Measuring Public Benefit From Energy Efficient Homes

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Table of Contents

Executive Summary

For more than 30 years, a variety of approaches have been tried to improve the energy efficiency of newly-constructed homes. In the Phoenix area over the last few years, homes can be placed in three broad categories based on the energy "labeling" selected by the builder:

1) Baseline homes - the current building code
2) Energy Star® labeled homes
3) Guaranteed Performance homes

There are millions of homes constructed to code minimums, about 400,000 Energy Star® compliant homes and over 60,000 Guaranteed Performance homes have been built to date. However, there is not enough actual consumption data being analyzed to determine the impact these programs are having on energy reduction. The objective of the Phoenix Home Energy Efficiency Study was to assess Baseline, Energy Star® (ES) and Guaranteed Performance (GP) homes and determine if homes in these three groups can be distinguished from each other in terms of actual energy usage.

This study showed that the bar has been raised for home energy performance in the Phoenix area as a result of U.S. Environmental Protection Agency's Energy Star® and various Guaranteed Performance home programs. These programs have been instrumental in the education and training of consumers, builders and contractors about the benefits and construction of higher performing homes. The Environmental Protection Agency, Arizona Public Service and Southwest Gas should be especially recognized for their support of this study, which was initiated to provide a model for ongoing efforts to illuminate impact as well as provide a model feedback mechanism to support continuous improvement.

A study conducted in May 2000 surveyed 291 homes in the Arizona Public Service territory, segregating the homes into four categories based only on their Energy Star® status and the presence of swimming pools. The conclusions of this previous study indicated that Energy Star® homes as a whole (pool or no pool) used only 2.3% less energy per square foot than non-Energy Star® homes. However, the limited size and scope of the research does not represent the two categories adequately.

The Phoenix Home Energy Efficiency Study included a much larger and more diverse sample size. We evaluated a total of 7,141 houses, including 3,336 Baseline homes, 2,979 Energy Star® homes and 826 Guaranteed Performance homes. In addition to energy use profiles, we also collected information on square footage, number of stories, vintage, orientation, existence of a pool and other general characteristics.

The energy consumption habits of sample home occupants were not evaluated as part of this study. While lifestyle choices can affect the overall energy consumption of a home, the large statistical sample of homes used for this study should reduce the significance of this variable.

The effects of variables were limited by creating similar subsets of homes. The most comparable subset suggested that the Energy Star® homes on average used 3.50 kWh/ft^2, compared to 4.16 kWh/ft^2 for the typical Baseline (BaseREG) homes. This represents a savings of 16% for summer/cooling intensity. The same subset of Guaranteed Performance homes consumed 2.80 kWh/ft^2 on average, 33% lower summer/cooling intensity than the typical Baseline homes and 20% below Energy Star® homes.

However, since the typical Energy Star® and Guaranteed Performance home used in this study were physically larger than the typical Baseline home, the average annual electric consumption for both groups was larger than the Baseline homes. Baseline homes used 14,107 kWh per year on average, Guaranteed Performance homes used 14,904 kWh per year and Energy Star® homes used an average of 15,831 kWh per year.

Implementation of the Energy Star® and Guaranteed Performance programs can yield improvements in the overall energy efficiency of new homes, as compared to homes built to standard practices. It also appears that the increasing size of the average home, a trend the entire country is experiencing (and the subsequent increasing energy use), offsets to a large degree the savings achieved through improvements in home energy efficiency. To realize actual reductions in overall energy usage along with the environmental, economic and health benefits associated with those reductions, the trend to build larger homes must also be addressed.

Introduction

This report documents the methodology and findings of the Phoenix Home Energy Efficiency Study, performed by Advanced Energy and sponsored by the U.S. Environmental Protection Agency. The purpose of this study was to assess and compare energy consumption patterns of homes in three different categories of energy efficiency construction – Baseline homes, Energy Star® (ES) homes and Guaranteed Performance (GP) homes.

Background

The United States, with 4.6% of the world's population, accounts for 24.9% of the world's primary energy consumption. Housing accounts for 36% of all the nation's electrical demands. This consumption is expected to grow 39% between 2000 and 2010[1].

During the past several decades, rising energy prices have driven a demand for more energy-efficient homes. Builders initially responded with simple energy-saving remedies: increased insulation, double-paned glass, tighter door seals, window awnings and other measures. Recent advancements in building science, building practices and materials technology, have continued to offer more sophisticated and effective methods of providing energy savings, such as high-efficiency HVAC equipment, improved duct sealing, infiltration barriers, low emissivity glass and compact fluorescent lighting. Each of these measures, in theory, should help reduce overall home energy usage. However, factors such as homeowners' lifestyles (with respect to energy use), effective installation and operation of HVAC systems, increasing average home sizes and others, make it difficult to assess the actual impact that these energy conservation methods have on lowering home energy bills nationwide.

In 1995, the EPA launched its Energy Star® Homes program, which established guidelines for reducing home energy use and promoted partnerships with homebuilders to construct energy-efficient homes. It was reasoned that Energy Star® labeled homes would offer consumers dependable savings on their monthly energy bills and reduce the overall consumption and impact of residential sector energy use. To qualify for labeling as an Energy Star® home, home design plans must first meet the criteria for energy use, as predicted using computer energy simulation modeling. Second, for the Phoenix market, a random sample of Energy Star® homes must pass a minimum of two field tests (duct and house leakage tests) to ensure that actual construction matches the computer modeling in terms of whole house infiltration and duct leakage. To date there are approximately 400,000 Energy Star® labeled homes nationwide.

More recently, several organizations (Masco Corporation's Environments For Living® program, US Greenfiber's now defunct Engineered for Life program and Tucson Electric

[1] *2004 Buildings Energy Databook*, U.S. Department of Energy.

Power's program) have been promoting the construction of Guaranteed Performance homes. These homes are designed to go a step beyond the Energy Star® program, using advanced building science materials and techniques to lower home energy use even further. For Guaranteed Performance homes, the standards and testing protocol are even more stringent than Energy Star® in order to ensure increased energy performance. To offset the slightly higher cost of these Guaranteed Performance homes and enhance their marketability, the builders or program administrators actually *guarantee* that the homes' energy usage will not exceed a certain average level or the excess costs will be refunded to the homeowners. The programs also include a comfort guarantee that compliments the cooling/heating usage guarantee. But once again, no comprehensive study has been conducted to show how these Guaranteed Performance homes compare to Baseline homes of similar style in terms of actual energy use over time. To date, more than 60,000 houses nationwide have been built and certified to the Guaranteed Performance standards (Masco, US Greenfiber and Tucson Electric Power).

Little data has been collected to date on how these homes (Baseline, Energy Star®, Guaranteed Performance) actually performed while occupied under real world conditions. Five years ago an Arizona State University (ASU) thesis study[2] conducted in the Phoenix, Arizona area examined the energy consumption of 291 homes, comparing Energy Star® homes to non-Energy Star® (Baseline) homes, both with and without pools. The report concluded that the Energy Star® homes in the study used only 2.3% less energy per square foot than the Baseline homes, a much smaller savings than anticipated. However, the sample size of that study was too small to be indicative of the market at large. The ASU study also used houses from some of the first Energy Star® communities built in the Phoenix area; earlier homes with energy performance may have been substantially lower than newer homes built to current Energy Star® levels.

Phoenix Building Market Overview

The Phoenix, Arizona market was an early adopter of both the Energy Star® and Guaranteed Performance programs. It is also one of the first areas in the country to realize significant market penetration of energy-efficient home construction with large populations of Baseline, Energy Star® and Guaranteed Performance homes. Given that these programs have been operating in Arizona for over five years now, Phoenix offers an excellent opportunity to verify energy consumption data on the three home types under real-world conditions.

In 2004, the Phoenix area became the largest market in the country for new housing construction, with more than 60,000 new homes started. Production construction dominates the new construction market in Phoenix, with many national residential homebuilders working in the area. Home building contractors are more consolidated in Phoenix than in most cities,

[2] Energy Consumption Comparison of Energy Star Homes in Phoenix, Arizona, Bradley Jay Bashford, Arizona State University, May 2000.

which means that when one contractor changes their business practices, it can impact a significant portion of the market. One HVAC contractor in particular installs more than 70% of all new residential HVAC systems in the Phoenix market area. This same contractor installed the majority of the HVAC systems on the homes in our study.

The builders in Phoenix have provided strong support of the Energy Star® and Guaranteed Performance programs through consistent and rigorous field testing of duct leakage and home infiltration. An important driver for their support is that the cost of performance testing for the builders is partially subsidized through a utility company, furthering the acceptance of energy-efficient homes.

Study Objectives

This study was structured to compare the actual energy efficiency of Baseline homes, Energy Star® and Guaranteed Performance program homes, while taking into consideration a large number of variables in home design. The study looks at real data and real energy performance of occupied houses, not computer models. The results of the study could then be used to answer several fundamental questions about the effectiveness of these efficiency programs:

- How much energy did the Baseline, Energy Star® and Guaranteed Performance homes actually consume?
- How much energy savings are actually realized by Energy Star® and Guaranteed Performance homes, compared to similar Baseline homes?
- Has the implementation of energy efficiency programs in new home construction resulted in a reduction of total energy consumption?

This study was not intended to determine the degree of success of the Energy Star® and Guaranteed Performance programs. It does not make any interpretations as to why certain houses performed well or performed poorly, nor does it compare actual performance against computer modeling.

