339		$ 253.97	168		$ 126.36
Space Cooling		2,076	$ 176.43		498	$ 42.30
Water Heating	230		$ 172.13	131		$ 98.07
Other Uses						
cooking	78		$ 58.50	78		$ 58.50
dishwasher		206	$ 17.51		206	$ 17.51
electric or gas dryer		835	$ 70.98	72		$ 54.00
refrigerator		669	$ 56.87		669	$ 56.87
Miscellaneous (Appliances + Plug)		2,510	$ 213.35		2,510	$ 213.35
Lighting		2,007	$ 170.63		833	$ 70.81
reduce kWh by solar contribution		n/a	n/a		(3,420)	$ (290.70)
Total use	646	8,303	$ 1,190.36	449	1,296	447.06
Total Annual Energy Use		149,628	kBtu/yr		58,191	kBtu/yr
Reduction in Energy Use				30%	84%	62%
Total for Column in kBtu/yr	64,613	85,015		44,925	13,266	
Total kBtu/yr for BA Benchmark House	149,628	kBtu/yr				
Total kBtu/yr for Prototype House	58,191	kBtu/yr				
Percent End Use Energy Savings	**61%**					
Estimated Montly Energy Bill			$ 99.20 /mo			$ 37.26 /mo
Reduction in Energy Cost						38%
price of gas/therm	$0.75					
price of electricity/kWh	$0.08500					

Comparison of Total Energy Use

PLAN 1625	**Base Case / BA Benchmark House**			**BA Prototype House** - 40% Energy Savings (Upgraded Features, Fluorescent, Gas Dryer Stub, 2.4 kW PV and Tankless Hot Water)		
	\		Dollars	Energy Use		Dollars
	Therms	kWh	$	Therms	kWh	$
Energy Code Related						
Space Heating	371		$ 278.61	188		$ 141.01
Space Cooling		2,266	$ 192.64		651	$ 55.31
Water Heating	235		$ 176.48	136		$ 102.13
Other Uses						
cooking	78		$ 58.50	78		$ 58.50
dishwasher		206	$ 17.51		206	$ 17.51
electric or gas dryer		835	$ 70.98	72		$ 54.00
refrigerator		669	$ 56.87		669	$ 56.87
Miscellaneous (Appliances + Plug)		2,714	$ 230.67		2,714	$ 230.67
Lighting		2,105	$ 178.93		842	$ 71.57
reduce kWh by solar contribution		n/a	n/a		(3,420)	$ (290.70)
Total use	685	8,795	$ 1,261.16	474	1,661	496.86
Total Annual Energy Use		158,530	kBtu/yr		64,430	kBtu/yr
Reduction in Energy Use				31%	81%	61%
Total for Column in kBtu/yr	68,478	90,053		47,419	17,012	
Total kBtu/yr for BA Benchmark House	158,530	kBtu/yr				
Total kBtu/yr for Prototype House	64,430	kBtu/yr				
Percent End Use Energy Savings	**59%**					
Estimated Montly Energy Bill			$ 105.10	/mo		$ 41.41 /mo
Reduction in Energy Cost						39%
price of gas/therm	$0.75					
price of electricity/kWh	$0.08500					

Comparison of Total Energy Use

PLAN 1846	**Base Case / BA Benchmark House**			**BA Prototype House** - 40% Energy Savings (Upgraded Features, Fluorescent, Gas Dryer Stub, 2.4 kW PV and Tankless Hot Water)		
	\		Dollars	Energy Use		Dollars
	Therms	kWh	$	Therms	kWh	$
Energy Code Related						
Space Heating	391		$ 293.24	216		$ 162.26
Space Cooling		2,194	$ 186.50		389	$ 33.10
Water Heating	246		$ 184.42	146		$ 109.38
Other Uses						
cooking	78		$ 58.50	78		$ 58.50
dishwasher		206	$ 17.51		206	$ 17.51
electric or gas dryer		835	$ 70.98	72		$ 54.00
refrigerator		669	$ 56.87		669	$ 56.87
Miscellaneous (Appliances + Plug)		3,083	$ 262.04		3,083	$ 262.04
Lighting		2,282	$ 193.95		913	$ 77.58
reduce kWh by solar contribution		n/a	n/a		(3,420)	$ (290.70)
Total use	715	9,269	$ 1,324.00	512	1,840	540.54

Total Annual Energy Use		166,390	kBtu/yr		70,058	kBtu/yr
Reduction in Energy Use				28%	80%	59%
Total for Column in kBtu/yr	71,487	94,903		51,219	18,839	
Total kBtu/yr for BA Benchmark House	166,390	kBtu/yr				
Total kBtu/yr for Prototype House	70,058	kBtu/yr				
Percent End Use Energy Savings	**58%**					
Estimated Montly Energy Bill			$ 110.33	/mo		$ 45.04 /mo
Reduction in Energy Cost						41%
price of gas/therm	$0.75					
price of electricity/kWh	$0.08500					

Comparison of Total Energy Use 5 Bedrooms

PLAN 2248	Base Case / BA Benchmark House			**BA Prototype House** - 40% Energy Savings (Upgraded Features, Fluorescent, Gas Dryer Stub, 2.4 kW PV and Tankless Hot Water)		
	\		Dollars	Energy Use		Dollars
	Therms	kWh	$	Therms	kWh	$
Energy Code Related						
Space Heating	569		$ 426.56	280		$ 210.24
Space Cooling		3,052	$ 259.40		696	$ 59.16
Water Heating	265		$ 198.95	164		$ 122.74
Other Uses						
cooking	78		$ 58.50	78		$ 58.50
clothes washer		140	$ 11.90		140	$ 11.90
dishwasher		275	$ 23.33		275	$ 23.33
electric or gas dryer		1,113	$ 94.61	96		$ 72.00
refrigerator		669	$ 56.87		669	$ 56.87
Miscellaneous (Appliances + Plug)		3,754	$ 319.10		3,754	$ 319.10
Lighting		2,603	$ 221.29		938	$ 79.73
reduce kWh by solar contribution		n/a	n/a		(3,420)	$ (290.70)
Total use	912	11,606	$ 1,670.50	618	3,052	722.87
Total Annual Energy Use		210,033	kBtu/yr		93,044	kBtu/yr
Reduction in Energy Use				32%	74%	57%
Total for Column in kBtu/yr	91,201	118,832		61,798	31,246	

