EUI: A Metric for Energy Savings for New Homes with ENERGY STAR Programs

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ABSTRACT

Many of the New Homes with ENERGY STAR Programs across the United States employ a tiered structure to encourage participants to build to a higher energy efficiency level. Builders are paid higher incentives if they meet the criteria for higher tiers. The tier levels are generally based on the HERS (Home Energy Rating System) Index; the lower the Index, the more energy efficient the home and the higher the tier that can be achieved. Since a lower Index means that a home is more energy efficient, it is generally assumed that more energy savings will be achieved. Analysis of energy savings was conducted on recently completed ENERGY STAR homes for a program funded by a group of Program Administrators in the New England area. It was found that for the program a lower HERS Index does not necessarily correlate with greater energy savings. The possible reasons for the lack of correlation between the HERS index and energy savings are discussed in the paper.

This paper outlines an alternative methodology to determine energy savings and incentive tier structure by employing Energy Utilization Index (EUI) percent energy savings of the baseline home over the rated home energy consumption. The analysis that was conducted to determine a level of EUI percent energy savings for developing incentive structure is discussed. It was concluded that requiring a home to achieve a certain EUI percent energy savings over the baseline home would help achieve the goal of better guaranteeing energy savings.

Introduction

In 1995, EPA launched its ENERGY STAR Qualified New Homes program, an initiative to transform the housing market through the voluntary adoption of efficient technologies and practices. Several electric and gas utilities across the United States have since sponsored the program as a part of the Demand Side Management (DSM) effort. The Program generally employs a tiered structure to encourage participants to build to a higher energy efficiency level. Builders are paid higher incentives if they meet the criteria for higher tiers. Historically the tier levels have been based on the HERS (Home Energy Rating System) Index; the lower the Index, the more energy efficient the home and the higher the tier that can be achieved. Since a lower Index means that a home is more energy efficient, it is generally assumed that more energy savings will be achieved.

This paper discusses data that do not follow the "lower HERS index means more energy savings" trend from recently completed ENERGY STAR homes for a program funded by a group of Program Administrators in New England. An explanation of the reasons behind this trend is given. A discussion follows that gives an alternative metric to develop an incentive tier structure that could better guarantee energy savings. An explanation of the process that was used to determine the incentive tiered structure based on the new metric is also given.

Background

It was found that for the program a lower HERS Index does not necessarily correlate with greater energy savings.

For the past couple of years the Program Administrators have been using a three tiered program, which included “ENERGY STAR 1”, “ENERGY STAR 2” and “Code Plus”, hereon referred to as ES1, ES2 and C+, respectively. A home that complies with the requirements of the ENERGY STAR performance path (ref-1) is considered to achieve ES1 tier. The ES2 tier includes the requirements of ES1 as well as a HERS Index of 65 or lower. A home achieves the C+ tier if it fails to comply with the requirements of the ENERGY STAR performance path but does achieve specific requirements for house infiltration (less than 6 ACH50) and duct leakage (less than 8CFM per 100 sq. ft.).

While these requirements were simple to follow for both the raters and builders, as explained in section 2.1, they did not guarantee absolute energy savings across all homes. This was problematic for the Program Administrators as they were tying progressively higher incentives to the ES1 and ES2 tiers.

Background on the Relationship of Energy Savings and Incentive

The program employs a market based baseline home, or internally referred to as the User Defined Reference Home (UDRH). This is different from some of the other New Homes with ENERGY STAR programs as they employ the local energy code to determine the energy efficiency characteristics of the baseline homes.

Exhibit 2.1 and 2.2 identify that no clear trend is present for HERS Index as a function of electricity savings (R^2 of less than 0.1) and a poor trend for a HERS Index as a function of fossil fuel energy (R^2 of 0.6) and peak electric demand (R^2 of 0.2) savings over the UDRH.

There are three underlying reasons for the lack of a good correlation between HERS index and energy savings as discussed below:

First, the “normalization methodology[1]” used to generate a HERS Index can skew the energy savings. Though this methodology has an undesirable effect on energy savings, it was devised to address concerns about neutrality between gas and electricity with regards to the HERS indices for homes heated primarily with those fuels.