Survey Population

More than 7,000 homes built from 1995-2004 by six different production building companies, were included in this study: 3,336 Baseline homes, 2,979 Energy Star® homes, and 826 Guaranteed Performance homes. Details on the physical design and construction of the various homes (such as HVAC ratings, window size and types and volume) were obtained from the home builders, utilities, contractors and testing companies. Energy use histories for the homes were provided by Arizona Public Service (APS) and Southwest Gas Corporation, over the period of 1998 through 2004. County records were used to identify those homes with swimming pools and to collect additional information on floor area.

Study Limitations

One significant factor not addressed by this study is the impact of the energy consumption habits (lifestyle) of the home occupants on overall energy use. Lifestyle choices can result in wide variances in both the total energy use and the efficiency or performance of a home. Some lifestyle differences, such as variations in thermostat settings, could reasonably be documented. Other choices that affect home energy use can be much more difficult to verify. Opening and closing doors and windows can greatly affect the performance of some HVAC systems. Even something as simple as occupants running repeat loads of laundry could skew the survey results for an otherwise energy-efficient home. To account for this variability, the authors used a statistically large sample of homes to diffuse the impact of the lifestyle variable on the results of the study. It is assumed that the range of homeowner behavior is equally represented across all three categories.

Anticipated Significance of Study Findings

The results of this study will offer a better understanding of the true energy value of the three levels of home construction (Baseline, ES and GP). These findings will help the managers of the EPA Energy Star® program fine-tune their program guidelines to ensure that the most cost-effective, energy saving measures are identified and implemented into new home construction. For homebuilders, utilities, contractors and other industry professionals, the positive results of this study will provide compelling evidence to support their claims of increased energy savings and help expand the market share of energy-efficient homes. Utility services may also benefit from this study by using the data results to help identify future trends in the housing market and predict patterns of energy use.

Data Collection

Data Sets

For the 7,141 houses included in this study, data was compiled and analyzed based on the following three categories:

- Baseline Homes
  These "code" homes were not built as part of any energy efficiency program, but their building characteristics resemble those of the other homes in the study. Typical baseline homes built between 1998 and 2004 in the Phoenix area are anecdotally considered to be 20% more efficient than homes built to the 1993 Model Energy Codes (MEC) standards. The Baseline homes provide a standard for energy use, allowing the research team to determine the actual savings presented by the ES and GP program homes. Most of the builders included in the study offer Baseline homes for sale, as well as similar homes built to ES and/or GP program standards.

- Energy Star® Homes
  Energy Star® (ES) homes meet or exceed the energy efficiency standards set by the EPA's Energy Star® program. By definition, Energy Star® qualified homes are independently verified to be at least 30% more energy efficient than the same home built to 1993 MEC or 15% more efficient than state energy code, whichever is more rigorous. These savings are based on heating, cooling and hot water energy use. Approximately 15% of the ES homes in this study were field tested for duct and envelope leakage.

  A typical upgrade to qualify for Energy Star® in Phoenix during the time of this study was either to install a SEER 12 air conditioner or low emissivity windows (Low E) or both.

- Guaranteed Performance Homes
  Guaranteed Performance (GP) homes not only qualify for Energy Star® status but also generally include additional energy efficiency improvements. The energy performance of these homes is actually guaranteed by the builders or program managers not to exceed a certain level based on energy modeling. The GP program guarantees that the energy used to heat and cool the home will not exceed the Guaranteed Usage listed on the front of the homeowners guarantee (www.eflhome.com). In order to successfully deliver on these guarantees, a minimum of 15% of these homes undergo a framing inspection, air barrier inspection, insulation inspection, duct leakage testing, envelope leakage testing and room pressure testing. Homes in this category are Energy Star® qualified but

for purposes of this report, they were not included in the data set for homes that exclusively participated in the Energy Star® program.

For each home used in the study, the researchers attempted to obtain information on the design characteristics outlined in Table 1.

Table 1: Home Design Characteristics

PARAMETERS	NOTES
Home category	Baseline, Energy Star® or Guaranteed Performance home
Builder	Name of the homebuilder
Model	Model number/floor plan of the house, as provided by the builders
Square footage	Square footage for the specific home model
Orientation	Front orientation of the house
Year built	Year that the house was built
Pool	In-ground pool included in energy use of home
Stories	Number of floors
HVAC type	Type of HVAC units: gas furnace or heat pump
HVAC tonnage	Capacity rating of the HVAC unit
SEER	Seasonal Energy Efficiency Ratio of the HVAC system
Window type	Type of windows used (energy-efficient, double-paned, Low E glass, clear or tinted)
Exterior wall	Exterior wall structure (2×4 or 2×6)
Number of Gas Appliances	Number of gas furnaces, water heaters, range/ovens or gas dryers in the home
HERS	Home Energy Rating System score
Volume	Interior volume of the home
Percentage of glass	Amount of glass surfaces, compared to the total exterior surface area of the home

Sources of Information

Home addresses and model-specific information such as stories, window type, interior volume, percentage of glass, square footage and exterior wall construction, were provided by the homebuilders and/or home testing companies. The existence of swimming pools, orientation of the homes and year of construction were obtained from the Maricopa County, Arizona, Website (www.maricopa.gov).

The square footage of each house published on the county Website was also recorded and compared to the square footage obtained from the homebuilders. In cases where a discrepancy existed between county records of square footage and the builder's plans, the builder square footage is used for the analysis.

The electric usage (kWh) history from January 1998 to 2004 was provided by Arizona Public Service (APS). The gas usage (therm) history for 2002 and 2003 was provided by Southwest Gas (SWG).

Survey Methodology

To maximize energy savings in this geographic area and climate at a reasonable cost, most builders in the area focus on energy efficiency improvements related to the following items:

- Square footage
- Higher performance windows
- Higher performance HVAC equipment (SEER rating)
- Properly installed insulation
- Reduced duct leakage

By no means is this list complete. Builders and homeowners may elect to include many other energy efficiency improvements. However, current research argues that the areas outlined above are the largest contributors to energy savings – or waste – outside occupant lifestyle.

The data collection and analysis process for this study is detailed below:

- Selected most builders based on current involvement in Energy Star® and Guaranteed Performance programs. These builders also built houses in the Baseline category prior to implementing the home efficiency programs.
- Selected one production builder who was not involved in any home efficiency program.
- Selected all GP subdivisions and most ES subdivisions in APS territory.
- Selected Baseline subdivisions from GP and ES builders built prior to entering the efficiency programs.
- Collected data directly from builders.
- Collected data from the county Website, contractors, utilities and home performance testing companies.
- Entered all data into a database designed by APS and Advanced Energy.
- Collected utility data from APS and SWG. Links between utility data and street addresses were hidden to protect the privacy of the homeowners.
- Analyzed data.

Caveats

- Data provided by supporting organization, individual and homebuilders and obtained from the Maricopa County Website were not field verified by Advanced Energy.

- Not all information on all the parameters listed in Table 1 is completed for every house in the study. Therefore, some parameters were not able to be used during the analysis.
- In the case of discrepancies between county records and builder square footage, the builder square footage was used for the analysis. This could lead to discrepancies of the square footage of a home. In rare cases, the discrepancies, due to misidentification of a model number, may lead to incorrect assumptions on model-specific information.
- The energy consumption habit of the occupants (lifestyle) is not directly evaluated in this study. Advanced Energy realizes that lifestyle is an important variable that can affect the energy consumption of a home significantly. Therefore, a large statistical sample size is used to minimize the significance of the variable.

Data Segregation

The 7,141 homes included in this study were segregated into the three home categories (Baseline, Energy Star® and Guaranteed Performance), then broken down for comparison by builder, year built, square footage, pool, orientation, and HVAC type. These groupings help to identify patterns in the data that can point to those factors with the greatest effect on home efficiency within the boundaries of the study.

Table 2: Number of Houses by Homebuilder

Builder	Number of Communities	Baseline	Energy Star®	Guaranteed Performance
Builder A	7	1,035	1,520	0
Builder B	8	536	273	706
Builder C	3	619	1,135	0
Builder D	1	0	0	120
Builder E	1	81	51	0
Builder F	11	1,065	0	0
Total # Homes	**31**	**3,336**	**2,979**	**826**

Table 3: Number of Houses by Square Footage*

Interior Size	Baseline	Energy Star®	Guaranteed Performance	Total
< = 1,000	83	7	0	**90**
1,001-1,500	702	816	64	**1,582**
1,501-2,000	1,283	1,126	283	**2,692**
2,001-2,500	426	680	239	**1,345**
2,501-3,000	91	159	68	**318**
3,001-4,000	23	167	57	**247**
> = 4,001	0	11	8	**19**

** Did not have square footage for every home.*

Table 4: Number of Houses with Pools

	Baseline	Energy Star®	Guaranteed Performance	Total
Pool	587	506	160	**1,253**
No Pool	2,749	2,473	666	**5,888**

** Did not have pool information for every house.*

Table 5: Number of Houses in Each Category by Orientation*

Orientation	Baseline	Energy Star®	Guaranteed Performance	Total
North	720	816	153	**1,689**
South	674	773	179	**1,626**
East	305	198	98	**601**
West	345	213	86	**644**
Northwest	363	138	73	**574**
Northeast	298	339	81	**718**
Southwest	294	363	81	**738**
Southeast	337	145	76	**558**

** Did not have orientation for every home.*

Table 6: Number of Houses by HVAC Type*

HVAC Type	Baseline	Energy Star®	Guaranteed Performance	Total
Heat Pump	186	1,203	0	**1,389**
Gas	1,247	1,786	707	**3,740**

