EVALUATING THE ENERGY PERFORMANCE OF HERS-RATED HOMES USING ANNUAL COMMUNITY BASELINES

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BACKGROUND

The residential building sector accounts for a significant portion of US energy consumption (EIA 2009) and associated greenhouse gas emissions. The sector also offers substantial opportunities for efficiency gains and overall energy savings (Dietz 2010; Horowitz 2007). The federal government has promoted residential energy efficiency for decades. One of the earliest and best known programs, the Weatherization Assistance Program, targets existing homes. It was launched in 1976, following the 1973 oil crisis, to provide energy efficiency retrofits for low-income households.[1] Subsequent federal programs targeted efficiency in new homes, promoting the adoption of better home and system design, product specification and construction practices. This evolution of energy efficiency programs spurred and has been accompanied by a concerted effort to develop methods assessing performance, prioritizing practices and estimating expected benefits of efficiency gains.

Home energy ratings date back to the early 1980s when the mortgage industry sought to establish a method of incorporating energy efficiency features into home values. These efforts culminated in 1995 with establishment of the Residential Energy Services Network (RESNET), which developed the Home Energy Rating System (HERS) (Fairey et al. 2000). In the same year, the Environmental Protection Agency (EPA) launched its ENERGY STAR® certification program for newly constructed single-family homes. Also in the same year, the Federal Housing Administration (FHA) implemented its Energy Efficient Mortgage (EEM) program designed to help homebuyers save money on their utility bills by improving their home's operating efficiency. The EEM program is intended to enable homebuyers to finance energy efficiency measures as part of their mortgage by stretching the debt-to-income ratio limits on loans. In essence, borrowers are allowed to qualify for larger loan amounts, insured by FHA, to purchase energy-efficient (i.e., superior energy performance) homes.[2,3] Home energy ratings "verify" the efficiency of qualified homes:

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"To get an EEM a borrower typically has to have a home energy rater conduct a home energy rating before financing is approved. This rating verifies for the lender that the home is energy-efficient."[2]

Over the last 15 years, federal, state and utility residential energy efficiency programs have continued to develop and expand. While some are prescriptive, the most highly regarded are based on HERS scores. Of these programs, the best known are the ENERGY STAR Qualified New Homes and the Department of Energy's (DOE) Building America and Builder's Challenge programs. These programs set goals ranging from 15 to 30% energy savings relative to conventionally built homes.[4,5]

HERS relies on modeled performance using software accredited by RESNET to generate a HERS score (or index). A complete HERS rating includes a comprehensive floor plan review; specification of insulation values, lighting efficiencies, window types, and mechanical system efficiency ratings; an on-site thermal bypass inspection of the insulation and building envelope before drywall is installed; performance tests of building envelope air tightness (blower door test) and HVAC ductwork leakage (duct blaster test); and finally, a modeled energy analysis. The HERS rating process continues to be the most recognized and accepted tool in the mortgage industry for qualifying (i.e., verifying) energy performance and for assessing the relative energy efficiency of homes.[6]

While it is understood that the fundamentals of the HERS process, and programs that rely on it, are based on sound building science principles, few studies have evaluated how program implementation, regional impacts and occupant behavior affect actual homes' absolute and relative energy consumption (i.e., performance) and the expendable income via reduced utility bills on which energy efficiency mortgages are predicated. In a seminal study evaluating post-occupancy home performance, Smith and Jones (2003) found that the annual energy consumption of ENERGY STAR Qualified New Homes in one neighborhood was significantly lower (~12% less) than comparable conventionally built homes. Later studies suggested that the performance of the same homes had deteriorated over the first ten years of occupancy (Jones and Vyas 2008; Jones, et al. 2010). If this was indeed the case, loans under the EEM program may actually have been less secure than anticipated.