Total kBtu/yr for BA Benchmark House	210,033	kBtu/yr
Total kBtu/yr for Prototype House	93,044	kBtu/yr
Percent End Use Energy Savings	**56%**	

Estimated Montly Energy Bill	$ 139.21 /mo		$ 60.24 /mo
Reduction in Energy Cost			43%

price of gas/therm	$0.75
price of electricity/kWh	$0.08500

Appendix II - Peak Demand Monitoring Methodology

“To study the impact near ZEH homes have on peak demand, SMUD’s Pricing and Rules Metering Group designed a monitoring experiment comparing the peak demand of the ZEH homes to the non-ZEH homes that would achieve a 90% confidence interval with a +/- 10% margin of error. To achieve a 90% confidence level sample, 18 randomly selected homes in each subdivision are being monitored. As part of this sample, Pricing and Rates developed a random selection process based on comparably sized homes and their distribution in each subdivision to be used in selecting which homes to be monitored. The orientation of the PV systems found on the ZEH sample includes 11 south facing (61%), five-east facing (28%) and two west facing (11%) solar systems. The table below summarizes the sample distribution from each subdivision.

Premier Gardens		Adjacent Non ZEH Subdivision	
SqFt Category	# of Samples	SqFt Category	# of Samples
1285	2	1610	3
1503	4	1720	3
1625	2	1850	2
1846	4	2000	2
2248	6	2042	3
		2384	5
Total	18		18

Figure 32: Monitoring Sample Square Footage and Distribution (courtesy of SMUD).

SMUD’s Metering group installed and calibrated MV-90 recording meters at the designated sites to record 15-minute interval data for ZEH and non-ZEH energy use (kWh) and peak demand (kW), and for power produced by the ZEHs’ PV system (SMUD employs the MV-90 data monitoring system to analyze SMUD’s system loads). Data from the MV 90 recording meters is being collected by District meter readers as part of their monthly electric meter reads. Metering staff then compiles the 15-minute interval data into Excel spreadsheets that are easily manipulated into daily, weekly and monthly energy use, peak demand, and PV power production averages.

MV 90 recording meters were installed in April 2005 after the two subdivisions were fully occupied. The Metering group began downloading data in May 2005 and developing a data report format. The first complete energy use data reports were received in June 2005.

Appendix III – ACEEE Abstract

This abstract was recently submitted to ACEEE highlighting the benefits Zero Energy Communities have for multiple stakeholders. This builds on a paper presented by Ryan Kerr at ASES Solar 2007 titled *Putting It All Together: Aggregating Benefits, Selling to Stakeholders The Benefits of Zero Energy Homes Reach Far Past Homeowners*.

Finding a Market for Positive Externalities:
Jump Starting Change in Production Home Building

Oral Presentation
Lead Author: Ryan Kerr (ConSol/BIRA)
Second Author: Rob Hammon, Ph.D. (ConSol/BIRA)

Today, production homebuilders are able to build homes and communities that consume up to 60% less energy than their traditional counterparts using off the shelf efficiency and solar technologies. This market transformation has taken root in areas like Sacramento, California yet remains illusive on a national scale.

As the concept has matured and more communities have been built in California, evidence is beginning to accumulate demonstrating the quantifiable value these homes have on the environment, climate protection, utility bills, electric utility peak, builder marketing, and jurisdictional infrastructure. Through engaging stakeholders and measuring this value, then communicating the value to other markets, high performance solar communities can become the norm. The total potential value for all stakeholders outweighs costs, but will not be realized if homebuilders and homebuyers are obligated to pay for value gained by parties external to their exchange.

This paper will identify a model for marketing these positive externalities to parties beyond the homeowner using a strategy pioneered by Texas Instruments in their effort to market digital movie projectors. In this case, the most significant benefits of digital projectors are realized by movie studios, yet movie theaters buy and operate projectors and have little reason to make the expensive upgrade. While moving away from film offers tremendous cost savings and improved quality for studios and the industry it cannot be realized if movie theaters cannot play the digital movies.

This comparative evaluation will offer a model for market transformation in production home building.

Appendix IV – Statistical Challenges

Overview

Challenges began with the sensitivity of sharing Premier and Cresleigh data with outside reviewers. BIRA's access to this data is invaluable and closely related to our ongoing working relationship with SMUD. SMUD has heavily invested in gathering data at these two communities and is hesitant to share it for legal reasons given customer privacy and because they need to closely monitor what is reported about Premier and Cresliegh. Given these factors, BIRA worked with Professor Dan Toy and Danny Parker at FSEC to create non-disclosure agreements that worked for SMUD, BIRA, and each reviewers' respective internal legal requirements. This process took several months.

