ENERGY STAR® PortfolioManager®

Technical Reference

ENERGY STAR Score for Hotels in the United States

OVERVIEW

The ENERGY STAR Score for Hotels applies to properties renting overnight accommodations on a room/suite and nightly basis. 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 hotels applies to properties renting overnight accommodations on a room/suite and nightly basis. The score applies to an entire hotel whether it is a single building or a campus of buildings.
- **Reference Data.** The analysis for hotels is based on data from the Department of Energy, Energy Information Administration's 2003 Commercial Building Energy Consumption Survey (CBECS).
- **Adjustments for Weather and Business Activity.** The analysis includes adjustments for:
    - Building Size
    - Number of Rooms
    - Number of Workers
    - Number of Commercial Refrigeration Units
    - Presence of a Commercial Food Preparation Area
    - 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 hotels is updated periodically as more recent data becomes available:
    - Most Recent Update: February 2009
    - Original Release: April 2002

This document presents details on the development of the 1 - 100 ENERGY STAR score for hotel properties. 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 hotels:

REFERENCE DATA & FILTERS

For the ENERGY STAR score for hotels, 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) 2003 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 hotels, 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 142 properties.

Figure 1 – Summary of Filters for the ENERGY STAR Score for Hotels

Condition for Including an Observation in the Analysis	Rationale	Number Remaining
PBAPLUS8 = 38 or 39	Building Filter – CBECS defines building types according to the variable "PBAPLUS8." Hotels are coded as PBAPLUS=38 and Motels are coded as PBAPLUS=39.	195
Must have at least 1 room	EPA Program Filter – Baseline condition for being a full time hotel.	195
Must operate for 168 hours per week	EPA Program Filter – Baseline condition for being a full time hotel.	192
Must have at least 1 worker	EPA Program Filter – Baseline condition for being a full time hotel.	190
Must operate for at least 10 months per year	EPA Program Filter – Baseline condition for being a full time hotel.	182
A single activity must characterize greater than 50% of the floor space[1]	EPA Program Filter – In order to be considered part of the hotel peer group, more than 50% of the building must be defined as a hotel.	180
If propane is used, the amount category (PRAMTC8) must equal 1, 2, or 3	Data Limitation Filter – Cannot estimate propane use if the quantity is "greater than 1000" or unknown.	161

[1] This filter is applied by a set of screens. If the variable ONEACT8=1, then one activity occupies 75% or more of the building. If the variable ONEACT8=2, then the activities in the building are defined by ACT1, ACT2, and ACT3. One of these activities must be coded as lodging (PBAX=21), with a corresponding percent (ACT1PCT8, ACTPCT8, ACT3PCT8) that is greater than 50.

Condition for Including an Observation in the Analysis	Rationale	Number Remaining
If propane is used, the maximum estimated propane amount must be 10% or less of the total source energy	Data Limitation Filter – Because propane values are estimated from a range, propane is restricted to 10% of the total source energy.	159
Must not use chilled water	Data Limitation Filter – CBECS does not collect quantities of chilled water.	157
Must be at least 5,000 square foot	Analytical Filter – Analysis could not model behavior for buildings smaller than 5,000 ft^2.	149
Must have Source EUI less than or equal to 600 kBtu/ft^2	Analytical Filter – Values determined to be statistical outliers.	147
Must have Source EUI greater than or equal to 10 kBtu/ft^2	Analytical Filter – Values determined to be statistical outliers.	146
Must have fewer than 5 rooms per 1,000 square foot	Analytical Filter – Values determined to be statistical outliers.	143
Must have fewer than 0.5 commercial refrigeration units per 1,000 square foot	Analytical Filter – Values determined to be statistical outliers.	142

The reasons for applying filters on the use and quantity of propane are worthy of additional discussion. In CBECS, major fuel use is reported in exact quantities. However, if a building uses propane, the amount of propane is reported according to the variable PRAMT8, which uses ranges rather than exact quantities (e.g., less than 100 gallons, 100 to 500 gallons, etc.). Therefore, the quantity must be estimated within the range. To limit error associated with this estimation, EPA applies two filters related to propane.

