Do ENERGY STAR® Homes Live Up to their Promoted Energy Savings?: A Comparison of Utility Bill Data for Recently Built ENERGY STAR and Control Homes in Alachua County, Florida

Eric Martin, Robin Vieira, Brian Hanson, Jeff Sonne, Florida Solar Energy Center
Pierce Jones, University of Florida
Kik Koppitch, Gainesville Regional Utilities
Sherman Phillips, Tom Gumber, Clay Electric Cooperative, Inc.

ABSTRACT

One of the most productive markets of ENERGY STAR homes has been the Gainesville metropolitan area of Alachua County, Florida. Since 1998 approximately 10% of all new single-family detached homes have been built to the ENERGY STAR level - a 30% improvement in energy efficiency from the National Model Energy Code using the Home Energy Rating System (HERS) methodology. This market penetration of ENERGY STAR homes in Alachua County has created a large number of homes experiencing the same climatic conditions.

This paper provides a statistical comparison of total household electric and natural gas use for ENERGY STAR homes and other new single-family detached homes built in Alachua County. A methodology was employed to disaggregate utility bills in order to determine energy used for cooling, heating, and other uses, which is explained in this paper. Utility data from Alachua County, FL ENERGY STAR homes are compared with the rest of the local population of new single-family detached homes within a defined square footage range. The range of estimated savings of ENERGY STAR over Control homes calculated using utility data for the years 2000 and 1999 is 36%-18% for heating, 16%-6% for cooling, and 10%-4% for total energy use.

Introduction

The Environmental Protection Agency developed the ENERGY STAR Homes program in 1995. Significant effort has been involved in determining methods of qualifying for the ENERGY STAR homes program and in informing builders and consumers about the program. The key advantage to builders is market differentiation. Their product will carry the recognized ENERGY STAR label while others will not. Consumers are usually informed that they will save more in energy costs than the increase in the mortgage payments due to energy-efficient measures. Financial partners offer rebates that may match the amount of any extra down payment required. Thus the marketing slogan, “more house for less money”.

Initially the only way to qualify for the ENERGY STAR program was to have an energy rater inspect and test the home according to national guidelines and determine that the home scores 86 or greater on the home energy rating scale. The scoring system is set up so that a home that meets minimal 1993 Council of American Building Officials – Model Energy Code (CABO MEC) would typically score 80.0, and every one-point increase in the score represents 5% savings. Thus, a HERS score of 86 would represent 30% savings of the items included in the score (heating, cooling, and water heating) over the 1993 CABO MEC

minimal code. More recently a sampling methodology has been implemented whereby only a small percentage of homes are individually rated, and regional builder option packages have been developed with which compliance is accomplished by following prescriptive guidelines.

Florida is unique in having a state legislated method of conducting a home energy rating. It is an extension of the Florida energy code that has been in place for over twenty years. The state code has been updated every three years and has usually been stricter than national MEC codes while also being more relevant to a climate where cooling is a larger concern than heating. The North Florida code (which includes Alachua County) has been particularly strict, having to respond to both heating and cooling, although the code offers significant credit for using gas heating and hot water. A 1500 square-foot house with a heat pump heating system and electric resistance hot water system that just meets the North Florida code will score an 82 on the HERS scale. Changing the heating and hot water systems to National Appliance Energy Conservation Act minimum gas appliances *on the same house* will result in the same HERS Score[1]. However, due to the code credit, the home with gas will exceed Florida code. In essence, the gas credit would allow for building envelope efficiency levels to be reduced to the point whereby a home may only score 79 on the HERS scale. The methodology of the Florida energy code differs from the HERS system and there is no one-to-one correlation that can be applied to all homes.

The Alachua County, FL market penetration creates an excellent opportunity for evaluation of ENERGY STAR homes. First, there are many homes in one climatic area. Second, the Control homes must meet the state Energy Code and are thus more consistent than those that may be found in other states. Third, to date, the ENERGY STAR homes have all been *rated* using one state-mandated procedure and thus there are no variables as to the method of EPA compliance or the rating method used. Fourth, almost all of the homes have been rated by one individual.

