ENERGY STAR® PortfolioManager®

Technical Reference

ENERGY STAR Score for Hotels in Canada

OVERVIEW

The ENERGY STAR score for hotels applies to hotels, as well as to hostels, lodges, motels and resorts. The objective of the ENERGY STAR score is to fairly assess how a property's energy use measures up against similar properties considering the climate, weather and business activities. A statistical analysis of the peer building population is performed to identify the aspects of property activity that are significant drivers of energy use and to normalize for those same factors. The result of this analysis is an equation that predicts the energy use of a property, based on its business activities. This prediction is compared to the property's actual energy use to yield a 1 - 100 percentile ranking in relation to the national population of properties.

- **Property types.** The ENERGY STAR score for hotels in Canada applies to hotels and other nightly lodgings. The score applies to an entire hotel, whether it is a single building or a campus of buildings.
- **Reference data.** The analysis for hotels in Canada is based on data from the Survey on Commercial and Institutional Energy Use (SCIEU), which was commissioned by Natural Resources Canada (NRCan) and carried out by Statistics Canada. The SCIEU represents the energy use for the year 2014.
- **Adjustments for weather and business activity.** The analysis includes adjustments for:
  - Number of rooms
  - Number of workers on the main shift
  - Gross floor area used for food preparation
  - Percentage of the building that is heated
  - Percentage of the building that is cooled
  - Weather and climate (using heating degree and cooling degree days, retrieved based on postal code)
- **Release date.** This is the original release of the *ENERGY STAR Score for Hotels in Canada*.

This document details the development of the 1 - 100 ENERGY STAR score for hotel properties. For more information on the methodology used to develop ENERGY STAR scores, see the *Portfolio Manager Technical Reference: ENERGY STAR Score* at www.energystar.gov/ENERGYSTARScore.

The following sections explain how the ENERGY STAR score for hotels is developed.

REFERENCE DATA & FILTERS

The reference data used to form the peer property population relies on the Survey on Commercial and Institutional Energy Use (SCIEU), which was commissioned by Natural Resources Canada (NRCan) and conducted by Statistics Canada in late 2015 and early 2016. The energy data for the survey was from the calendar year 2014. The raw collected data file for this survey is not available publicly, but a report providing summary results is available on the NRCan website at oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/scieu/2014/tables.cfm.

Four types of filters are applied to analyze the building energy and operating characteristics in the survey. They are set to define the peer population for comparison and to overcome any technical limitations. Those filters are Building Type Filters, Program Filters, Data Limitation Filters, and Analytical Filters.

A complete description of each category is given in the *Portfolio Manager Technical Reference: ENERGY STAR Score* at www.energystar.gov/ENERGYSTARScore. **Figure 1** summarizes each filter used to develop the ENERGY STAR score for the hotels model and the rationale that supports the filter. After all filters are applied, the remaining data set has 118 observations. NRCan cannot identify the number of cases after each filter because the survey data are confidential.

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

Condition for Including an Observation in the Analysis	Rationale
Defined as category 6 in the SCIEU – Hotel, Motel and/or Lodge	The SCIEU survey covered the commercial and institutional sector and included buildings of all types. For this model, only the observations identified as primarily hotels are used.
Must be more than 50% hotel and less than 50% of another building type	Building Type Filter – To be considered part of the hotel peer population, the building must have a minimum hotel space.
Must have electricity consumption data	Program Filter – Hotels that do not use electricity are rare or non-existent and may indicate an omission in energy data. Electricity can be grid-purchased or produced on site.
Must not use any "other" fuels for which the consumption is not reported	Data Limitation Filter – The survey asked if fuels other than those in the following list were consumed in the facility: purchased electricity, electricity generated on-site from renewable sources, natural gas, light fuel oil, diesel, kerosene, propane, district steam, district hot water or district chilled water. Either the energy type was not defined or, in the case of wood, the unit of energy was not easily convertible. Therefore, the energy provided by these fuels could not be compared directly. In such cases, these observations were removed from the analysis.
Must be built in 2013 or earlier	Data Limitation Filter – The survey reported the energy consumption data for calendar year 2014. Therefore, if the building was being built in 2014, a full year of energy consumption data would not be available.
Must operate for at least 30 hours per week	Program Filter – Hotels must operate for at least 30 hours per week to be considered a full-time operating hotel.