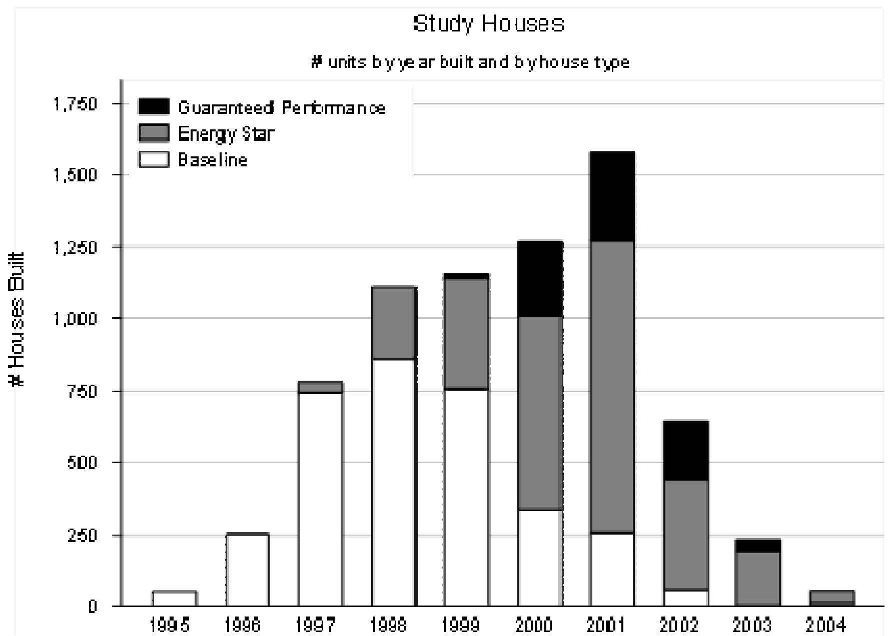
** Did not have HVAC type for every home.*

Data Analysis

Homes by Category

Figure 1 represents the number of homes built by category for each year. Baseline homes were primarily built prior to 2000, while Energy Star® homes began to appear in late 1997 and increased through 2001. Guaranteed Performance homes did not begin to contribute significantly to the market until 2000.

Figure 1: Study Homes by Year Built and Category



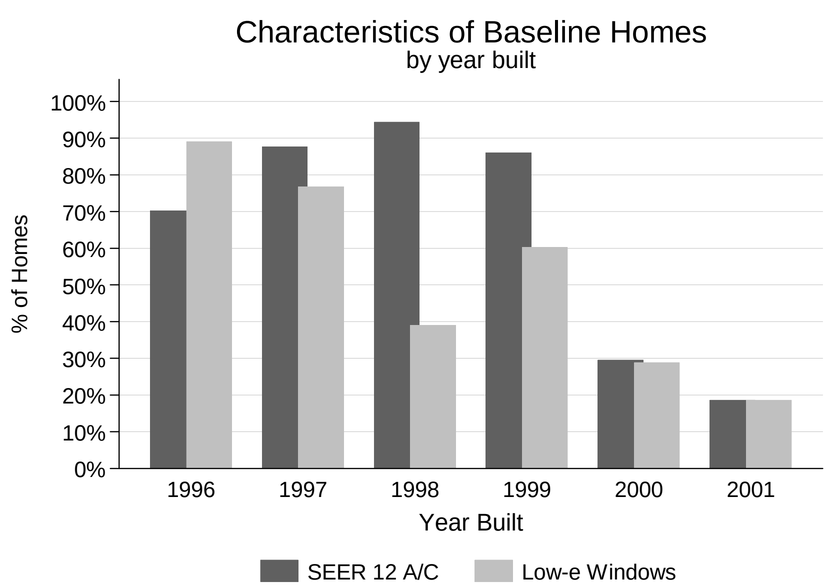
Of the six builders used in the study, a wide variation exists in types of homes built. Two builders constructed many Baseline homes up through 1999, and then switched to Energy Star® homes. One smaller builder built a combination of Baseline and Energy Star® homes each year. One builder switched from producing Baseline to primarily Guaranteed Performance, with a few Energy Star® homes. One builder has only Guaranteed Performance homes in the study, while another builder has only Baseline homes. **Given the differences in the composition of the homes over time and between different builders, comparisons must be made carefully to avoid confusing potential builder-specific effects with efficiency category effects.**

A closer examination of the building characteristics found that three of the builders (including the two large builders who switched from Baseline to Energy Star® production) had been constructing Baseline homes that appear likely to have met Energy Star® standards. All three builders used SEER 12 air conditioners in all of their Baseline homes, and two of the builders also used all Low E windows. These two energy saving features – SEER 12 HVAC and Low E glass – are perhaps the main changes required to meet Energy Star® standards in Phoenix. Indeed most homes only need one of these two features to meet Energy Star® standards given the already tight construction and high envelope R-values common to Phoenix construction practices.

Overall, slightly more than half of all Baseline homes appear to have met Energy Star® standards. This has the effect of raising the overall average efficiency of the Baseline homes and could skew the amount of energy savings apparently available in the Energy Star® and Guaranteed Performance homes. For this reason, the Baseline category of homes was broken down further (BaseES and BaseReg) to distinguish between those Baseline homes "masquerading" as Energy Star® homes and the true, standard efficiency, Baseline homes built to MEC 1993 requirements.

Figure 2 shows the percentage of Baseline homes that included SEER 12 air conditioners and Low E windows by year built. The figure shows that a high proportion of the earlier Baseline homes had these energy features, but the percentages declined over time. This change is primarily due to the migration of the two large builders' production into Energy Star® homes. Baseline home production that already met Energy Star® standards became Energy Star®, leaving the Baseline category primarily to homes that do not reach the standards.

Figure 2: Percentage of Baseline Homes with Efficiency Improvements



Key Characteristics of Study Homes

Key characteristics of the study homes are summarized in the table below. The Baseline homes category is broken down into BaseES and BaseReg to represent the homes that apparently already complied with Energy Star® versus the homes that did not.

Table 7: Key Characteristics of Study Homes (average values)

	Baseline Homes			Program Homes	
	BaseES	BaseReg	All Base	Energy Star®	Guaranteed Performance
# homes	1,805	1,534	3,336	2,979	826
Year built	1998	1999	1998	2000	2001
Living area (sq. ft.)	1,724	1,732	**1,728**	**1,870**	**2,164**
# stories	1.21	1.16	1.19	1.24	1.15
All electric	54%	69%	**61%**	**40%**	**0%**
Swimming pool	19%	16%	18%	17%	19%
A/C SEER	12.0	10.3	11.6	11.9	11.6
A/C tons	4.0	3.8	4.0	4.4	4.8
A/C size (sq. ft./ton)	424	**428**	425	**424**	**468**
Windows: Low E	70%	0%	56%	58%	100%
Attic R-value	30	30	30	30	30
Wall R-value	20	19	19	19	19

This table shows that Baseline homes tend to be the smallest, and Guaranteed Performance homes are the largest. Baseline homes are also much more likely to be all electric (electric heat pump and water heater; no gas service), while none of the Guaranteed Performance homes are all electric.

The three major categories of homes are similar in many respects. Between 17% and 19% of all homes have swimming pools. The vast majority of homes are one story, with attics insulated to R-30, walls insulated to R-19 and an average A/C SEER between 11.6 and 11.9. Baseline and Energy Star® homes have comparable proportions of Low E windows and similar air conditioner sizing on a square foot per ton basis (common rule of thumb).

The Guaranteed Performance homes in general appear to have downsized their air conditioners and incorporated all Low E windows. Downsizing equipment is an important part of both the ES and GP programs. As home thermal envelopes are improved, the total heating and cooling load on the house should be reduced, which translates to using a smaller HVAC system.

Energy Use Data

Advanced Energy collaborated with Arizona Public Service and Southwest Gas to gather monthly electric and gas usage data for each study home. Matching electric usage data were found for 7,141 homes, while records for gas use were found for 2,030 homes. A large number of gas-heated homes could not be matched and so could not be used for the energy analysis portion of the study.

Gas Usage Analysis Methodology

The gas utility provided data spanning approximately two years, from 2003 through 2004. The data was analyzed using a variable-base heating degree day regression analysis, which is similar to the widely-used PRISM software. Energy usage data was first screened to exclude periods when the property was vacant. These screens eliminated about 7% of all meter readings. Analysis results were classified as unreliable if the usage data spanned less than half a typical winter's degree days, if the regression r-squared was less than 0.7 or if the estimated standard error of the annualized usage was greater than 20%. These screening criteria eliminated 13% of the cases analyzed, leaving gas usage analysis results for 1,760 homes.

Gas Usage Results

Table 8 summarizes the gas usage by category. The entire Baseline group of gas-heated homes with results is in the BaseES group (effectively Energy Star® compliant).

Table 8: Summary of Gas Usage Results

	Baseline	Energy Star®	Guaranteed Performance
# homes	81	1,388	291
Living area	**1,565**	**2,052**	**1,779**
Raw use (annualized therms/year)	188	258	196
Adjusted total use (therms/year)	213	300	226
• Baseload	79	129	103
• Winter/heating	134	171	123
Usage intensity (1000s Btu/ft²)			
• Adjusted total	13.6	15.2	12.9
• Winter/heating	**8.6**	**8.6**	**7.0**

The "raw" usage is simply the usage over the two years of data, adjusted to a 365 day year. This value is lower than the "adjusted" (i.e., weather normalized) usage because the raw data typically ended in midwinter, leaving less than two winters of data.

The table shows that all categories of homes had quite modest gas usage – between 213 and 300 therms per year. These levels are comparable to just the water heating loads in most heating climates. The Energy Star® homes are 31% larger than the Baseline homes on average, and they have the highest gas usage. Much of the difference in gas usage is in the estimated baseload portion of use – representing estimated water heating and cooking usage. This difference could be due to potentially greater occupancy in the larger homes.

