ENERGY STAR® PortfolioManager® Technical Reference

ENERGY STAR Score for Single-Family Homes in the United States

OVERVIEW

The 1 – 100 ENERGY STAR score for Single-Family Homes applies to single-family detached and attached homes. The objective of the ENERGY STAR score is to provide a fair assessment of the energy performance of a property relative to its peers, taking into account the climate, weather, and activities at the property. To identify the aspects of building activity that are significant drivers of energy use and then normalize for those factors, a statistical analysis of the peer building population is performed. The result of this analysis is an equation that will predict the energy use of a property, based on its experienced operations. The energy use prediction for a building is compared to its actual energy use to yield a 1 to 100 percentile ranking of performance, relative to the national population.

- **Property Types.** The ENERGY STAR score for Single-Family Homes applies to standalone buildings, or an individual structure that shares one or more exterior vertical wall with other buildings, such as a duplex or townhome. Single-Family Homes have their own lot and provide living space for one household or family. The score applies to individual buildings only and is not available for neighborhoods.
- **Reference Data.** The analysis for single-family detached and attached homes is based on data obtained from the U.S. Department of Energy's (DOE's) 2015 Residential Energy Consumption Survey (RECS).
- **Adjustments for Weather and Business Activity.** The analysis includes adjustments for:
  - Gross Floor Area
  - Number of Household Members
  - Weather and Climate (using Heating and Cooling Degree Days, retrieved based on ZIP code)
- **Release Date.** The ENERGY STAR score for Single-Family Homes[1] is updated periodically as more recent data becomes available:
  - Original Release: September 2022[1]

This document presents details on the development of the 1 – 100 ENERGY STAR score for Single-Family Homes. More information on the overall approach to develop ENERGY STAR scores is covered in our Technical Reference for the ENERGY STAR Score, available at www.energystar.gov/ENERGYSTARScore. The subsequent sections of this document offer specific details on the development of the ENERGY STAR score for single-family detached and attached homes:

[1] The 1 – 100 ENERGY STAR score for Single-Family Homes is based on the Home Energy Yardstick most recently updated in April 2019. The Home Energy Yardstick used a 1 – 10 scale for the tool, so that was adapted to a 1 – 100 scale to align with the ENERGY STAR score methodology.

REFERENCE DATA & FILTERS

The 1 – 100 ENERGY STAR score for Single-Family Homes is based on data obtained from the U.S. DOE's 2015 RECS. Only standalone buildings, or individual structures that share one or more exterior vertical wall with other buildings, such as a duplex or townhome are used in the analysis.

To analyze the building energy and operating characteristics in the RECS data, four types of filters are considered to define the peer group for comparison and to overcome any technical limitations in the data: Building Type Filters, Program Filters, Data Limitation Filters, and Analytical Filters. A complete description of each of these categories is provided in our Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore. ***Figure 1*** presents a summary of each filter applied in the development of the ENERGY STAR score, the rationale behind the filter, and the resulting number of properties in the data set after the filter is applied. After all filters are applied, the remaining data set has 3,495 properties.

Figure 1 – Summary of Filters for the ENERGY STAR Score for Single-Family Homes

Condition for Including an Observation in the Analysis	Rationale	Number Remaining
Must be a single-family detached or attached house.	Building Type Filter – RECS defines building types according to the variable "TYPEHUQ." Single-family detached houses are coded as TYPEHUQ = 2; Single-family attached houses are coded TYPEHUQ = 3.	4,231
Natural Log of Total Source Energy divided by Total Square Feet must fall within two standard deviations of the mean.	Analytical Filter – Values determined to be data entry errors or statistical outliers.	4,040
Must not use wood.	Data Limitation Filter	3,495

Of the filters applied to the reference data, some result in constraints on calculating a score in Portfolio Manager and others do not. Building Type and Program Filters are used to limit the reference data to include only properties that are eligible to receive a score in Portfolio Manager and are therefore related to eligibility requirements. In contrast, Data Limitation Filters account for limitations in the data availability, but do not apply in Portfolio Manager. Analytical Filters are used to eliminate outlier data points or different subsets of data and may or may not affect eligibility. In some cases, a subset of the data will have different behavior from the rest of the properties in which case an Analytical Filter will be used to determine eligibility in Portfolio Manager. In other cases, Analytical Filters exclude a small number of outliers with extreme values that skew the analysis, but do not affect eligibility requirements. A full description of the criteria you must meet to get a score in Portfolio Manager is available at www.energystar.gov/EligibilityCriteria.