OBJECTIVES

This paper examines the energy performance of homes participating in various energy efficiency programs for new residential construction with the objective of assessing whether HERS-rated performance is a reliable indicator of post-occupancy energy performance. Specifically, it measures the consumptive use data of over 400 homes in Gainesville, Florida that were HERS rated between February 1998 and July 2008 for participation in green building programs(including ENERGY STAR, Building America, and Builder's Challenge). Florida's first ENERGY STAR home (in Gainesville) was constructed in 1997 and HERS rated in 1998. On average over the next ten years, 160 homes were scored annually in Gainesville and Alachua County using the HERS protocol. By 2008, over 1,600 homes in the area had been HERS rated (Figure 1). Since the first builder to construct an ENERGY STAR home in Gainesville (Howard Wallace) had his home rated in 1998, nearly 100 builders in the county have done the same, using HERS to score their homes. Our objective is to evaluate the performance of these HERS-rated homes using metered energy consumption data provided by local utilities. Findings are critical to validate investments in performance via energy efficiency mortgages.

METHODS

This study analyzes a decade of energy performance data of HERS-rated homes in the Gainesville, Florida area using the *Annual Community Baseline* (ACB) protocol, a multivariate regression analysis technique described by Jones et al. (2010). ACB fundamentally relies on access to monthly energy consumption and building attribute data. Gainesville Regional Utilities (GRU) provided electric and natural gas consumption data and the Alachua County Property Appraiser provided housing characteristics data. Additionally, the Florida Solar Energy Center provided data on HERS-rated homes in Alachua County, Florida. Finally, 2001-2010 monthly electricity prices for Gainesville, Florida were retrieved from Florida Municipal Electric Association (FMEA) archives and were used to create annual, nominal energy cost averages for the study population.[7] Data fields used in this analysis are listed in Table 1.

Household monthly electric and natural gas consumption were combined and expressed in units of equivalent kilowatt hours[8] (ekWh) to quantify total annual energy use. Annual energy consumption data were normalized to reflect the full calendar year by taking average daily use for the number of days recorded (between 350 and 380 days) and multiplying by 365 days. Residential units consuming less than 3,000 ekWh per year or more than 65,000 ekWh per year were considered to be either unoccupied or outliers, and were excluded from the analysis.

The ACB model uses heated area of the home (a statistical measure of conditioned floor area, number of bedrooms and number of bathrooms), vintage (based on construction date) and census block (a proxy for building construction and behavioral characteristics) in a regression as predictors of annual energy use for single-family detached homes in the GRU service territory. Residual values (the difference between the measured and ACB-predicted values) of all HERS-rated homes and performance of homes constructed by each HERS builder are tested against those of the rest of the population of Gainesville homes. These residual values represent annual energy savings (Jones, et. al. 2010). Annual savings estimates are reported as average energy savings in ekWh and dollars (i.e., homeowners' marginal energy costs avoided). All HERS-rated homes were tested for years 2001 through 2010 while builder subgroups were tested for years 2004 through 2010[9].

RESULTS AND DISCUSSION

Over the years of the study, the number of HERS-rated homes with sufficient data for analysis increased from 65 in 2001 to 409 in 2009, as increasing numbers of builders adopted HERS. These numbers reflect homes in GRU's electric service territory for which complete consumption records are available for the entire year of interest. The number of HERS homes with full data records drops from 403 in 2006 to 360 in 2008, then rebound to 409 in 2009. This variation in sample size is partially a result of the strict screening process for our analysis and partially a result of error in the utility's data collection process. Generally, HERS-rated homes in our sample follow a similar distribution by size relative to standard homes constructed during the same period, yet on average they were ~10% larger: 2,415 ft^2 vs. 2,174 ft^2, respectively (Figure 2). Average energy savings in HERS-rated homes steadily decreased over the study period, ranging from a high in 2001 (saving4,731 ekWh) to a low in 2009 (consuming an extra 53 ekWh) (Figure 3). Next, average annual (nominal) electricity rates were applied to the energy savings to estimate average dollars saved per home in each year. Monetary savings ranged from $396 in 2001 to an added expenditure of $7 in 2009 (Figure 3).[10]

Confidence intervals were then calculated for the expected range of annual mean energy savings (Figure 4). For those years in which the confidence interval does not include 0 (2001 through 2006), we can say with 95% confidence that HERS-rated homes, on average, performed differently than standard housing stock, and indeed provided energy savings. For years 2008 through 2010, however, there is no statistically significant difference between the average energy performance of HERS-rated homes and that of standard housing stock.