Once Professor Toy had access to data, he had to learn what BIRA's objectives were and understand homebuilding and energy use. This learning curve is steep and required a significant time investment by Professor Toy. Because of this learning curve, BIRA and CSU experienced some issues in analyzing and reporting energy savings. In some cases the wrong set of data was evaluated that was intended to be compared to predicted energy levels. The other issue was with the advanced statistical tools used to evaluate Premier and Cresleigh data. The way the data was collected and labeled made it difficult to transfer to these programs and made some analysis impossible, including validating the 18 homes with interval data actually represented the 95 home community. Additionally, Statistica and SPSS, two statistics programs, had trouble analyzing the large data sets that reported the 15-minute interval data important for peak analysis. With over 100,000 data points, this data set caused problems both with Professor Toy's processing ability relative to hardware and the program's ability to sort and evaluate the data. These issues are still being investigated by Professor Toy and the providers of the statistical software tools and will be reported on in later reports.

Peak

Below is the analysis performed by Professor Toy aimed at evaluating the kW differences at peak between Premier and Cresleigh homes. The kW numbers are too small given comparison to the data set. As stated previously, this is likely a problem with the way Statistica was calculating the data set. This problem is being evaluated by Professor Toy and Statistica and should be solved by the end of 2007, but not before this report is submitted.

The below table provides an example of the energy reduction capabilities of the PG homes during a particularly hot day during the summer of 2005. The consumption of energy during the period from 12 PM to 8 PM on this day (measured in average use at 15 minute intervals) was substantially less for the PG homes compared to the energy consumption of similar homes in the C development. The "peak demand" for energy in the Sacramento, CA area where these homes are located is at 5 PM. The analysis shows that the PG homes performed 62% better (from 5 to 6 PM) than the C homes. In both cases, the results of this analysis are significant at the $\alpha = .05$ level.

Net Grid Load in Kw:	Net Grid Load for Cresleigh Homes	Net Grid Load for Premier Garden Homes (Including PV)	t - statistic	P value
Average kW for July 15, 2005 for from 12 PM to 8 PM (for 15 minutes of energy use)	1.358 (n = 576)*	-0.032 (n = 576)	17.46	0.000
Average kW for July 15, 2005 at 5 PM (for 15 minutes of energy use)	1.426 (n = 72)**	0.546 (n = 72)	4.05	0.000

* Sample size refers to the number of observations taken on the 18 homes in the Cresleigh and Premier Gardens Developments. Since there were 18 homes in each neighborhood that were monitored, and there were 8 hours of 15 minute data for each home, the number of observations for each development is 18*8*4 = 576.

** Sample size refers to the number of observations taken on the 18 homes in the Cresleigh and Premier Gardens Developments. Since there were 18 homes in each neighborhood that were monitored, and there was 1 hour of 15 minute data for each home, the number of observations for each development is 18*1*4 = 72.

	2-Way Tables of Descriptive Statistics (Premier vs. Cresleigh - 15 Minute data - July 15 2005 .sta) N=1152 (No missing data in dep. var. list)				
p vs. c code Hours of day	**Net Grid Load (kW) Means**	Confidence -95.000%	Confidence +95.000%	Net Grid Load (kW) N	Net Grid Load (kW) Std.Dev.
1: Premier Gardens	-0.031833	-0.13056	0.066897	576	1.206424
12	-0.906667	-1.05807	-0.755259	72	0.644318
13	-0.864000	-1.03518	-0.692824	72	0.728446
14	-0.732667	-0.90977	-0.555563	72	0.753669
15	-0.306333	-0.51662	-0.096047	72	0.894880
16	0.079333	-0.16831	0.326973	72	1.053836
17	0.546667	0.26611	0.827228	72	1.193935
18	0.814000	0.55476	1.073240	72	1.103204
19	1.115000	0.85171	1.378294	72	1.120455
2: Cresleigh	1.358424	1.23718	1.479667	576	1.481516
12	1.007333	0.69075	1.323915	72	1.347221
13	1.131847	0.75793	1.505760	72	1.591195
14	1.200486	0.87616	1.524811	72	1.380172
15	1.545764	1.13376	1.957765	72	1.753283
16	1.459264	1.11192	1.806606	72	1.478126
17	1.425528	1.09602	1.755036	72	1.402230
18	1.472833	1.15273	1.792939	72	1.362218
19	1.624333	1.28338	1.965285	72	1.450928
All Groups	0.663295	0.57549	0.751101	1152	1.518951

Table 7: Comparison of 15 Minute Net Grid Energy Consumption (Kwh) for Cresleigh and Premier Gardens Homes

Net Grid Energy Consumption in Kwh:	Net Grid Energy Consumption for Cresleigh Homes	Net Grid Energy Consumption for Premier Garden Homes (Including PV)	t - statistic	P value
Average Kwh for July 15, 2005 for from 12 PM to 8 PM (for 15 minutes of energy use)	0.339 (n = 576)*	-0.008 (n = 576)	17.46	0.000
Average Kwh for July 15, 2005 at 5 PM (for 15 minutes of energy use)	0.356 (n = 72)**	0.137 (n = 72)	4.05	0.000

2-Way Tables of Descriptive Statistics (Premier vs. Cresleigh - 15 Minute data - July 15 2005 .sta)
N=1152 (No missing data in dep. var. list)

p vs. c code Hours of day	Net Grid Energy Consumption (kWh) Means	Confidence -95.000%	Confidence +95.000%	Net Grid Energy Consumption (kWh) N	Net Grid Energy Consumption (kWh) Std.Dev.
1: Premier Gardens	-0.007958	-0.032641	0.016724	576	0.301606
12	-0.226667	-0.264518	-0.188815	72	0.161079
13	-0.216000	-0.258794	-0.173206	72	0.182112
14	-0.183167	-0.227443	-0.138891	72	0.188417
15	-0.076583	-0.129155	-0.024012	72	0.223720
16	0.019833	-0.042077	0.081743	72	0.263459
17	0.136667	0.066526	0.206807	72	0.298484
18	0.203500	0.138690	0.268310	72	0.275801
19	0.278750	0.212926	0.344574	72	0.280114
2: Cresleigh	0.339677	0.309366	0.369988	576	0.370379
12	0.251917	0.172762	0.331072	72	0.336847
13	0.283069	0.189589	0.376550	72	0.397808
14	0.300181	0.219109	0.381252	72	0.345003
15	0.386486	0.283503	0.489469	72	0.438246
16	0.364875	0.278028	0.451722	72	0.369579
17	0.356458	0.274078	0.438838	72	0.350570
18	0.368250	0.288225	0.448275	72	0.340548
19	0.406181	0.320935	0.491426	72	0.362763
All Groups	0.165859	0.143907	0.187812	1152	0.379754