Distribution of Homes

A database was created of all *Alachua County single-family homes* built between January 1998 and December 1999 that were in the range of 1200 square feet to 4000 square feet. Utility data on these homes, along with an indication of whether the home had qualified for the ENERGY STAR designation, was supplied by two utilities that participated in this study: Gainesville Regional Utilities (GRU) and Clay Electric Cooperative (Clay). GRU serves gas to the majority of the Alachua County area and electricity to most city residents while Clay serves outlying areas and some city residents with electricity. There are very limited data available on the characteristics of non- ENERGY STAR homes outside of the utility bill information, however square footage of homes was obtained either from GRU or the property appraisers office for most homes. Although more data are available for the ENERGY STAR homes due to a rating database, analysis had to rely on information available for all homes: monthly electricity use, monthly gas use, and square footage.

[1] Determined using the EnergyGauge® Florida energy rating software.

The Database of Homes for Analysis

We selected only homes that had good data entries for each of twelve months for 1999, or for each twelve months of 2000 and placed them into two groups. To be included in the analysis, a home did not have to have good data for both years. For the most part, analysis of the two groups was handled separately. Homes that had good data for both years were included in both groups, while homes with only one year of good data were only included in one of the groups. Overall, there were 1074 homes that had twelve months of processed data for 2000 and 695 for 1999. The 1999 group contained fewer homes for in order to have 12 months of data in 1999, a home needed to be built and occupied in 1998. The 2000 group included homes built in 1998 or 1999. A number of these homes were then eliminated from further analysis because of peculiarities in the data. In some cases they were eliminated because their heating types could not be determined with a reasonable amount of certainty, or there was a strong suspicion of gas pool heating based on the data.

Creating Six Groups of Homes Based on Service and Heating Types

Since homes in Alachua County with gas service may be heated with an electric heat pump or a gas furnace, the data were tested in various ways to determine the type of heating system employed. The resulting distribution of the homes with "good" data and heating types is given in Table 1. Based on the number of homes available in each group, only the ENERGY STAR and Control groups with electric and gas service *and* gas heat were selected for analysis.

Table1. Groups of Homes Available for Analysis

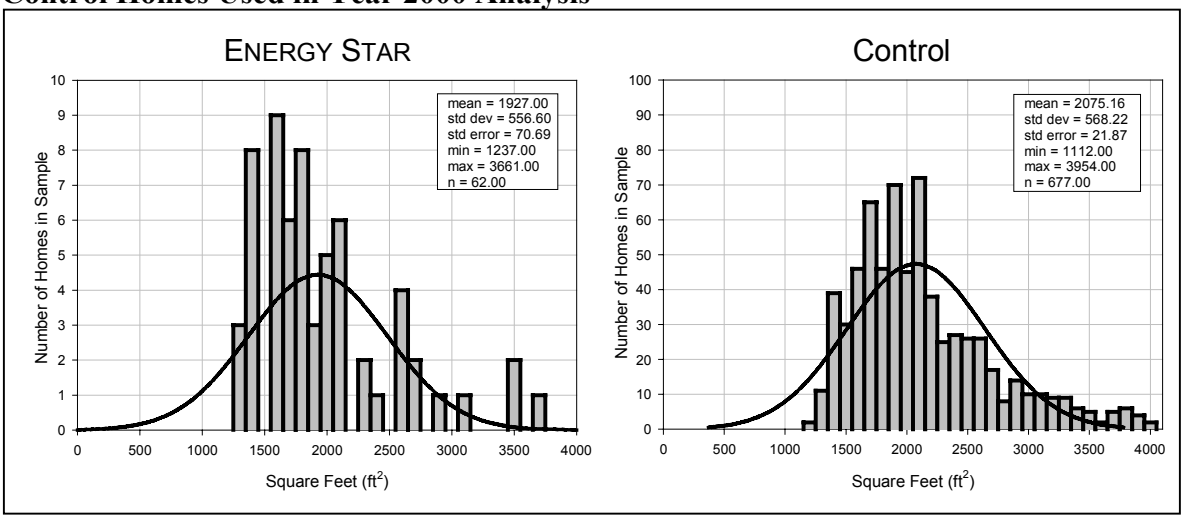
GROUP OF HOMES	Number for 1999	Number for 2000
Energy Star with electric and gas service and gas heat	**23**	**64**
Control with electric and gas service and gas heat	**402**	**688**
Energy Star with electric and gas service and electric heat (heat pump)	1	1
Control with electric and gas service and electric heat (heat pump)	2	4
Energy Star with all electric service	9	13
Control with all electric service	209	133

In the interest of space, only plots that contain results for year 2000 will be displayed in this paper. Any differences seen in data for year 1999 are communicated within the text.

