A Yardstick Consumers Use to Measure Home Energy Performance

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ABSTRACT

ENERGY STAR has developed a software application, the Home Energy Yardstick (www.energystar.gov/yardstick), that compares the annual energy use of a home to the energy use of other homes nationally using data from the 1997 Residential Energy Consumption Survey (RECS). The comparison is made through a simple metric that ranks a home on a 0 to 10 scale after adjusting for home size and age, occupant number, climate, and whether a home has a well pump. This adjustment allows the tool to compare energy use across homes with different climates, size, age and number of occupants, and compensates for homes with well pumps. The adjustment is based on a regression model developed from analysis of RECS. These factors, which are considered beyond the control of the homeowner in the short-term, accounted for 20 - 30% of energy use variability, based on model R-square. Once energy use is adjusted, the application compares the adjusted energy use to the energy use of other homes within the RECS database and assigns a performance ranking. The performance ranking depends on the building envelope, the heating and cooling system, and the homeowner's appliances (i.e. pool/spa), lighting and consumer electronics. Homeowner behavior is also important. This paper will describe the development of the adjustment procedure, and the results from testing the application using actual home energy data from the RECS 1993 database. In addition, a brief discussion of the potential applications and implications of this new metric for measuring home energy performance is included.

Development of the Home Energy Yardstick

Purpose

ENERGY STAR, a voluntary labeling program that promotes energy-efficient products, equipment, homes and commercial buildings, has developed a new web-based software application that measures home energy performance. ENERGY STAR received statistical support from Oak Ridge National Laboratory. The application, titled the Home Energy Yardstick, was developed to support a new ENERGY STAR effort to promote energy efficient home improvements. The Yardstick was designed for homeowners to compare the overall energy performance of their homes to other homes. By comparing their homes to other homes nationally, homeowners with poor performing homes may feel compelled to improve their home's energy performance. The Yardstick provides the homeowner with a baseline energy performance ranking. For the poor performing home, the homeowner has several options such as adding insulation, air sealing or buying ENERGY STAR labeled products to improve the overall energy performance of the home. A homeowner can also return to the Yardstick to evaluate the effectiveness of energy performance improvements, after implementing different solutions.

Background

In 1999 ENERGY STAR began labeling commercial office buildings based on an energy performance rating that compares building energy performance against the energy performance of the national market of similar commercial buildings. (Hicks & von Neida 2000) ENERGY STAR has since expanded this performance ranking to schools, supermarkets, hospitals and hotels/motels. The ENERGY STAR label for commercial office buildings, schools and supermarkets is awarded to buildings that rank 75 or above on a 0 to 100 scale. ENERGY STAR labeled buildings rank within the top 25 percent nationwide in terms of energy performance. EPA's performance rating system is based on a regression model developed from an analysis of data from the Energy Information Administration's 1992 and 1995 Commercial Buildings Energy Consumption Survey (EPA 2001).

The ENERGY STAR Commercial Building label served as one possible program model for the home improvement market. However, the ENERGY STAR label for new homes is based on a different methodology than is used in the commercial buildings program. Homes that receive a score of 86 or above on the Home Energy Rating System are eligible for the ENERGY STAR label for homes. The score of 86 is roughly 30% better than the 1993 Model Energy Code[1]. This score is based on modeling analysis, not actual energy consumption. In order to not confuse the market, EPA has decided to continue to label homes as ENERGY STAR if homes, both new or existing, score an 86 or greater under HERS. ENERGY STAR will promote the Home Energy Yardstick to homeowners as an easy to use tool to see how well their home performs, and to serve as an impetus for improvement to homeowners whose homes perform poorly. A home energy rating will always be important to homeowners who intend to make significant, cost-effective improvements to their home.

Data Analysis

The Yardstick is based on data obtained from the US Department of Energy's (DOE) Residential Energy Consumption Survey (RECS). RECS is a national survey of building features, energy consumption, and energy expenditures in homes. DOE's Energy Information Administration administers RECS to collect information about energy consumption and energy-related characteristics of residential buildings in the United States. EIA uses an interview survey to collect information concerning the physical features of a building, occupancy characteristics and energy usage and cost as well as other data (EIA 1999). The most recent RECS was collected in 1997. EIA is currently conducting the 2001 RECS. This data will be available in 2003.

