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Analysis of the ENERGY STAR Reference Home Concept as Proposed for EPA's 2011 National Program Requirements

FSEC-RR-342-09

Research Report

June 14, 2009

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Analysis of the ENERGY STAR Reference Home Concept as Proposed for EPA's 2011 National Program Requirements¹

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Introduction

Using EnergyGauge[®] USA v.2.8.02, the Florida Solar Energy Center (FSEC) has conducted an analysis of EPA's proposed ENERGY STAR Reference Design Home specification. A single-story, 2344 ft², slab-on-grade, 3-bedroom, frame home is evaluated in each of the seven contiguous U.S. climate zones. The ENERGY STAR Reference Design Home was evaluated using three metrics: 1) EPA's threshold qualifying HERS Index (including the Size Adjustment Factor – 0.984 for this home), 2) the 2006 IECC Standard Reference Design and 3) the 2009 IECC Standard Reference Design. Evaluations using the IECC Standard Reference Design were computed using source energy, where the source energy factors were 3.16 for electricity use and 1.1 for natural gas use.² For the IECC analyses, results are expressed as an e-Ratio, where the total source energy use for heating, cooling and hot water for the ENERGY STAR Reference Design Home is divided by the total source energy use for heating, cooling and hot water for the IECC Standard Design Home, as follows:

$$\text{e-Ratio} = (\text{e-Star RefDsn energy use}) / (\text{IECC StdDsn energy use})$$

The EnergyGauge simulations were conducted using TMY3 weather data for the following standard climate zones and TMY weather sites:

- CZ1 – Miami, FL
- CZ2 – Daytona Beach, FL
- CZ3 – Dallas, TX
- CZ4 – St. Louis, MO
- CZ5 – Indianapolis, IN
- CZ6 – Burlington, VT
- CZ7 – Duluth, MN

The analysis is limited in scope. The following limitations should be considered when reviewing the results.

- Only a single home size is represented. Larger homes or smaller homes with the same Size Adjustment Factor will necessarily produce slightly different results
- Only a single foundation type is represented. Crawl space foundations, basement foundations and mixed foundations will produce different results
- Only a limited number of weather sites have been considered. Other TMY3 weather sites will likely yield slightly different results.

¹ EPA, "Proposed New Guidelines for ENERGY STAR Qualified New Homes"

http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_2011_comments

² In accordance with Section 405.3, 2009 International Energy Conservation Code (IECC)

Notwithstanding the above limitations, the analysis is instructive with regard to EPA’s proposed specification for an ENERGY STAR Reference Design Home.

Results

Results are presented in chart format. Figure 1 shows the qualifying HERS Index for the ENERGY STAR Reference Design Home in each of the seven climates for homes equipped with electric heat pumps and with natural gas furnaces. Figure 1 clearly shows that, with respect to the HERS Index, the ENERGY STAR Reference Design home is quite sensitive to climate and even more sensitive to the fuel type of the selected heating system. If the home is located in a cold climate, the electric heat pump provides a significantly larger HERS Index than the natural gas furnace. It is also clear from the data that there is a substantial difference in qualifying HERS Index across climates, where the same heat pump equipped home requires a HERS Index of 69 in Miami, FL, and 84 in Duluth, MN.

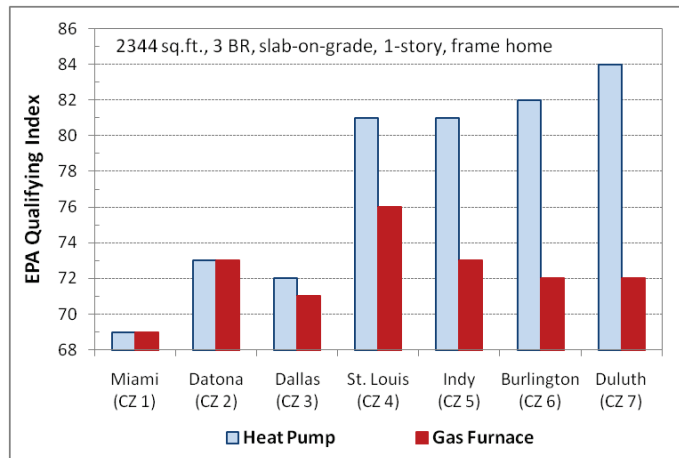


Figure 1. Qualifying HERS Index for selected home in seven climate zones, showing qualifying HERS Index criteria for homes with electric heat pumps and natural gas furnaces.