Next, HERS-rated homes were grouped by builder and savings estimates were computed against ACB for years 2004-2010. Figure 5 shows the annual savings estimates and sample sizes for the four builders with the most HERS-rated homes in our sample. Savings estimates among this subgroup vary as much as 7,795 ekWh/yr (2004) with the average range of estimates equal to 4,618 ekWh/yr for all years included in the study. This wide variation indicates that savings trends may be related to program implementation by different builders and that the correlation between HERS rating and reduced energy consumption/performance may be weaker than previously thought.

Finally, we examined 95% confidence intervals of the annual mean savings for builders 1 and 2, those with the highest numbers of homes rated across the study period. In Figure 6a, for those years where the confidence interval includes 0 (2004-2008), we fail to reject the null hypothesis that the energy performance of HERS-rated homes built by Builder 1 is equivalent to that of comparable, conventional housing stock. For years 2009 and 2010, we can say with 95% confidence that, on average, HERS-rated homes built by Builder 1 consumed *more* energy than standard housing stock. In Figure 6b, for those years where the confidence interval does not include 0 (2004, 2005, 2006, 2009 and 2010), we can say with 95% confidence that, on average, HERS-rated homes built by Builder 2 performed better than standard housing stock, and occupants realized annual energy savings. For 2008, although average savings is slightly positive, there is no statistically significant difference in energy performance of HERS-rated homes built by Builder 2 and that of standard housing stock.

Table 2 shows that the average size of homes constructed by Builder 1 was 2,785 ft^2, with 3.8 bedrooms and 2.9 bathrooms. These homes were 6.4 years old on average and consumed an average of 26,419 ekWh annually over the study period (2004-2010). Homes constructed by Builder 2 had an average size of 1,450 ft^2, with 3.4 bedrooms and 2 bathrooms. These homes averaged 9.3 years old and consumed an average of 17,107 ekWh annually over the study period. Figure 7 shows the distribution of home sizes for these two builders and for all HERS-rated homes in our sample.

Homes by Builder 1 are larger, more recently constructed homes that performed poorly compared to similar, conventional housing stock. Homes constructed by Builder 2 are smaller, older homes that performed better than similar, conventional housing stock. It should be noted that while homes built by Builder 1 were less energy intense, using 9.5 ekWh/ ft^2/year compared to 11.8 ekWh/ ft^2/year for Builder 2, they used over 9,000 ekWh/year more absolute energy. Although it is reasonable for absolute energy use to increase with home occupancy rates, homes by Builder 1 used over 1,600 ekWh/year more energy per "expected occupant"[11] while conforming to the same standards and being tested under the same rating system as homes constructed by Builder 2.

CONCLUSIONS

This study shows that average energy savings for HERS-rated homes in Gainesville, Florida have decreased over the past 10 years and have yielded no significant energy savings in recent years. As a result, no substantial and consistent monetary savings from reduced utility bills have accrued for the average HERS homeowner. In addition, differences in savings among builders indicate that variations in program implementation can yield significantly different results. Overall, findings of this study suggest that participation in programs that depend on HERS ratings is not a reliable indicator of post-occupancy energy performance. Additionally, both EEM lenders and EEM mortgage holders may be unduly burdened by the current context in which HERS is used as a basis to extend debt-to-income ratios when rated homes often provide only marginal energy performance returns.

With concerted efforts by builders, building scientists, engineers, mortgage industry professionals, and government agencies, a unified system was instituted to rate new homes for energy efficiency performance prior to occupancy. Although this system creates an accurate record of engineering specifications and laboratory test results, it does not provide reliable estimates or projections of actual, post-occupancy energy performance. The only way to accurately gauge the results of building practices is to examine the energy consumption history of “energy efficient” and standard homes.

If lenders want a true test of how well they might expect a given builder’s home to perform, it would be most helpful to review consumption history for similar homes constructed by the same builder in a given geographic area. If it is necessary to offer incentives to homebuyers who choose energy efficient homes, they should be linked to actual performance after a track record of reduced consumption and conservation behavior has been established. Under a performance-based structure such as this, homebuyers would be rewarded for wise choices with respect to both the built home *and* their consumption behavior. Homebuyers would also be doubly rewarded for reducing their debt-to-income ratio rather than for extending it. For energy efficient home mortgage programs to be successful there must be accurate, transparent measurement and verification of post occupancy savings related to these various programs and their implementation.