1. The quantity of propane expressed by PRAMT8 must be 1000 gallons or smaller.
2. The value of propane cannot account for more than 10% of the total source energy use. Because the exact quantity of propane is not reported, this cap ensures that the quantity of propane entered will not introduce undue error into the calculation of total energy consumption. In order to determine if the 10% cap is exceeded, the value at the high end of the propane category is employed (e.g., for the category of less than 100, a value of 99 is used). If the 10% cap is not exceeded, then EPA will use the value at the middle of the range to calculate total energy use for the regression analysis (e.g., for the category of less than 100, a value of 50 is used).

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 ft^2 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 hotels, the score is based on a campus of buildings, because each building on the campus is necessary to make the complete function of the property. For property types that earn a campus score, the entire campus will receive a 1 - 100 score and no individual buildings on the campus can earn a separate score. When there is a single building property of this type (e.g., entire hotel in one building), it is also eligible for 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., number of guest rooms, number of workers, and 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 hotels.

Dependent Variable

The dependent variable is what we try to predict with the regression equation. For the hotel analysis, the dependent variable is energy consumption expressed in source energy use intensity (source EUI). This is equal to the total source energy use of the property divided by the gross floor area. The regressions analyze the key drivers of source EUI – those factors that explain the variation in source energy use per square foot in a hotel.

Independent Variables

The reference survey collects numerous property operating characteristics that were identified as potentially important for hotels. 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:[3]

- SQFT8 – Square footage
- LODGRM8 – Number of guest rooms
- NWKER8 – Number of employees during the main shift
- COOK8 – Energy used for cooking (yes/no)
- FDRM8 – Commercial food preparation area (yes/no)

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

[3] Note that the number 8 at the end of all variables indicates that the 2003 CBECS survey is the eighth survey conducted by the Energy Information Administration.

- SNACK8 – Snack bar (yes/no)
- FASTFD8 – Fast food or small restaurant (yes/no)
- CAF8 – Cafeteria or large restaurant (yes/no)
- FDPREP8 – Food preparation area (yes/no)
- KITCHN8 – Small kitchen area (yes/no)
- OTFDRM8 – Other food prep area (yes/no)
- RFGWIN8 – Number of walk-in refrigeration units
- RFGOPN8 – Number of open refrigerated cases
- RFGRSN8 – Number of residential refrigerators
- RFGCLN8 – Number of closed refrigerated cases
- RFGVNN8 – Number of refrigerated vending machines
- PCNUM8 – Number of personal computers
- SVRNUM8 – Number of servers
- TRNGRM8 – Computer-based training room (yes/no)
- STDNRM8 – Student or public computer center (yes/no)
- OTPCRM8 – Other computer area (yes/no)
- POOL8 – Pool (yes/no)
- HWTRM8 – Large amounts of hot water used (yes/no)
- LAUNDR8 – Laundry onsite (yes/no)
- NFLOOR8 – Number of floors
- ELEVTR8 – Elevators (yes/no)
- NESLTR8 – Number of escalators
- SRVNUM8 – Number of servers

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 (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. For example, the number of workers on the main shift is typically evaluated in a density format. The number of workers *per square foot* (not the gross number of workers) is expected to be correlated with the energy use per square foot. In addition, based on analytical results and residual plots, variables are examined using different transformations (such as the natural logarithm, abbreviated as Ln). 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 EUI.

The final regression equation includes the following variables:

- Number of lodging rooms per 1,000 square feet
- Natural log of the number of workers per 1,000 square feet
- Presence of a commercial food preparation area (yes/no)
- Number of commercial refrigeration units (walk-in, open, and closed) per 1,000 square feet
- 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 source EUI for hotels. The predicted source EUI is the mean EUI 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.

Testing

Finally, we test the regression equation using actual hotel buildings that have been entered in Portfolio Manager. 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, room density, worker density, 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 142 observations. The dependent variable is source EUI. Each independent variable is centered relative to the mean value, presented in ***Figure 2***. The final equation is presented in ***Figure 3***. All variables in the regression equation are significant at the 90% confidence level or better, as shown by the significance levels (a p-level of less than 0.10 indicates 90% confidence).