In terms of usage per square foot, the Energy Star® and Baseline homes have the same winter/heating intensity of 8,600 Btu/ft²/year while the GP homes have a 19% lower intensity at 7,000 Btu/ft²/year. Given the low absolute usage levels, even a 20% difference in heating intensity only amounts to about 25 therms of gas per year.

It appears that heating in Phoenix is to some extent similar to cooling in Maine – mostly optional for much of the season and potentially dominated by individual preferences and behaviors more than building envelope and equipment differences. Midwinter usage averages in the 30-50 therms/month range and summer usage drops to less than 10 therms – considerably lower than the typical water heating loads in cold climates but consistent with the expected seasonality of water heating loads in such a hot climate.

Electric Usage Analysis Approach Methodology

For electric usage data, the primary method used for weather normalization was a cooling degree day (CDD) and heating degree day (HDD) adjustment. This approach classified each meter reading period as summer, winter or base load based on heating degree days (base 65°F) and cooling degree days (base 75°F[3]). The usage and degree days were summed for winter, summer and base load months. The resulting three equations were solved to estimate base load usage per day, summer/cooling usage per CDD75 and winter/heating usage per HDD65, assuming a linear relation between usage, CDD and HDD. This analysis approach allows for heating and cooling occurring within all seasons and appears to provide more reliable results in many cases than using a regression model. This analysis was run separately for each home during each calendar year.

Electric usage data were first screened using an approach similar to the gas data, excluding periods of likely vacancy and other anomalous/questionable data. In addition, periods with unusually low usage were also excluded, which were defined as use of less than 150 kWh/month, or less than 400 kWh and either less than 25% of the median month's use or less than 40% of the 25th percentile of use for that home. These data screens excluded about 11% of the total 400,027 meter readings from 1998 through 2004, but only about 6% of the 85,963 meter readings in 2004. The usage analysis results were considered reliable if they were based on at least nine meter readings that spanned at least 50% of a typical year's HDD65 and CDD75, included at least one period of true base load usage (very few CDD or HDD) and resulted in an estimated base load usage of at least 2,000 kWh/yr (to eliminate likely unoccupied homes not caught by the meter reading screens). This

[3] The CDD balance point temperature of 75° was derived from a variable base CDD regression analysis performed on homes that did not exhibit electric heating loads – 75°F was the median estimated balance point temperature for homes with gas heat and hot water.

screening eliminated 596 homes (8%), primarily due to the requirement for nine meter readings, leaving 6,545 houses with apparently reliable records of electric use for the study.

A considerable drawback of any energy use analysis based on CDD is that cooling loads are not directly proportional to CDD. Only about half or less of the typical Phoenix area home's cooling load is related to temperature difference and transfer through conduction and infiltration. The other half of the load is from solar gain and internal gains. The problem with CDD adjustments was confirmed by examining trends in the weather adjusted estimated cooling loads and finding that the hottest summer had the lowest estimated cooling load because the CDD adjustment overcompensates for weather. **Fortunately for this project, the primary analysis year of interest (2004) had 99% of a typical summer's CDD75, so the weather adjustment is essentially no adjustment at all for homes with complete data.**

In addition to the inherent problem with CDD corrections, electric usage weather normalization can be further confounded by seasonality in other end uses such as electric water heating, swimming pool pumps, ceiling fans and even lighting and refrigeration. To the extent that these end uses vary over the year in proportion to outdoor temperatures, the weather adjustment is sensible. But if they simply vary with the season, then the weather adjustment may be inappropriate and may overcompensate. Having a typical weather year as the analysis year (as 2004 was) reduces the potential for bias from these factors.

The seasonality of electric end uses caused us to refer to the CDD-adjusted estimated cooling load as the summer/cooling load because it does not directly estimate air conditioner usage. Instead, it utilizes the sum of all summer end-use variations. For most homes in Phoenix, the air conditioner load will tend to dominate this summer load, but other seasonal end uses can have a noticeable impact as well, especially swimming pools and water heaters. Similarly, the heating load estimate is referred to as the winter/heating load. In our comparison of usage between different types of houses, total usage was examined as well as the estimated components of baseload, summer/cooling load and winter/heating load.

Electric Use Survey Results

Of more than 7,000 original study homes, satisfactory electric use records were only available for 6,545 homes. Similarly, 86 attached townhouses and three houses without information on living area were eliminated, leaving 6,480 houses with electric data suitable for the analysis. The Electric Use Summary table displays electric use by home category. The table also provides a breakout by heating fuel type for the total heating and cooling usage per square foot. All-electric homes use heat pumps and electric hot water, while gas-heated homes also use gas hot water.

Table 9: Electric Use Summary

	Baseline Homes			Program Homes	
	All Base	BaseES	BaseReg	Energy Star®	Guaranteed Performance
# of homes	3,080	1,650	1,430	2,686	714
Living area (ft^2)	1,739	1,735	1,744	1,884	2,206
Raw use (kWh/yr)	16,870	16,206	17,636	16,858	16,715
Adjusted total use (kWh/yr)	16,835	16,188	17,583	16,781	16,725
Baseload (kWh/yr)	10,654	10,109	11,282	10,244	10,434
Summer/cooling (kWh/yr)	5,376	5,285	5,480	6,064	6,078
Winter/heating (kWh/yr)	806	793	820	473	212
Adjusted total (kWh/ft^2/yr)	9.88	9.57	10.23	9.16	7.73
Summer/cooling (kWh/ft^2/yr)	3.14	3.05	3.24	3.24	2.85
Electric Heat / Hot Water					
Living area (ft^2)	1,686	1,578	1,775	1,526	N/A
Adjusted total use (kWh/yr)	17,501	16,280	18,508	15,311	N/A
Baseload (kWh/yr)	11,581	10,745	12,270	10,070	N/A
Summer/cooling (kWh/yr)	4,804	4,397	5,139	4,298	N/A
Winter/heating (kWh/yr)	1,117	1,138	1,099	942	N/A
Adjusted total (kWh/ft^2/yr)	10.55	10.52	10.58	10.12	N/A
Summer/cooling (kWh/ft^2/yr)	2.87	2.81	2.93	2.83	N/A
All electric: % homes	62%	53%	70%	40%	0%
Gas Heat / Hot Water					
Living area (ft^2)	1,825	1,916	1,670	2,117	2,206
Adjusted total use (kWh/yr)	15,579	15,691	15,386	17,738	16,725
Baseload (kWh/yr)	8,978	9,001	8,939	10,357	10,434
Summer/cooling (kWh/yr)	6,322	6,341	6,288	7,214	6,078
Winter/heating (kWh/yr)	279	349	159	167	212
Adjusted total (kWh/ft^2/yr)	8.7	8.29	9.40	8.53	7.73
Summer/cooling (kWh/ft^2/yr)	3.57	3.34	3.97	3.5	2.85

The Electric Use Summary (Table 9) shows that the raw use data and the weather-adjusted data match very closely, as expected given the typical weather year in 2004. All categories of homes show an average electric use in a narrow range from 16,188 to 17,583 kWh/yr. **Baseload demands account for nearly two thirds of the total electric usage, with another 30% in summer/cooling loads, and a small amount of winter/heating load.**

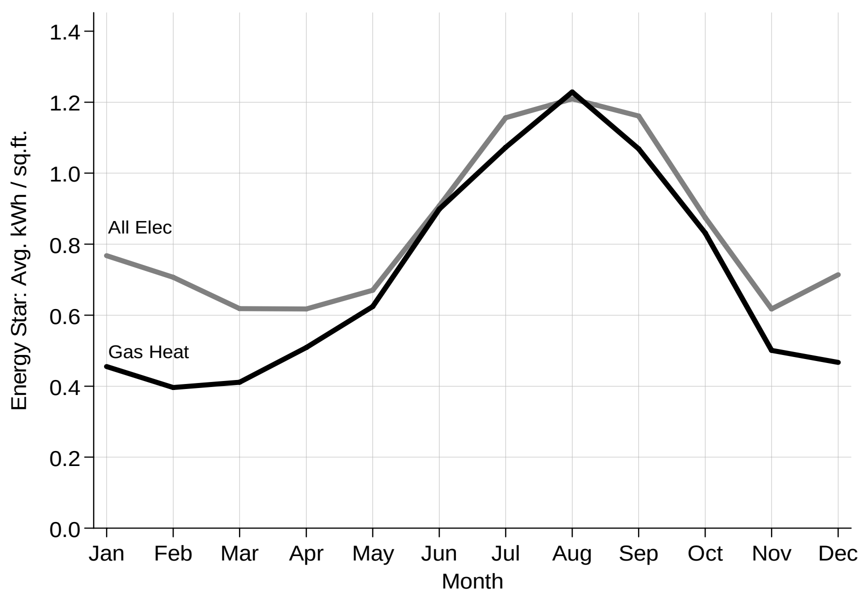
The Baseline homes, as predicted, have the highest overall energy use intensity (kWh/ft^2). However, the ES homes actually showed slightly higher summer/cooling load intensity than the average Baseline homes. The Guaranteed Performance homes averaged roughly 10% lower energy use than the Baseline homes. These simple comparisons are useful in a “big picture” sense: the presumably more efficient homes use about the same total amount of electricity as the Baseline homes because they are larger. However, these comparisons do not represent a fair assessment of the energy performance of the different homes, as many other factors besides square footage may differ between the home groups and have an effect on energy use, particularly the choice of heating/hot water fuel.

Heating/Hot Water Fuel Impacts

The lower portion of the Electric Use Summary table provides a breakout of usage based on heating/hot water fuel. The Baseline homes are much more likely to be all-electric than the ES homes, while none of the GP homes are all-electric. The all-electric Baseline homes have considerably greater baseload usage than the homes using gas, reflecting additional loads for water heating, some cooking and clothes drying. The Baseline all-electric homes are also smaller than the Baseline gas homes by about 10%. All-electric ES homes are much smaller than gas-heated ES homes making comparisons more difficult. Estimated winter/heating loads are quite small for these all-electric heat pump homes, averaging about 1,000 kWh/year.