TABLES

TABLE 1: DATA FIELDS USED IN HERS-RATED HOMES PERFORMANCE ANALYSIS

Source	**Data Field**
Gainesville Regional Utilities	Consumption
	Consumption Type
	Meter Read Date
	Billed Days
Alachua County Property Appraiser	Conditioned Floor Area
	Number of Bedrooms
	Number of Bathrooms
	Census Block Number
	Construction Date
Florida Solar Energy Center	Rating Date
	Builder
Florida Municipal Electric Association	Monthly Electricity Prices

TABLE 2: DESCRIPTIVE STATISTICS FOR HERS HOMES CONSTRUCTED BY BUILDERS 1 AND 2 VS. ALL HERS HOMES.

	Size (ft^2)	Beds	Baths	Age (yrs)	Average Annual Energy Use (ekWh)
Builder 1(n=211)	2,785	3.8	2.9	6.4	26,419
Builder 2 (n=79)	1,450	3.4	2.0	9.3	17,107
All HERS homes	2,415	3.6	2.6	7.8	19,791

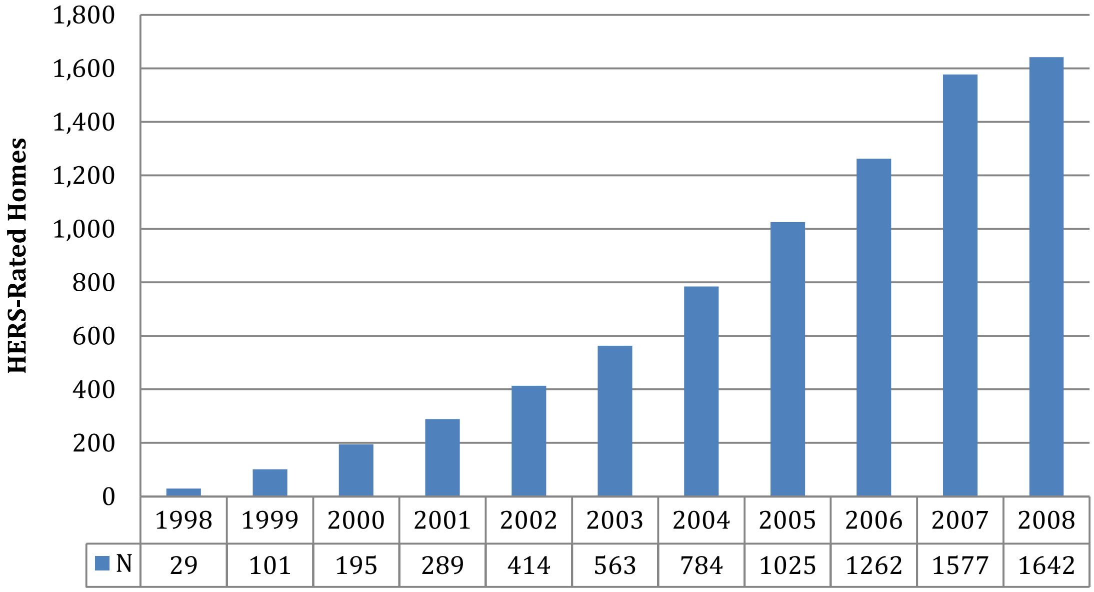


FIGURE 1: NUMBER OF HERS-RATED HOMES IN ALACHUA COUNTY, FLORIDA (FROM FEBRUARY 1998 TO JULY 2008).