The regression equation has a coefficient of determination (R^2) value of 0.3669 indicating that this equation explains 36.69% of the variance in source EUI for hotel buildings. Because the final equation is structured with energy per square foot as the dependent variable, the explanatory power of square foot is not included in the R^2 value, thus this value appears artificially low. Re-computing the R^2 value in units of source energy[4], demonstrates that the equation actually explains 87.8% of the variation of source energy of hotels. 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.

[4] The R^2 value in Source Energy is calculated as: 1 – (Residual Variation of Y) / (Total Variation of Y). The residual variation is sum of $(\text{Actual Source Energy}_i - \text{Predicted Source Energy}_i)^2$ across all observations. The Total variation of Y is the sum of $(\text{Actual Source Energy}_i - \text{Mean Source Energy})^2$ across all observations.

Figure 2 - Descriptive Statistics for Variables in Final Regression Equation

Variable	Mean	Minimum	Maximum
Source EUI (kBtu/ft^2)	182.5	49.08	544.3
Number of Rooms per 1,000 ft^2	1.951	0.5195	4.237
Ln (Number of Workers per 1000 ft^2)	-1.395	-3.245	1.008
Presence of Commercial Food Preparation	0.2056	0.000	1.000
Number of Commercial Refrigeration Units per 1,000 ft^2	0.0227	0.000	0.3125
Heating Degree Days x Percent Heated	4,120	31.90	9,928
Cooling Degree Days x Percent Cooled	1,224	0.000	4,871

Figure 3 - Final Regression Results

Summary				
Dependent Variable		Source Energy Intensity (kBtu/ft^2)		
Number of Observations in Analysis		142		
R^2 value		0.3669		
Adjusted R^2 value		0.3388		
F Statistic		13.04		
Significance (p-level)		0.0000		
	Unstandardized Coefficients	**Standard Error**	**T value**	**Significance (p-level)**
Constant	169.1	7.457	22.68	0.0000
C_Room Density	33.22	9.330	3.560	0.0005
C_Ln (Number of Workers per 1000 ft^2)	20.81	10.38	2.004	0.0471
FDRM	65.14	18.64	3.494	0.0006
Commercial Refrigeration Density	249.8	147.2	1.697	0.0920
C_HDD x Percent Heated	0.0107	0.0029	3.653	0.0004
C_CDD x Percent Cooled	0.0169	0.0085	1.988	0.0488

Note:
- *The regression is a weighted ordinary least squares regression, weighted by the CBECS variable "ADJWT8".*
- *The prefix C_ on each variable indicates that it is centered. The centered variable is equal to difference between the actual value and the observed mean. The observed mean values are presented in **Figure 2**.*
- *Unlike other variables, the yes/no variable FDRM is not centered. The coefficient adjustment represents the adjustment for Hotels with cooking facilities.*