One surprising difference between the all-electric and gas homes is that the summer/cooling intensity for the all-electric homes was roughly 20% lower than the gas homes summer/cooling intensity. This difference cannot be accounted for purely by the building characteristics, although the heat pumps tend to have slightly higher SEER ratings than the central A/C units. Figure 2 below compares the 2004 average monthly energy intensity (kWh/ft²) for Energy Star® homes, both all-electric and gas-heated homes.

Figure 2: Energy Use of ES Homes: Gas Heating vs. All-Electric



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raph shows that the all-electric homes use much more electricity during the winter and shoulder months than do the gas-heated homes, as expected. However, the peak summer electric usage is roughly the same for both gas and electric homes, when one would expect the all-electric home's use to again be much higher than the gas home. One possible explanation for the difference is the seasonal load shape for electric water heating, especially in a climate like Phoenix. Incoming cold water temperatures are quite warm in the hot summers of Phoenix, creating a substantial reduction in electric usage of water heaters. A model of water heating loads based on TMY2 (typical meteorological year) weather data revealed that reductions in electric water heating loads could lower the estimated seasonal summer/cooling loads by 800-900 kWh/year, or roughly 0.5 kWh/ft² in Phoenix. This estimated water heating effect explains almost the entire difference in estimated cooling loads between all-electric and gas-heated homes.

The substantial differences in load levels and seasonal load shapes require that any comparisons between homes must be performed separately for all-electric and gas-heated homes.

Impact of Swimming Pool on Energy Use

Another end use expected to have a large impact on electric usage is swimming pools. Pools can use thousands of kWh per year, especially in a climate like Phoenix with a long swimming season. Even without pool heating, the pumps alone can use more than 3,000 kWh per year (APS Website – www.aps.com). About 19% of all homes in the analysis have in-ground swimming pools. Table 10 below provides a detailed usage break out for all-electric homes with and without pools.

Table 10: Energy Usage for All-Electric Homes; Swimming Pool vs. No Pool

	Baseline Homes			Program Homes	
	All Base	BaseES	BaseReg	Energy Star®	Guaranteed Performance
All-Electric with Pool					
# homes	271	108	163	59	0
Living area (ft²)	**2,014**	**1,926**	**2,072**	**1,864**	N/A
Adjusted total use (kWh/yr)	**23,640**	**22,946**	**24,099**	**22,634**	N/A
Baseload (kWh/yr)	16,881	16,108	17,393	15,950	N/A
Summer/cooling (kWh/yr)	5,664	5,583	5,718	5,772	N/A
Adjusted total (kWh/ft²/yr)	12.03	12.25	11.88	12.31	N/A
Summer/cooling (kWh/ft²/yr)	2.85	2.93	2.81	3.12	N/A
Baseload (kWh/ft²/yr)	8.61	8.67	8.57	8.69	N/A
All-Electric, No Pool					
# homes	1,565	722	843	1,002	0
Living area (ft²)	**1,629**	**1,526**	**1,717**	**1,506**	N/A
Adjusted total use (kWh/yr)	**16,438**	**15,283**	**17,427**	**14,880**	N/A
Baseload (kWh/yr)	10,663	9,942	11,280	9,724	N/A
Summer/cooling (kWh/yr)	4,655	4,220	5,027	4,211	N/A
Adjusted total (kWh/ft²/yr)	10.29	10.26	10.33	9.99	N/A
Summer/cooling (kWh/ft²/yr)	2.88	2.79	2.95	2.82	N/A
Baseload (kWh/ft²/yr)	6.70	6.71	6.70	6.53	N/A

Houses with pools on average are considerably larger than those without pools and tend to use about 6,000 to 8,000 kWh more electricity per year, or 1.0-2.5 kWh/ft² higher energy intensity. The electricity used by a pool can vary widely depending upon occupancy patterns and preferences. Differences in living area between homes with and without pools, as well as between the different efficiency categories, make direct comparisons difficult and could lead to bias if, for example, people in GP homes tended to use their pools more or less than people in Baseline homes. Because of this potential bias and given the relatively small fraction of homes with pools, excluding homes with pools from the study will yield more reliable performance comparisons between home categories.

Given the lack of all-electric GP homes and potential variations in hot water loads, the best energy use comparisons are likely to come from analyzing gas-heated homes without pools – the final grouping in the table below.

Table 11: Energy Usage for Gas-Heated Homes; Swimming Pool vs. No Pool

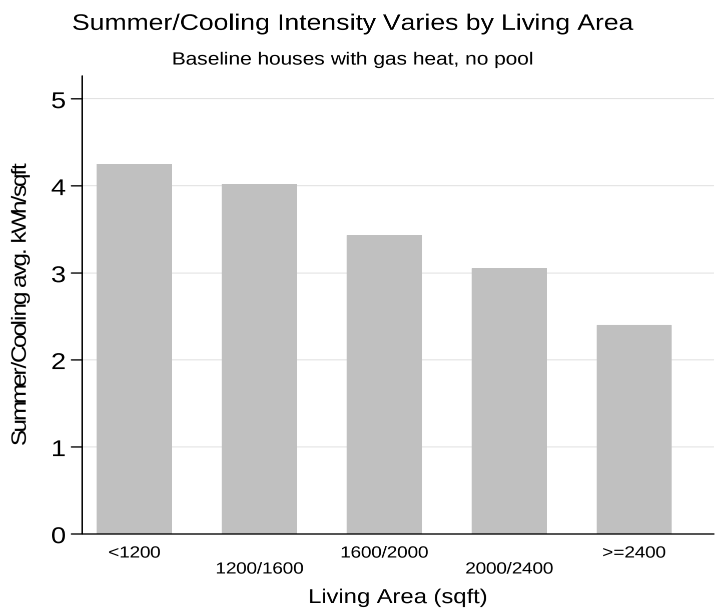
	Baseline Homes			Program Homes	
	All Base	BaseES	BaseReg	Energy Star®	Guaranteed Performance
Gas with Pool					
# homes	273	189	84	433	154
Living area (ft^2)	**2,112**	**2,021**	**2,318**	**2,530**	**2,546**
Adjusted total use (kWh/yr)	**20,309**	**19,849**	**21,342**	**23,001**	**23,344**
Baseload (kWh/yr)	12,772	12,336	13,753	14,278	15,666
Summer/cooling (kWh/yr)	7,150	7,158	7,132	8,534	7,477
Adjusted total ($kWh/ft^2/yr$)	9.8	9.94	9.47	9.40	9.39
Summer/cooling ($kWh/ft^2/yr$)	3.48	3.59	3.22	3.50	3.03
Baseload ($kWh/ft^2/yr$)	6.14	6.17	6.07	5.81	6.28
Gas, No Pool					
# homes	877	537	340	1,195	560
Living area (ft^2)	**1,735**	**1,878**	**1,509**	**1,967**	**2,112**
Adjusted total use (kWh/yr)	**14,107**	**14,228**	**13,915**	**15,831**	**14,904**
Baseload (kWh/yr)	7,797	7,827	7,750	8,936	8,996
Summer/cooling (kWh/yr)	6,064	6,054	6,080	6,736	5,694
Adjusted total ($kWh/ft^2/yr$)	8.36	7.71	9.39	8.22	7.27
Summer/cooling ($kWh/ft^2/yr$)	**3.60**	**3.26**	**4.16**	**3.50**	**2.80**
Baseload ($kWh/ft^2/yr$)	4.62	4.27	5.18	4.64	4.37

The summer/cooling intensity of gas-heated homes without pools is shown in bold in the table above, highlighting it as the clearest comparison between home efficiency categories shown thus far. The Baseline homes and ES homes have comparable summer/cooling intensity, though the BaseES homes that already appear to meet Energy Star® standards had dramatically lower summer/cooling intensity than other Baseline homes. The GP homes have the lowest summer/cooling intensity – 23% lower than the average Baseline home, 33% lower than the average BaselineReg home and 20% lower than the ES homes.

Energy Intensity Comparisons

The considerable differences in house size between different categories and groupings have caused the study to focus on energy intensity: electric usage per square foot of living area. This common measure of energy use is meant to provide an even basis for comparing homes of different sizes. However, energy usage per square foot tends to drop as homes get larger, since building shell area (and especially window area) tends to increase at a slower rate than floor area. The figure below shows how the average summer/cooling intensity (electric usage per square foot of living area) varies with house size for Baseline homes with gas heat and no pool.

Figure 3: Energy Intensity Compared to Living Area



The relationship appears quite strong and suggests that comparing energy usage per square foot may be almost as biased as comparing energy use without considering living area, especially for homes of widely different sizes. This bias of energy intensity must be addressed when comparing homes of different sizes. Two approaches were taken to deal with the kWh/ft² problem: (1) grouping homes together by similar sizes to make comparisons and (2) using regression modeling to account for the living area effect on kWh/ft².

Table 12 below shows average estimated summer/cooling intensity for gas-heated homes without pools in the various home categories. Results are shown for three ranges of living area: less than 1,600 ft²; 1,601-2,400 ft²; greater than 2,401 ft². Results are not shown for groups of fewer than 50 homes.