To determine the degree to which the characteristics in Figure 1 are solely a function of the RESNET method of evaluation, the ENERGY STAR Reference Design home was also evaluated against the 2006 IECC Standard Design Home and the 2009 IECC Standard Design Home. Results of the 2006 IECC evaluation are shown in Figure 2. This analysis is conducted using a different comparison method than the HERS method. For the HERS method, normalized, modified loads are used to determine the HERS Index. For Figure 2, an energy use ratio (e-Ratio) is determined by dividing the source energy use for the ENERGY STAR Reference Design Home by the source energy use for the IECC Standard Reference Design. Thus, an e-Ratio of 0.80 means that the ENERGY STAR Reference Design Home uses 80% as much source energy as the 2006 IECC Standard Reference Design home (i.e. it saves 20% compared to that standard). The same trends exist in Figure 2, where the ENERGY STAR Reference Design Home is compared against the 2006 IECC, as exist in Figure 1, where it is compared against the HERS Index.

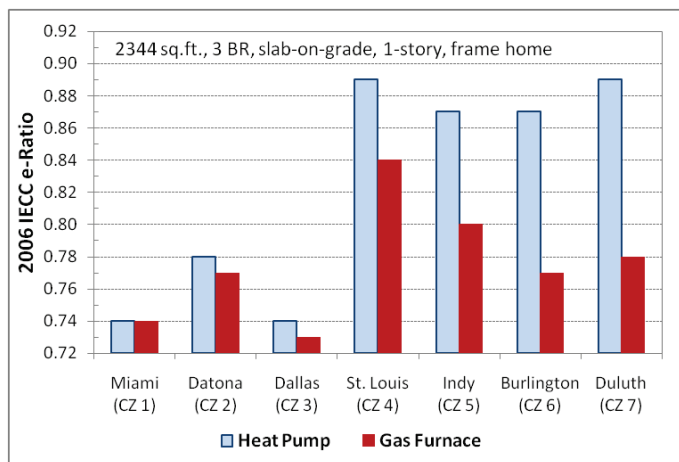


Figure 2. Comparison of the ENERGY STAR Reference Design Home against the 2006 IECC in seven climates, showing the IECC 2006 e-Ratio for homes with electric heat pumps and gas furnaces.

If site energy use rather than source energy use is used to make the comparisons, there is a slightly greater difference between heat pumps and gas furnaces in cold climates, with the e-Ratios for the heat pump home remaining the same and the e-Ratios for the gas furnace homes decreasing slightly.

The second code analysis uses the 2009 IECC Standard Reference Design³ as the basis of comparison. Figure 3 presents results from this analysis. With the exception a slight change for climate zone 3 (Dallas, TX), the patterns shown in Figure 3 are virtually identical to those shown in Figure 2. The additional item showing up in Figure 3 is the fact that ENERGY STAR Reference Design Homes with heat pumps sometimes barely comply with the 2009 IECC in cold climates. This is likely due to the fact that the ENERGY STAR Reference Design Home specification calls for an 18% window-floor area ratio while the 2009 IECC specification limits window-floor area ratio to 15%.

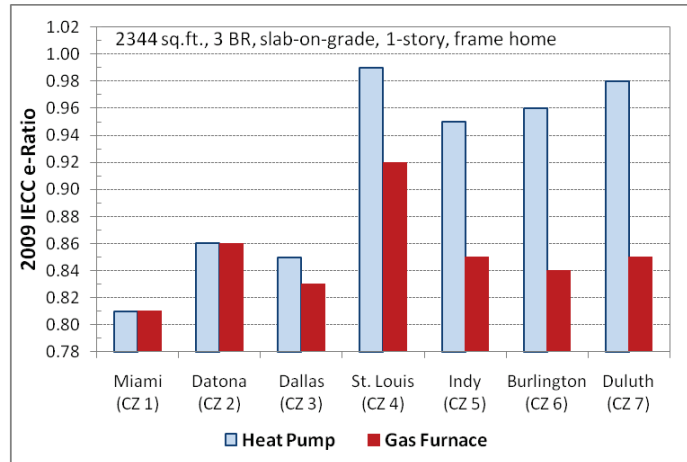


Figure 3. Comparison of the ENERGY STAR Reference Design Home against the 2009 IECC in seven climates, showing the IECC 2009 e-Ratio for homes with electric heat pumps and gas furnaces.