ENERGY STAR SCORE LOOKUP TABLE

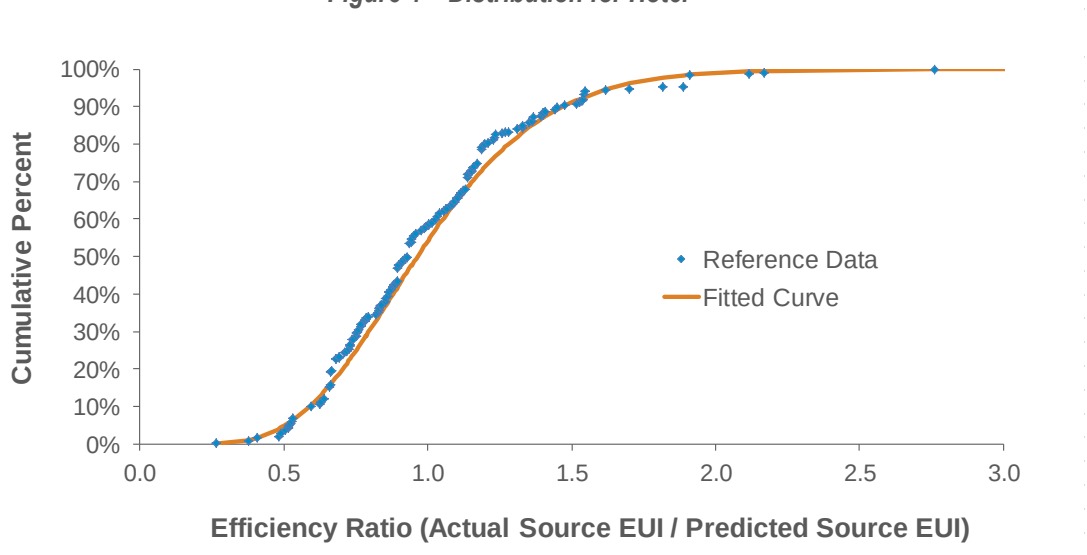
The final regression equation (presented in ***Figure 3***) yields a prediction of source EUI based on a building's operating characteristics. Some buildings in the reference data sample use more energy than predicted by the regression equation, while others use less. The *actual* source EUI of each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

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

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 4*** 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 8.229 and a scale parameter (beta) of 0.1220. For this fit, the sum of the squared error is 0.0485.

Figure 4 – Distribution for Hotel



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 5***.

Figure 5 – ENERGY STAR Score Lookup Table for Hotel

ENERGY STAR Score	Cumulative Percent	Energy Efficiency Ratio > =	Energy Efficiency Ratio <
100	0%	0.0000	0.3356
99	1%	0.3356	0.3816
98	2%	0.3816	0.4130
97	3%	0.4130	0.4378
96	4%	0.4378	0.4588
95	5%	0.4588	0.4772
94	6%	0.4772	0.4938
93	7%	0.4938	0.5088
92	8%	0.5088	0.5230
91	9%	0.5230	0.5361
90	10%	0.5361	0.5485
89	11%	0.5485	0.5604
88	12%	0.5604	0.5717
87	13%	0.5717	0.5827
86	14%	0.5827	0.5931
85	15%	0.5931	0.6033
84	16%	0.6033	0.6132
83	17%	0.6132	0.6229
82	18%	0.6229	0.6322
81	19%	0.6322	0.6413
80	20%	0.6413	0.6504
79	21%	0.6504	0.6592
78	22%	0.6592	0.6678
77	23%	0.6678	0.6764
76	24%	0.6764	0.6848
75	25%	0.6848	0.6931
74	26%	0.6931	0.7014
73	27%	0.7014	0.7095
72	28%	0.7095	0.7175
71	29%	0.7175	0.7255
70	30%	0.7255	0.7335
69	31%	0.7335	0.7413
68	32%	0.7413	0.7491
67	33%	0.7491	0.7569
66	34%	0.7569	0.7647
65	35%	0.7647	0.7724
64	36%	0.7724	0.7801
63	37%	0.7801	0.7878
62	38%	0.7878	0.7955
61	39%	0.7955	0.8032
60	40%	0.8032	0.8108
59	41%	0.8108	0.8185
58	42%	0.8185	0.8262
57	43%	0.8262	0.8339
56	44%	0.8339	0.8416
55	45%	0.8416	0.8494
54	46%	0.8494	0.8571
53	47%	0.8571	0.8649
52	48%	0.8649	0.8727
51	49%	0.8727	0.8806