Table 12: Summer/Cooling Intensity by Living Area: Gas Heat, No Pool (kWh/ft²/yr)

	Baseline Homes			Program Homes	
	All Base	BaseES	BaseReg	Energy Star®	Guaranteed Performance
Homes < 1,600 ft²					
# homes	407	125	282	326	141
Summer/cooling /ft²	**4.06**	**3.27**	**4.41**	**3.63**	**3.53**
Homes 1,601-2,400 ft²					
# homes	435	398	37	660	282
Summer/cooling /ft²	**3.28**	**3.29**		**3.59**	**2.68**
Homes > 2,401 ft²					
# homes	34	14	20	208	136
Summer/cooling /ft²	n/a	n/a	n/a	**3.02**	**2.30**

Table results: significant at >99% level.

Among the homes smaller than 1,600 ft², ES homes use 11% less and GP use 13% less than Baseline homes. Surprisingly enough, the BaseES homes scored the lowest energy intensity of all the homes, using roughly 18% less energy than the BaseReg homes. These BaseES homes actually had a greater percentage of Low E windows than the ES homes and all had SEER 12 A/C (compared to an average SEER 11 for GP and SEER 11.95 for ES). Smaller GP homes tended to have lower quality specs (SEER, in particular) and used slightly less energy than ES homes.

The largest grouping – homes between 1,600 ft² and 2,400 ft² – shows that ES homes actually had 9% higher summer/cooling intensity than Baseline homes (almost all the Baseline homes in this size category meet Energy Star® standards), while GP homes used 18% less than Baseline homes. GP homes use about 25% less summer/cooling energy than ES homes for houses larger than 1,600 ft².

Among homes larger than 2,400 ft² there are too few Baseline homes to draw reliable conclusions on total energy savings. However, the GP homes were shown to use 24% less energy than the ES homes in this category (significant at >99% level).

These results are the most "apples to apples" comparison we could generate while accounting for as many controlled variables as possible.

Regression Analysis

A regression analysis of summer/cooling intensity was also performed as a function of living area. These regression models attempt to control for factors such as house size, orientation and baseload to avoid having to perform comparisons on increasingly smaller groups of buildings. The study team used the regression modeling to estimate the energy usage for a 1,800 ft², gas-heated home without a pool, across the three home categories. The results from four of the regressions models are shown in Table 13.

Table 13: Regression Modeling of Summer/Cooling (kWh/ft²), Gas-Heated Homes without Pools

	Base Model		Base + Stories		Base + Stories + Baseload		All + Orientation	
# Observations	2,629		2,503		2,503		2,503	
Model constant	4.739*** (0.077)		4.586*** (0.090)		3.672*** (0.103)		3.716*** (0.120)	
Living area (ft²)	-0.00065*** (0.00004)		-0.00068*** (0.00004)		-0.00056*** (0.00004)		-0.00053*** (0.00004)	
Energy Star®	0.045 (0.047)		-0.018 (0.051)		-0.040 (0.049)		-0.059 (0.050)	
Guarantee Performance	-0.558*** (0.058)		-0.558*** (0.061)		-0.561*** (0.058)		-0.585*** (0.059)	
# Stories			0.203*** (0.056)		0.192*** (0.053)		0.182*** (0.053)	
Baseload kWh/ft²					0.155*** (0.010)		0.154*** (0.010)	
Orientation (Compared to East)								
North							-0.03 (0.08)	
Northeast							-0.33*** (0.10)	
Northwest							-0.15 (0.10)	
South							-0.09 (0.08)	
Southeast							-0.10 (0.09)	
Southwest							-0.13 (0.10)	
West							0.08 (0.10)	
Model R^2	0.160		0.158		0.236		0.240	
Adjusted Summer /cooling kWh	Use	Save%	Use	Save%	Use	Save%	Use	Save%
Baseline	6,413		6,485		6,797		6,801	
Energy Star®	6,493	-1%	6,452	1%	6,725	1%	6,694	2%
Guaranteed Perfm.	5,409	16%	5,481	16%	5,787	15%	5,747	16%

Note:

- Standard errors are shown in parentheses.
- Statistical significance is indicated by asterisks: *=p<.05, **=p<.01, ***=p<.001.
- No * means coefficient is not statistically significant with 95% confidence.
- Adjusted kWh values are based on model predictions from setting all covariates to their overall mean and setting living area to 1,800 ft².

The regression modeling yielded a number of conclusions:

- Guaranteed Performance homes have significantly lower summer/cooling intensity than Baseline homes. When adjusted to a standardized 1,800 ft² home, the estimated savings equals about 1,000 kWh/year or about 16% of the load.
- Energy Star® homes have about the same summer/cooling intensity as Baseline homes – the small differences ranging from -1% to 2% is not statistically significant.
- Larger homes have lower cooling intensity (as we found previously).
- Two-story homes have higher cooling intensity than one-story homes even after accounting for living area.
- Baseload electric usage constitutes about 0.15 kWh of additional summer/cooling load for each 1 kWh of annual baseload electric usage. This baseload electric impact is substantial – equal to about 1,300 kWh of summer/cooling for the average baseload usage of 8,571 kWh in the analysis sample, equal to about 20% of the entire summer/cooling load.
- Homes facing northeast have significantly lower summer/cooling intensity than homes facing east (the default category), but no other orientations show statistically significant differences.
- Annual summer/cooling loads estimated to average 6,413 kWh for Baseline homes, 6,493 kWh for Energy Star® (1% savings) and 5,409 kWh for Guaranteed Performance homes (16% savings).
- **Compared to Baseline homes that are *not* Energy Star®-compliant (BaseReg), Energy Star® homes use 10% less and Guaranteed Performance homes use 25% less for summer/cooling, saving about 1,800 kWh/year.**

Swimming pools are estimated to increase annual total usage by about 4,500 kWh, with 750 kWh of this appearing as increased summer/cooling load. Pool heaters, pumps and lighting constitute the majority of pool-related loads. But lifestyle factors associated with having and using a pool (such as patio lighting, increased opening and closing of doors, additional laundry loads) may also add to the increased energy use. Certainly, this substantial energy user should be targeted for reducing new home electric use, possibly through downsizing the pool pumps and using longer pump runtimes.

Homeowner Effects

While homeowner activity obviously has an effect on household energy use, it was uncertain how much overall energy use varied from one family to the next. The study data allowed the investigators to compare energy use for various families living in the same house over time (movers) versus homes with the same family over a similar period (stayers).

The study examined total and summer/cooling energy use in 2000 and again in 2004. These two years were chosen both for the span of time – allowing for a change in occupancy – and because the two years compare well in terms of weather, as shown in Table 14 below.

Table 14: 2000 and 2004 Temperature Statistics

Year	HDD65	CDD65
2000	944	4629
2004	968	4755

In this data set, there were 1,289 movers where there was a change in occupancy and 1,384 stayers with no change in occupancy. Relative change in summer/cooling usage declined 5% in 2004 compared to 2000 for both the movers and stayers. In terms of absolute change in consumption, the median change in usage between 2000 and 2004 was 14% for stayers and 21% for movers, implying that occupancy changes are typically responsible for less than a 10% change in use.

It is important to note that more movers experienced large changes in usage compared to stayers. One in four movers showed a usage change of 40% or more, but only one in ten stayers showed that significant of a change.

Estimated total energy use and cooling usage was tabulated for a set of houses in both 2000 and 2004. The houses with no change in occupancy over the period were separated from those houses that did have a change in occupancy.

The table below summarizes the average total usage intensity and cooling usage intensity in each year, as well as the change and absolute percent change in usage between the two years. The results are presented for cases where there were moves (movers) and where there were not any moves (stayers).

Table 15: Movers vs. Stayers: Total Energy and Cooling Use

Movers – 48.2%

Variable	N	Mean	sd	ci95	Min.	p10	p25	Median	P75	p90	Max.
Total usage kwh/ft2											
Year 2000	1,289	9.45	3.55	0.19	2.72	6.03	7.3	8.9	10.87	13.14	52.5
Year 2004	1,289	9.74	3.15	0.17	2.35	6.24	7.56	9.29	11.52	13.87	28.62
Change	1,289	0.29	4	0.22	-38.87	-3.49	-1.5	0.36	2.36	4.53	22.47
Absolute % change	1,289	0.29	0.3	0.02	0	0.03	0.1	0.21	0.4	0.64	3.92
Cooling intensity kwh/ft2											
Year 2000	1,289	3.33	1.12	0.06	0.34	2.07	2.61	3.24	3.91	4.61	11.51
Year 2004	1,289	3.17	1.08	0.06	0.19	1.89	2.48	3.14	3.79	4.42	11.17
Change	1,289	-0.016	1.3	0.07	-6.49	-1.66	-0.84	-0.09	0.61	1.31	7.15
Absolute % change	1,289	0.33	0.5	0.03	0	0.04	0.11	0.23	0.41	0.63	7.31

Stayers – 51.8%

Variable	N	Mean	sd	ci95	Min.	p10	p25	Median	p75	p90	Max.
Total Usage kwh/ft2											
Year 2000	1,384	8.76	2.64	0.14	2.27	5.68	6.91	8.48	10.18	12.22	23.83
Year 2004	1,384	9.65	3.18	0.17	2.93	6.02	7.35	9.36	11.5	13.73	28.87
Change	1,384	0.89	1.97	0.1	-11.79	-1.2	-0.26	0.7	1.89	3.4	12.69
Absolute % change	1,384	0.19	0.19	0.01	0	0.02	0.06	0.14	0.26	0.41	2.7
Cooling Intensity kwh/ft2											
Year 2000	1,384	3.25	0.96	0.05	0.21	2.14	2.62	3.17	3.84	4.47	10.2
Year 2004	1,384	3.09	0.92	0.05	0.26	2.03	2.48	3.01	3.66	4.25	7.6
Change	1,384	-0.16	0.83	0.04	-5.09	-1.14	-0.62	-0.14	0.3	0.8	4.26
Absolute % change	1,384	0.21	0.35	0.02	0	0.03	0.07	0.15	0.27	0.42	8.51

This table (15) shows the number of cases (N), the average (Mean), the standard deviation (sd), the 95% confidence interval of the mean (ci95), the minimum, the 10th, 25th, 50th, (median), 75th and 90th percentiles, and the maximum value.