The second, and most significant, reason for a lack of correlation between a HERS Index and the energy savings is the difference in reference homes used in the two methodologies. The reference home for a HERS Index analysis is the HERS reference home, defined in the RESNET standard[2] based on a national energy code performance baseline, whereas the UDRH used by the

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[1] Equipment efficiencies available in the marketplace are partly dependent on fuel type and not always consistent between fuel types. Therefore the normalization process attempts to provide equal credit within the HERS scoring methodology for relative improvement in equipment efficiency with consideration to the minimum and maximum efficiency available in the marketplace for that fuel type. For example, water heaters range in efficiency from 0.92 to 2.5 EF for electric water heaters and from 0.59 to 0.86 EF for gas water heaters. The normalization process provides equal credit for improving from 0.59 to 0.86 as it does for improving from 0.92 to 2.5 (i.e., both scenarios represent 100% improvement relative to what's available in the marketplace).For more information see http://fsec.ucf.edu/en/publications/html/FSEC-RR-54-00/index.htm

[2] *2006 National Mortgage Industry Home Energy Rating System Standards* as published by the Residential Energy Services Network (RESNET).

example program is based on a recent field survey of actual homes built in their respective territories. There are significant differences in the energy efficiency characteristics of the two reference homes. For this reason, the savings resulting from the difference of energy consumption between the rated home and either the HERS reference home (i.e. the HERS Index) or UDRH (i.e. program savings) cannot be correlated. It should be noted that programs employing baseline homes that are similar in energy efficiency characteristics to the HERS reference home may get a good correlation. However, this is not always true as explained in the preceding and following paragraph there are two other reasons to why HERS index may not correlate to energy or demand savings.

The third reason for the lack of a relationship between the HERS Index and savings over the UDRH is that the HERS Index is not based on any fixed reference home. In fact, the reference home shifts with each rating, making it hard to predict savings for any given home based on the HERS Index alone. In other words, the HERS Index is relative to the specific reference home used to create it. Therefore when two or more HERS Indices are compared to absolute energy savings the correlation may be poor. In fact, two homes with the same HERS Index do not necessarily have the same energy savings. However, it should be noted that HERS Index along with key characteristics of the home can be used to help determine the energy savings for each house. HERS Index is a single representation of all aspects of energy consumption within the house. To determine the constituent electricity and natural gas savings, key characteristics of the home that influence these metrics must be known, such as heating fuel, number of stories, and house size. Without knowing these key characteristics, too many unknowns exist to accurately estimate the savings.

