Aligning Incentives with Savings for Cost-Effective Residential New Construction Programs

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ABSTRACT

This study examines the relationship between predicted energy savings and the HERS Index – a metric often used as the primary determinant of residential new construction (RNC) program incentive levels – and helps program administrators understand how aligning incentives with savings increases the accuracy of predicted savings and improves cost-effectiveness. This study found that the correlation between HERS Index and savings is relatively weak, suggesting that program administrators that reward lower HERS Indexes have incentive structures that are misaligned with the desired outcome. The homes examined in this study were participants in the RNC program of a Midwest electric utility company in 2013 and 2014. Using a data set of over 1000 new homes, the authors performed a regression analysis comparing the relationship of the HERS Index to predicted energy savings. This relationship between HERS Index and predicted savings was determined separately for electric and gas savings. Given the weak correlation between HERS Index and savings, performance-based incentives that reward savings, rather than HERS index values, are likely to result in a more efficient use of program resources and yield a more cost-effective program.

Introduction

It is a widespread practice for utility programs to use the HERS Index as the primary determinant for program eligibility and incentive levels, but this may not be the best way to encourage builders to strive for deeper savings. The HERS Index has many advantages as a marketing tool: it's simple, widely understood by homebuyers and builders, and easily communicated in sales materials. However, because a 1,000 square foot cottage and a 6,000 square foot mansion can have the same HERS Index, and the Index is independent of fuel type, the HERS Index does not give specific insight into the electricity or gas savings from a given home. The HERS Index is a useful tool for potential homebuyers to broadly assess their choices, but it is not tied to an absolute savings amount.

Alternative program designs that directly reward savings rather than HERS Index may provide better alignment between incentives and claimed savings, allowing utilities to operate more cost-effective programs. Performance-based incentives can be designed to reward builders for each incremental unit of energy saved (e.g., base incentive plus $0.10/kWh). Performance-based incentives also encourage savings within incentive tiers. For example, with an incentive tier of HERS 61-70 there is no incentive to drive the HERS Index down below a 70 unless the builder can achieve an index of 60, but with performance-based incentives there is always an incentive to save more.

Methods

In this study we assessed the relationship between modeled energy savings and the HERS Index for a set of 1,854 homes that were approved in two states under the Residential New Construction programs of a major Midwest utility. Savings and HERS Index scores were determined using REM/Rate modeling software performed by independent HERS Raters. Savings were calculated using a reference home based on the 2009 International Energy Conservation Code (IECC) and federal minimum appliance and equipment efficiencies. Because of the small number of electrically heated homes submitted to the program, all of the homes in the sample use gas as the space heating fuel.

The correlation between modeled savings and HERS Index was investigated for gas and electricity savings. The strength of the correlations between HERS Index scores and modeled electricity savings (kWh) and modeled gas savings (kBtu) were determined by creating scatter plots with the associated R-squared values. We also created box and whisker plots for various HERS Index bins. These plots show the median savings value for each bin along with the distribution of savings.

The impact of house size on the correlation between HERS Index and savings was also investigated. A regression analysis was performed to investigate differences in the correlation between HERS Index and savings based on house size by creating trend lines for bins of less than 2,500 sq. ft., 2,500 to 3,500 sq. ft., and greater than 3,500 sq. ft. To further investigate the impact of house size, we controlled for house size by showing the distribution of savings per square foot for several HERS Index tiers.

To illustrate the wide range of savings that can occur from homes with the same HERS Index, we created a case study of three homes with high, medium, and low kWh savings. The REM/Rate files for the three homes were analyzed to determine what house characteristics impact savings the most including: house type, conditioned floor area, cooling equipment efficiency and capacity, and percent compact fluorescent lighting.

Results

Overall, there was a moderate relationship between HERS Index and savings. As expected, the correlation was stronger for gas savings since all homes have natural gas as the heating fuel. There was a very wide range in savings within HERS Index tiers and for a given HERS score. When controlling for square footage, we found very little difference in average electric savings for all HERS Index tiers. Square footage had a stronger impact on gas savings with average gas savings increasing as HERS Index decreases.

Correlation between HERS Index and Savings

The scatter plots showed moderate correlations between electricity savings and HERS Index, and gas savings and HERS Index. There is a large range of savings for a given HERS Index or HERS Index tier. The correlations between HERS Index and savings were stronger for gas savings, which is likely because of all homes having gas as the heating fuel in a heating-dominated climate. The scatter plots also show that large homes tend to have lower HERS Indexes as well as greater savings as compared to smaller homes.