Distribution of Home Size

Square footage of each home was either provided by GRU or was obtained by the authors from the Alachua County property appraiser's office. The home size could not be obtained for 13 homes in 2000 and 7 homes in 1999. These homes were left out of all analysis dependant on square footage. Figure 1 shows the square footage distribution for the homes analyzed in 2000. It is important to note that the ENERGY STAR group had a slightly smaller average home size in 2000, yet had a slightly larger average home size in 1999.

Figure 1. Distribution of Square Footage for Alachua County ENERGY STAR and Control Homes Used in Year 2000 Analysis



Analysis

Error Estimation and Statistical Significance of the Groups

It is difficult to comment on the statistical significance of the distribution shown in Figure 1, or the number of homes employed in the study. Rather than using a representative sample to draw conclusions about a population, this study involves data available on the population itself. Therefore, there are not errors present due to sampling, however there are un-quantifiable errors due to the lack of detailed data on the characteristics of each home. There are also errors present inherent to the methodologies applied to quantify energy end uses. Results shown in this paper may in no way correlate to ENERGY STAR and Control homes in a different market sector.

Determining Cooling Energy Use

Figure 2 shows that the ENERGY STAR homes used less electrical energy during the summer months. A similar trend was also observed in year 1999 data. Cooling energy use was determined by taking the lowest monthly electrical consumption of each home as its base and totaling all electrical use above that amount during the cooling months. Cooling months were determined to be June-September for 2000, and May-September for 1999 based on temperature data and observations of many of the utility bills.

Determining Portion of Bill Due to Heating Energy Use

The portion of the gas bill attributed to heating was determined by examining the lowest monthly gas consumption of each home and totaling all gas use above that amount for the winter months. Selection of winter months was based on monthly average temperatures and was determined to be Jan., Feb., Mar., Nov., Dec. for 2000; and Jan., Feb., Nov., Dec. for 1999. Figure 3 shows the ENERGY STAR homes used less gas energy during the winter

months. A similar trend was observed for year 1999. Referring back to Figure 2, one can also see less electrical energy use in the ENERGY STAR homes during these winter months, possibly due to the air handler running at a lower speed and/or for shorter lengths of time. There was no attempt to estimate the electric savings during the heating season.

Figure 2. Comparison of Monthly Average Electricity use in 2000 for ENERGY STAR and Control Homes

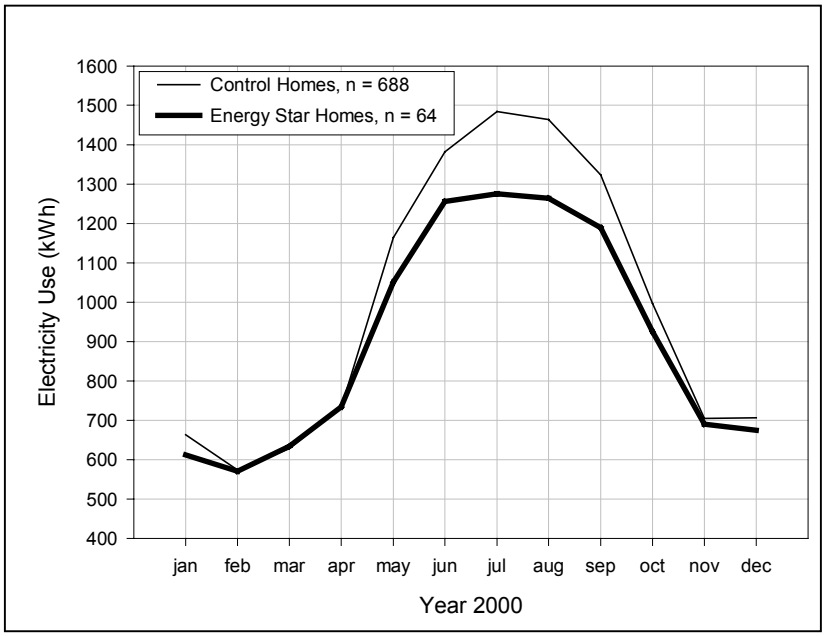
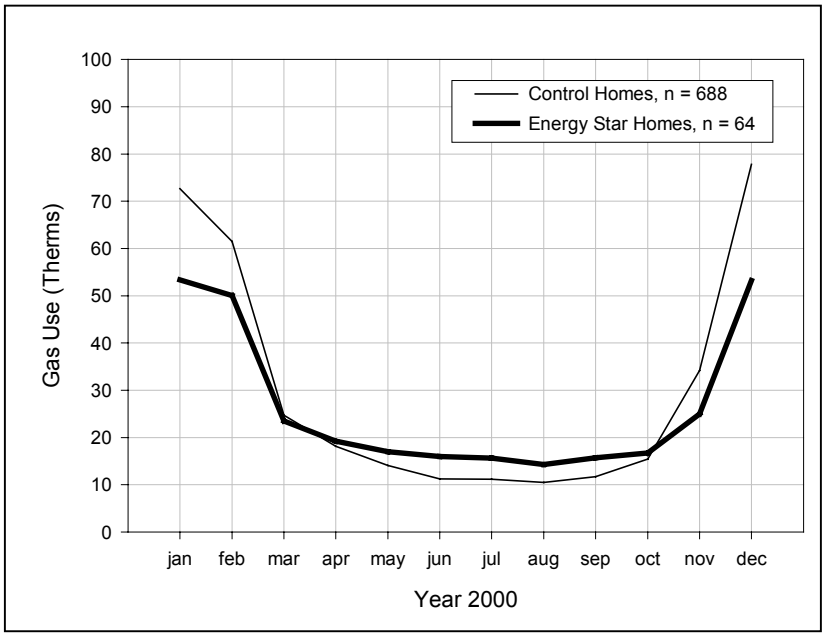