ENERGY STAR Score	Cumulative Percent	Energy Efficiency Ratio >=	Energy Efficiency Ratio <
50	50%	0.8806	0.8885
49	51%	0.8885	0.8965
48	52%	0.8965	0.9045
47	53%	0.9045	0.9126
46	54%	0.9126	0.9208
45	55%	0.9208	0.9290
44	56%	0.9290	0.9373
43	57%	0.9373	0.9458
42	58%	0.9458	0.9543
41	59%	0.9543	0.9629
40	60%	0.9629	0.9716
39	61%	0.9716	0.9804
38	62%	0.9804	0.9894
37	63%	0.9894	0.9984
36	64%	0.9984	1.0077
35	65%	1.0077	1.0171
34	66%	1.0171	1.0266
33	67%	1.0266	1.0364
32	68%	1.0364	1.0464
31	69%	1.0464	1.0564
30	70%	1.0564	1.0668
29	71%	1.0668	1.0774
28	72%	1.0774	1.0882
27	73%	1.0882	1.0993
26	74%	1.0993	1.1108
25	75%	1.1108	1.1225
24	76%	1.1225	1.1345
23	77%	1.1345	1.1470
22	78%	1.1470	1.1599
21	79%	1.1599	1.1733
20	80%	1.1733	1.1871
19	81%	1.1871	1.2016
18	82%	1.2016	1.2167
17	83%	1.2167	1.2325
16	84%	1.2325	1.2490
15	85%	1.2490	1.2665
14	86%	1.2665	1.2851
13	87%	1.2851	1.3048
12	88%	1.3048	1.3260
11	89%	1.3260	1.3488
10	90%	1.3488	1.3737
9	91%	1.3737	1.4009
8	92%	1.4009	1.4314
7	93%	1.4314	1.4659
6	94%	1.4659	1.5059
5	95%	1.5059	1.5538
4	96%	1.5538	1.6139
3	97%	1.6139	1.6962
2	98%	1.6962	1.8310
1	99%	1.8310	>1.8310

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 hotels:

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 (hours, etc.)

Energy Data	Value
Electricity	4,500,000 kWh
Natural gas	110,000 therms

Property Use Details	Value
Gross floor area (ft²)	300,000
Number of rooms	360
Workers on the main shift[5]	180
Commercial food preparation	1 (Yes)
Number of commercial refrigeration units	20
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)	4,532
CDD (provided by Portfolio Manager, based on Zip code)	1,388

2 Portfolio Manager computes the actual source EUI

- 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
- Source energy is divided by gross floor area to determine actual source EUI

Computing Actual Source EUI

Fuel	Billing Units	Site kBtu Multiplier	Site kBtu	Source kBtu Multiplier	Source kBtu
Electricity	4,500,000 kWh	3.412	15,354,000	3.14	48,211,560
Natural gas	110,000 therms	100	11,000,000	1.05	11,550,000
				Total Source Energy (kBtu)	59,761,560
				Actual Source EUI (kBtu/ft²)	**199.2**

[5] This represents typical peak staffing level during the main shift. For example, in an office if there are two daily 8 hour shifts of 100 workers each, the Workers on Main Shift value is 100.

3 Portfolio Manager computes the predicted source EUI

- 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 as necessary).
- The centering values are subtracted to compute the centered variable for each operating parameter.
- The centered variables are multiplied by the coefficients from the regression equation to obtain a predicted source EUI.

Computing Predicted Source EUI

Variable	Actual Building Value	Reference Centering Value	Building Centered Variable	Coefficient	Coefficient * Centered Variable
Constant	--	--	--	169.1	169.1
Room Density	1.200	1.951	-0.7510	33.22	-24.95
Ln (Number of Workers per 1000 ft^2)	-0.5110	-1.395	0.8840	20.81	18.40
FDRM	1.000	--	1.000	65.14	65.14
Commercial Refrigeration Density	0.0667	0.0227	0.0440	249.8	10.99
HDD x Percent Heated	4,532	4,120	412.0	0.0107	4.408
CDD x Percent Cooled	1,388	1,224	164.0	0.0169	2.772
				Predicted Source EUI (kBtu/ft^2)	**245.9**

4 Portfolio Manager computes the energy efficiency ratio

- The ratio equals the actual source EUI (Step 2) divided by predicted source EUI (Step 3)
- Ratio = 199.2/ 245.9 = 0.8101

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

- The ratio from Step 4 is used to identify the score from the lookup table
- A ratio of 0.8101 is greater than 0.8058 and less than 0.8136
- ***The ENERGY STAR score is 63***