Survey Weights

The 2015 RECS used a multi-stage area probability design to select a sample of households that represents the population. To produce population estimates, the sample cases were weighted to represent all households, including those not in the sample. Base sampling weights, which are the reciprocal of the probability of selection for the RECS sample, were first calculated for each sampled household.

Similar to previous RECS, the 2015 RECS final analysis weights were calculated by applying eligibility, unit nonresponse, and poststratification adjustments to the base weights. The eligibility adjustment was calculated differently for the in-person and web/mail cases. Unlike the in-person cases where eligibility was determined by field interviewers, the eligibility of the web/mail cases was determined by a propensity model based on survey responses and contact mailing status. The Generalized Exponential Model (GEM) calibration method was used for the nonresponse and poststratification adjustments, the. The weights were then post-stratified to the 2015 American Community Survey (ACS), which estimated a total of 118.2 million occupied housing units in the United States. The variables used for poststratification included Census Division, housing unit type, and age of housing unit.

The final sample weight for each responding household (i.e., NWEIGHT in the data set), is the number of households in the population that the observation represents. For example, if the analysis weight for a household is 5,000, that household represents itself and 4,999 other non-sampled households.

VARIABLES ANALYZED

To normalize for differences in operations, we perform a statistical analysis to understand what aspects of building activity are significant with respect to energy use. The filtered reference data set described in the previous section is analyzed using a weighted ordinary least squares regression, which evaluates energy use relative to business activity (e.g., number of household members, climate). This linear regression yields an equation that is used to compute energy use (also called the dependent variable) based on a series of characteristics that describe the business activities (also called independent variables). This section details the variables used in the statistical analysis for single-family homes.

Dependent Variable

The dependent variable is what we try to predict with the regression equation. For the single-family home analysis, the dependent variable is source energy consumption equal to the total source energy use of the property. The regressions analyze the key drivers of source energy consumption – those factors that explain the variation in source energy consumption in single-family homes.

Independent Variables

The reference survey collects numerous property operating characteristics that were identified as potentially important for single-family homes. Based on a review of the available variables in the data, in accordance with the criteria for inclusion in Portfolio Manager,[2] the following variables were analyzed:

- Gross Floor Area
- Electric Well Pump
- Geographic Location
- More than 20 Showers per Week
- Number of Household Members
- Number of Lights on > 12 hours/day
- Number of Televisions
- Number of Windows

[2] For a complete explanation of these criteria, refer to our Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore.

- Refrigeration / Freezers
- Year Built
- Heating Degree Days
- Cooling Degree Days

We perform extensive review on all of these operational characteristics. In addition to reviewing each characteristic individually, characteristics are reviewed in combination with each other. As part of the analysis, some variables are reformatted to reflect the physical relationships of building components. The analysis consists of multiple regression formulations. These analyses are structured to find the combination of statistically significant operating characteristics that explain the greatest amount of variance in the dependent variable: source energy consumption.

The final regression equation includes the following independent variables:

- Gross Floor Area
- Number of Household Members
- Heating Degree Days
- Cooling Degree Days

These variables are used together to compute the predicted source energy consumption for the home. The predicted source energy consumption is the mean source energy consumption for a hypothetical population of homes that share the same values for each of these variables. That is, the mean energy consumption for a building that operates just like the home being assessed.

REGRESSION EQUATION RESULTS

The final regression is a weighted ordinary least squares regression across the filtered data set of 3,495 observations. The dependent variable is source energy consumption. The final equation is presented in ***Figure 2***. All variables in the regression equation are significant at the 95% confidence level or better, as shown by the significance levels (a p-level of less than 0.05 indicates 95% confidence).