Figure 3. Comparison of Monthly Average Gas Use in 2000 for ENERGY STAR and Control Homes



Determining Non-Heating Gas Use

All gas use that was not allocated as space heating was labeled "non-heating gas use" (NHGU). In some homes, water heating is the only non-heating gas use and would represent 100% of the gas use during the non-heating months. Utility advisors in Alachua County indicated that all homes with gas service have gas water heaters. However, there are other gas uses that can make this estimation less than exact. Other gas use could be due to ranges, fireplaces, outdoor barbeques, dryers and pool/spa heating. The last two end-uses could represent large quantities of energy. Dryer use is difficult to depict as it occurs throughout the year. Pool heating is assumed to occur more often in spring when the desire to swim is strong but the pool is still cooler than desired. Analysis did yield some likely gas pool heating use and those homes were eliminated as described above. Alachua County advisors also informed the authors that there are few homes with gas dryers. Although gas ranges are believed to be in approximately 50% of the homes, breaking out which homes have gas ranges is not possible with the data available. Therefore, we applied all gas use that was not allocated as space heating to be "non-heating gas use" (NHGU). As shown in Figure 3, the ENERGY STAR homes used more gas in non-winter months than did the Control homes.

Total Energy Use

End use data expressed in therms and kWh were converted to site use Mbtu and added together. Table 2 shows the annual Mbtu by end use for 1999 and 2000. In 2000, the ENERGY STAR homes analyzed used 36% less energy for heating and 16% less energy for cooling than the Control homes. However, energy used for NHGU is 21% higher than the Control homes. When the three components are summed together, ENERGY STAR homes used 13% less energy than the Control homes for heating + cooling + NHGU. Looking at total overall electric and gas use, ENERGY STAR homes used 10% less energy than the Control homes. Saving percentages in 1999 were lower in magnitude than the 2000 data.

Table 2. Average Energy Consumption of ENERGY STAR and Control Homes by End Use

End Use	Year	ENERGY STAR (Mbtu)	Control (Mbtu)	% Savings
Heating	2000	13.63	21.40	36
	1999	13.62	16.51	18
Cooling	2000	11.72	14.01	16
	1999	11.43	12.18	6
NHGU	2000	19.31	16.01	-21
	1999	17.13	14.66	-17
Heat+Cool+NHGU	2000	44.66	51.42	13
	1999	42.19	43.36	3
Total	2000	70.06	77.76	10
	1999	70.03	72.58	4

Energy Consumption and House Size

The correlation between energy consumption and house size was examined for the two groups. Figures 4 and 5 show the relationship of electrical and gas usage, respectively, versus house size. The correlation between electrical consumption and square footage is relatively strong compared to the relationship between gas consumption and square footage, which is extremely weak. This possibly indicates that heating was not the primary overall driver of the gas bill for ENERGY STAR homes in 1999 and 2000.