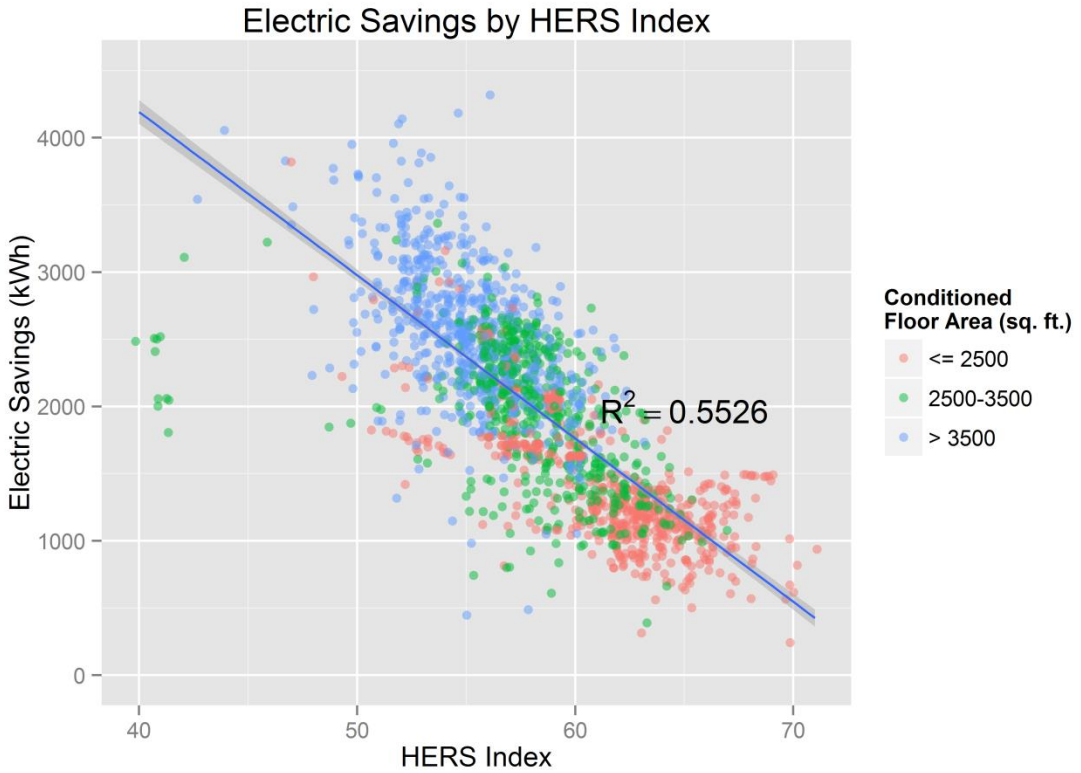

Figure 1. Electric Savings by HERS Index. A linear regression model shows a moderate percent variance explained between kWh savings and HERS Index with a high statistical significance ($P < 0.001$) for the 1,854 homes in the two-state sample.

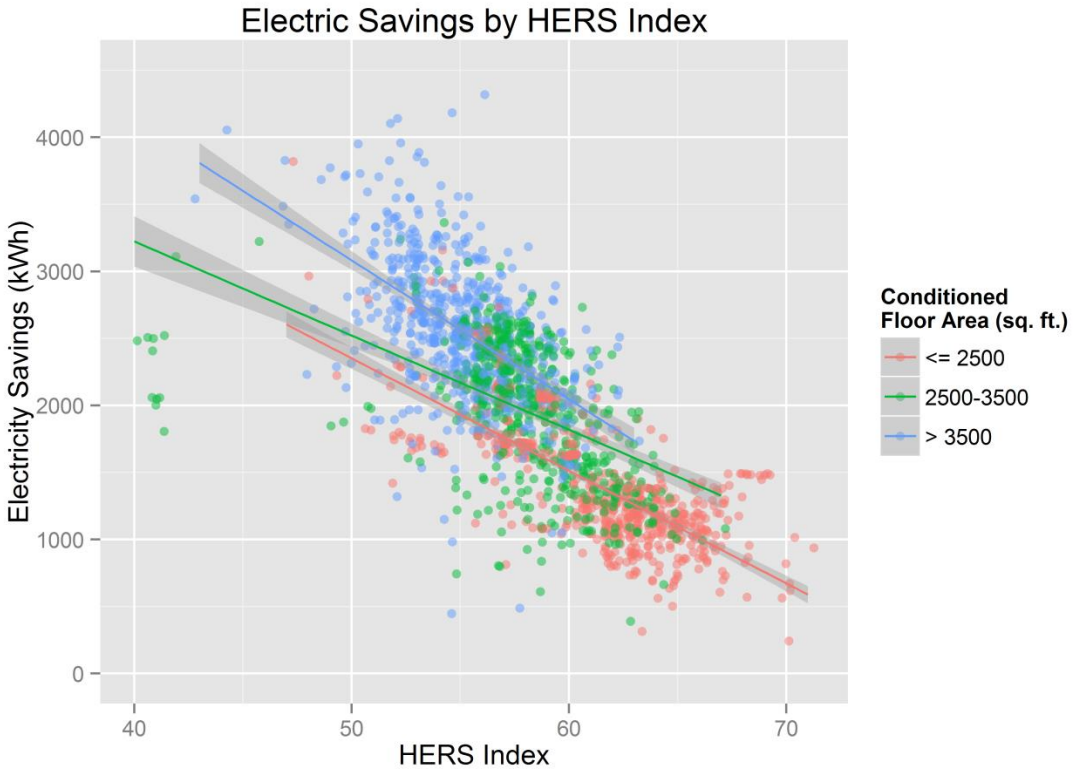

Figure 2. kWh Savings vs. HERS Index. Using a multiple linear regression model, the stratification of trend lines shows higher savings for larger homes than smaller homes with the same HERS Index. The slopes of the lines for the three square footage bins are different, indicating that the relationship between savings and HERS Index varies depending on house size.