The regression equation has a coefficient of determination (R^2) value of 0.9026, indicating that this equation explains 90.26% of the variance in source energy consumption for single-family homes. This is an excellent result for a statistically based energy model.

Detailed information on the ordinary least squares regression approach is available in our Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore.

Figure 2 - Final Regression Results

Summary				
Dependent Variable		Source Energy (kBtu)		
Number of Observations in Analysis		3,495		
R^2 value		0.9026		
Adjusted R^2 value		0.9025		
F Statistic		8,086		
Significance (p-level)		< 0.0001		
	Unstandardized Coefficients	**Standard Error**	**T value**	**Significance (p-level)**
GFA	29.05	0.8377	34.68	< 0.0001
Number of Household Members (max value of 6)	12,073	688.2	17.54	< 0.0001
CDD	17.38	0.7696	22.58	< 0.0001
HDD	9.763	0.4589	21.27	< 0.0001

Notes:

- The regression is a weighted ordinary least squares regression, weighted by the RECS variable "NWEIGHT."
- The adjustment for Number of Household Members is capped at a maximum value of six (6).

ENERGY STAR SCORE LOOKUP TABLE

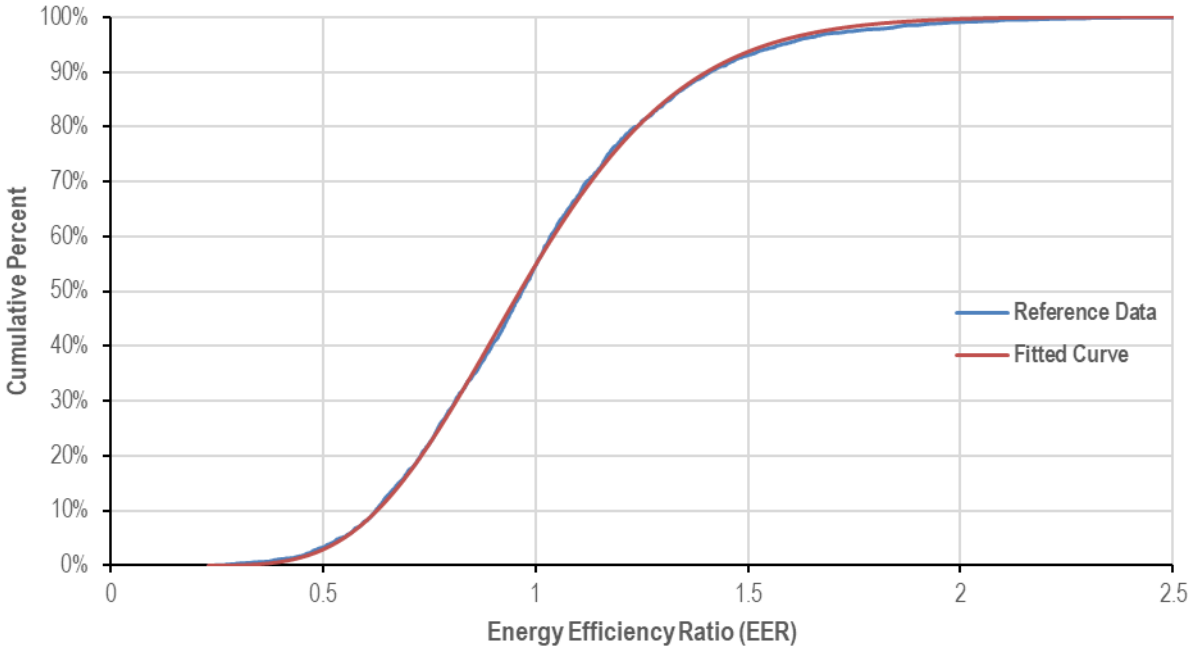
The final regression equation (presented in ***Figure 3***) yields a prediction of source energy based on a building's operating characteristics. Some buildings in the reference data sample use more energy than predicted by the regression equation, while others use less. The *actual* source energy of each reference data observation is divided by its *predicted* source energy consumption to calculate an energy efficiency ratio:

$$Energy\ Efficiency\ Ratio = \frac{Actual\ Source\ Energy\ Consumption}{Predicted\ Source\ Energy\ Consumption}$$

A lower efficiency ratio indicates that a building uses less energy than predicted, and consequently is more efficient. A higher efficiency ratio indicates the opposite.