Figure 6 depicts an average of monthly electrical consumption per 1000 square feet for each group. The summer cooling season savings of the ENERGY STAR homes are very obvious in the 2000 data. Off-season consumption is slightly higher on a per square-foot basis for 2000, possibly due to the smaller average house size in the ENERGY STAR group. For unexplained reasons, the 1999 data tends to show no strong seasonal differences.

Figure 7 depicts monthly gas consumption per 1000 square feet, on average, for each group. The heating consumption is very pronounced for each group, each year. Consistent with Figure 3, the ENERGY STAR homes used more off-season gas than the Control homes.

Figure 8 illustrates the cooling portion of electricity consumption per square foot. The best-fit shows a slightly higher slope for the ENERGY STAR homes, but this is in part due to not forcing the same y-intercept for each group. The highest points plotted all belong to control homes. Similar trends were observed in year 1999.

Figure 4. Annual Electricity Use in 2000 vs. Square Footage for ENERGY STAR and Control Homes

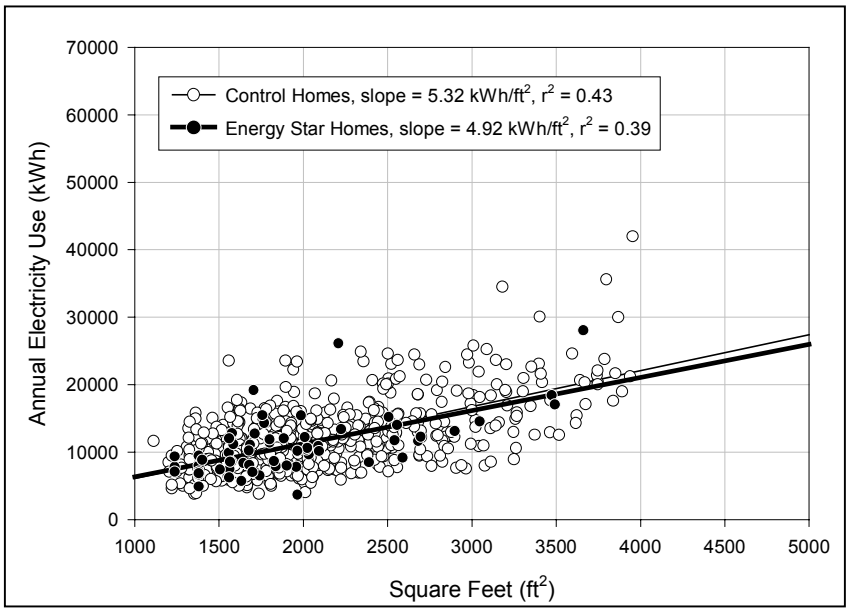


Figure 5. Annual Gas Use in 2000 vs. Square Footage for ENERGY STAR and Control Homes

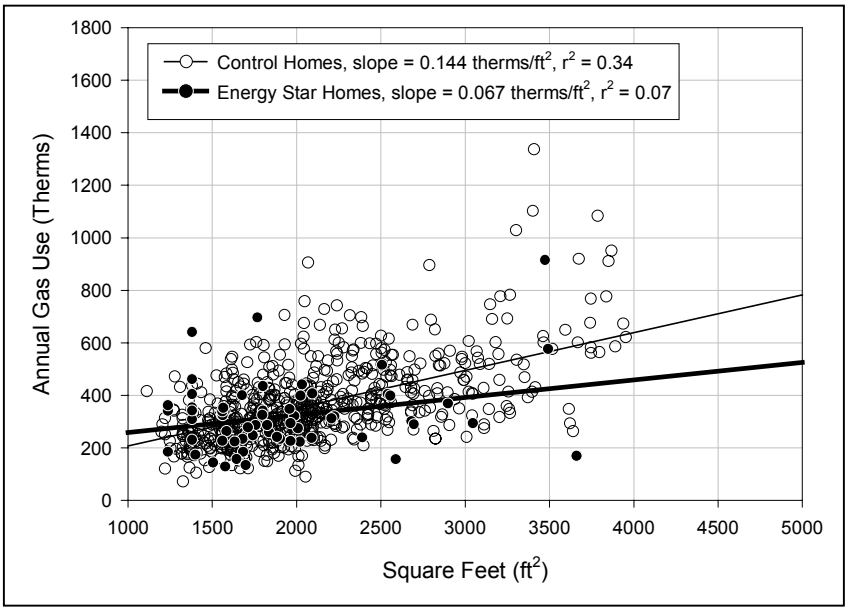


Figure 6. Comparison of Monthly Average Electricity Use in 2000 per Conditioned Square Feet for ENERGY STAR and Control Homes