Exhibit 2-1: Average Energy Savings Over UDRH for Homes at Specific HERS Indices

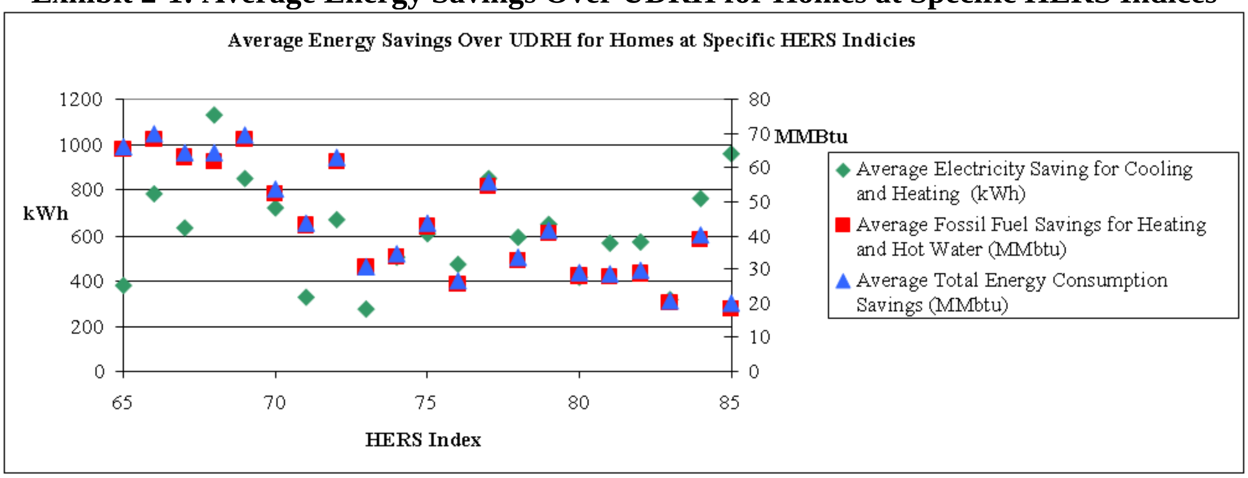
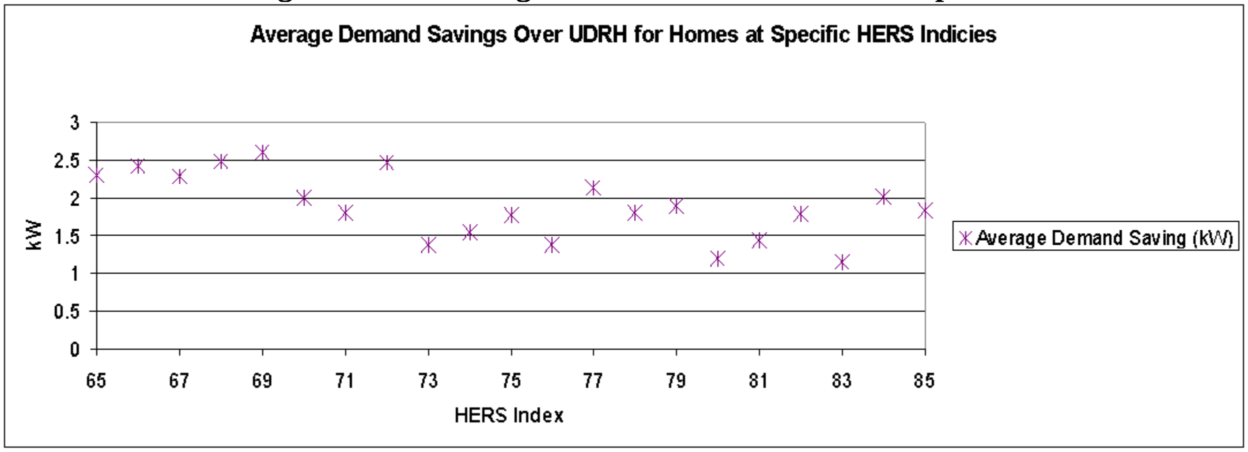


Exhibit 2-2: Average Demand Savings Over UDRH for Homes at Specific HERS Indices



Methodology

As discussed in the section above, the analysis to determine the relationship between HERS Index and energy savings did not result in a statistically useful correlation. Therefore, a new metric was determined by analyzing various options that would be flexible for builders and at the same time help Program Administrators realize maximum energy savings.

The various options that were analyzed include HERS Index based performance requirements, prescriptive requirements, a hybrid performance and prescriptive approach, the proposed new version of ENERGY STAR, and the EUI percent savings obtained by comparing the rated home to the UDRH performance requirements.

Section 3.1 explains the merits and disadvantages of each of the options. Section 3.2 explains the methodology used to determine the tier structure.

Program Design Options

Several options were discussed and considered for defining a new metric that would be used to determine energy savings and develop tier structure

HERS index based performance requirements. While the HERS Index is a well known performance metric to the raters and builders, as explained in section 2.1, using the HERS Index for the basis of program design does not ensure the Program Administrators will capture maximum or reliable energy savings.

Prescriptive requirements. A prescriptive energy efficiency characteristics requirement would help the Program Administrators better estimate energy savings, but as it is less flexible most builders will not be willing to do a prescriptive approach. Also, using a prescriptive approach would negatively impact the HERS raters infrastructure in the region served by this program.

Hybrid performance and prescriptive requirements. A hybrid of performance and prescriptive requirement would allow the builders a more flexible performance approach with some prescriptive measures that would assure energy savings (e.g., ducts in conditioned space, low infiltration, etc.). The prescriptive requirements in this approach are less flexible for the builders, and so are likely to draw resistance.

Proposed new version of ENERGY STAR. Using the more energy efficient new version of ENERGY STAR specifications Advanced New Home Construction (ANHC) BOP (as proposed by EPA) as the goal for builders would help get the builders accustomed to the new program that is scheduled to become a requirement in 2011, but the specifications are subject to change which could cause problems for the program implementers.