The Home Energy Yardstick follows an approach that is similar to the method used in ENERGY STAR's commercial buildings program. This approach uses multiple regression models to develop a procedure that adjusts for key variables affecting energy use to facilitate

[1] The Reference Home is configured in accordance with the specifications set forth in the Guidelines for Uniformity developed by the Home Energy Rating Systems (HERS) Council, and endorsed by the National Association of State Energy Officials (NASEO). The minimum energy efficiency standards set forth in the Guidelines for Uniformity include elements of the 1993 Council of American Building Officials, Model Energy Code (CABO-MEC) and minimum equipment efficiencies established in the National Appliance Energy Conservation Act (NAECA) that has been in effect since January 1, 1992.

comparison and ranking of energy performance. Researchers[2] at Oak Ridge National Laboratory using data from the 1997 RECS and a step-wise linear regression analysis, regressed total annual energy use on independent variables to identify the key variables that affect energy consumption. Once a set of variables was identified, standard regression analysis was used to obtain statistics on the model.

The 1997 RECS identifies 5 different housing types: single-family detached, single-family attached, apartment buildings with 2-4 units; apartment buildings with 5 or more units; and mobile homes (EIA 1999). Only single-family detached and attached homes were included in this analysis. Based on experience, the ORNL researchers decided to eliminate extremely high and low energy use homes from the analysis because of concern that possible outliers could bias the results. The sample of homes was selected as the mean +/- 2 standard deviations based on the logs of total energy use. This selection reduced the sample by about 2.5% of homes with the highest and lowest energy use. In addition, 123 homes were excluded because of uncertainty about whether water heating was included. From a total of 4213 single-family home records, 3876 were included in the analysis including any with imputed data.

The ORNL researchers began with an evaluation of 581 variables associated with each record. Variables that are dependent on total energy use or indicated the imputation of missing data were excluded while some variable transformations were added to enhance the results.

The RECS public use files do not list the state or zip code associated with each record or records for Hawaii or Alaska to maintain confidentiality. The only geographic indicators are Census Region, Census Division and a variable representing the four largest states: Florida, New York, Texas and California. Using Census Division and the *largest states* variable it was possible to create logical variables for each of the four largest states and the remaining states in the division. For example, the Pacific Census Division (California, Oregon and Washington) was divided into two logical variables: *California,* and *Oregon and Washington*.

The RECS data includes a variable for the year the home was built, but allowable responses are limited to specific decades except if built after 1990. Logical variables were created based on the response options. For example, one logical variable is *home built between 1940 and 1949*.

As a result of the regression analysis, the ORNL researchers selected 49 independent variables that explain variations in residential energy use. If a variable or logical variable did not stand out as a statistically significant indicator of energy use it was not selected. From this subset of variables the researchers proposed an initial simple model (Table 1 - MacDonald & Livengood 2001) to explain total energy use.

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[2] Michael MacDonald and Sherry Livengood