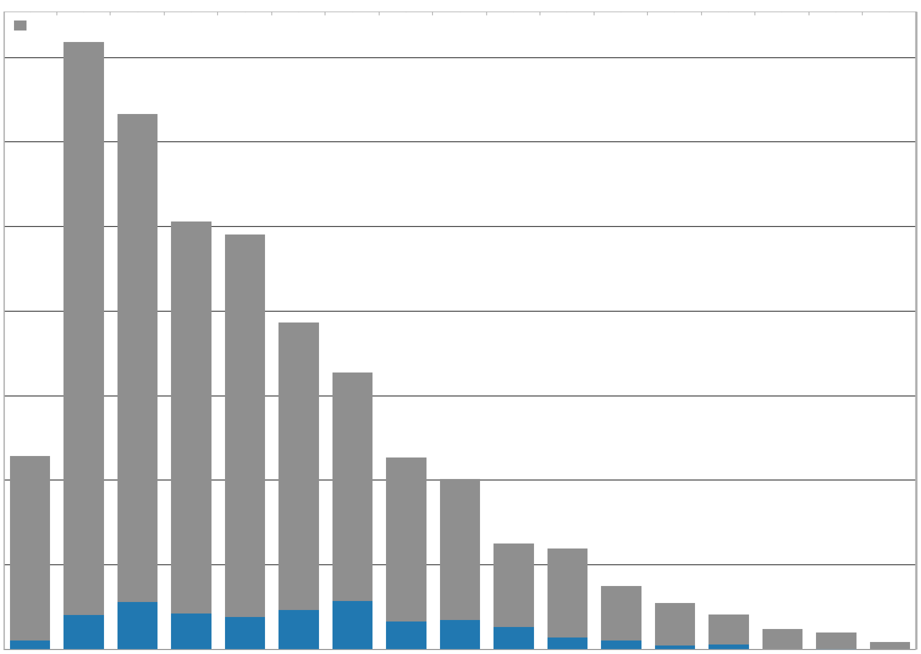
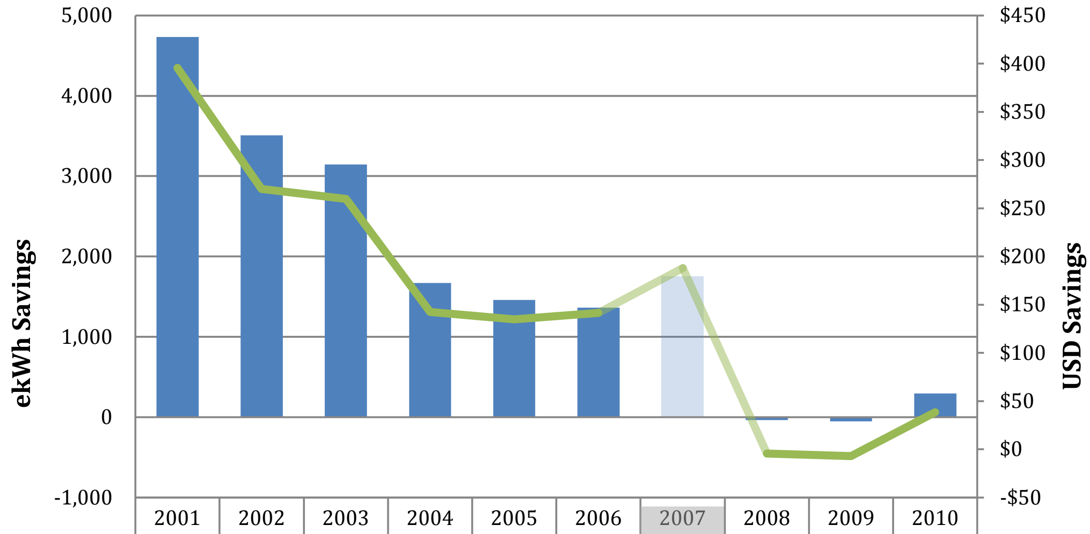
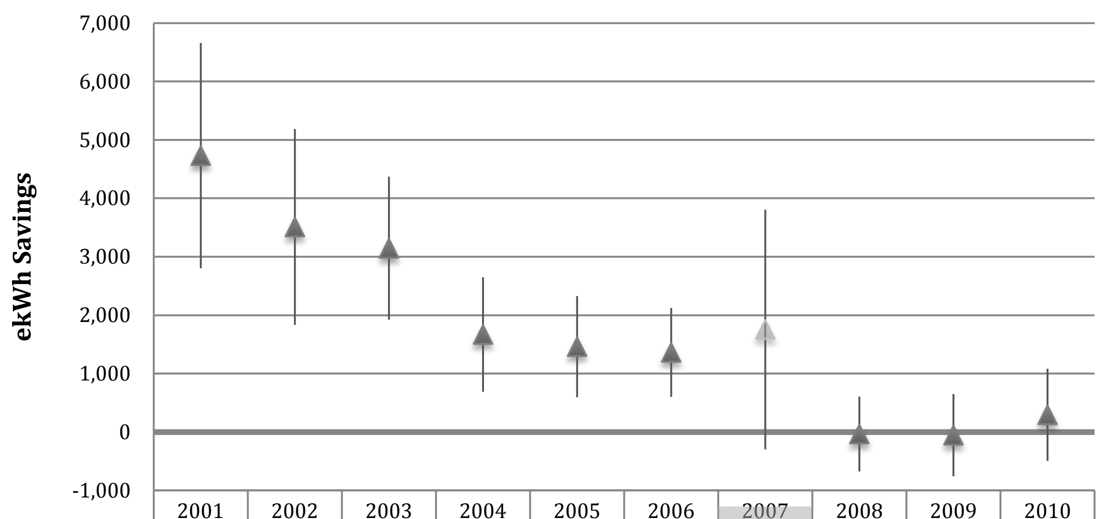