EUI percent energy savings compared to the UDRH performance requirements. A performance approach based on the estimated energy consumption of the rated home when compared to the UDRH would guarantee that metrics for participation correspond fully with program-reported savings, precisely because they are based on the same savings calculations that the program uses. This metric also normalizes the energy savings for the size of the home (rather than basing the metric on an absolute savings threshold of MMBTU/year). This is beneficial because absolute energy savings tend to give credit to larger homes.

EUI Percent Energy Savings as the New Metric

EUI percent energy savings over the UDRH was selected as the new metric because it allows the builders a performance approach and will ensure that the program will provide incentives to construction practices that specifically lead to program savings.

To determine the tiered incentive structure for the program using the new metric, the following were analyzed: the energy savings from over 2,000 ENERGY STAR homes completed in previous program years, a parametric analysis of both the current ENERGY STAR Builder Option Package (ES BOP) and the current version of the ANHC BOP.

The ES BOP parametric analysis was conducted by varying several architectural parameters but keeping the energy efficiency features as specified in the ES BOP. This resulted in about 70,000 simulations. The architectural parameters that were varied included house size, orientation, window area, number of stories, HVAC system types, duct location, DHW fuel, wall construction, and weather locations. While the ES BOP parametric analysis was not used in determining the tiered incentive structure, it helped identify the range of parameters with the highest sensitivity. This was useful in limiting the number of parametric simulations for analyzing the ANHC BOP. About 15,000 simulations were done for ANHC BOP analysis with the range of variables similar to ES BOP except for a limited range for house sizes and window areas.

The ANHC BOP parametric analysis was useful in determining the characteristics, and ultimately rate of adoption, of homes that achieve the tiers in incentive structure because the goals of the ANHC program are aligned with that of the incentive structure goal. That is to say, both programs are promoting energy efficiency by employing a bundle of technologies that are just beyond the normal set of technologies used in a mass-market transformation program.

Exhibits 3.1 and 3.2 shows the EUI percent energy savings over the UDRH as a function of single family and multifamily homes, respectively for the homes from previous program years and the parametric analysis of both the ES BOP and ANHC BOP. These exhibits were helpful to determine the tiered incentive structure by analyzing the number of homes that were able to reach a specific percent energy savings. Since only a few homes were able to achieve 60% energy savings, it was decided to be used as the highest tier for the program year. 30% energy savings was decided to be used as the second tier level which was the median of the number of homes achieving the energy savings.

Exhibits 3.3 and 3.4 shows the energy savings in MMBTU per 1000 sq. ft. over the UDRH as a function of single family and multifamily homes, respectively for the homes from previous program years and the parametric analysis of both the ES BOP and ANHC BOP.

To determine the energy savings in MMBTU per 1000 sq. ft. for the selected tier of 60% energy savings, a regression analysis was conducted on energy savings in MMBTU and energy savings in percent. The regression analysis resulted in a good fit with linear equations as shown in Exhibit 3.5. The resulting energy savings are shown in Exhibit 3.6. These energy savings were used to help determine the potential incentive dollar amount that could be adopted for the benefits created by the potential savings.