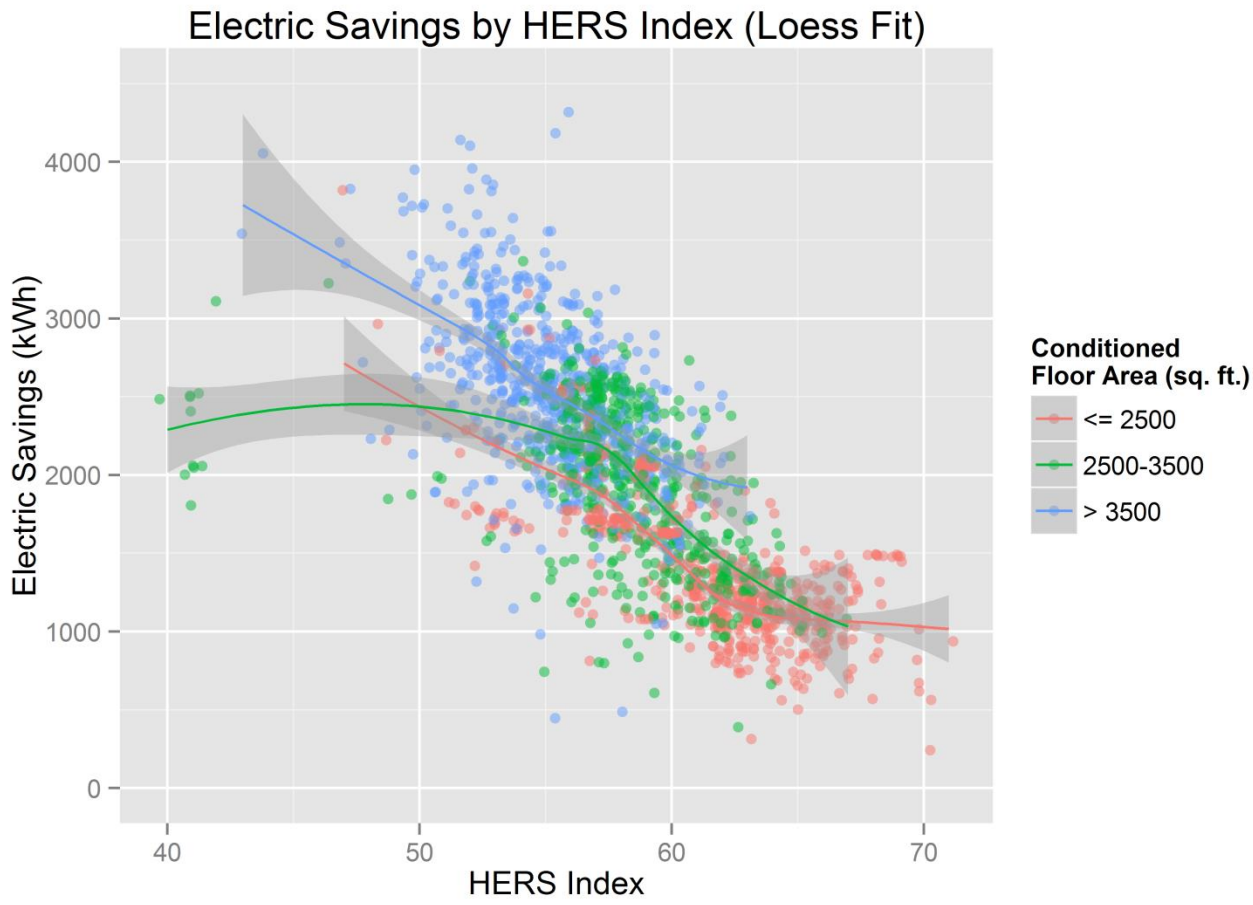

Figure 3. Electric savings by HERS Index: Loess fit model. The regression using a Loess fit model shows that the relationship between kWh savings and HERS Index is not linear, indicating unpredictability of savings based solely on the HERS Index.