Table 1. First Simple Model of Total Energy

Variable Description	Parameter Estimate (kBtu/yr)	Standard Error (kBtu/yr)	F Value	Pr > F	Partial R-Square	Model R-Square
Intercept	61,618.0	7,757.5	63.09	<.0001		
Total Heated Floor Space	29.7	1.7	293.54	<.0001	0.2718	0.2718
No Crawlspace	-4,764.9	2,322.5	4.21	0.0403	0.0005	0.479
Number of Windows	6,957.8	1,433.0	23.57	<.0001	0.0075	0.4051
California	-37,024.0	4,039.0	84.03	<.0001	0.0486	0.3203
Oregon and Washington	22,761.0	4,996.4	20.75	<.0001	0.0022	0.4592
East North Central Census Division	9,594.5	3,036.2	9.99	0.0016	0.0013	0.4728
East South Central Census Division	30,281.0	3,726.8	66.02	<.0001	0.0086	0.452
West South Central Census Division	35,911.0	3,761.1	91.17	<.0001	0.0047	0.4379
Delaware, DC, Georgia, Maryland, North Carolina,	8,157.1	3,625.0	5.06	0.0245	0.001	0.4761
Number of Televisions	8,500.8	959.6	78.47	<.0001	0.0373	0.3576
Number of Lights on > 12 hours/day	5,142.3	610.9	70.86	<.0001	0.0163	0.3739
More than 20 Showers per Week	7,486.1	2,637.9	8.05	0.0046	0.0016	0.4702
1 Household Members	-36,706.0	3,465.4	112.2	<.0001	0.0147	0.3887
2 Household Members	-18,617.0	2,907.7	40.99	<.0001	0.009	0.3976
3 Household Members	-6,578.3	2,946.5	4.98	0.0256	0.0006	0.4778
6 or more Household Members	11,549.0	4,947.0	5.45	0.0196	0.0011	0.4772
Home Built before 1940	13,214.0	2,588.2	26.07	<.0001	0.0024	0.4616
Home Built between 1990 and 1997	-28,666.0	3,688.3	60.41	<.0001	0.0073	0.4199
Home Built between 1980 and 1989	-15,495.0	4,519.0	11.76	0.0006	0.0013	0.4715
Home Built between 1940 and 1949	11,034.0	3,278.1	11.33	0.0008	0.0017	0.4686
Use Dryer Every time Clothes are Washed	19,330.0	2,720.7	50.48	<.0001	0.0074	0.4126
Use Dryer for Some but Not All Loads	9,902.1	3,388.6	8.54	0.0035	0.0011	0.4739
Heating Degree Days to base 65	5.1	0.6	76.15	<.0001	0.0055	0.4434
Use Central AC About All Summer	18,909.0	2,666.5	50.29	<.0001	0.0051	0.4571
Use Central AC Quite a Bit	7,284.4	3,397.1	4.6	0.0321	0.0006	0.4784
One Refrigerator	-8,404.6	2,589.8	10.53	0.0012	0.0019	0.4635
Three or more Refrigerators	26,816.0	9,128.4	8.63	0.0033	0.0011	0.4751
Chest Freezer	-12,536.0	2,501.9	25.11	<.0001	0.0061	0.4332
Upright Freezer	-11,108.0	2,935.4	14.32	0.0002	0.0017	0.4669
Electric Well Pump	9,588.9	2,612.8	13.47	0.0002	0.0018	0.4653
Home has Heated Hot Tub/Spa/Jacuzzi	33,181.0	4,714.3	49.54	<.0001	0.0071	0.427

Model Development

This initial simple model seems reasonable, but it is only a starting point for selecting the final set of independent variables. Because the coefficients of the final regression model are used in the adjustment procedure, variable selection is as much dependent on policy decisions as statistical consideration. In the end, ENERGY STAR selected those factors that were statistically significant and were believed to be beyond the immediate control of the homeowner. For example, since climate is beyond the control of the homeowner and is statistically significant, it should be included in the final regression model and adjustment procedure. This would allow homeowners in different climates, with all other variables equal, to compare their energy use with the Home Energy Yardstick. Conversely, the number of refrigerators, although statistically significant, is under the control of the homeowner, and should not be included in the final regression model and adjustment procedure. If energy use is not adjusted for the number of refrigerators, a home with three refrigerators are “penalized” with a lower Yardstick score than a home with one refrigerator, with all other variables being equal.

Based on these considerations, ORNL researchers completed several regressions with different, selected combinations of the variables from the first model. Table 2 (MacDonald & Livengood 2001) shows five of the regression models presented to EPA for review. EPA desired a final model that contained a small number of variables that were easy for homeowners to obtain and yet explained the most variation in residential energy use. Selection of the final model was based on evaluation of statistical indictors (R^2, ANOVA) and balancing policy goals and model simplicity.