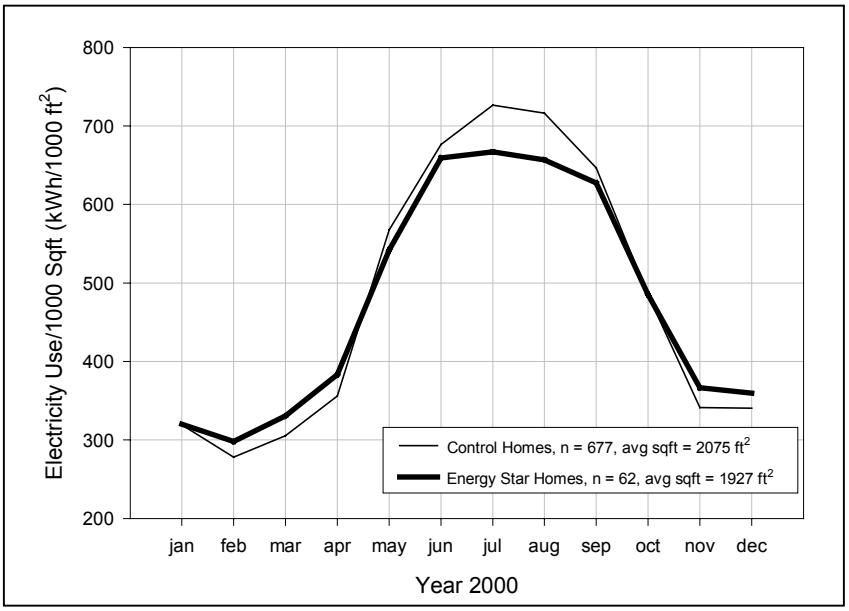


Figure 7. Comparison of Monthly Average Gas Use in 2000 Per Conditioned Square Feet for ENERGY STAR and Control Homes

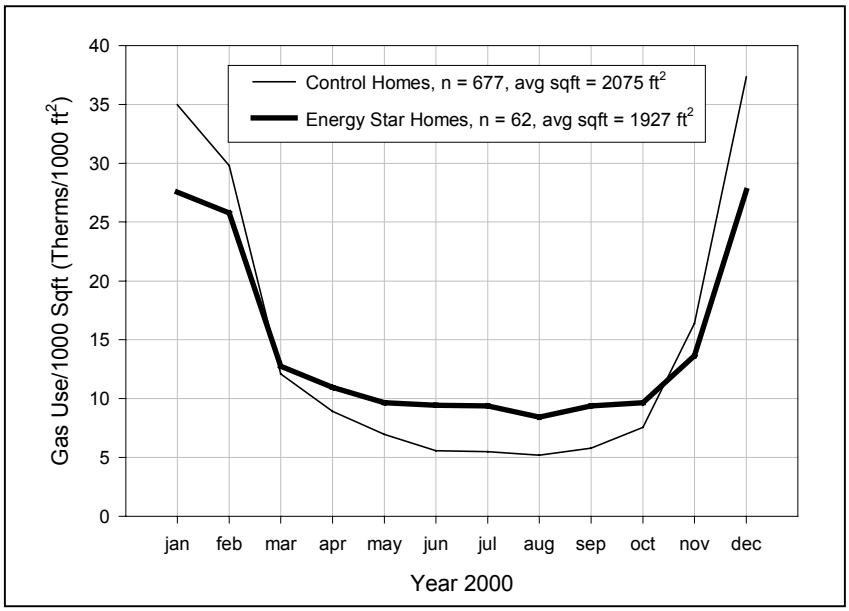


Figure 8. Annual Cooling Energy Use in 2000 vs. Square Footage for ENERGY STAR and Control Homes