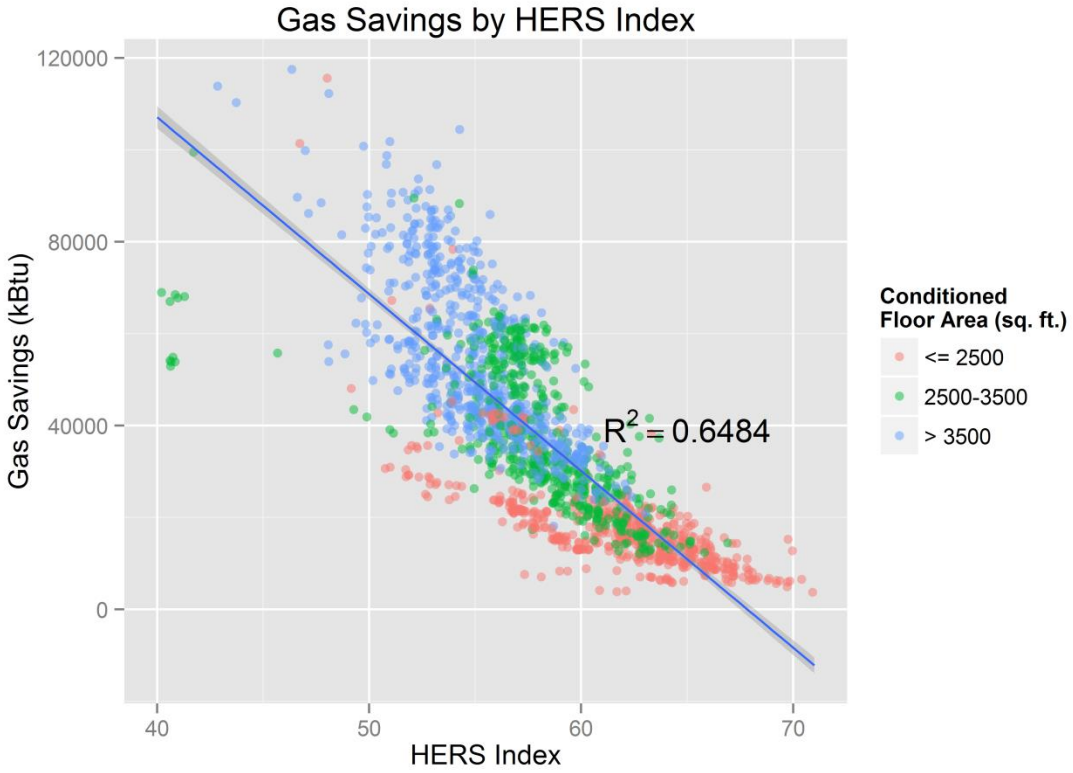

Figure 4. Gas Savings vs. HERS Index: Single Linear Regression Model. A linear regression model shows a moderate percent variance explained between gas savings and HERS Index with a high statistical significance ($P < 0.001$).

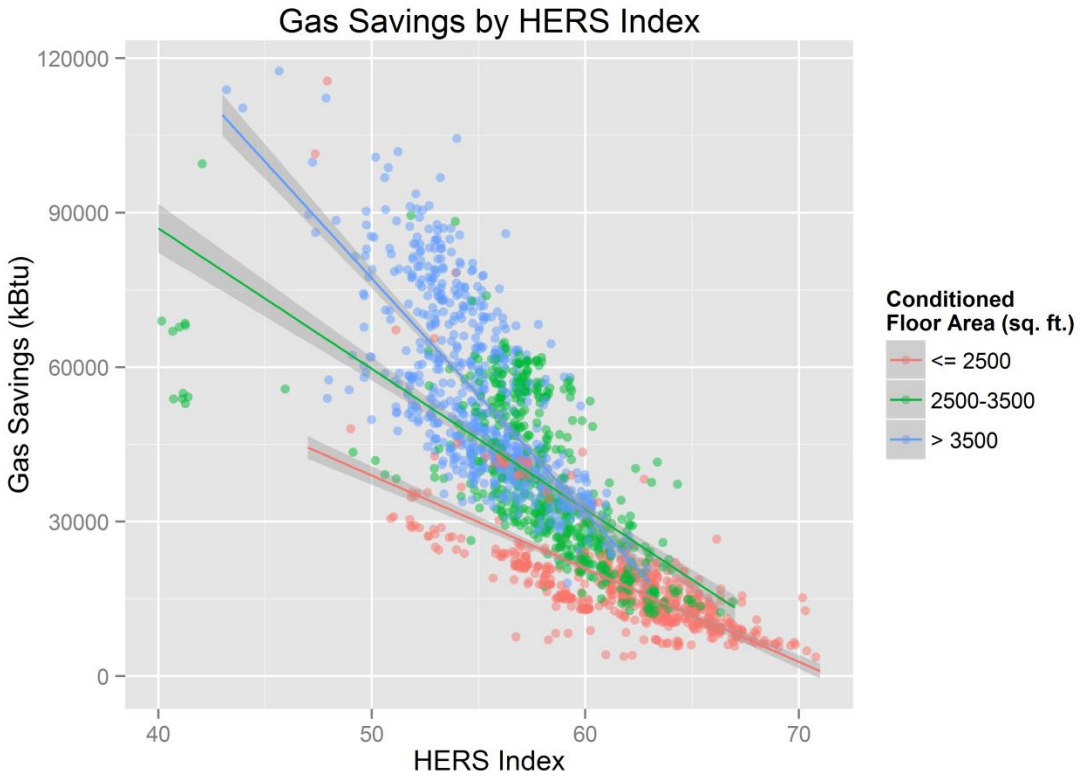

Figure 5. Gas Savings vs. HERS Index: Multiple Linear Regression. A multiple linear regression shows that gas savings are generally higher for larger homes than smaller homes with the same HERS Index. The varying slopes of the trend lines indicate that the relationship between gas savings and HERS Index is different depending on house size. Larger houses also tend to have lower HERS Indexes than smaller houses.

