

ENERGY STAR Score for Residence Halls/Dormitories in the United States

OVERVIEW

The ENERGY STAR Score for Residence Halls/Dormitories applies to buildings associated with educational institutions (residence halls/dormitories) or military facilities (barracks) which offer multiple accommodations for long-term residents. 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 business 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 business activities. 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 residence halls/dormitories applies to buildings associated with educational institutions (residence halls/dormitories) or military facilities (barracks) which offer multiple accommodations for long-term residents. The score applies to individual buildings only and is not available for campuses.
- **Reference Data.** The analysis for residence halls/dormitories is based on data from the Department of Energy, Energy Information Administration's 1999 Commercial Building Energy Consumption Survey (CBECS).
- **Adjustments for Weather and Business Activity.** The analysis includes adjustments for:
 - Building Size
 - Number of Guest/Occupant Rooms
 - Weather and Climate (using Heating and Cooling Degree Days, retrieved based on Zip code)
 - Percent of the Building that is Heated and Cooled
 - **Release Date.** The ENERGY STAR score for residence halls/dormitories was released in January 2004.

This document presents details on the development of the 1 - 100 ENERGY STAR score for residence hall/dormitories. 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 residence halls/dormitories:

OVERVIEW	1
REFERENCE DATA & FILTERS	2
VARIABLES ANALYZED	3
REGRESSION EQUATION RESULTS.....	4
SCORE LOOKUP TABLE.....	5
EXAMPLE CALCULATION.....	8

REFERENCE DATA & FILTERS

For the ENERGY STAR score for residence hall/dormitory properties, the reference data used to establish the peer building population in the United States is based on data from the Department of Energy, Energy Information Administration's (EIA) 1999 Commercial Building Energy Consumption Survey (CBECS). Detailed information on this survey, including complete data files, is available at: <http://www.eia.doe.gov/emeu/cbecs/contents.html>.

To analyze the building energy and operating characteristics in this survey data, four types of filters are applied 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 for residence halls/dormitories and the rationale behind the filter. After all filters are applied, the remaining data set has 79 properties.

Figure 1 – Summary of Filters for the ENERGY STAR Score for Residence Halls/Dormitories

Condition for Including an Observation in the Analysis	Rationale
PBAPLUS7= 9	Building Type Filter – CBECS defines building types according to the variable “PBAPLUS7.” Residence Hall/Dormitory buildings are coded as PBAPLUS7= 9.
Source energy use intensity (kBtu/ft ² -yr) must be greater than 40 and less than 425 kBtu/ft ² -yr	Analytical Filter – Values determined to be statistical outliers.

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 (e.g., hotels smaller than 5,000 ft² do not behave the same way as larger buildings), 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.

Related to the filters and eligibility criteria described above, another consideration is how Portfolio Manager treats properties that are situated on a campus. The main unit for benchmarking in Portfolio Manager is the property, which may be used to describe either a single building or a campus of buildings. The applicability of the ENERGY STAR score depends on the type of property. For residence hall/dormitory properties, the score is based on individual buildings, because the primary function of the residence hall/dormitory is contained within a single building and because the properties included in the reference data are single buildings. In cases where multiple residence halls/dormitories are situated together, each individual building can receive its own ENERGY STAR score, but the group of buildings together cannot earn a score.

VARIABLES ANALYZED

To normalize for differences in business activity, 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., guest/occupant rooms). 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 residence halls/dormitories.

Dependent Variable

The dependent variable is what we try to predict with the regression equation. For the residence hall/dormitory analysis, the dependent variable is energy consumption expressed as the natural log of source energy use, or Ln (source energy). The regressions analyze the key drivers of Ln (source energy) – those factors that explain the variation in the natural log of source energy in residence halls/dormitories.

Independent Variables

The reference survey collects numerous property operating characteristics that were identified as potentially important for residence halls/dormitories. These include characteristics such as the total square footage, the number of guest/occupant rooms, the percent of the building that is heated and cooled, and the number of heating and cooling degree days.