Nonetheless, the same patterns emerge in the IECC 2009 analysis, with the ENERGY STAR Reference Design Home being significantly more stringent (with respect to the model code) in southern, warm climates than it is in northern, cold climates. While this difference is exaggerated in electric heat pump homes, it is also significant in homes with gas furnaces. For example, while the estimated savings with respect to the 2009 IECC for the ENERGY STAR Reference Design Home equipped with a gas furnace are 19% in Miami, FL, they are only 8% in St. Louis.

To determine the degree of correlation between the 2009 IECC e-Ratios and the HERS Indices for the ENERGY STAR Reference Design Home, the e-Ratio data shown in Figure 3 were regressed against the HERS Index data shown in Figure 1. The result, presented in Figure 4, shows a quite good correlation between these two metrics, with a correlation coefficient (R-square) of 0.9589. This indicates that the HERS Index correlates well with the minimum requirements of the 2009 IECC

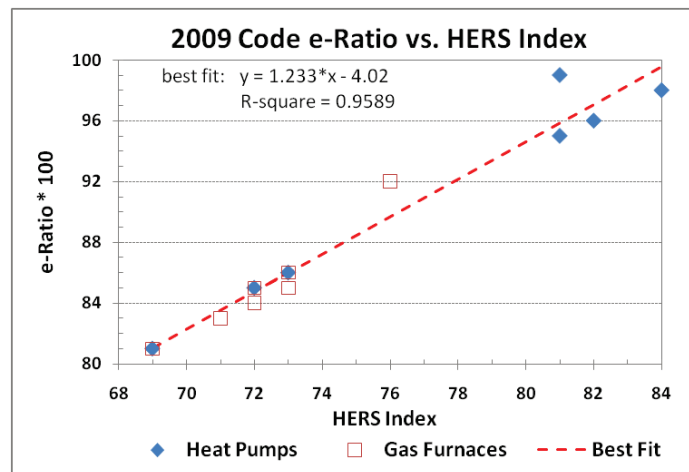


Figure 4. Correlation between 2009 IECC e-Ratio and the HERS Index for the ENERGY STAR Reference Design.

³ To facilitate comparison, the thermostat set points for the 2009 IECC Standard Reference Design were maintained at the same temperatures as the 2006 IECC Standard Reference Design and the HERS Reference Home.

when source energy use is the metric for determining energy savings relative to the minimum requirements of the 2009 IECC.

Since this correlation appears valid, additional analyses are conducted to examine the HERS Index for the home size/bedroom pair sets provided in EPA’s Exhibit 3: Benchmark Home Size. For each of the eight size/bedroom pair sets, an IECC 2009 Standard Reference Design Home is constructed for each of the seven contiguous U.S. climates, yielding 56 distinct IECC 2009 Standard Reference Design homes. Since EPA’s proposed standard includes a requirement for mechanical ventilation in accordance with ASHRAE Standard 62.2, the minimum standard mechanical ventilation system was included in these IECC 2009 Standard Reference Design homes. Each of the 56 homes is evaluated for its HERS Index using the EnergyGauge rating software. Once the individual HERS Indices are determined, they are averaged across all climate zones by home size, yielding an average HERS Index for homes of the specified size and number of bedrooms.

It is the stated policy of EPA that their ENERGY STAR new homes program produces homes that are at least 15% more efficient than required by codes. Thus, the resulting average HERS Indices are multiplied by 0.85 to determine a minimum qualifying HERS Index for a program that is 15% more efficient than the 2009 IECC across climates. The results from this analysis are provided in Table 1.