Predicted Vs. Actual: Electricity Consumption at Premier Gardens

In this case BIRA and CSU compared kWh consumption for a period of 19 months from March 2005 to September 2006 to predicted use. Given that building energy simulation tools and assumptions for non building energy use predict use for a calendar year, BIRA cannot compare the Premier average for this period to predicted use. This problem is relatively easy to fix once data is sorted and loaded into the statistical programs, but not in the short term. Moving forward BIRA will evaluate a consecutive 12 month period of use and compare this to predicted values and report in a future BA report.

Test 5: Predicted (and modified) estimate of kWh usage for Premier Homes with PV – March 05 to Sept. 06)

Predicted KwH = 296 KwH
Premier Avg. KwH = 313.9 KwH

t = .688, p = .493

95% Confidence interval = 262 to 365

This analysis compares the predicted energy (in Kwh) consumption of Premier homes using PV with the actual Kwh of the homes. It is called a one sample t-test. The results show that there is no statistical difference between the estimated and predicted Kwh values (which is good).

Table 3: Predicted vs. Actual Electrical Energy Consumption of Premier Garden Homes With PV Input

Utility Consumption Measure for period from March 2005 to September 2006	Predicted Mean for Premier Homes With PV Included	Mean for Premier Garden Homes With PV Included (n = 88)	t - statistic	P value
Average Kwh consumption	296.0	313.9	0.69	0.493

Table 4: Predicted vs. Actual Electrical Energy Consumption of Premier Garden Homes Without PV Input

95% Confidence interval = 571 to 674

Utility Consumption Measure for period from March 2005 to September 2006	Predicted Mean for Premier Homes Without PV Included	Mean for Premier Garden Homes Without PV Included (n = 88)	t - statistic	P value
Average Kwh consumption	581.0	622.9	1.61	0.110

Appendix V – Sacramento Weather: Peak Analysis

Peak Analysis at Premier Gardens: What to Evaluate

Summer 2005

Evaluate:
7 Day Period: July 12-18
1 Day Period: July 15th
1 Day Period: July 23rd
3 Day Period: August 6-8

Notes:
All good data, good data means I have checked out all interval data and it is complete, no missing interval collections

Summer 2006

Evaluate:
6 Day Period: June 21-26 if possible, see below
5 Day Period: July 15-19
1 Day Period: July 17th

Notes:
June 21-26 better (No data for house 1053708-ZEPG) If its hard to eliminate this house for technical or statistical reasons, forget this period.)

July 8 + 9 (of marginal interest, don't use unless we're really thin in 2006 for some reason or another)

July 15-26 (best peak opportunity of 2006) *Bad data on the 20 –26 on Premier (110 degrees on the 17th, third day over 100)*