FIGURE 2: HISTOGRAM OF HERS-RATED VS. STANDARD HOMES BY CONDITIONED FLOOR AREA (FOR HOMES BUILT AFTER 1997).



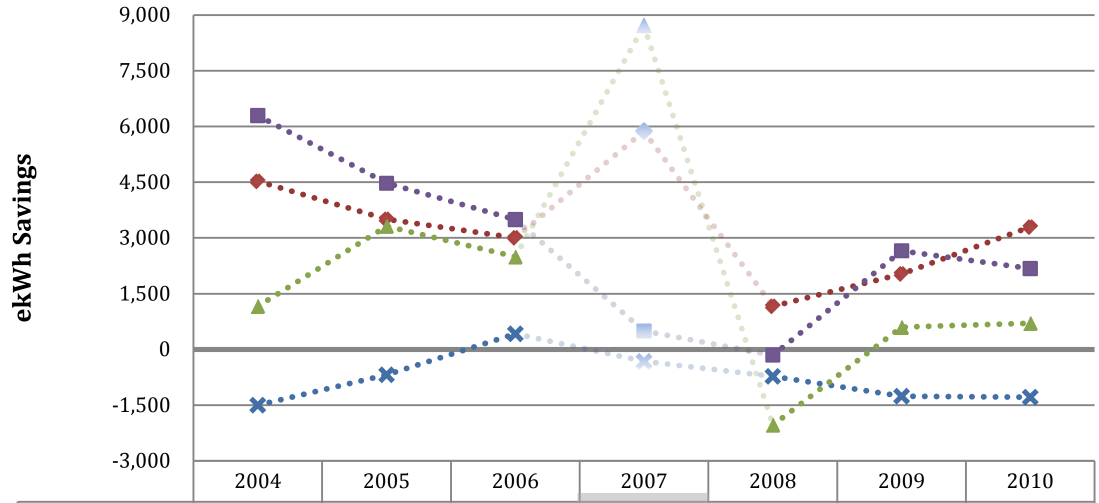
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
n	65	91	172	256	329	403	53	360	409	407
Savings	4,731	3,510	3,145	1,669	1,461	1,363	1,756	-34	-53	296
$ Saved	$396	$270	$260	$143	$135	$141	$188	-$4	-$7	$38

FIGURE 3: ANNUAL ENERGY AND UTILITY BILL SAVINGS ESTIMATES FOR GAINESVILLE, FLORIDA HERS-RATED HOMES.