The table shows that, for these homes, average total usage increased from 2000 to 2004 by about 3% for movers and by about 10% for stayers. In terms of cooling intensity, usage decreased by about 5% for both movers and stayers. It appears that baseload usage (e.g., plug loads) was responsible for overall usage increases.

The typical percentage change in total energy use was 21% for movers and 14% for stayers (these numbers are from the median column of absolute percentage change). The typical changes in cooling load were 23% for movers and 15% for stayers. These results both indicate that differences between households typically do not have a large effect on cooling loads or total loads, with a typical incremental change in energy use of less than 10%. The 75^{th} and 90^{th} percentiles of the absolute percentage change reveal that larger swings in usage are more common among the movers group: 40% versus 26% for the 75^{th} percentile and 64% versus 41% in the 90^{th} percentile. But for most households, the changes are not very large.

In conclusion, a modest increase in energy use variability was found between different occupants, as compared to the same occupants over time. But typically, the effect of this change in energy use is on the order of 10%.

Builder Effects

The study found that, even among homes with gas heat and no pool and within the same size category, there were noticeable differences among builders. For example, one Guaranteed Performance builder's homes averaged 3.9 kWh/ft² among small homes and 3.7 kWh/ft² among midsize homes, while the other GP builder averaged 3.4 kWh/ft² and 2.5 kWh/ft² respectively. Builder variations were evident among all house types and categories. One way to control for this effect is to compare houses within a single builder's product. One builder produced homes in all three categories (Baseline, ES and GP). The summer/cooling intensity for their homes averaged 4.0 kWh/ft² for Baseline, 3.0 kWh/ft² for ES and 2.6 kWh/ft² for GP. This decrease in average energy use tracks with the builders' decision to upgrade from Baseline to ES and GP programs.

For informational purposes, a plot of the average cooling intensity by builder, community and efficiency category is provided in the Appendix. The number of homes in each group is shown in parentheses. The figures do not control for heating fuel, swimming pools or building size.

Market Transformations

A number of different factors have helped to transform the Phoenix area housing market in terms of energy performance. When the Energy Star® program entered the Phoenix market area and gathered a number of avid supporters, it raised the energy performance bar for *all* housing in the market, since few people wanted to purchase an energy *inefficient* home, given the alternatives. Consumers are requesting energy efficient features because programs such as Energy Star® and Environments For Living® have educated them.

Another major market transformation occurred when the HVAC contracting company that installs more than 70% of all HVAC systems in Phoenix, required duct sealing training for all of its installers. In doing so, they initiated a significant change in the entire market which resulted in a steady decline in duct leakage performance numbers. Similarly, training in other energy performance enhancements offered through these programs brought testers, builders and contractors up to speed quickly.

As Low E glass and higher efficiency HVAC units were incorporated into early Energy Star® homes, the price for these products dropped noticeably, due mostly to its increased market penetration and competition for supply. Lowered prices equates to more frequent requests by homeowners for efficient glass.

Energy Star® and Guaranteed Performance programs brought the concept of “right-sizing” into the market, leading HVAC system designers to use more sophisticated software (such as Manual J) to size HVAC units for homes. This has resulted in smaller units being installed, saving the homeowner money over purchasing a larger unit, while preventing short cycling and allowing the HVAC units to reach their maximum SEER efficiency. Typical HVAC sizing in Phoenix previously was 400 sq. ft. of livable floor space per ton; this figure has increased, as more attention is being given to improved thermal performance.

Results

Direct comparisons of energy use between the three home categories – Baseline, Energy Star® and Guaranteed Performance – are difficult at best, given the vast number of variables that can affect both home performance and total energy use. Swimming pools, in particular, add significantly to the overall energy use of a home. But it is difficult (at least within this study) to isolate those pool-related costs, since most pool systems are not metered separately from the home energy supply. Even seasonal differences in the costs of operating electric water heaters versus gas heaters could alter energy use profiles by as much as 900 kWh/year, invalidating certain study results. To reduce the chance for such variables to skew the results of this study, it is essential to compare "apples to apples" and directly compare homes only within certain definite data sets. **Since no all-electric Guaranteed Performance homes were available for this study, the cleanest comparison is to look at gas-heated homes with no pool, within different size ranges.**

Energy Intensity

The following tables outline the energy intensity of gas-heated Baseline, Energy Star® and Guaranteed Performance homes with no swimming pools. Baseline home results are differentiated for standard Baseline homes that meet only MEC 1993 standards (BaseREG), Baseline homes that meet Energy Star® standards (BaseES) and an average for all Baseline homes. Results for both tables are separated by house size into small (< 1,600 ft^2), medium (1,601-2,400 ft^2) and large (> 2,400 ft^2) homes.

Table 16: Energy Intensity of Baseline Gas-Heated Homes with No Pool

BASELINE HOMES									
	All Base			**BaseREG**			**BaseES**		
	Sm	**Md**	**Lg**	**Sm**	**Md**	**Lg**	**Sm**	**Md**	**Lg**
# of homes	407	435	34	282	37	20	125	398	14
Summer/cooling ($kWh/ft^2/year$)	**4.06**	**3.28**	n/a	**4.41**	n/a	n/a	**3.27**	**3.29**	n/a

* All data in this table is >99% statistically significant.
Sm = <1,600 ft^2
Md = 1,601-2,400 ft^2
Lg = > 2,400 ft^2

Table 17: Energy Intensity of ES and GP Gas-Heated Homes with No Pool

PROGRAM HOMES						
	Energy Star®			Guaranteed Performance		
	Sm	Md	Lg	Sm	Md	Lg
# of homes	326	660	208	141	282	n/a
Summer/Cooling ($kWh/ft^2/yr$)	**3.63**	**3.59**	**3.02**	**3.53**	**2.68**	n/a

* All data in this table is >99% statistically significant.
Sm = <1,600 ft^2
Md = 1,601-2,400 ft^2
Lg = > 2,400 ft^2

Energy Savings

After applying regression analysis for this same data set (gas heated, no pool), the annual summer/cooling loads were estimated to average 6,413 kWh for all Baseline homes, 6,493 kWh for Energy Star® (1% savings) and 5,409 kWh for Guaranteed Performance homes (16% savings). Compared to Baseline homes that are *not* Energy Star® compliant (BaseReg), Energy Star® homes used 10% less summer/cooling energy, while Guaranteed Performance homes realized an energy savings of 25% or roughly 1,800 kWh/year.

Table 18: Summer/Cooling Energy Savings (Regression Analysis)

	ES	GP
Base All	1%	16%
BaseREG	10%	25%

Conclusions

This Study Produced Statistically Valid Results

At the beginning of this project, there was much skepticism around the validity of conducting a study to compare homes across the three categories we selected (Baseline, Energy Star® and Guaranteed Performance). The concern was that the amount of variability due to factors that have nothing to do with the programs we were studying or that could not be controlled would mask any noticeable differences. However, after having completed this study, and confirming that there is tremendous variability, we still see statistically significant differences among the three categories.

While we have accumulated a body of evidence which indicates that the programs are a driver of these savings, the data should not be viewed as proof. We recognize that there are many issues such as and we can't prove the exact amount of savings, but we now have a jumping point for further investigation and benchmarking. **The bottom line is this kind of study can produce valid results, and those results will be strengthened with additional data.**

We also learned a lot along the way and are prepared to make the necessary improvements that will generate even stronger results.

The Programs Appear To Be Working

Statistically valid energy savings were found for both the Energy Star® and Guaranteed Performance homes, when compared to Baseline homes (BaseREG). One surprise was how well the BaseES houses performed, but it is our belief that this is partly due to the impact made on the marketplace by the Energy Star® and Guaranteed Performance programs. Obviously, savings are directly related to how far a builder/contractor pushes specifications (toward energy efficiency) and improves installation. A major catalyst for this push (market transformation) is programs such as Energy Star® and Guaranteed Performance and all the activities that go into supporting them.

Baseloads Are Large and Need To Be Addressed

Continued efforts to reduce the overall energy usage in Phoenix, residential buildings should not be focused solely on space cooling/heating and water heating. While the savings are positive, the larger context of these savings is not as impressive. Space cooling/heating and water heating are the largest individual energy users in a home, although they represent roughly 40% of the home's overall energy usage. This means that even a 10% reduction in cooling/heating and water heating costs – a significant reduction – only equates to a 4% savings on the home's total energy bill. Obviously, all areas of energy use within residential buildings must be investigated to discover the maximum energy savings potential.

Need for Further Investigation

While the results of this study offer many clues into improving home energy performance, only continued monitoring of homes in the Phoenix area will promote improvements and demonstrate success of the Energy Star® and Guaranteed Performance programs. Providing feedback to these programs on a real world energy use and savings will help to make these programs more effective and further entrench the principles they teach into the residential building trade. The data collected will also help those in the residential building industry focus their efforts on the energy efficiency features that have the most impact – while cost effective – and in turn provide a more energy-efficient home to the consumer.

Recommendations

For Further Study

Further studies of baseload energy usage (including lights, appliances, TV/computers and other household loads) and energy use in swimming pools may identify additional opportunities for significant energy savings. The Energy Star® appliances program is one measure to manage baseload. However, it is clear that more energy reduction methods are needed, since the average size of new homes is increasing along with the number of appliances. Energy Star® has also recently developed a residential lighting program which should prove to be a very effective means for reducing baseload usage. However, pool pump motors, pool/outdoor lighting and plug loads that reside in a “sleep” or “standby” mode (like computers, microwaves, and stereos) – all of which may contribute significantly to overall energy use – have largely been ignored as a subject of study.