We perform extensive review on all operational characteristics available in the data, in accordance with the criteria for inclusion in Portfolio Manager.¹ In addition to reviewing each characteristic individually, characteristics are reviewed in combination with each other (e.g., Heating Degree Days times Percent Heated). As part of the analysis, some variables are reformatted to reflect the physical relationships of building components. In addition, based on analytical results and residual plots, variables are examined using different transformations (such as the natural logarithm). 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: Ln (source energy).

The final regression equation includes the following variables:

- Natural log of gross square foot
- Natural log of number of guest/occupant rooms
- Heating degree days times Percent of the building that is heated
- Cooling degree days times Percent of the building that is cooled

These variables are used together to compute the predicted Ln (source energy) for residence halls/dormitories. The predicted Ln (source energy) is the mean Ln (source energy) for a hypothetical population of buildings that share the same values for each of these variables. That is, the mean energy use for a building that operates just like your building.

¹ For a complete explanation of these criteria, refer to our Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore.

Testing

Finally, we test the regression equation using actual residence hall/dormitory buildings, using supplemental data provided by ENERGY STAR partners. This provides another set of buildings to examine in addition to the CBECS data, to see the average ENERGY STAR scores and distributions, and to assess the impacts and adjustments. This analysis provides a second level of confirmation that the final regression equation produces robust results that are unbiased with respect to the key operational characteristics such as building size, guest/occupant rooms, and heating and cooling degree days.

It is important to reiterate that the final regression equation is based on the nationally representative reference data, not data previously entered into Portfolio Manager.

REGRESSION EQUATION RESULTS

The final regression is a weighted ordinary least squares regression across the filtered data set of 79 observations. The dependent variable is Ln (source energy). Each independent variable is presented in **Figure 2**. The final equation is presented in **Figure 3**. 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), with the exception of guest/occupant rooms, which has a lower level of significance (75%). However, given the physical relationship between guest/occupant room and energy consumption, this result was considered acceptable, and therefore guest/occupant rooms was retained in the analysis.

The regression equation has a coefficient of determination (R^2) value of 0.8834, indicating that this equation explains 88.34% of the variance in Ln (source energy) for residence hall/dormitory buildings. 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 - Descriptive Statistics for Variables in Final Regression Equation

Variable	Mean	Minimum	Maximum
Ln (Source energy) (kBtu)	15.717	12.584	18.699
Ln (Square Foot)	10.705	8.161	13.653
Ln (Number of Rooms)	4.417	1.386	6.397
Heating Degree Days x Percent Heated	4575	116.2	7339
Cooling Degree Days x Percent Cooled	510.3	0.000	3162

Figure 3 - Final Regression Results

Summary				
Dependent Variable	Ln (Source Energy) (kBtu)			
Number of Observations in Analysis	79			
R ² value	0.8834			
Adjusted R ² value	0.8771			
F Statistic	140.1			
Significance (p-level)	0.000			
	Unstandardized Coefficients	Standard Error	T value	Significance (p-level)
Constant	4.99455	0.5671	8.81	<.0001
Ln (Square Foot)	0.91308	0.07724	11.82	<.0001
Ln (Number of Rooms)	0.09455	0.08141	1.16	0.2492
Heating Degree Days x Percent Heated	0.00009774	0.00003297	2.96	0.0041
Cooling Degree Days x Percent Cooled	0.00016279	0.08141	2.14	0.0357

Notes:

- The regression is a weighted ordinary least squares regression, weighted by the CBECS variable "ADJWT8".