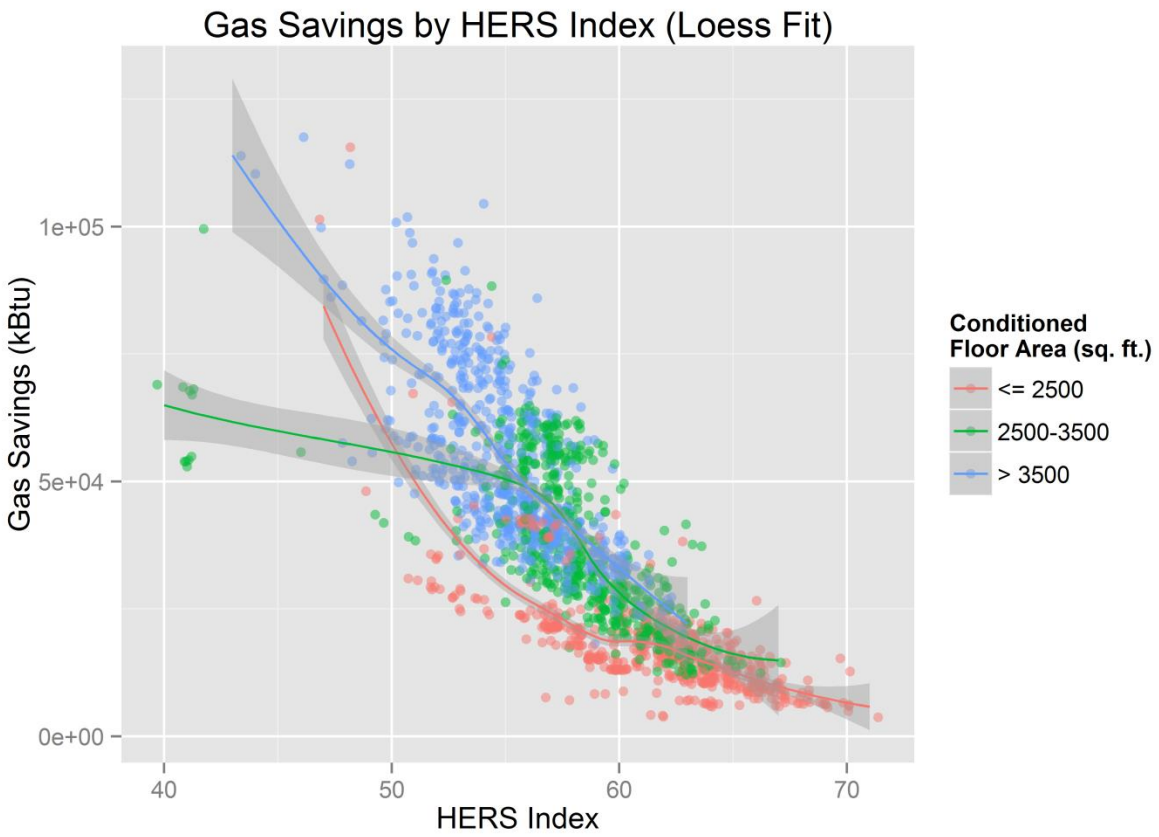

Figure 6. Gas Savings vs. HERS Index: Loess Fit Model. A Loess fit regression model shows that the relationship between gas savings and HERS Index is not linear and the shape of the curve varies by groups based on house size. This further demonstrates the unpredictability of savings based solely on the HERS Index.

Distribution of Savings

As expected, there is a general shift from lower savings to higher savings as the HERS Index decreases, but there is a large range within each tier with many outliers. However, when controlling for house size, the HERS Index does not appear to be a significant factor in determining electric savings. Gas savings are much better predicted by HERS Index as savings per square foot increases consistently as HERS Index decreases. The following two figures below show HERS Index tiers and the distribution of savings amounts within each tier. The subsequent figures show similar distributions, but savings amounts are controlled by house size (savings per square foot).