Table 2. Five Model Options

Variable Description		MODELS I	II	III	IV	V
Intercept		80,490	106,585	129,322	70,882	93,821
1	Total Heated Floor Space	28	31	35	30	35
2	More than 20 Showers per Week	10,699	11,086		14,243	
3	Number of Windows	8,524				
4	East North Central Census Division	10,917	8,819			
5	East South Central Census Division	23,717	24,700			
6	California	-31,788	-38,326			
7	Oregon and Washington	15,101	17,553			
8	Arkansas, Louisiana, and Oklahoma	31,088	27,420			
9	Texas	32,945	30,080			
10	1 Household Member	-41,043	-40,383	-44,926	-33,819	-44,775
11	2 Household Members	-18125	-18438	-23,117	-14,844	-22,875
12	3 Household Members	-8,664	-9,095	-9,356	-562	-8,777
13	Use Dryer Every time Clothes are Washed		19,376		26,328	
14	Use Dryer for Some but Not all loads		10,102		15,094	
15	One Refrigerator	-9,888	-9,468		-8,170	
16	Outdoor lights on all Night	6,676				
17	Heating Degree Days to base 65	4.8	3.3	2.7	7.6	7.1
18	Cooling Degree Days to base 65				13.5	12.6
19	Number of Lights on > 12 hours/day	4,595	4,627		5,299	
20	Electric Well Pump	6,370	9,115	6,104	7,977	5,844
21	Use Central AC Quit a Bit	10,053	8,645			
22	Use Central AC About all Summer	18,599	17,979			
23	Home built before 1940	10,858	12,821	5,447	8,697	4,800
24	Home Built between 1940 and 1949	8,314	9,360	1,173	6,395	
25	Home built between 1980 and 1989	-12,177	4,107	-11,274	-12,197	-11,730
26	Home build between 1990 and 1997	-21,324	3,393	-18,584	-18,658	-18,259
27	Home Heating Fuel	17,158				
R SQUARE		0.3992	0.3932	0.2732	0.3272	0.2841
Lowest t-Value		2.70	2.82	2.18	2.04	1.98
Pr > [t]		0.0069	0.0048	0.0293	0.0415	0.0481
Var w/ lowest t-Val			20 2 1	23	24	23

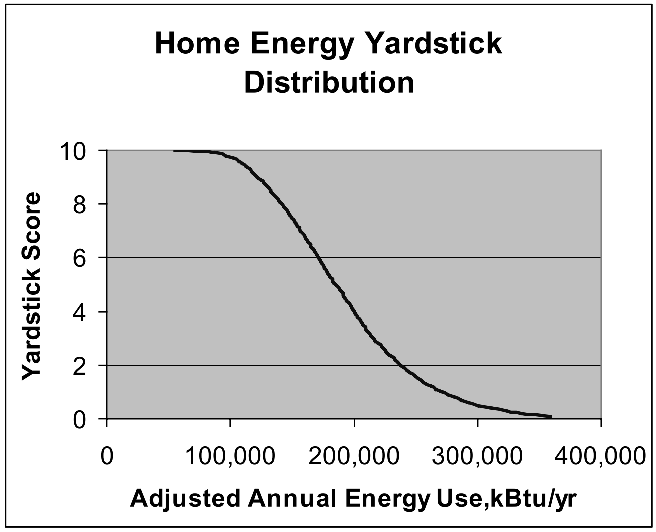
Model V, (far right of table 2) was selected as the basis of the Yardstick adjustment procedure. The following algorithm shows how model V is used to determine the adjustment

$$Adjustment\ Factor = \frac{C_0 \quad C_1\ FloorArea \quad \begin{matrix} C_2, if\ 1\ occupant \\ C_3, if\ 2\ occupants \\ C_4, if\ 3\ occupants \end{matrix} \quad C_5\ HDD65 \quad C_6\ CDD65 \quad C_7, if\ well\ pump \quad \begin{matrix} C_8,\ if\ built\ before\ 1939 \\ C_9,\ if\ built\ 1980\ 89 \\ C_{10},\ if\ built\ after\ 1990 \end{matrix}}{Model\ Mean}$$

factor. This algorithm is used by the Yardstick to adjust or normalize a home’s actual energy use. The *Model Mean* is calculated using model V and the mean value of each variable. The *Model Mean* is192,253 kBtu/yr. A home's actual energy use is divided by the adjustment factor to produce the adjusted energy. The score is determined by using a look-up table. The table consists of scores from 0 to 10 (1/10th increments or essentially 0–100%) and corresponding values of adjusted annual energy use. The table is created by rank ordering the values of adjusted annual energy use and assigning a percentage. Figure 1 is a graph representing the look-up table values. The values of adjusted annual energy use were calculated using model V and the subset of homes in the 1997 RECS used in the regression analysis.