ENERGY STAR SCORE LOOKUP TABLE

The final regression equation (presented in **Figure 3**) yields a prediction of Ln (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* Ln (source energy) of each reference data observation is divided by its *predicted* Ln (source energy) to calculate an energy efficiency ratio:

$$\text{Energy Efficiency Ratio} = \frac{\text{Actual Ln (source energy)}}{\text{Predicted Ln (source energy)}}$$

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. For each building, the ratio is expressed in terms of a normalized Ln (source energy) to represent the value for Ln (source energy) that the building would have if it were average. This normalized energy use is obtained by multiplying the efficiency ratio by the mean value of Ln (source energy):²

$$\text{Normalized Ln (Source Energy)} = \text{EnergyEfficiency Ratio} \times 15.717$$

The normalized Ln (source energy) values are sorted from smallest to largest and the cumulative percent of the population at each energy value is computed. A smooth curve is fitted to the data using a two parameter gamma

² The mean value of Ln (source energy) is determined by the dataset and is presented in **Figure 2**. It is 15.717.

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 fit is performed with the constraint that the gamma value of Ln (source energy) at an ENERGY STAR score of 75 must equal the actual value of Ln (source energy) at 75.

The final gamma shape and scale parameters are used to calculate the normalized Ln (source energy) value at each percentile (1 to 100) along the curve. For example, the normalized Ln (source energy) value on the gamma curve at 1% corresponds to a score of 99; only 1% of the population has a value this small or smaller. The normalized Ln (source energy) value on the gamma curve at the value of 25% will correspond to the normalized Ln (source energy) value for a score of 75; only 25% of the population has normalized Ln (source energy) values this small or smaller. The complete lookup table³ is presented in **Figure 4**.

³ The lookup table was adjusted in 2018 to account for updated ratios used in Portfolio Manager to convert site energy to source energy.

Figure 4 – ENERGY STAR Score Lookup Table for Residence Halls/Dormitories

ENERGY STAR Score	Cumulative Percent	Normalized Ln (Source Energy)		ENERGY STAR Score	Cumulative Percent	Normalized Ln (Source Energy)	
		>=	<			>=	<
100	0%	0.0000	14.5554	50	50%	15.6844	15.6954
99	1%	14.5554	14.6204	49	51%	15.6954	15.7064
98	2%	14.6204	14.6814	48	52%	15.7064	15.7184
97	3%	14.6814	14.7384	47	53%	15.7184	15.7294
96	4%	14.7384	14.7924	46	54%	15.7294	15.7404
95	5%	14.7924	14.8424	45	55%	15.7404	15.7514
94	6%	14.8424	14.8894	44	56%	15.7514	15.7624
93	7%	14.8894	14.9334	43	57%	15.7624	15.7744
92	8%	14.9334	14.9744	42	58%	15.7744	15.7854
91	9%	14.9744	15.0134	41	59%	15.7854	15.7964
90	10%	15.0134	15.0494	40	60%	15.7964	15.8074
89	11%	15.0494	15.0834	39	61%	15.8074	15.8184
88	12%	15.0834	15.1154	38	62%	15.8184	15.8304
87	13%	15.1154	15.1454	37	63%	15.8304	15.8414
86	14%	15.1454	15.1734	36	64%	15.8414	15.8524
85	15%	15.1734	15.1994	35	65%	15.8524	15.8634
84	16%	15.1994	15.2244	34	66%	15.8634	15.8754
83	17%	15.2244	15.2484	33	67%	15.8754	15.8864
82	18%	15.2484	15.2704	32	68%	15.8864	15.8984
81	19%	15.2704	15.2914	31	69%	15.8984	15.9094
80	20%	15.2914	15.3104	30	70%	15.9094	15.9214
79	21%	15.3104	15.3294	29	71%	15.9214	15.9334
78	22%	15.3294	15.3474	28	72%	15.9334	15.9454
77	23%	15.3474	15.3644	27	73%	15.9454	15.9574
76	24%	15.3644	15.3804	26	74%	15.9574	15.9694
75	25%	15.3804	15.3964	25	75%	15.9694	15.9824
74	26%	15.3964	15.4114	24	76%	15.9824	15.9954
73	27%	15.4114	15.4254	23	77%	15.9954	16.0094
72	28%	15.4254	15.4394	22	78%	16.0094	16.0224
71	29%	15.4394	15.4524	21	79%	16.0224	16.0364
70	30%	15.4524	15.4654	20	80%	16.0364	16.0514
69	31%	15.4654	15.4784	19	81%	16.0514	16.0664
68	32%	15.4784	15.4914	18	82%	16.0664	16.0824
67	33%	15.4914	15.5034	17	83%	16.0824	16.0994
66	34%	15.5034	15.5154	16	84%	16.0994	16.1164
65	35%	15.5154	15.5274	15	85%	16.1164	16.1344
64	36%	15.5274	15.5384	14	86%	16.1344	16.1534
63	37%	15.5384	15.5504	13	87%	16.1534	16.1734
62	38%	15.5504	15.5614	12	88%	16.1734	16.1954
61	39%	15.5614	15.5734	11	89%	16.1954	16.2174
60	40%	15.5734	15.5844	10	90%	16.2174	16.2414
59	41%	15.5844	15.5954	9	91%	16.2414	16.2664
58	42%	15.5954	15.6064	8	92%	16.2664	16.2934
57	43%	15.6064	15.6174	7	93%	16.2934	16.3224
56	44%	15.6174	15.6294	6	94%	16.3224	16.3524
55	45%	15.6294	15.6404	5	95%	16.3524	16.3844
54	46%	15.6404	15.6514	4	96%	16.3844	16.4194
53	47%	15.6514	15.6624	3	97%	16.4194	16.4554
52	48%	15.6624	15.6734	2	98%	16.4554	16.4954
51	49%	15.6734	15.6844	1	99%	16.4954	>16.4954