The efficiency ratios are sorted from smallest to largest and the cumulative percent of the population at each ratio is computed using the individual observation weights from the reference data set. ***Figure 3*** presents a plot of this cumulative distribution. A smooth curve (shown in orange) is fitted to the data using a two-parameter gamma distribution. The fit is performed in order to minimize the sum of squared differences between each building's actual percent rank in the population and each building's percent rank with the gamma solution. The final fit for the gamma curve yielded a shape parameter (alpha) of 10.45 and a scale parameter (beta) of 0.0952. For this fit, the sum of the squared error is 0.1369.

Figure 3 - Distribution for Single Family Homes



The final gamma shape and scale parameters are used to calculate the efficiency ratio at each percentile (1 to 100) along the curve. For example, the ratio on the gamma curve at 1% corresponds to a score of 99; only 1% of the population has a ratio this small or smaller. The ratio on the gamma curve at the value of 25% will correspond to the ratio for a score of 75; only 25% of the population has ratios this small or smaller. The complete score lookup table is presented in ***Figure 4***.

Figure 4 – ENERGY STAR Score for Single-Family Homes Lookup Table

ENERGY STAR Score	Cumulative Percent	Energy Efficiency Ratio > =	Energy Efficiency Ratio <	ENERGY STAR Score	Cumulative Percent	Energy Efficiency Ratio >=	Energy Efficiency Ratio <
100	0%	0.0000	0.4205	50	50%	0.9633	0.9709
99	1%	0.4205	0.4687	49	51%	0.9709	0.9785
98	2%	0.4687	0.5013	48	52%	0.9785	0.9862
97	3%	0.5013	0.5268	47	53%	0.9862	0.9939
96	4%	0.5268	0.5482	46	54%	0.9939	1.0017
95	5%	0.5482	0.5669	45	55%	1.0017	1.0096
94	6%	0.5669	0.5837	44	56%	1.0096	1.0175
93	7%	0.5837	0.5990	43	57%	1.0175	1.0256
92	8%	0.5990	0.6132	42	58%	1.0256	1.0337
91	9%	0.6132	0.6264	41	59%	1.0337	1.0418
90	10%	0.6264	0.6389	40	60%	1.0418	1.0501
89	11%	0.6389	0.6507	39	61%	1.0501	1.0585
88	12%	0.6507	0.6620	38	62%	1.0585	1.0670
87	13%	0.662	0.6729	37	63%	1.0670	1.0756
86	14%	0.6729	0.6833	36	64%	1.0756	1.0844
85	15%	0.6833	0.6934	35	65%	1.0844	1.0933
84	16%	0.6934	0.7032	34	66%	1.0933	1.1023
83	17%	0.7032	0.7127	33	67%	1.1023	1.1115
82	18%	0.7127	0.7220	32	68%	1.1115	1.1209
81	19%	0.7220	0.7310	31	69%	1.1209	1.1305
80	20%	0.731	0.7399	30	70%	1.1305	1.1402
79	21%	0.7399	0.7486	29	71%	1.1402	1.1502
78	22%	0.7486	0.7571	28	72%	1.1502	1.1604
77	23%	0.7571	0.7655	27	73%	1.1604	1.1709
76	24%	0.7655	0.7737	26	74%	1.1709	1.1816
75	25%	0.7737	0.7819	25	75%	1.1816	1.1927
74	26%	0.7819	0.7899	24	76%	1.1927	1.2040
73	27%	0.7899	0.7979	23	77%	1.204	1.2157
72	28%	0.7979	0.8057	22	78%	1.2157	1.2278
71	29%	0.8057	0.8135	21	79%	1.2278	1.2404
70	30%	0.8135	0.8212	20	80%	1.2404	1.2533
69	31%	0.8212	0.8289	19	81%	1.2533	1.2669
68	32%	0.8289	0.8365	18	82%	1.2669	1.2810
67	33%	0.8365	0.8441	17	83%	1.281	1.2957
66	34%	0.8441	0.8516	16	84%	1.2957	1.3112
65	35%	0.8516	0.8591	15	85%	1.3112	1.3275
64	36%	0.8591	0.8665	14	86%	1.3275	1.3448
63	37%	0.8665	0.8740	13	87%	1.3448	1.3631
62	38%	0.874	0.8814	12	88%	1.3631	1.3828
61	39%	0.8814	0.8888	11	89%	1.3828	1.4040
60	40%	0.8888	0.8962	10	90%	1.404	1.4270
59	41%	0.8962	0.9036	9	91%	1.427	1.4523
58	42%	0.9036	0.9110	8	92%	1.4523	1.4804
57	43%	0.911	0.9184	7	93%	1.4804	1.5123
56	44%	0.9184	0.9258	6	94%	1.5123	1.5491
55	45%	0.9258	0.9333	5	95%	1.5491	1.5932
54	46%	0.9333	0.9407	4	96%	1.5932	1.6484
53	47%	0.9407	0.9482	3	97%	1.6484	1.7237
52	48%	0.9482	0.9557	2	98%	1.7237	1.8467
51	49%	0.9557	0.9633	1	99%	1.8467	>1.8467