Exhibit 3-1: Fraction of Total Energy Savings (%) for Single Family Homes

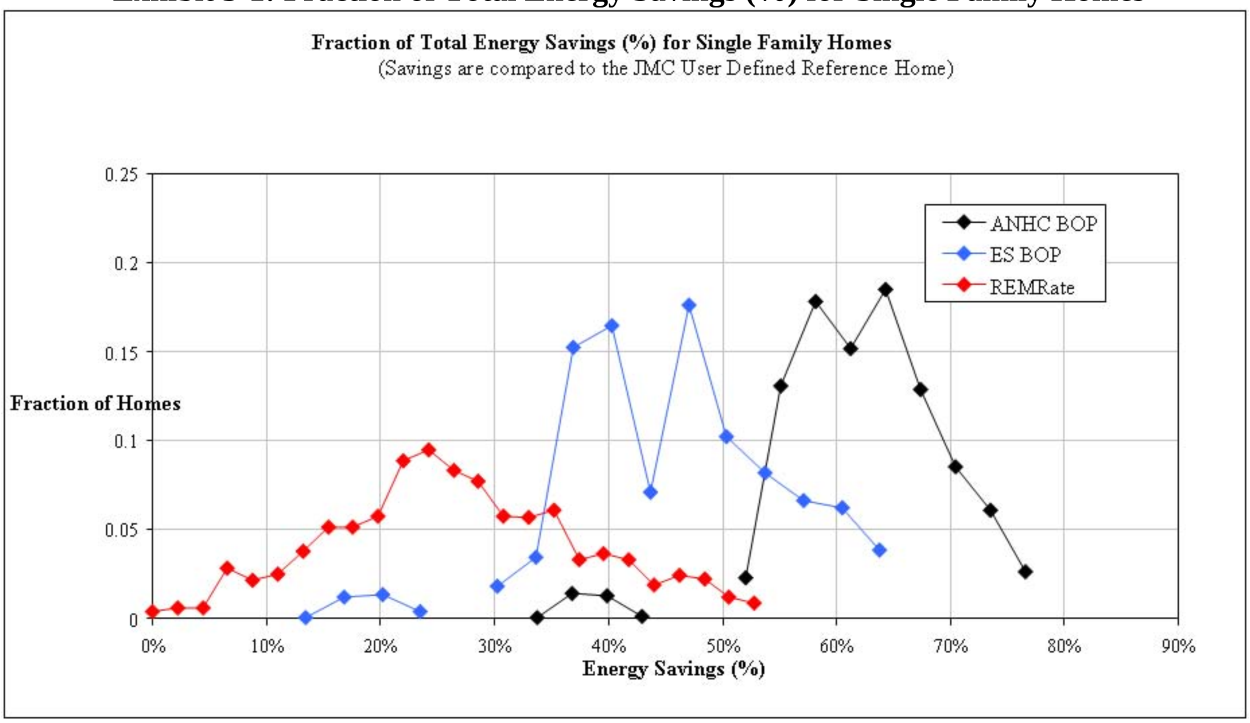


Exhibit 3-2: Fraction of Total Energy Savings (%) for Multi-Family Homes

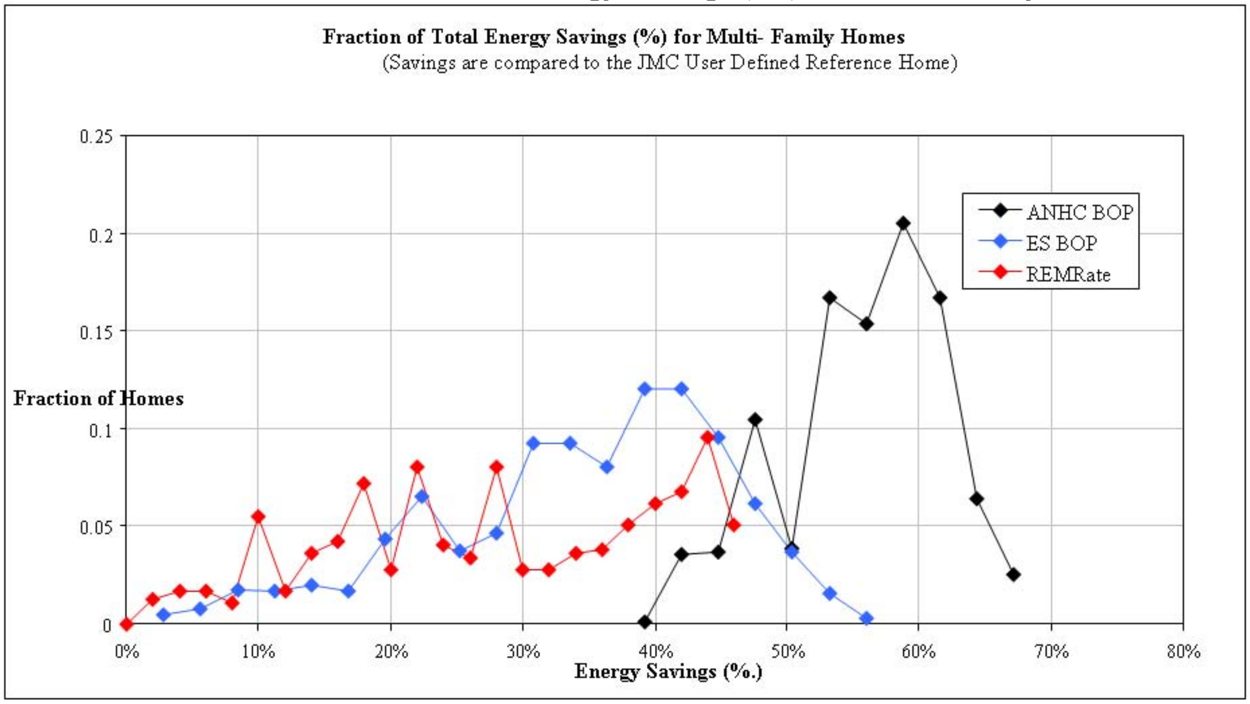


Exhibit 3-3: Fraction of Total Energy Savings (MMBTU / 1000 sq. ft.) for Single Family Homes