The Yardstick score represents how a home's energy consumption compares to other homes after adjusting for the size and age of the home, the number of occupants living in the home, the climate where the home is located, and if the home uses an electric well pump.

Figure 1. Distribution of Yardstick Score vs. Residential Energy Use



Yardstick Data Requirements

When homeowners use the Yardstick they are required to provide the following information:

- *Total Annual Energy Use* – The homeowner can enter annual or monthly gas, oil and electric use obtained from bills. The applicable fuel and fuel units can be selected by the user on the input screen. All energy inputs are converted to British Thermal Units (Btu) and include energy losses due to electric power generation and transmission.
- *Conditioned Floor Area (sq. ft.)* - The conditioned floor area includes areas heated and cooled. This information can be obtained from real estate records or by measuring the homes floor area.
- *Zip Code* – The home's zip code is used to determine heating degree-days (HDD) and cooling degree-days (CDD). CDD and HDD are calculated from average daily temperatures for a 12- month period that corresponds to the energy use.
- *Number of Occupants* - Occupants must live in the house most of the year.
- *Age of structure* – The decade that the home was built can be obtain from home real estate records.
- *Electric Well Pump* - Well pumps consume considerable energy and are required to provide water for some residences. However, homes without wells (in cities or rural water districts) will not see the energy load associated with water and sewer service reflected in their electric bill. The Yardstick adjusts the total annual energy based on whether a home has an electric well pump so homes can be compared on a fair basis.

Because the 1997 RECS public data files do not include data from Alaska or Hawaii the Yardstick is only applicable for single-family attached and detached homes in the continental United States.

Testing the Home Energy Yardstick

EPA conducted a series of tests to evaluate The Home Energy Yardstick. EPA entered data from the 1993 RECS to determine whether scores were evenly distributed when segmented by adjustment variables.

Tests and Results

The first series of tests used data from the 1993 RECS. Each home in the database was scored using the Yardstick. The 1993 RECS data is ideal for this purpose because it is independent from the data used to develop the model, yet it includes all of the model parameters, and is national in scope. If the Yardstick performs as designed, approximately 25% of homes will score within each of the 4 quartiles [<2.5, 2.5-5.0, 5.0-7.5, > 7.5]. This test is not an absolute indicator of the Yardsticks performance, but does provide a reasonable check that the Yardstick is performing as expected.

Table 3. Range of Yardstick Scores for 1993 RECS Homes

Home Energy Yardstick Score	Percentage of homes
> 7.5	25%
5.0 to 7.5	24%
2.5 to 5.0	26%
< 2.5	26%
Number of Homes	4875

Percentages may not add up to 100% due to rounding

Table 3 shows that, although there is some variation, the results appear as expected. To determine how well the tool adjusted the energy use to compensate for house size, occupant number, and climate, EPA compared the distribution of scores for each variable found within the adjustment factor. If the Yardstick properly adjusts energy use for these selected variables, the distribution of homes across the quartiles for each variable should look similar to Table 4

Size. Table 4 shows that both small homes (less than 1,001 sq ft) and large homes (greater than 3,000 sq ft) score somewhat better than homes in the middle size range. Although there is variation, the results appear to be reasonable. The model appears to account for floor area, allowing the Yardstick to compare the energy use of homes of different sizes.

Table 4. Range of Yardstick Scores for 1993 RECS Homes Based on Floor Area

Home Energy Yardstick Score	0-1000 sq. ft.	1001 -1500 sq. ft.	1501 - 2000 sq. ft.	2001 - 3000 sq. ft.	> 3001 sq. ft.
> 7.5	32%	24%	21%	22%	29%
5.0 to 7.5	23%	23%	24%	25%	24%
2.5 to 5.0	20%	27%	28%	26%	25%
< 2.5	25%	26%	26%	27%	22%
# of Homes	660	1188	1027	1261	739

Percentages may not add up to 100% due to rounding

Age. The Yardstick adjusts energy use based on the decade the home was built. As expected, the test results for the 1993 data in Table 5 indicate that the model, with these adjustments included, is mostly neutral with respect to year of construction. By normalizing based on age of construction, new homes do not tend to receive better scores, although new homes use less energy. This is important because many older homes are inherently less efficient and could not cost-effectively be upgraded to new home efficiency levels.