EXAMPLE CALCULATION

As detailed in our Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore, there are five steps to compute a score. The following is a specific example for the ENERGY STAR score:

1 User Enters Building Data into Portfolio Manager

- 12 months of energy use information for all energy types (annual values, entered in monthly meter entries)
- Physical building information (e.g., size, location) and use details describing building activity (e.g., number of household members)

Energy Data	Value
Electricity	10,551 kWh
Natural gas	240 therms

Property Use Details	Value
Gross floor area (ft^2)	1,600
Number of Household Members	4
CDD (provided by Portfolio Manager, based on ZIP code)	6,126
HDD (provided by Portfolio Manager, based on ZIP code)	1,074

2 Portfolio Manager Computes the Actual Source Energy Consumption

- Total energy consumption for each fuel is converted from billing units into site energy and source energy.
- Source energy values are added across all fuel types.

Computing Actual Source Energy Consumption

Fuel	Billing Units	Site kBtu Multiplier	Site kBtu	Source kBtu Multiplier	Source kBtu
Electricity	10,551 kWh	3.412	36,000	2.80	100,800
Natural Gas	240 therms	100	24,000	1.05	25,200
			Total Source Energy (kBtu)		**126,000**

3 Portfolio Manager computes the predicted source energy consumption

- Using the property use details from Step 1, Portfolio Manager computes each building variable value in the regression equation (determining the natural log or density or applying any minimum or maximum values used in the regression model, as necessary).
- The actual building values are multiplied by the coefficients from the regression equation and then summed to obtain a predicted source energy consumption.

Computing Predicted Source Energy Consumption

Variable	Actual Building Value	Coefficient	Coefficient * Variable
Gross Floor Area	1,600	29.05	46,480
# Of Household Members	4	12,073	48,292
CDD	1,074	17.38	18,666
HDD	6,126	9.763	59,808
	Predicted Source Energy (kBtu)		**173,246**

4 Portfolio Manager computes the energy efficiency ratio

- The energy efficiency ratio equals the actual source energy consumption (Step 2) divided by predicted source energy consumption (Step 3)
- Energy Efficiency Ratio = 126,000 / 173,246 = 0.7273

5 Portfolio Manager uses the efficiency ratio to assign a score via a lookup table

- The energy efficiency ratio from Step 4 is used to identify the score from the lookup table
- An energy efficiency ratio of 0.7273 is greater than or equal to 0.7220 and less than 0.7310.
- ***The ENERGY STAR score is 81.***