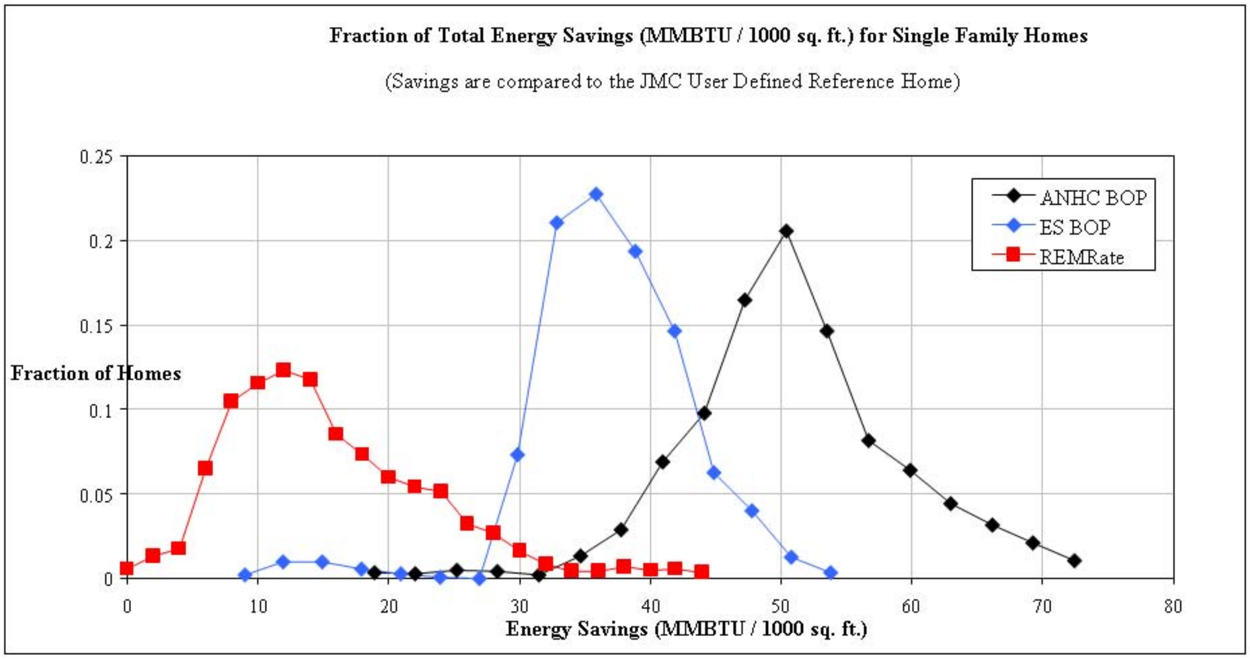


Exhibit 3-4: Fraction of Total Energy Savings (MMBTU / 1000 sq. ft.) for Multi-Family Homes