Table 5. Yardstick Scores for 1993 RECS Homes based on Decade Built

Home Energy Yardstick Score	Decade Built						
	Before 1940	1940s	1950s	1960s	1970s	1980s	1990s
> 7.5	27%	27%	25%	21%	24%	25%	23%
5.0 to 7.5	23%	21%	23%	25%	24%	24%	29%
2.5 to 5.0	25%	25%	27%	28%	23%	26%	26%
< 2.5	25%	27%	25%	26%	29%	25%	22%
# of Homes	957	358	683	584	689	1023	581

Percentages may not add up to 100% due to rounding

Climate. The model includes adjustments for both CDD and HDD. In order to evaluate this adjustment, score distributions were segmented based on 5 climate zones.Results in Table 6 show that homes in zones 1 and 4 tend to score higher than homes in the other three climate zones. This difference is substantial and raises concerns about the model's ability to normalize climate variations based on CDD and HDD. One alternative model that could be tested includes census region and air conditioning use as normalizing variables and not include CDD. This and other model configurations could be considered in an attempt to improve climate zone normalization.

Table 6. Range of Yardstick Scores for 1993 RECS Homes Based on Climate Zone

Home Energy Yardstick Score	Climate Zone				
	1	2	3	4	5
> 7.5	40%	26%	24%	40%	28%
5.0 to 7.5	29%	29%	26%	24%	21%
2.5 to 5.0	20%	27%	23%	19%	27%
< 2.5	11%	18%	27%	17%	24%
# of Homes	710	1413	855	900	997
Climate Zone 1 is less than 2,000 CDD and greater than 7,000 HDD. Climate Zone 2 is less than 2,000 CDD and 5,500-7,000 HDD. Climate Zone 3 is less than 2,000 CDD and 4,000-5499 HDD. Climate Zone 4 is less than 2,000 CDD and less than 4,000 HDD. Climate Zone 5 is 2,000 CDD or more and less than 4,000 HDD.					

Percentages may not add up to 100% due to rounding

Number of occupants. The model adjusts for household sizes of one, two or three members. The results in Table 7 indicate households with 6 or more members tend to score lower than households with 1 or 2 members. This may be due to limitations in the 1997 RECS data for households greater than 5 members, which were fewer in number. The regression analysis did not indicate that 4, 5 or 6 or more household members were statistically significant. Therefore, to address this bias would require a non-statistical solution.

Table 7. Range of Yardstick Scores for 1993 RECS Homes Based on Number of Household Members

Home Energy Yardstick Score	Number of Household Members					
	1	2	3	4	5	6 or More
> 7.5	28%	27%	23%	23%	21%	18%
5.0 to 7.5	25%	24%	25%	24%	22%	18%
2.5 to 5.0	23%	25%	28%	26%	28%	27%
< 2.5	23%	24%	24%	28%	29%	37%
# of Homes	755	1676	891	918	434	201

Percentages may not add up to 100% due to rounding

Heating fuel. The results in Table 8 indicate that homes using electricity for the primary heating fuel tend to perform lower than homes using gas or oil. This is expected because heating fuel was not a variable in the model and adjustment factor. Similar results were obtained when looking at primary water heating fuel. Kerosene and No Heat are not included in the table because the small sample sizes are unreliable. Homes with wood as a primary heating fuel tend to perform very well. This is expected given that wood is not recorded as part of the total energy used in the home.

Table 8. Range of Yardstick Scores for 1993 Homes Based on Primary Heating Fuel

Home Energy Yardstick Score	Primary Heating Fuel				
	Natural Gas	Electric	Fuel Oil	LP Gas	Wood
> 7.5	23%	19%	23%	32%	60%
5.0 to 7.5	26%	20%	27%	24%	18%
2.5 to 5.0	28%	26%	25%	20%	14%
< 2.5	24%	35%	25%	24%	8%
# of Homes	2594	1111	604	287	226

Percentages may not add up to 100% due to rounding

Census division. Table 9 shows that some significant differences between Census divisions in scoring. The scores for New England and the Mid-Atlantic division are slightly better than expected, with the scores for the Mountain division being better than expected and the Pacific being dramatically better than expected. The other divisions are noticeably worse than expected.