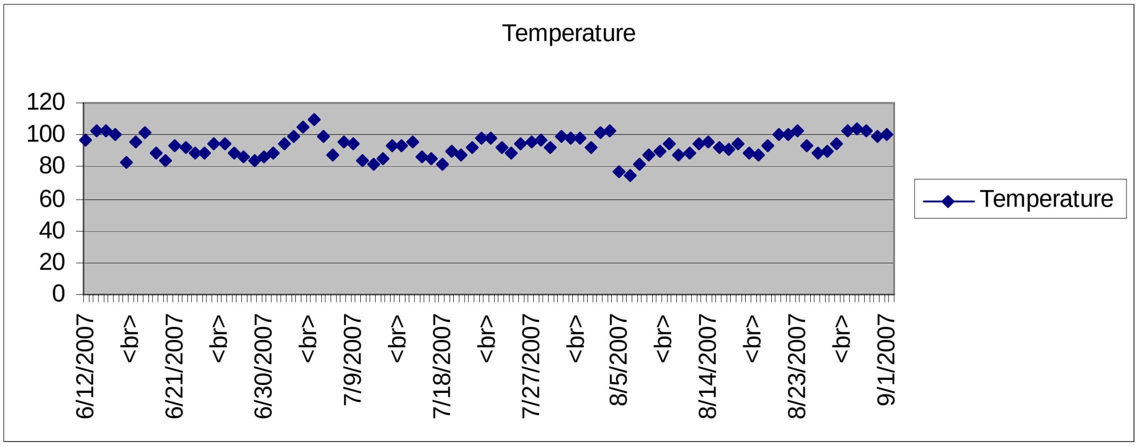
Summer 2007

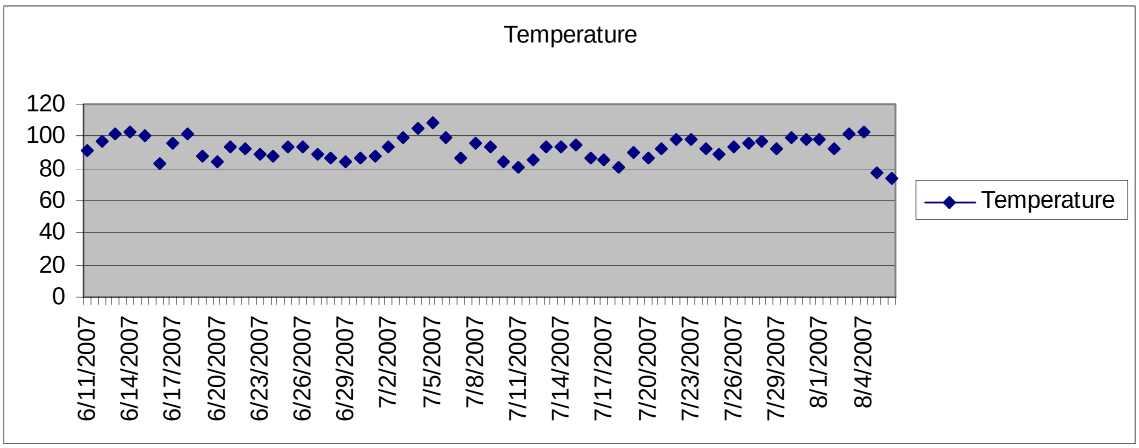
Evaluate:
1 Day Period: June 15th
4 Day Period: July 3-6
1 Day Period: July 5th

Notes:
June 13-15 (same), plot the 15th (data good)

July 3-6 (best) plot the 5th (data good)

August 3-4 (same), 21-23 (same), 28-30 (second to July) no August Data





The below table looks at comparable weather days from 2005-2007. The rows represent days of the year while the columns represent years beginning with 2005 to 2006…

This table was used to evaluate the best days to look at to determine how peak electricity use compares year to year.

PDT	Max TemperatureF	Max TemperatureF	Max TemperatureF		Min TemperatureF	Min TemperatureF	Min TemperatureF
6/1/2007	82	100	87		50	55	60
6/2/2007	86	89	86		46	59	62
6/3/2007	87	93	89		51	57	57
6/4/2007	86	87	78		55	59	53
6/5/2007	75	89	77		57	53	51
6/6/2007	73	91	73		46	55	46
6/7/2007	80	91	75		50	57	46
6/8/2007	86	82	64		48	51	53
6/9/2007	89	87	78		51	51	57
6/10/2007	89	84	84		55	50	53
6/11/2007	91	80	87		53	53	55
6/12/2007	96	73	89		53	55	55
6/13/2007	100	73	93		62	53	55
6/14/2007	102	77	91		62	50	60
6/15/2007	102	87	89		66	53	51
6/16/2007	84	100	66		57	62	51
6/17/2007	95	98	69		53	60	53
6/18/2007	98	93	73		55	57	51
6/19/2007	89	89	82		55	53	51
6/20/2007	86	98	84		51	59	50
6/21/2007	93	100	82		48	60	53
6/22/2007	93	105	87		53	69	48
6/23/2007	91	107	87		53	64	55
6/24/2007	87	102	82		48	64	53
6/25/2007	93	102	82		51	62	53
6/26/2007	96	102	82		60	68	53
6/27/2007	89	95	80		53	66	51
6/28/2007	87	91	86		55	66	57
6/29/2007	87	98	96		57	62	57
6/30/2007	87	87	100		55	57	62
7/1/2007	89	96	100		51	53	62
7/2/2007	93	93	95		55	57	60
7/3/2007	98	95	95		57	55	57
7/4/2007	105	91	98		60	59	57
7/5/2007	109	87	91		68	55	57
7/6/2007	100	87	95		68	55	57
7/7/2007	87	96	91		55	55	60
7/8/2007	98	100	87		55	32	57
7/9/2007	93	102	84		60	69	62
7/10/2007	84	93	80		62	60	57
7/11/2007	78	87	96		60	55	60
7/12/2007	84	87	102		84	53	62
7/13/2007	80	96	104		64	60	68
7/15/2007	96	98	105		71	59	69
7/16/2007	89	105	107		82	66	68
7/17/2007	78	109	105		75	66	66
7/18/2007	80	104	98		68	71	62
7/20/2007	64	105	102		64	53	64
7/25/2007	91	107	100		86	75	59
7/26/2007	93	104	102		53	69	64
7/27/2007	80	100	100		51	64	62
7/28/2007	64	91	98		59	59	62
7/31/2007	98	89	100		66	44	62
8/1/2007	98	91	102		57	53	59
8/2/2007	93	93	96		57	60	59
8/3/2007	100	95	98		57	57	59
8/4/2007	104	87	100		60	55	60
8/5/2007	75	84	102		55	60	64
8/6/2007	75	89	105		57	59	64
8/7/2007	82	78	102		51	57	64
8/8/2007	87	89	96		53	53	62
8/9/2007	91	98	100		53	62	62
8/10/2007	93	100	96		60	64	60
8/11/2007	89	89	98		57	59	59
8/12/2007	89	91	100		66	53	62
8/13/2007	93	91	86		51	55	53
8/14/2007	95	87	87		55	55	55
8/15/2007	93	86	84		57	53	55
8/16/2007	91	84	95		53	57	66
8/17/2007	91	93	96		53	53	59
8/18/2007	89	91	84		53	57	53
8/19/2007	80	93	87		55	53	57
8/20/2007	93	89	95		59	53	53
8/21/2007	98	91	95		60	51	55
8/22/2007	98	96	96		73	55	55
8/23/2007	100	93	96		73	60	60
8/24/2007	93	93	89		59	55	55
8/25/2007	73	84	91		59	53	55
8/26/2007	91	89	98		59	53	55
8/27/2007	87	93	100		60	57	60
8/28/2007	98	95	100		35	55	53
8/29/2007	105	86	91		71	57	55
8/30/2007	102	93	93		69	57	60
8/31/2007	98	96	96		73	57	60

Appendix VI – Power Meter Project at Premier Gardens

Summary and Outline:

Evaluating the Effectiveness and Behavioral Response of Real-Time Electricity Feedback Systems in Near Zero Energy Homes

Overview:

The U.S. Department of Energy's Building America Program (BAP) conducts research on Zero Energy Homes throughout the United States. BAP has successfully focused on building technologies and design to reduce energy consumption in homes. In today's BAP energy-efficient solar electric home water heating, space heating, cooling, and lighting loads have been significantly reduced, often by 50% or more. However, miscellaneous electricity use, including all plug loads such as consumer electronics, is on the rise.