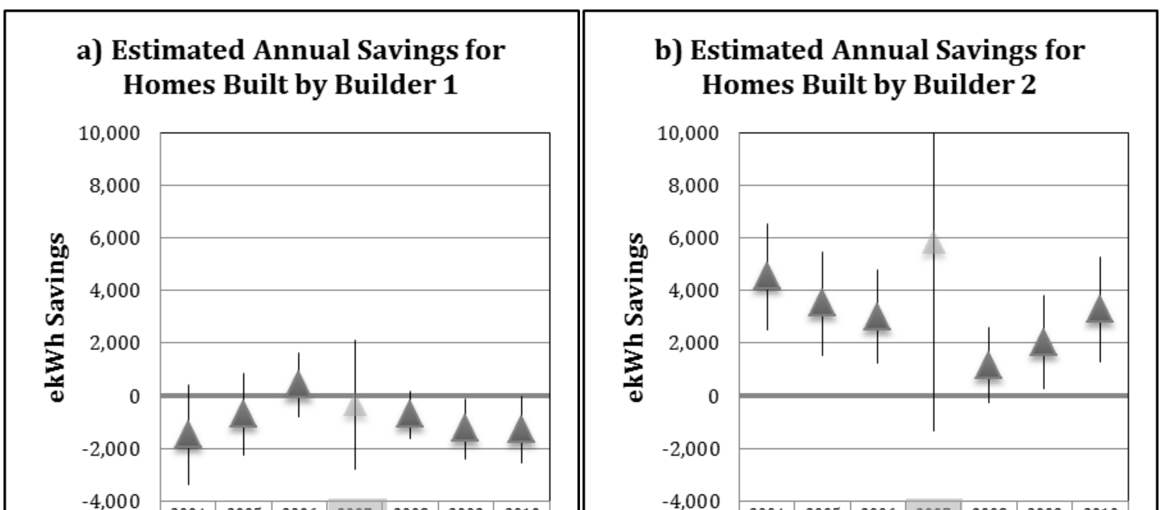
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Upper 95%	6,661	5,187	4,368	2,652	2,328	2,125	3,808	608	651	1,085
Savings	4,731	3,510	3,145	1,669	1,461	1,363	1,756	-34	-53	296
Lower 95%	2,801	1,833	1,921	687	594	601	-296	-676	-756	-493

FIGURE 4: ESTIMATED ANNUAL ENERGY SAVINGS FOR GAINESVILLE, FLORIDA HERS-RATED HOMES, INCLUDING 95% CONFIDENCE INTERVALS FOR THE MEAN.



	2004	2005	2006	2007	2008	2009	2010
Builder 1	-1500	-682	422	-323	-727	-1258	-1286
n(B1)	73	117	173	26	170	186	188
Builder 2	4524	3503	3006	5873	1163	2034	3293
n(B2)	65	74	79	3	70	75	73
Builder 3	1163	3317	2492	8715	-2031	598	706
n(B3)	22	25	27	3	16	31	27
Builder 4	6295	4472	3493	494	-153	2655	2178
n(B4)	3	9	16	9	19	13	16

FIGURE 5: AVERAGE ANNUAL ENERGY SAVINGS ESTIMATES FOR GAINESVILLE, FLORIDA HERS-RATED HOMES BUILT BY FOUR DIFFERENT BUILDERS.



	2004	2005	2006	2007	2008	2009	2010
Upper 95%	-3404	-2237	-784	-2776	-1648	-2393	-2535
Mean	-1500	-682	422	-323	-727	-1258	-1286
Lower 95%	404	874	1629	2130	193	-122	-38

	2004	2005	2006	2007	2008	2009	2010
Lower 95%	6541	5459	4792	13094	2597	3822	5297
Upper 95%	2506	1548	1221	-1348	-272	246	1290
Mean	4524	3503	3006	5873	1163	2034	3293

FIGURE 6: ESTIMATED ANNUAL ENERGY SAVINGS FOR BUILDERS 1 AND 2, INCLUDING 95% CONFIDENCE INTERVALS FOR THE MEAN.