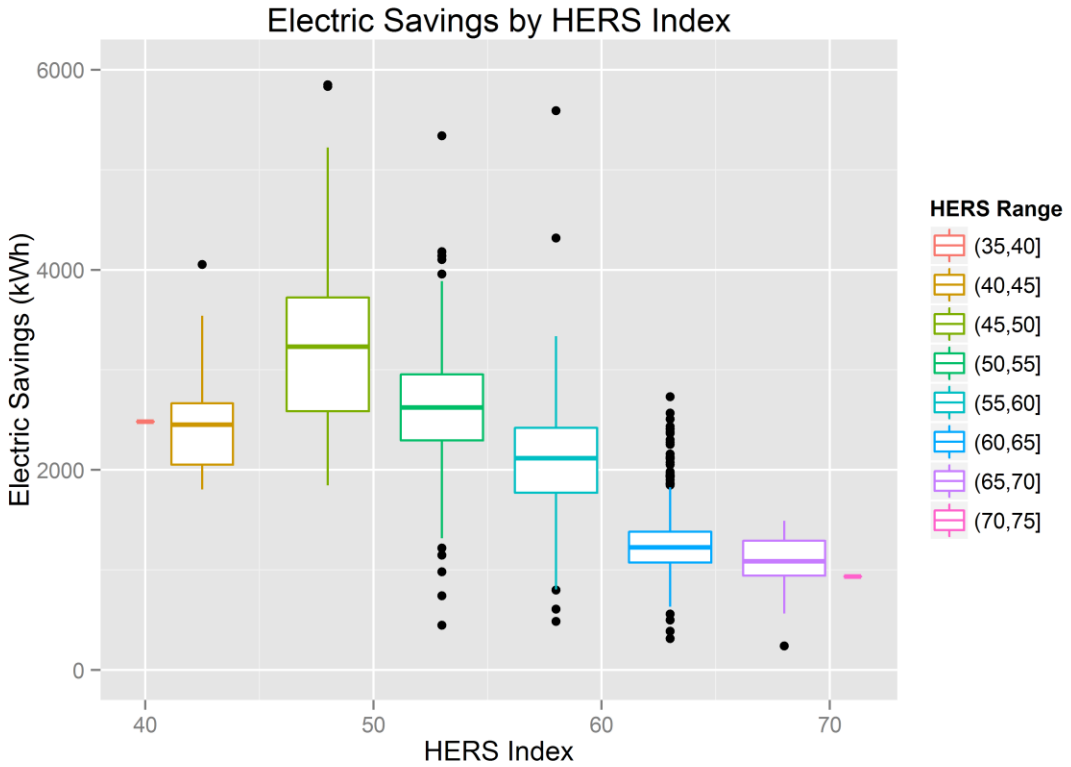

Figure 7. Distribution of Electric Savings by HERS Index Tier. With the exception of homes with HERS Indexes below 45, there is an overall trend of increasing savings as HERS Index decreases. The median savings increases for each tier from HERS 75 through 45. There is, however, a very wide range of savings for the most common HERS Indexes with a large number of outliers. Extreme outliers were removed to improve the legibility of the chart.

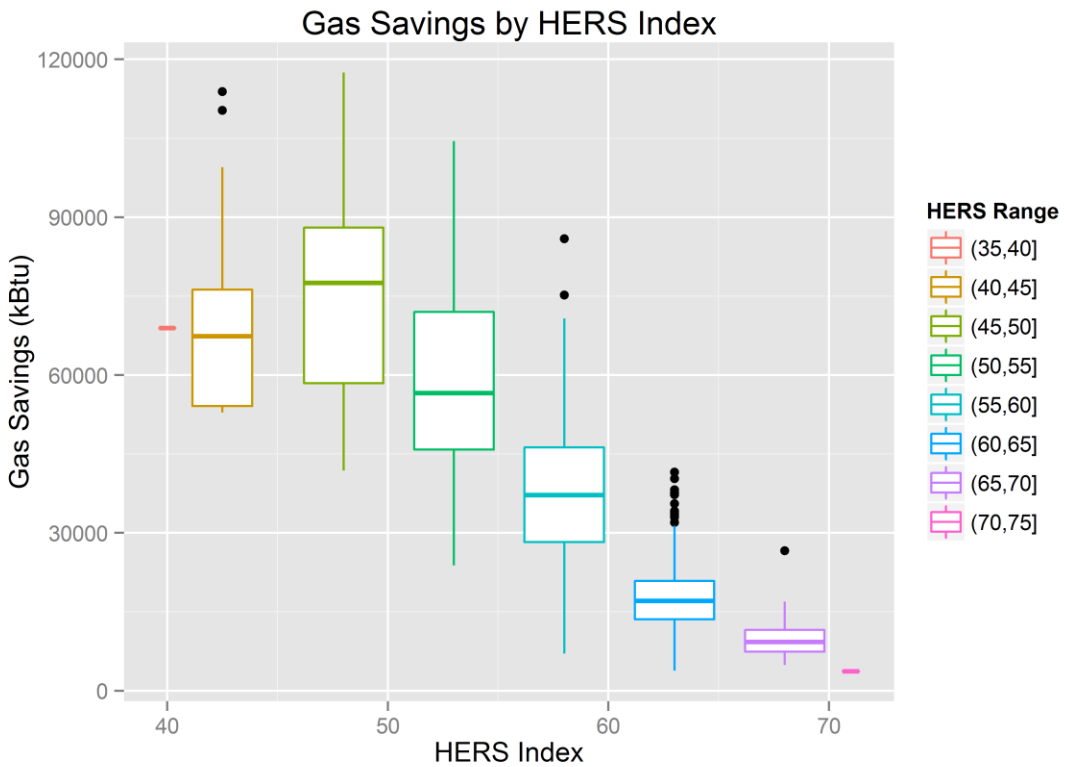

Figure 8. Distribution of Gas Savings by HERS Index Tier. With the exception of homes with HERS Indexes below 45, there is an overall trend of increasing savings as HERS Index decreases. The median savings increases for each tier from HERS 75 through 45. There is, however, a very wide range of savings for the most common HERS Indexes with a large number of outliers. Extreme outliers were removed to improve the legibility of the chart. This trend is consistent with electric savings.