The impact of homeowner behavior is also a significant variable in energy consumption in homes. Premier Gardens, a community of 95 near Zero Energy Homes and the test site for this experiment, provides an example. In this community homeowners operating the same highly efficient solar homes consumed electricity in vastly different ways with some homes consuming more than double the electricity of the exact same home across the street.[10] This means that the way consumers use their homes may be as important as how the home is built and the energy saving devices in the home.

A powerful tool to reduce miscellaneous and behavioral based electricity use in homes is a real-time electricity feedback system. According to a Florida Solar Energy Center (FSEC) publication, "A compilation of available data on real-time feedback studies (Darby, 2000) suggests an average of 10-15% reduction in overall energy."[11] Another study done by Hydro One, released after the FSEC publication, installed meters in 435 homes in Canada and found that each home reduced total energy consumption by 7-10%.[12]

While these studies display the overall electricity reduction from the addition of feedback, they tell us little of the time of day impacts or behavioral responses which contributed to these reductions. Furthermore, there has been no large-scale testing done to display the impact of real-time electricity feedback in energy-efficient solar homes. With different electrical load structures, energy-efficient homes use less electricity to

[10] BIRA & SMUD research at Premier Gardens
[11] "How Much Energy Are We Using? Potential of Residential Energy Demand Feedback Devices" Danny Parker and David Hoak, Florida Solar Energy Center
[12] "Monitors cut Energy Usage, Study Finds" 17 Dec. 2005 Technology Reporter authored by Tyler Hamilton.

cool and illuminate the home while a higher percentage of electricity is used for miscellaneous electrical loads.

Experimental Team:

The Building America Program is a public/private partnership aimed at working with building industry stakeholders to reduce energy consumption in homes and increase adoption of on-site renewable energy. The Building Industry Research Alliance (BIRA), led by ConSol, is a diverse group of industry leaders working with BAP to promote their goals. ConSol is working with its BIRA partners (Sacramento Municipal Utility District (SMUD), GE, California State University Chico, FSEC, the University of the Pacific, and the National Renewable Energy Center (NREL)) to research, design, and execute this experiment. A student from the University of the Pacific will do an independent study as part of the BIRA team. It should be noted that SMUD is involved in parallel research funded by the California Energy Commission (CEC) PIER Program. This SMUD-PIER project will directly benefit from a number of aspects of our electric feedback research. Because of this, SMUD is working to ensure that these two research projects will be comparable and complimentary.

Experimental Design:

For the past three years, SMUD and the BAP have been monitoring homes in Premier Gardens in the Sacramento, California area. The 95 home community contains highly energy-efficient BAP homes with solar-electric systems. The BAP, working closely with key partners, has collected and analyzed electricity use data, gas use data and buyer demographics. SMUD and BAP are also collecting and analyzing 15-minute consumption and PV production data at 18 homes within the community. This existing data will provide the control against which electricity consumption patterns can be compared after the inclusion of a feedback system. The statistical efficiency of a paired approach (pre/post) for evaluating technology impacts in this application is superior to side-by-side testing.[13] A paired (pre/post) experimental approach is approximately 467% more efficient than the standard technique.[14]

GE's new Solar Electric Power Meter will be installed in the BAP community homes. The meter displays both solar electric (PV) production and whole house kW consumption graphically and numerically. It also provides the owner with energy production information measured as a percentage of total energy consumption. The occupants will be instructed on how to read the meters and will be encouraged through educational materials to use the meters to improve their efficiency (reduce electricity use) and thereby lower their bills. Initial results from multiple small-scale studies suggest displaying PV production to consumption is a powerful incentive to reduce electricity use.[15]

[13] George W. Snedecor and William G. Cochran, Statistical Methods, Sixth Edition, Iowa State University Press, Ames, Iowa, 1968
[14] Internal Building America document. Florida Solar Energy Center. Danny Parker.
[15] Personal Interviews with Danny Parker and Gerald Curtain. May-June 2007.

Research Objectives:

1) Analyze whole-house electricity use impact from generation/consumption electricity feedback systems in highly efficient solar electric homes
   a) Measures required: Monthly electricity use before (control) and after (treatment) inclusion of feedback device
   b) Results normalized based on: Demographic information, weather data, appliance and plug load considerations, and home size
2) Analyze impact of feedback on time-of-day whole-house electricity use
   a) Measures required: Fifteen minute electricity use data before (control) and after (treatment) inclusion of feedback device, impact on peak electricity use, and impact on base/phantom loads through analysis of "quiescent" electricity use
   b) Results normalized based on: Demographic information, weather data, appliance and plug load as learned from individual homeowners, and home size
3) Determine what contributes to reductions in electricity use (how the feedback device impacts consumer beliefs attitudes and behavior)
   a) Measures required: Consumer feedback information gathered via pre/post surveys, interviews, and/or diaries
4) Analyze impact of PV feedback
   a) Measures required: Monitor monthly electricity use vs. pretest use and get consumer feedback via pre/post surveys, interviews, and/or diaries
5) Analyze impact of educating homeowner on feedback device and how it can be used to reduce energy consumption (e.g., checking it before you leave the house to see if you have left an electrical device on)
   a) Measures required: Consumer feedback information gathered via pre/post surveys, interviews, and/or diaries
6) Determine most effective education protocols to create electricity use reductions in line with future program goals (e.g., peak aversion, overall electricity reductions)
   a) Measures required: Peak energy use and consumer feedback via pre/post surveys, interviews, and/or diaries
7) Analyze tradeoffs consumers make in terms of energy reducing behavior
   a) Measures required: Consumer feedback collected via conjoint analysis