Table 1. HERS Index for IECC 2009 Standard Reference Design Homes of Specified Size and Number of Bedrooms across U.S. Climate Zones

| Cond. floor area (ft²): | 1000 | 1600 | 2200 | 2800 | 3400 | 4000 | 4600 | 5200 | Range (max-min) |
|---|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|----------------------------|
| No. bedrooms: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| Miami (CZ1) | 90 | 89 | 88 | 88 | 87 | 87 | 87 | 87 | 3.0 |
| Daytona Bch (CZ2) | 91 | 90 | 89 | 89 | 88 | 88 | 88 | 88 | 3.0 |
| Dallas (CZ3) | 89 | 88 | 87 | 87 | 86 | 86 | 86 | 86 | 3.0 |
| St. Louis (CZ4) | 91 | 90 | 89 | 88 | 88 | 88 | 88 | 87 | 4.0 |
| Indianapolis (CZ5) | 92 | 91 | 91 | 90 | 90 | 90 | 89 | 89 | 3.0 |
| Burlington (CZ6) | 93 | 93 | 93 | 93 | 92 | 92 | 92 | 92 | 1.0 |
| Duluth (CZ7) | 93 | 93 | 93 | 92 | 92 | 92 | 92 | 92 | 1.0 |
| Average: | 91.3 | 90.6 | 90.0 | 89.6 | 89.0 | 89.0 | 88.9 | 88.7 | 2.6 |
| 85% of Average: | 77.6 | 77.0 | 76.5 | 76.1 | 75.7 | 75.7 | 75.5 | 75.4 | 2.2 |

The range of resulting HERS Indices are given in Table 1 for each climate. These ranges show that the maximum range occurs in St. Louis (CZ4) at 4 HERS points. The minimum range occurs in both Burlington (CZ6) and Duluth (CZ7) at only 1 HERS point. It is important to also note that EnergyGauge does not produce decimal HERS Indices, so the HERS Indices presented in Table 1 are rounded values.

A regression analysis is performed to determine the “goodness of fit” for the resulting “85% of Average” HERS Indices. The values for the 3400 ft² and the 4600 ft² homes were omitted from the regression analysis. They were omitted due to the fact that the values for the 3400 ft² home are identical to the values for the 4000 ft² home. One sees from Table 1 that this is due to the fact that the HERS Indices are not determined to their decimal values, leading to the values for

the 3400 ft² and 4000ft² homes being identical in all climates. It is evident from the data that the differences in HERS Index across home sizes is non linear, with larger differences occurring for the smaller home sizes. As a result of these observations, every other home following the 2800 ft² home (3400 ft² and 4600 ft²) was omitted from the analysis.

The results are shown graphically in Figure 5. The regression equation is non-linear, as expected, and is very well correlated with the HERS Index results, showing a correlation coefficient (R-square) of 0.999. Due to the fact that the HERS Index values are not calculated to their decimal values, the curve fit is actually more accurate than the raw data. This fact can be explicitly seen in the data for the 3400 ft² home which has identical values as the 4000 ft² home. This point, due to rounding of the HERS Indices, represents a distinct outlier with respect to the remainder of the home sizes.

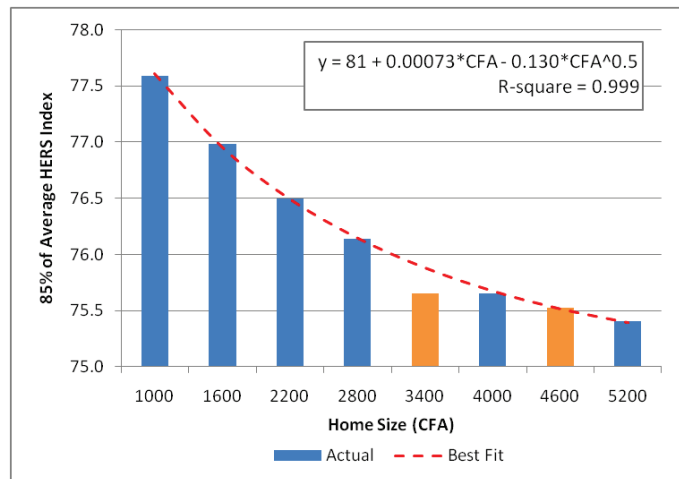


Figure 5. 85% of Average IECC 2009 Standard Reference Design HERS Index as a function of home size, showing regression results. (Note that results from the 3400 ft² and 4600 ft² homes were omitted from the regression analysis.)