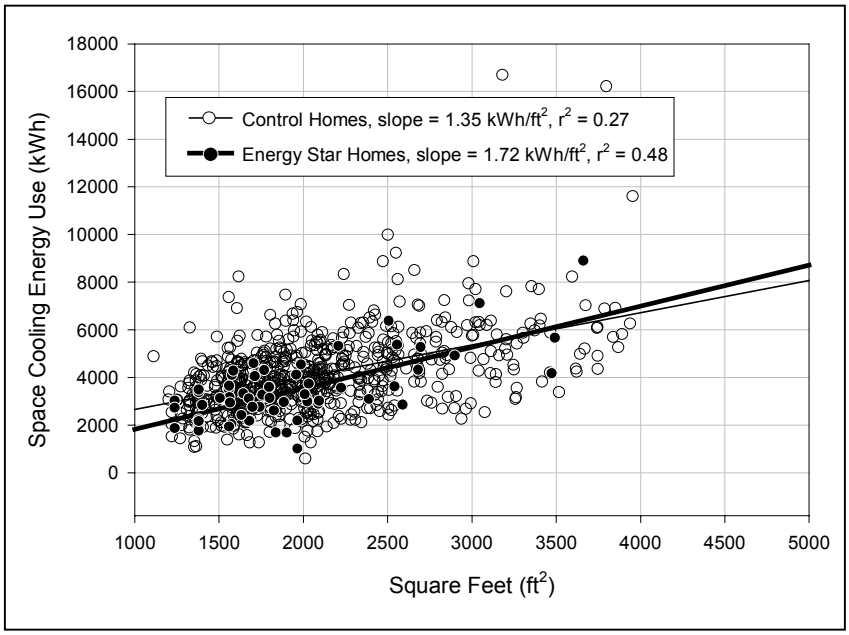


Figure 9 is a similar graph for heating. Control home heating use is visually greater than the ENERGY STAR group. Many control homes are above 200 therms, and some are above 400 therms, whereas only a few ENERGY STAR homes exceed 200 therms.

Figure 9. Annual Heating Energy Use in 2000 vs. Square Footage for ENERGY STAR and Control Homes

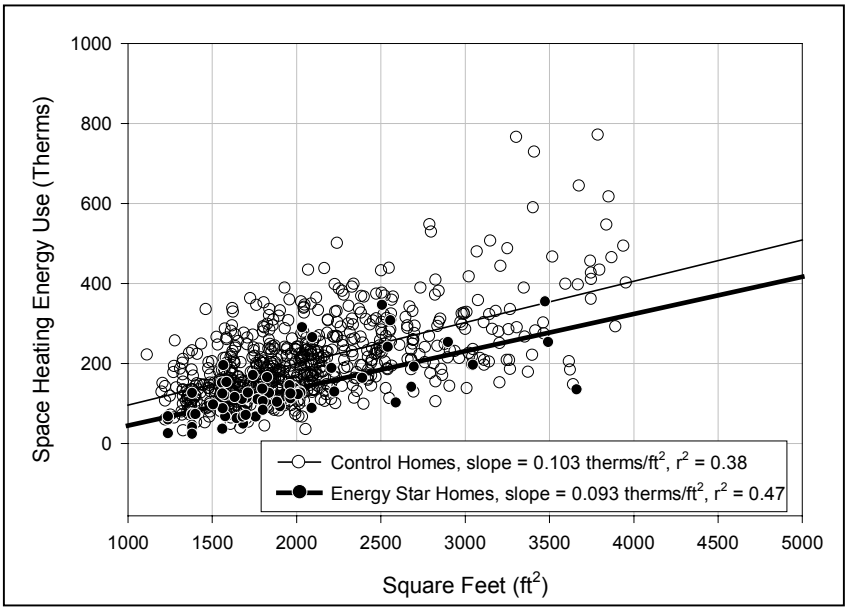


Table 3 shows results derived from the regressions described above for a 2000 square foot home. The table lists energy used for heating and cooling, along with percent savings of an ENERGY STAR home over a Control home. As seen in the table, the ENERGY STAR home saves 31% and 12% in heating and cooling energy, respectively, over a Control home with the year 2000 data. The ENERGY STAR home saves 23% and 11% in heating and cooling energy, respectively, over a Control home with year 1999 data.