Impact of Conditioned Floor Area

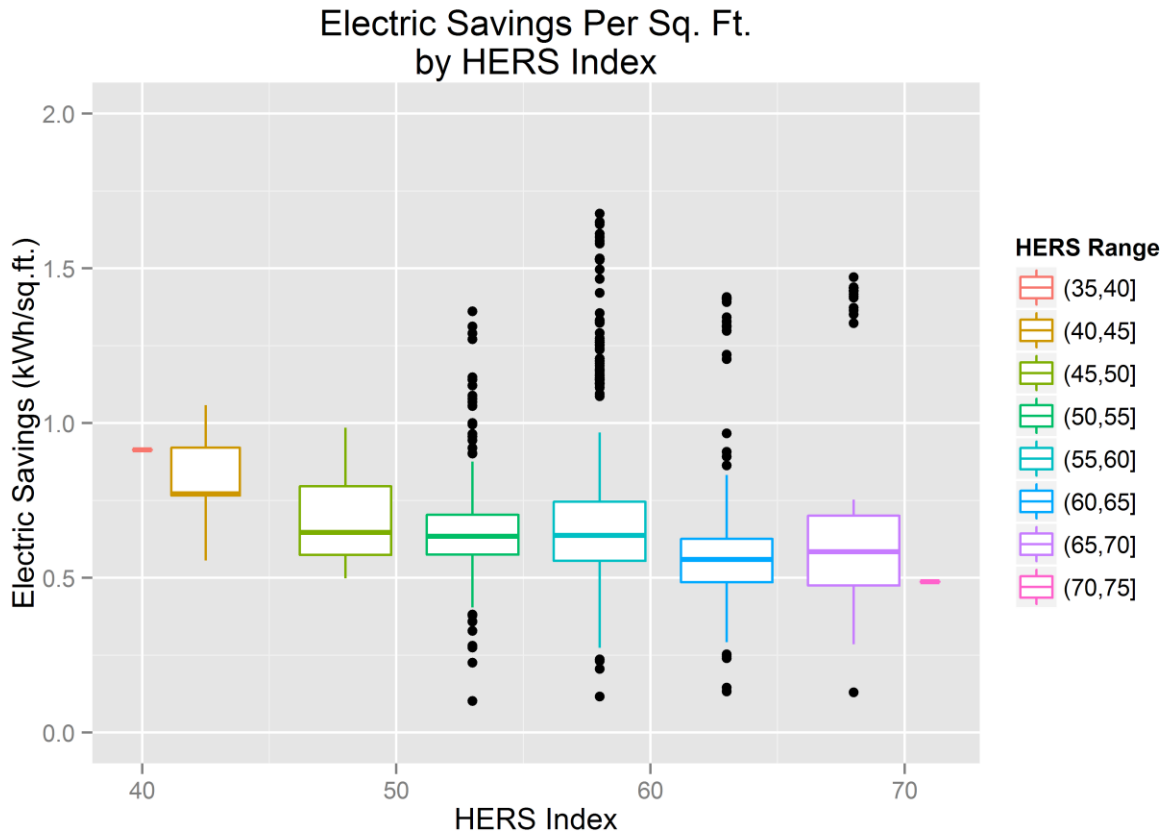

Figure 9. Distribution of Electric Savings per Square Foot by HERS Index Tier. Electric savings per square foot holds remarkable steady across all HERS Index tiers. This indicates that the HERS Index is not the predominant factor in determining savings amounts and the impact of house size is much more significant.

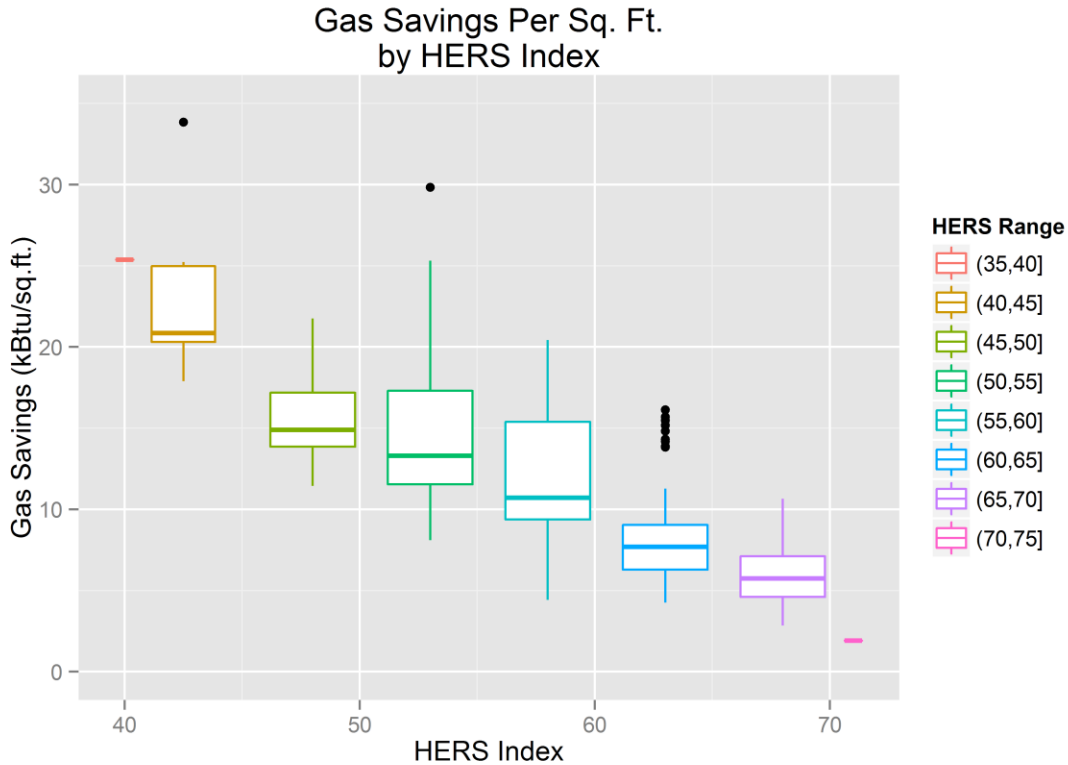

Figure 10. Distribution of Gas Savings per Square Foot by HERS Index Tier. Unlike with electric savings, median gas savings per square foot increase consistently as HERS Index decreases. This suggests that HERS Index is a driving factor in determining gas savings amounts.