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 score for residence halls/dormitories:

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 (size, location, etc.) and use details describing building activity (rooms, etc.)

Energy Data	Value
Electricity	271,500 kWh
Natural gas	5,900 therms

Property Use Details	Value
Gross floor area (ft ²)	44,000
Number of rooms	80
Percent of the building that is heated	100%
Percent of the building that is cooled	100%
HDD (provided by Portfolio Manager, based on Zip code)	4500
CDD (provided by Portfolio Manager, based on Zip code)	500

2 Portfolio Manager computes the actual Ln (source energy)

- 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
- The natural log of total source energy consumption is computed

Computing Actual Ln (Source Energy)

Fuel	Billing Units	Site kBtu Multiplier	Site kBtu	Source kBtu Multiplier	Source kBtu
Electricity	271,500 kWh	3.412	926,358	2.80	2,593,802
Natural gas	5,900 therms	100	590,000	1.05	619,500
Total Source Energy (kBtu)					3,213,302
Actual Ln (Source Energy) (kBtu)					14.983

3 Portfolio Manager computes the predicted Ln (source energy)

- 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 variables are multiplied by the coefficients from the regression equation to obtain a predicted Ln (source energy).

Computing Predicted Ln (Source Energy)

Variable	Actual Building Value	Coefficient	Coefficient * Variable
Constant	--	4.995	4.995
Ln (Square Foot)	10.69	0.9131	9.763
Ln (Number of Rooms)	4.382	0.0946	0.414
HDD x Percent Heated	4500	0.0001	0.440
CDD x Percent Cooled	500	0.0002	0.081

Predicted Ln (Source Energy) (kBtu) 15.693

4 Portfolio Manager computes the energy efficiency ratio

- The ratio equals the actual Ln (source energy) (Step 2) divided by predicted Ln (source energy) (Step 3)
- Ratio = 14.983 / 15.693 = 0.9548

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

- The ratio from Step 4 is converted into normalized Ln (source energy)
 - Normalized Ln (source energy) = energy efficiency ratio * mean Ln (source energy)
 - Mean Ln (source energy) is provided in **Figure 2** = 15.717
 - Normalized Ln (source energy) = 0.9548 * 15.717 = 15.007
- This value is then then used to identify the score from the lookup table
- A normalized value of 15.007 is greater than 14.9744 and less than 15.0134.
- The ENERGY STAR score is 91.**