Table 3. Percent Heating and Cooling Savings of a 2000 sqft. ENERGY STAR Home Based on Regression Analysis

End Use	Year	ENERGY STAR	Control	% Savings
Cooling (kWh)	2000	3535	4000	12
	1999	3131	3532	11
Heating (therms)	2000	138	199	31
	1999	122	158	23

Discussion

Overall, results show that ENERGY STAR homes save energy over Control homes in the Alachua County, FL market. How much energy should they save over the Control homes? Due to the available gas fuel code credit, it is possible that Control homes may score as low as 79 on the HERS scale. However, it is possible that many Control homes could score much higher, possibly even 86. Without undertaking an extensive Control home rating program, it is difficult to determine if the observed savings are consistent with program goals.

Cooling Energy and Electricity Use

In the North Florida climate zone, energy used for cooling is certainly the largest driver of electricity use during the summer months. As seen in Table 2, the ENERGY STAR homes used between 16% and 6% less electricity for cooling on average than the Control homes during 1999 and 2000. During periods of the year when the cooling system is not operating, it is expected that electricity use would be similar for both ENERGY STAR and Control homes that use gas for a heating fuel. This trend can be seen in Figure 2.

Heating Energy and Non-Heating Gas Use

In homes with gas heat, energy used for heating is the largest driver of gas use during the winter months in the North Florida climate zone. As seen in Table 2, the ENERGY STAR homes used between 36% and 18% less gas for heating on average than the Control homes during 1999 and 2000. Virtually all of the homes studied also use gas for water heating, therefore it was expected that both groups would use similar amounts of gas during periods of the year when the heating system is not operating. As seen in Figure 3, the ENERGY STAR homes used slightly more gas than the Control homes during the non-heating season. This trend could be due to differences in average home size between the two groups, as well as other unknowns such as occupancy characteristics and saturation of gas appliances.

Factors Influencing Energy End Uses

Overall electrical consumption, as well as the portions used for cooling and lighting end uses, is usually somewhat related to the square footage of the home. Cooling energy use is generally not as well correlated with home size as heating energy use. Cooling energy is highly dependent on internal loads and solar gain from windows which do not uniformly vary with home size, while heating energy use is usually highly related to the amount of area exposed to the inside-outside temperature difference. Although none of the data regressions produced very strong correlation coefficients, the relationship between total gas use and home size for the ENERGY STAR homes was found to be the weakest. Other statistical analysis indicates the presence of a relationship to home size is significant at the 99.9% level for all graphed end uses except ENERGY STAR home total gas use.

Other factors that influence energy end uses could explain why this relationship is weak for the ENERGY STAR homes, as well as the tendency for the Energy Star homes to use more gas during the non-heating season. Water heating energy is highly dependent on occupancy, and occupancy in single-family homes is not highly correlated with home size (Bouchelle et al. 2000; EIA 1999). Miscellaneous uses, such as ranges, dryers, and various plug loads are also not highly correlated with home size. Thus a small home with a greater number of occupants will typically use more energy per square foot than a large home with fewer occupants. On one hand, the ENERGY STAR group was shown to have a smaller average home size in 2000 than the Control group. This fact, coupled with the unknown saturation of gas appliances across homes studied, could lead to a higher gas use per square foot in the ENERGY STAR group. In addition, occupancy characteristics of the homes studied are not known. If indeed occupancy is greater in the ENERGY STAR homes, a higher baseline gas use (NHGU) would be expected.

Additional Data Collection and Analysis

New data including year 2001 energy usage, occupancy, and saturation of gas appliances should be collected and combined with existing data in order to increase confidence in the results. A large variance was observed in homes above 3000 square feet, thus reducing the current home size range might eliminate some outliers that could bias the data. Also, one particular subdivision of low-income ENERGY STAR homes may have high occupancy per square foot, resulting in high water heating use without high heating use. Obtaining occupancy data and eliminating smaller homes would reduce such possible bias.

This research does not attempt to ascertain market penetration of energy efficient technology due to the local presence of an ENERGY STAR program. More historic home audit and billing data, as well as other contributing factors, would need to be researched.

Conclusions

Monthly electric and gas consumption along with square footage data were collected and analyzed for the population of recently built single-family homes in Alachua County, FL. Methodologies were employed to separate the utility data into three major end uses: heating, cooling, and non-heating gas use.

Analysis indicates that ENERGY STAR homes use less electricity for cooling and less gas for space heating than Control homes. However, the ENERGY STAR homes appear to use more gas for non-heating end uses than the Control homes. Further data collection and analysis should be undertaken to increase the confidence in these results. An in depth study of Control home characteristics is needed to determine if the magnitude of ENERGY STAR savings is consistent with program goals.

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