Figure 1: BAP 95-home Solar Community (courtesy of SMUD)

Figure 2: GE Solar Electric Power Metering System (courtesy of GE)

Outline:

1) **Participants**
   a) Premier Gardens homeowners who respond to invitation (95 possible) – See Figure 1

2) **Equipment**
   a) GE Solar Electric Power Meter – See Figure 2
   b) New SMUD meters to gather real time (15-minute) electricity consumption

3) **Experimental Design**
   a) Single treatment group consisting of Premier homeowners. These homeowners will have GE Solar Electric Power Meters installed in their homes. They will also be educated about the meter's technical aspects and how it can be used to reduce electricity use.
   b) Control is served by historic data (more statistically efficient than side-by-side)
   c) DRCC/PIER coordination
   d) Interaction with Homeowners
      i) Recruitment letter- *see Appendix*

ii) Coordinate installations with homeowners and SMUD
iii) SMUD installation of outside meter while BIRA team installs interior meter. During this visit homeowner fills out demographic and pre-test questions. BIRA team member provides education about the use of the Power Meter- *see Appendix*
iv) Six month follow-up - BIRA team visits homeowners to: drop off new batteries, answer questions about meter and energy use, provide additional education about ways to reduce energy use, and survey homeowners about changes in behavior that are the result of their using the Power Meter - *see Appendix*
v) One year follow-up – Questionnaire sent to homeowners and homeowners also respond to a conjoint analysis questionnaire via the web – *see Appendix*
vi) Two year follow-up – Questionnaire sent to homeowners and homeowners also respond to a conjoint analysis questionnaire via the web – *see Appendix*

4) Appendixes (to come)

a) Recruitment letter for potential participants (95 Premier homeowners)
   i) Outline participation expectations and how to respond: password protected website, email and phone
      (1) What if response is low, add incentive?
      (2) User Contract/Agreement
         (a) Keep meter at end of study
         (b) Rules for opting out?
         (c) Liability Issues inside and outside equipment- holes in wall/exterior
         (d) What if meter breaks?
         (e) Use of data, their information?
         (f) Agreement to participate for duration of study
b) SMUD installation protocols
c) BIRA installation and follow-up protocols
   i) Where to install meter, use double sided tape?
   ii) Install meter while homeowner fills out demographics survey and pre-test
      (1) Demographics
         (a) Include questions about orientation of homes, appliances, electrical loads, basic demographics, length of time at current residence, when and who occupies home (unusual situation like day care or working at home), on TOU rate
      (2) Pre-test
         (a) Attitudes, beliefs, behaviors and knowledge concerning sustainability
   iii) Cover educational materials and display use of meter by walking around with homeowner showing impact of turning on TV, lights, electric dryer, etc
      (1) Education materials
         (a) Drive a hybrid home sidebar altered for Premier homeowners
         (b) Influence of behavior, show distribution of bills in community
         (c) Basics about how homes use electricity with pie charts + basics about how to use meter to lessen use
   iv) Drop off diary and contact information for questions or concerns
      (1) Diary

(a) Include ability to discuss interaction with meter, likes, dislikes, alternate displays, impact of education, likes and dislikes about education program

(2) Contact information with phone, email, and website

v) Six month follow-up with participants

(1) Drop off new batteries

(2) Show homeowners electricity use before/after treatment (compared to neighbors?)

(3) Homeowner takes questionnaire

(a) Understand interaction with meter, likes, dislikes, alternate displays, solar fraction number important and why, impact of education, likes and dislikes about education, how did education affect use of meter and affect behavior, how have you used meter in different ways then instructed, what else would you like to know about energy use, would addition of web access be helpful, when do you use your meter, energy use reductions from meter, education, did you learn certain things from meter and sustain changed behavior, have you done anything to improve non-behavior based efficiency (e.g., adding CFL's, changing HVAC filters)

(4) Questions about meter or electricity use

(5) Offer additional techniques for further reducing use

vi) Twelve month follow-up with participants

(1) Questionnaire

(2) Conjoint analysis

(a) Understand tradeoffs consumers make in energy reducing behavior

(b) Designed by CSU Chico Professor Dan Toy

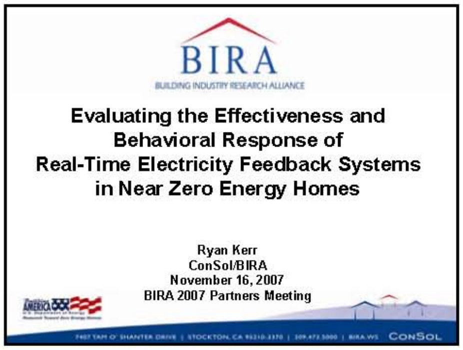
vii) Twenty four month follow-up with participants