The following recommendations will assist in answering these questions.

- **Expand the energy use data set** by surveying more builders and more communities/subdivisions. A random sample of homes from each community/subdivision would be needed (versus surveying all homes), since each subdivision tended to consist of similar homes and homebuyers.
- **Research typical base energy loads and plug loads.** Baseloads and plug loads average 70% of total home energy use. A 10% to 30% savings in base/plug loads yields overall energy savings of 7% to 21%. By comparison, a 10% savings in cooling costs reduces total energy use by only 3%.
- **Research pool energy use and savings.** Energy use for swimming pools (pumps, lighting and fountains) can equal the entire cooling load of a home. By implementing efficient pool pumps, run time controllers and pool lighting, similar energy savings can be realized at considerably less effort and cost than cooling system upgrades.
- **Continue monitoring homes in Phoenix area.** Long-term monitoring (yearly) of Baseline, ES and GP houses in the Phoenix market (and others) will provide the necessary feedback for improvement and a clearer picture of progress.
- **Repeat study in different market/climate.** Repeating this home energy study in various markets and/or climates would examine differences in both geographical and market forces, and help identify opportunities to expand energy-efficient construction. Different locations have different drivers. Therefore, the focus will be different – first, we must identify the drivers by setting up a data collection and analysis system much like this study. Include comparison of actual energy consumption to energy modeling.

- **Homeowner follow-up**. Advanced Energy is following up this study by sending each of the study homeowners a survey regarding home comfort as it relates to the HVAC system (i.e. room temperature variance, HVAC noise and overall satisfaction).

Resources

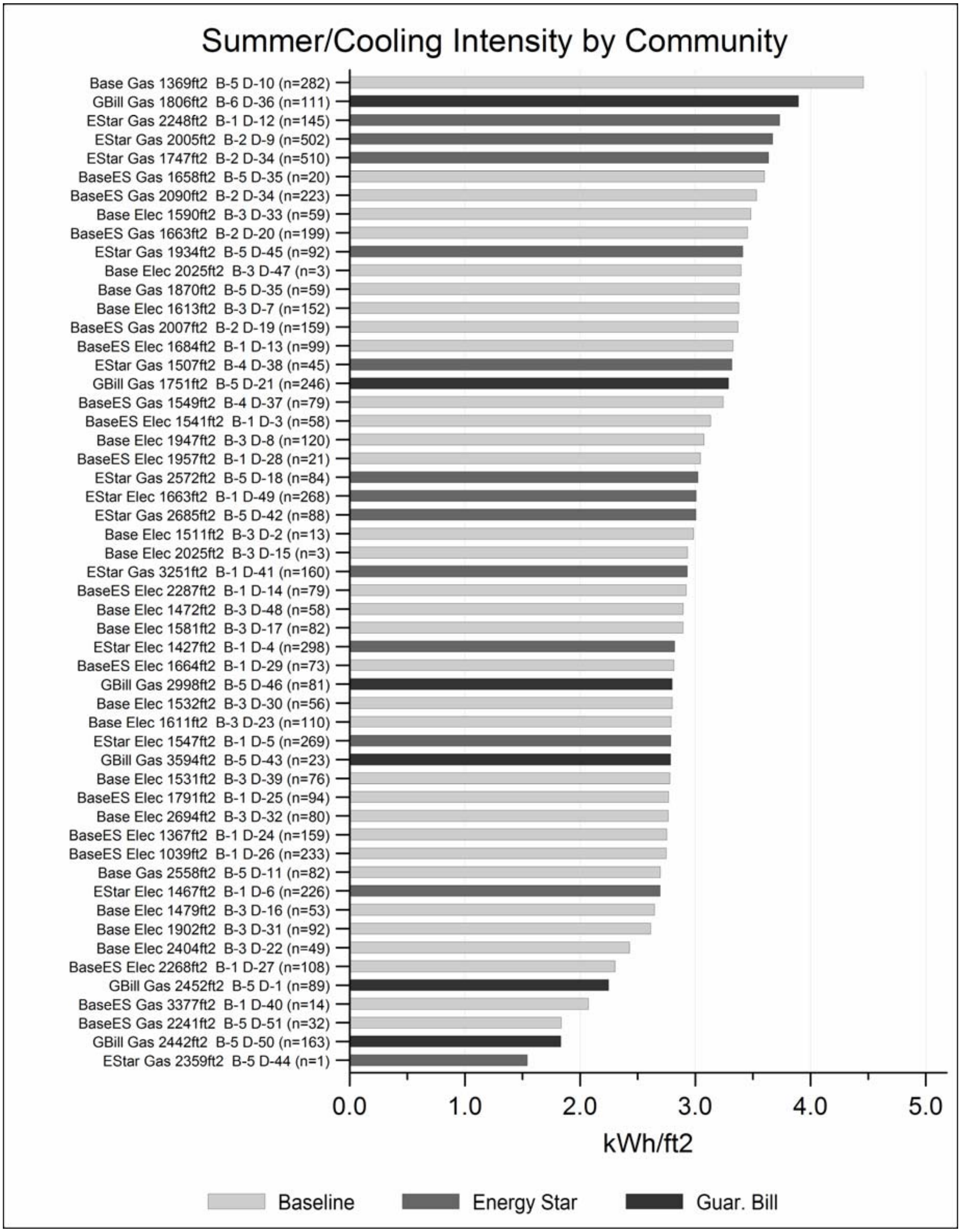
Website references

- www.advancedenergy.org
- www.aps.com
- www.eflhome.com
- www.maricopa.gov
- www.swgas.com

Published references

- *2004 Buildings Energy Databook*, U.S. Department of Energy.
- *Energy Consumption Comparison of Energy Star® Homes in Phoenix, Arizona*, Bradley Jay Bashford, Arizona State University, May 2000.

Appendix



Summer/Cooling Intensity by Community
Base Gas 1369ft2 B-5 D-10 (n=282)
GBill Gas 1806ft2 B-6 D-36 (n=111)
EStar Gas 2248ft2 B-1 D-12 (n=145)
EStar Gas 2005ft2 B-2 D-9 (n=502)
EStar Gas 1747ft2 B-2 D-34 (n=510)
BaseES Gas 1658ft2 B-5 D-35 (n=20)
BaseES Gas 2090ft2 B-2 D-34 (n=223)
Base Elec 1590ft2 B-3 D-33 (n=59)
BaseES Gas 1663ft2 B-2 D-20 (n=199)
EStar Gas 1934ft2 B-5 D-45 (n=92)
Base Elec 2025ft2 B-3 D-47 (n=3)
Base Gas 1870ft2 B-5 D-35 (n=59)
Base Elec 1613ft2 B-3 D-7 (n=152)
BaseES Gas 2007ft2 B-2 D-19 (n=159)
BaseES Elec 1684ft2 B-1 D-13 (n=99)
EStar Gas 1507ft2 B-4 D-38 (n=45)
GBill Gas 1751ft2 B-5 D-21 (n=246)
BaseES Gas 1549ft2 B-4 D-37 (n=79)
BaseES Elec 1541ft2 B-1 D-3 (n=58)
Base Elec 1947ft2 B-3 D-8 (n=120)
BaseES Elec 1957ft2 B-1 D-28 (n=21)
EStar Gas 2572ft2 B-5 D-18 (n=84)
EStar Elec 1663ft2 B-1 D-49 (n=268)
EStar Gas 2685ft2 B-5 D-42 (n=88)
Base Elec 1511ft2 B-3 D-2 (n=13)
Base Elec 2025ft2 B-3 D-15 (n=3)
EStar Gas 3251ft2 B-1 D-41 (n=160)
BaseES Elec 2287ft2 B-1 D-14 (n=79)
Base Elec 1472ft2 B-3 D-48 (n=58)
Base Elec 1581ft2 B-3 D-17 (n=82)
EStar Elec 1427ft2 B-1 D-4 (n=298)
BaseES Elec 1664ft2 B-1 D-29 (n=73)
GBill Gas 2998ft2 B-5 D-46 (n=81)
Base Elec 1532ft2 B-3 D-30 (n=56)
Base Elec 1611ft2 B-3 D-23 (n=110)
EStar Elec 1547ft2 B-1 D-5 (n=269)
GBill Gas 3594ft2 B-5 D-43 (n=23)
Base Elec 1531ft2 B-3 D-39 (n=76)
BaseES Elec 1791ft2 B-1 D-25 (n=94)
Base Elec 2694ft2 B-3 D-32 (n=80)
BaseES Elec 1367ft2 B-1 D-24 (n=159)
BaseES Elec 1039ft2 B-1 D-26 (n=233)
Base Gas 2558ft2 B-5 D-11 (n=82)
EStar Elec 1467ft2 B-1 D-6 (n=226)
Base Elec 1479ft2 B-3 D-16 (n=53)
Base Elec 1902ft2 B-3 D-31 (n=92)
Base Elec 2404ft2 B-3 D-22 (n=49)
BaseES Elec 2268ft2 B-1 D-27 (n=108)
GBill Gas 2452ft2 B-5 D-1 (n=89)
BaseES Gas 3377ft2 B-1 D-40 (n=14)
BaseES Gas 2241ft2 B-5 D-51 (n=32)
GBill Gas 2442ft2 B-5 D-50 (n=163)
EStar Gas 2359ft2 B-5 D-44 (n=1)
0.0
1.0
2.0
3.0
4.0
5.0
kWh/ft2
Baseline
Energy Star
Guar. Bill