Table 9. Range of Yardstick Scores for 1993 RECS Homes Based on Census Division

Home Energy Yardstick Score	Census Division								
	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mtn	Pacific
> 7.5	30%	28%	16%	19%	24%	14%	17%	36%	44%
5.0 to 7.5	28%	27%	28%	26%	23%	18%	17%	24%	24%
2.5 to 5.0	23%	25%	29%	30%	28%	28%	26%	25%	15%
< 2.5	19%	20%	26%	24%	25%	40%	42%	16%	17%
# of Homes	352	591	684	428	868	442	560	364	586

Percentages may not add up to 100% due to rounding

Lower scores in the southern divisions could be a result of the dominance of cooling driven electricity load. However, there are other possibilities for regional differences that should be expected. Many factors could contribute to these differences including Census division boundaries, the regional cost of energy, personal income levels, poverty levels, and amount of government assistance As mentioned earlier, climatic differences that are not fully explained by heating degree days and cooling degree days may contribute to census division energy use differences to some extent, but no information exists to do more than speculate about those causes. The regression analysis conducted by ORNL did consider including regional variables in the model. However, when CDD was included in the model with the regional variables, the results were not reasonable. The coefficient for CDD was negative implying that increasing CDD would result in less energy use. Because CDD is supported by a physical explanation of increased energy use it was decided to include it instead of the regional variables.

The census division differences are dramatic enough to warrant further investigation and possible modification of the model in later versions.

Potential Applications

Home energy audits have existed for several years and offer a valuable service. Online energy audits are easy for consumers to use and provide useful energy information and recommendations for reducing energy use. In-home energy audits provide more detailed information than online audits and are based on measurements and inspections by a trained inspector. Even when results are modeled, an experienced technician can often times come close to estimating actual energy bills. In addition to energy information and recommendations for improvement, in-home audits can include a home energy rating. Ratings provide an objective metric for comparing homes, but can be time consuming and labor intensive. The Yardstick is not intended to replace energy audits or home energy ratings. Instead, the Yardstick is a new type of tool that can be used by homeowners to self-screen their home's energy performance. The results are based on the homeowners actual energy use, and the answers to seven questions. Homeowners that receive a low score are good prospects for efficiency improvements and will be more likely to see the value in energy audits to help identify the most cost-effective improvements.

The Home Energy Yardstick is similar to using Energy Use Intensity to assess the cost effectiveness of improving a building. The Home Energy Yardstick is ideally suited as a self-screening tool for consumers. It is relatively easy to use, has manageable data requirements and straightforward results. The Home Energy Yardstick is a low cost, low commitment starting point for homeowners interested in assessing their potential for energy efficient improvements. Homes that score below 5.0 are more likely to offer prospects for substantial energy savings. The Home Energy Yardstick can also be used as a marketing tool to identify and motivate homeowners with the biggest opportunity for energy efficiency improvements and energy savings. After receiving a low score the homeowners next step will be to use online energy audit software or hire a professional to assess the home, recommend improvements and calculate potential savings. An additional application, for the inquisitive homeowner, is to reassess their home twelve months after improvements have been completed to verify that improvements were effective.

Conclusions

The Home Energy Yardstick offers a new approach to measuring residential energy performance that is ideal for homeowners who want know how their energy use compares to other homes. Testing of the Yardstick shows that it performs as expected in most cases, however there are a few issues that can be addressed in future versions.

From a technical perspective further investigation into improving the models adjustment for climatic and regional drivers of energy use is warranted. The use of CDD and HDD to adjust for climatic difference is supported by a physical explanation of increased energy use, but does not completely account for all variations. One alternative model could include air conditioning use instead of CDD. Both models would need to be tested to see which performs better. However neither the existing model or an alternative model will be perfect.

Overall the Home Energy Yardstick works well. And, it offers a new tool for homeowners to measure their energy performance that includes not only the efficiency of the home, but also the efficiency of the energy using items in the home (TV, lights, appliances, etc.), and the behavior of the homeowner.

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