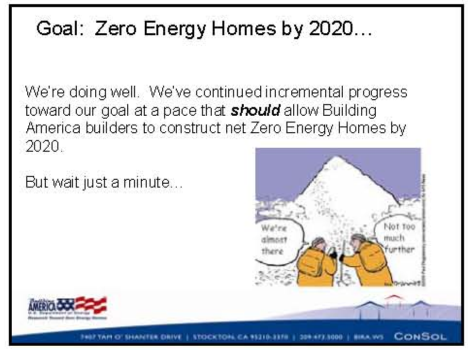
(1) Questionnaire

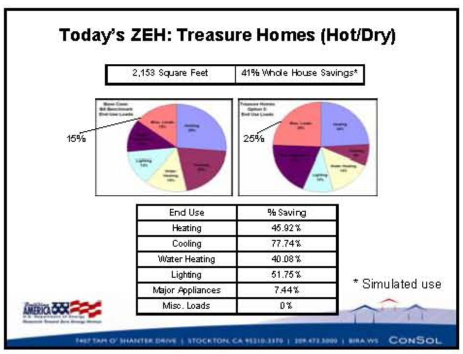
(2) Conjoint Analysis

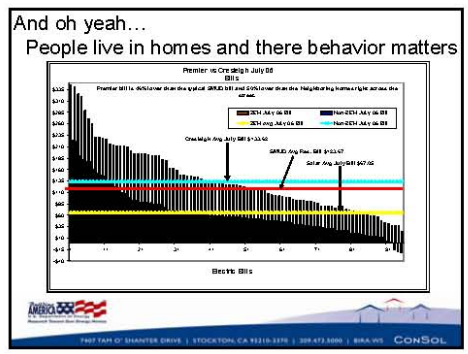
viii) Solar Electric Power Meter Manual (provided by GE)

Power Meter Project Presented at 2007 BIRA Partners Meeting:



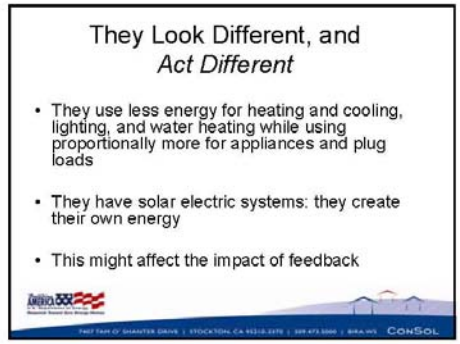




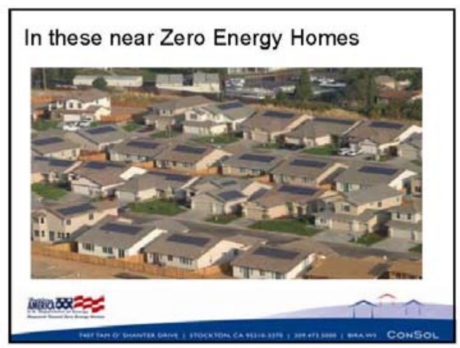


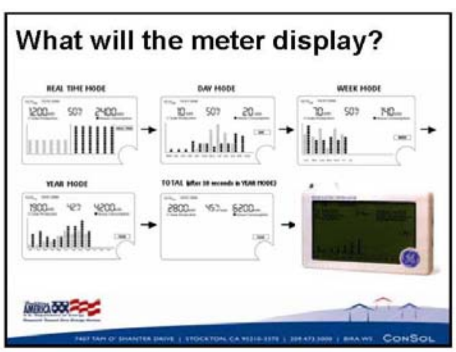
1

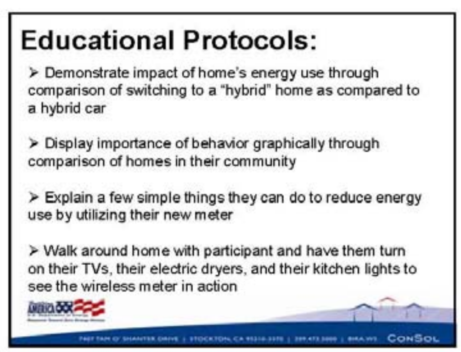

But Building America Homes don't look like this…
They look like this…


They Look Different, and *Act Different*
• They use less energy for heating and cooling, lighting, and water heating while using proportionally more for appliances and plug loads
• They have solar electric systems: they create their own energy
• This might affect the impact of feedback


So…time for some research
BIRA and our partners SMUD, GE, and the California State University Chico are undergoing an experiment using this


In these near Zero Energy Homes


What will the meter display?
REAL TIME MODE
DAY MODE
WEEK MODE
YEAR MODE


Educational Protocols:
➢ Demonstrate impact of home's energy use through comparison of switching to a "hybrid" home as compared to a hybrid car
➢ Display importance of behavior graphically through comparison of homes in their community
➢ Explain a few simple things they can do to reduce energy use by utilizing their new meter
➢ Walk around home with participant and have them turn on their TVs, their electric dryers, and their kitchen lights to see the wireless meter in action

2

What do we want to learn?

- What is the monthly and time of day energy impact of whole-house consumption and PV production electricity feedback in near-ZEHs? (i.e. total energy reductions, peak)
- What behaviors are contributing to changes in consumption (i.e. turning lights off, thermostat up)
- What is motivation for reductions: money, environmental, maximizing solar, "its like playing a game"
- What component does education play in energy reductions and how can education be leveraged to maximize impacts

How are we going to evaluate?

- Energy use after installation of meter will be compared to 3 years of historic 15-minute interval and monthly energy consumption data serving as control
- Changes in behavior and motivations for reducing consumption will be evaluated using diaries, surveys, and conjoint analyses
- Evaluating the impact of education will come from interviews, behaviors, and surveys

When can we start?

ASAP!

Recruitment letters will be going out *very* early next year

BIRA

BUILDING INDUSTRY RESEARCH ALLIANCE

What do you think?

To request additional information, make suggestions, or to ask questions contact me at:

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