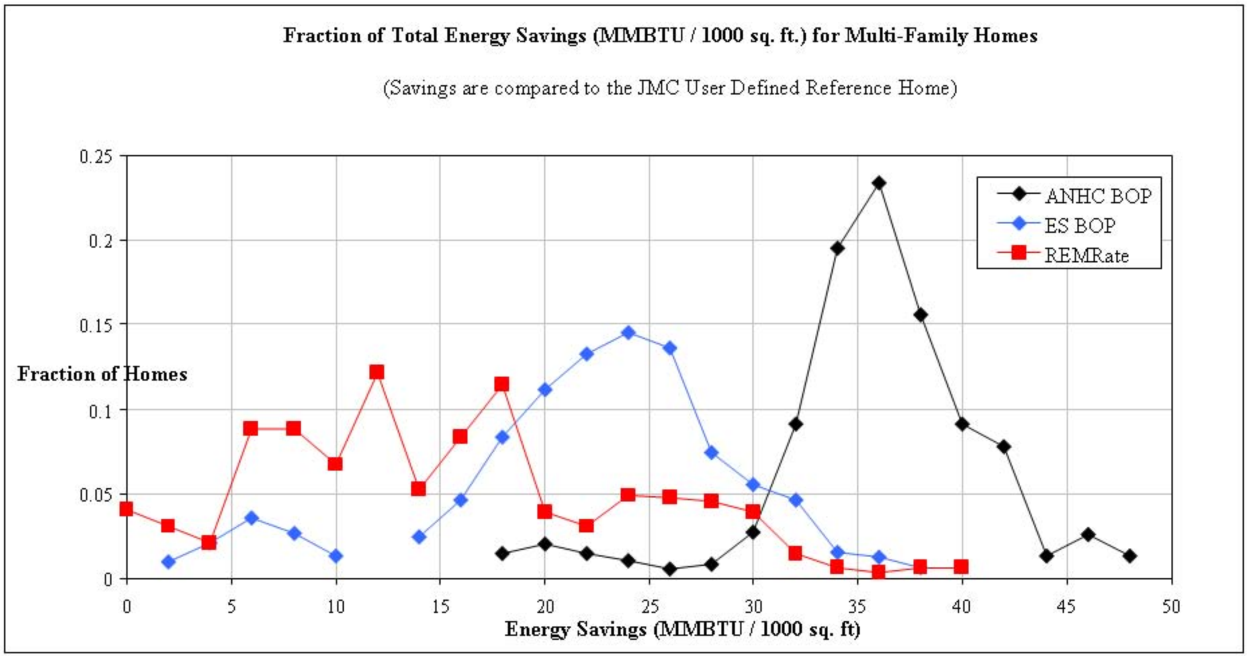


Exhibit 3-5: Linear Equations Representing the Relationship between MMBtu Savings and % Savings for Single and Multifamily Homes

Single Family Dwellings:	(MMBtu Savings) = 85.5 * (% Savings)	R^2 of 0.74
Multifamily Dwellings	(MMBtu Savings) = 61.3 * (% Savings)	R^2 of 0.9

Exhibit 3-6: Energy and Demand Savings at 60% Savings. over UDRH

Single Family

Total Energy	**51 MMBTU/1000 sq. ft.**
Fuel Type	
Electricity	469 kWh/1000 sq. ft.
Fossil Fuel	49.4 MMBTU/1000 sq. ft.
End-Use	
Cooling	264 kWh/1000 sq. ft.
Heating (Gas)	41.4 MMBTU/1000 sq. ft.
Heating (Electricity)	205 kWh/1000 sq. ft.
DHW	8.0 MMBTU/1000 sq. ft.
Summer Demand	**0.42 kW / 1000 sq. ft.**
Winter Demand	**0.55 kW / 1000 sq. ft.**
Average Area	**1739 sq. ft.**

Multi-Family

Total Energy	**37 MMBTU/1000 sq. ft.**
Fuel Type	
Electricity	117 kWh/1000 sq. ft.
Fossil Fuel	36.6 MMBTU/1000 sq. ft.
End-Use	
Cooling	29 kWh/1000 sq. ft.
Heating (Gas)	30 MMBTU/1000 sq. ft.
Heating (Electricity)	88 kWh/1000 sq. ft.
DHW	6.6 MMBTU/1000 sq. ft.
Summer Demand	**0.5 kW /1000 sq. ft.**
Winter Demand	**0.7 kW / 1000 sq. ft.**
Average Area	**1190 sq. ft.**

Note: (MMBTU=Million Btu)

Conclusions

Based on the analyses explained in section 3.2, it was determined that using EUI percent savings over the UDRH as a metric would result in accurate correlation of increased savings with higher tiers as compared to HERS index as the metric. Using this method the Program Administrators decided that a minimum HERS Index of 85 (to conform with ENERGY STAR performance path requirements) will be tier-1, 30% or more EUI percent savings over the UDRH will be tier-2, and 60% or more EUI percent energy savings over the UDRH will be tier-3. The tier structure was implemented in the 2010 program year therefore no results were available at the time this paper was being written.