Recommendations

While it is clear that the current HERS Index is not independent of home size, the relationship is not pronounced for the ENERGY STAR Reference Design home. This is probably due to the fact that the number of bedrooms (which functions as the surrogate for the number of occupants and impacts hot water use, internal gains, etc.) is incremented for each 600 ft² increment of conditioned floor area for these homes. It is also important to note at this point that this size dependency is a matter of physics and that it also exists in performance-based code compliance methods as well. The proposed ENERGY STAR Reference Design Home concept was developed in part to resolve this challenge.

However, as noted above, the proposed produces energy savings that cannot be directly related to the national model energy codes, yielding differing efficiency improvements with respect to codes in hot, mixed and cold climates. As shown in Figure 3, the EPA ENERGY STAR Reference Design Home proposal would allow homes that are only 1% - 5% more efficient than the minimum requirements of the 2009 IECC. This is counter to EPA's stated policy goal of achieving at least 15% savings with respect to prevailing minimum standards. It is recommended that EPA seriously reconsider their treatment of heat pumps in this regard. Figure 3 also illustrates that even gas furnaces are unlikely to satisfy their policy goal in climate zone 4, where only 8% savings with respect to IECC 2009 are shown.

EPA has stated that one of their concerns and one of the reasons that they propose the ENERGY STAR Reference Design Home concept stems from the fact that the HERS Index advantages large homes and disadvantages small homes. The use of an ENERGY STAR Reference Design

Home would resolve this size challenge. While this may be true in the narrow sense, as has been shown here, use of the proposed ENERGY STAR Reference Design Home would also generate other issues with potentially more profound impacts than home size.

However, the analysis presented above offers a potential solution to these challenges. It is recommended that EPA add a third row to their Exhibit 3: Benchmark Home Size table. This row should contain the Base HERS Index that is required to achieve a performance level that exceeds national model codes by 15%. Table 2, below, is provided as an example:

Table 2. Example Expansion of EPA Exhibit 3: Benchmark Home Sizes

| No. of Bedrooms | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Benchmark CFA | 1,000 | 1,600 | 2,200 | 2,800 | 3,400 | 4,000 | 4,600 | 5,200 |
| Base HERS Index | 78 | 77 | 77 | 76 | 76 | 76 | 76 | 75 |

It is important to point out that Table 2 is only presented as an example and that the values shown for the Base HERS Index should be considered only “placeholders.” While these values stem from the preceding analysis, this analysis is limited to only a single home type. If EPA chooses to adopt this approach, it is recommended that they conduct a national analysis to develop a final set of Base HERS Indices. It is recommended that such analysis consist, at a minimum, of the following steps:

1. Determine HERS Index for IECC 2009 Standard Reference Design for all home sizes, in all climates for all reasonable foundation types using electric space air conditioning, gas furnace space heating and gas hot water heating in all climates.
2. Determine the average HERS Index for each home size across all climates and all building foundation types (this average could just as well be a weighted average based on expected or historic home starts).
3. Multiply the resulting average HERS Indices by 85% to establish the Base HERS Index for each base home size (Benchmark CFA).
4. Use actual home size (CFA) and EPA’s proposed Size Adjustment Factor (SAF) to establish the “Qualifying HERS Index” for proposed ENERGY STAR homes.
5. Adjust BOP requirements to be in line with the above.

The above procedures will resolve some of the largest challenges with respect to advancement the ENERGY STAR new homes program. It will document and explicitly remove the home size factor that currently advantages larger homes and disadvantages smaller homes. It will achieve EPA’s policy objective of providing ENERGY STAR new homes that are at least 15% more efficient than prevailing national model codes. It will also provide clear guidance to builders and consumers regarding the HERS Indices that are expected from ENERGY STAR labeled homes. And when coupled with EPA’s proposed Size Adjustment Factor, it is likely to seriously impact home size selection. For example, if a builder or homeowner chooses to build a 5,000 ft², 3-bedroom home, they will quickly and easily be able to determine from EPA’s qualification guidelines that the required qualifying HERS Index for this home is $76 * (2200/5000)^{0.25} = 62$. This level of explicitness likely will result in additional success for EPA’s home size initiative.