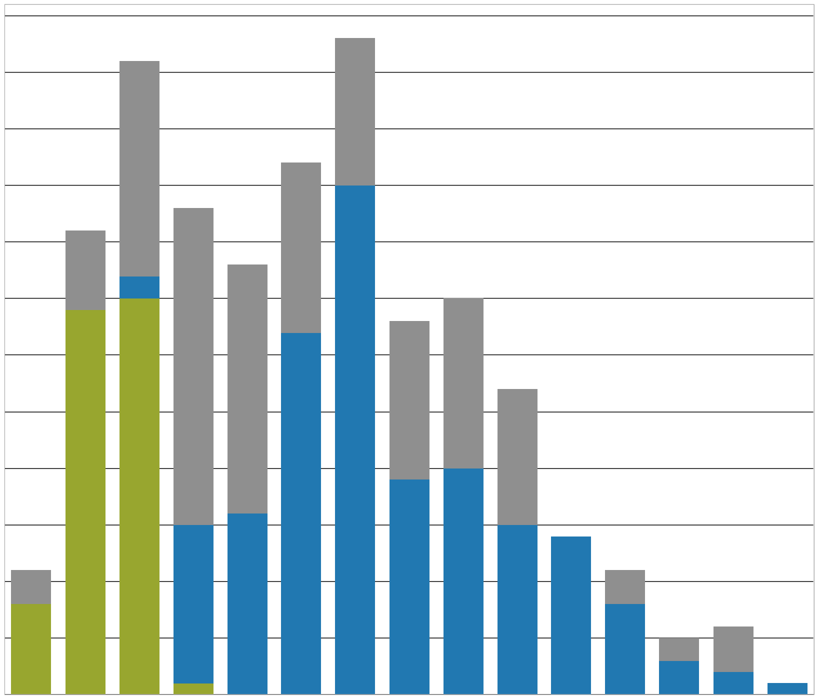


FIGURE 7: HISTOGRAM OF HERS-RATED HOMES BY CONDITIONED FLOOR AREA
(FOR BUILDERS 1 AND 2 VS. ALL OTHERS).

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NOTES

1 "Weatherization and Intergovernmental Program: History Of the Weatherization Assistance Program." Web. 13 Feb 2011. http://www1.eere.energy.gov/wip/wap.html.

2 "Energy Efficient Mortgages: ENERGY STAR." Web. 11 Feb 2011. http://www.energystar.gov/index.cfm?c=mortgages.energy_efficient_mortgages.

3 "HUD FHA Insured Energy Efficient Mortgages." 2011. Web. 11 Feb 2011. http://www.hud.gov/offices/hsg/sfh/eem/energy-r.cfm.

4 To qualify for ENERGY STAR, a home must meet strict guidelines for energy efficiency set by the U.S. Environmental Protection Agency. These homes are at least 15% more energy efficient than homes built to the 2004 International Residential Code (IRC), and include additional energy-saving features that typically make them 20–30% more efficient than standard homes. (12)

5 To meet performance criteria for Builder' Challenge homes must:

1. *Achieve a HERS Index of 70 or lower based on an energy rating using RESNET-accredited software (this is the number which appears on the E-Scale).*
2. *Meet the Builders Challenge Quality Criteria (BCQC), a set of best practices for durability, comfort, and* indoor air quality in homes.
3. Undergo verification by a third-party verifier who is a registered Builders Challenge partner. RESNET-certified Home Energy Rating System (HERS) raters and DOE Building Consortia team members qualify as third-party verifiers for the Builders Challenge. (2)

6 "What Is a Home Energy Rating? | RESNET." Web. 11 Feb 2011. http://www.resnet.us/home-energy-ratings

7 "Florida Municipal Electric Association." Archive Florida Electric Utility Rate Comparisons. Web. 11 Feb 2011. http://www.publicpower.com/archive_electricrates.shtml.

8 Natural gas therms were converted to British Thermal Units (BTUs) and then to equivalent kilowatt hours.

9 Years 2001 through 2003 were excluded from the evaluation of builder sub-groups because numbers of homes for individual builders were too low to produce an adequate sample size. In addition, Builder 4 only has 3 homes for 2004 but is included in results due to increased sample size in subsequent years.

10 Natural gas costs are not factored into monetary savings estimates, although they are partially captured by the conversion to equivalent kilowatt hours, which results in a best-case-scenario estimate of dollars saved via reduced utility bills.

11 If homes by Builder 1 were considered to have 4 bedrooms on average, at full occupancy we would expect there to be 5 residents. Usually this would be 2 adults and 3 children. The same goes for Builder 2 where we could conservatively consider homes to have 3 bedrooms on average, housing 4 residents. We calculated the average energy consumption per expected resident by taking average consumption and dividing by the average number of bedrooms plus one.