Case Study

	House 1	House 2	House 3
HERS Index	53	53	53
kWh Savings	3886	2141	1534
House Type	Single-family, detached	Single-family, detached	Townhouse, inside unit
Conditioned area	6473	3920	4050
SEER	13	13	13
Total capacity (tons)	4.5	2.5	2.5
CFL %	100	85	88
Cooling kWh Savings	1530	978	490
Lighting kWh Savings	1827	815	910

To illustrate the divergence between HERS Index and savings, we look at three actual homes with a HERS Index of 53 that were submitted to our RNC programs. The major factors here are house type, size, cooling load, and lighting, with the last two factors strongly influenced by house size. House 1 is much larger than House 2 and House 3, which results in a larger cooling equipment capacity and more installed lighting. A larger cooling load results in more savings because all else being equal, the higher the consumption, the higher the savings. In this case, since the cooling equipment has the federal minimum efficiency, the savings are attributable to the building envelope, primarily reduced air infiltration. The RESNET protocol for determining the consumption attributable to installed lighting is based on square footage, so with efficient lighting installed, the larger the house, the higher the savings. In this case, House 1 also has the advantage of a higher percentage of efficient lighting than House 2 and House 3. For these three homes with a HERS Index of 53, the highest overall savings are 250% greater than the lowest savings value.

Discussion

This research was performed to illustrate the pros and cons of HERS-based incentives versus performance-based incentives. For the purposes of this discussion, a HERS-based program is one that varies incentive amounts based on the HERS Index, which could mean different incentives for each individual HERS Index value or for tiers of HERS Index values (e.g. HERS 51-55, 56-60, etc.). The main disadvantage of the HERS Index is its relatively poor ability to predict savings amounts with a large amount of variability among homes with the same or similar HERS Index values. This variability in savings results in homes with widely disparate savings amounts receiving the same incentive.

The results show a large range of savings for homes within a HERS Index tier or having the same HERS Index value and that house size is a better predictor of savings than HERS Index. Several factors drive this variation, including of course heating fuel type. However, this research shows that even a large range in savings exists within a given HERS Index tier, even when controlling for heating fuel type. Another factor that impacts the proportion of gas versus electricity savings in homes with identical HERS Indexes is climate zone. A gas-heated home in a location with higher design temperatures is likely to use more electricity because of the shift from more gas-fueled heating to more electrically-fueled cooling. This, obviously, only impacts programs that span more than one climate zone. All the homes in this study were within two climate zones (Zones 4 and 5), but still displayed a high variability in savings within a HERS Index tier.

Two other very important factors are house size and house type (single-family, townhouse, apartment). In addition to being fuel neutral, the HERS Index is size neutral. This means that two houses of very different sizes could have the same HERS Index, but vastly different consumption levels. The smaller house will consume less energy to begin with and therefore has less potential for savings. House size impacts nearly all end use consumption, including space heating, space cooling, water heating, and lighting. All else being equal, heating and cooling loads will vary directly with house size. The number of gallons of water used is dependent on the number of bedrooms. REM/Rate algorithms for lighting loads also vary according to house size. For each end-use, two houses with the same HERS Index and proportionally similar savings can have a huge disparity in absolute savings. For house type, not only are townhouses and apartments likely to be smaller than single-family homes, they also have significantly reduced exposure to the elements. Similarly, this results in lower overall consumption and therefore reduced savings potential. The fuel and size neutrality of the HERS Index means that a HERS-based program that does not vary incentives based on house size or fuel is likely to issue the same incentive for homes with produce very different savings results.

Programs with different incentives for different HERS Index tiers also provide no incentive for a builder to strive for deeper savings within a tier (e.g. HERS 51 receives same incentive as HERS 55), whereas a performance-based structure always provides an incentive for more savings.

HERS-based programs do have some advantages. First, the HERS Index is well-understood by Raters who have been trained to think in terms of driving down the HERS Index (not in terms of creating savings of a particular fuel). Many builders are also coming to understand the HERS Index and recognize its marketing value. HERS Index tiers are also more easily understood than performance-based incentives and are therefore more easily communicated to builders.

While there was a great range in savings amount, there was a trend toward increased savings as HERS Index decreases. The correlation between HERS Index and gas savings is stronger than for electricity, so gas programs are likely to see incentives somewhat more closely aligned with the HERS Index than electric programs.

HERS-based programs may require added complexity to ensure the proper signals are being sent to reward savings for the desired fuel. A purely HERS-based incentive program that wanted to reward only gas savings or only electricity savings would want to carefully consider different incentives for homes with different heating fuels. These programs should also consider different incentives for different house sizes and/or house types.

Alternatively, a performance-based program allows a simple incentive structure that rewards precisely the desired savings (per kWh or per kBtu), yielding a more cost-effective program.. Performance-based incentives are incentives that vary directly by the amount of predicted savings, so there is by definition a one-to-one correlation between savings and incentives. These incentives can be set to reward one type of fuel and not another, which can help influence builder choices for fuel and equipment types, depending on the size of the incentive.

A performance-based incentive program does require a more sophisticated program submittal/tracking system, to extract relevant usage data from the REM file, compare this usage to that of the appropriate reference home, and calculate the resultant savings. The submittal/tracking system will also need to calculate the incentive value from the savings data, and clearly communicate the incentive to the rater, and builder, so that the dollar value of the incentive is obvious to all concerned. This example of a "builder dashboard" shows one approach to straightforwardly communicating incentive value.