Condition for Including an Observation in the Analysis	Rationale
More than 50% of the building must be heated	Program Filter – More than 50% of a hotel must be heated for it to be considered a hotel.
Must not include energy supplied to other buildings	Data Limitation Filter – The survey asked if the energy use reported at the facility included energy supplied to other buildings such as a multi-building complex or portables. Usage data may not have been included; therefore these buildings were removed.
The area of the indoor or partially enclosed parking structures must be less than 50% of the gross floor area of the hotel and the parking structures combined.	Program Filter – If the combined area of the parking structures is more than 50% the area of the hotel building, the overall structure is classified as a parking structure, not as a hotel.
The area of the vacant space must be less than 50% of the gross floor area of the building.	Program Filter – Occupancy of the building, by area, must be greater than 50% for a hotel to meet ENERGY STAR certification requirements.
Must operate at least 10 months per year	Program Filter – Hotels must operate for at least10 months per year to be considered a full-time operating hotel.
Must have a point-of-sale device (computer or cash register) unless it is located on a campus	Program Filter – Hotels that do not have computers are rare or non-existent and may indicate an omission in data.
The combined area for commercial food preparation, conferences, a gym, walk-in refrigeration, and the pool area must be less than 50% of the total area of the hotel.	Program Filter – The combined area for commercial food preparation, conferences, a gym, walk-in refrigeration, and the pool area must be less than 50% of the total area of the hotel for the building to be considered a hotel.
Must have at least one worker	Program Filter – Hotels that do not have workers are rare or non-existent and may indicate an omission in data.
Must be at least 464.5 m^2 (5,000 sq. ft.) in area	Analytical Filter – The analysis could not model behaviours for buildings smaller than 464.5 m^2 (5,000 sq. ft.).
Must have at least 7 rooms	Analytical Filter – Values determined to be statistical outliers.
Must have a room density of at least 0.1 rooms/100 m^2	Analytical Filter – Values determined to be statistical outliers.
Must have a worker to room ratio of at least 0.08	Analytical Filter – Values determined to be statistical outliers.
Must have a worker density of no more than 1.6 workers per 100 m^2	Analytical Filter – Values determined to be statistical outliers.
Must have a source EUI of 5 GJ/m^2 or less	Analytical Filter – Values determined to be statistical outliers.

Some of the filters applied to the reference data result in constraints on calculating a score in Portfolio Manager. Building Type and Program filters are used to limit the reference data to include only properties that are intended 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 available during the analysis but do not apply in Portfolio Manager. Analytical Filters are used to eliminate outlier data points or different subsets of data and may affect eligibility. In some cases, a subset of the data has a different behaviour from the rest of the properties (e.g. hotels smaller than 464.5 m^2 do not behave the same way as larger buildings). In that case, an Analytical Filter is 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 obtain a score in Portfolio Manager is available at nrcan.gc.ca/energy/efficiency/buildings/energy-benchmarking/faq/3787#faq292.

Related to the filters and eligibility criteria described previously, another consideration is how Portfolio Manager treats properties 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 applies to the entire hotel, whether it is a single building or a campus of buildings. Hotels may have multiple buildings that are all integral to the primary activity. One building may be the reception and administration and another may be the actual accommodations. In these cases, the campus can receive an ENERGY STAR score if the energy use for all the buildings is metred and reported. For cases in which all the activities are contained within one building, that hotel can receive an ENERGY STAR score.

VARIABLES ANALYZED

To normalize for differences in business activity, NRCan performed 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, was analyzed using a weighted ordinary least squares regression. This analysis evaluated energy use relative to business activity (e.g. number of workers, operating hours per week, floor area, and climate). This linear regression gives an equation to compute energy use (also called 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 in Canada.

Dependent Variables

The dependent variable is what NRCan tries to predict with the regression equation. For the hotel analysis, the dependent variable is energy use, expressed in source energy use intensity (source EUI). This source EUI is equal to the total source energy use of the property divided by the gross floor area. The regression analyzes the key drivers of source EUI, which are those factors that explain the variation in source energy use per square metre in hotels. The units for source EUI in the Canadian model are annual gigajoules per square metre (GJ/m^2).

Independent Variables

The reference survey contains numerous property operation questions that NRCan identified as likely to be important for hotels. Based on a review of the variables found in the reference data, and following the criteria for inclusion in Portfolio Manager,[1] NRCan initially analyzed the following variables in the regression analysis:

- Gross floor area (m^2)
- Cooling degree days (CDD)
- Heating degree days (HDD)
- Percentage of floor space that is cooled
- Percentage of floor space that is heated
- Weekly hours of operation

[1] For a complete explanation of these criteria, see the *Portfolio Manager Technical Reference: ENERGY STAR Score* at www.energystar.gov/ENERGYSTARScore.

- Number of workers during the main shift
- Length of all open/closed refrigeration/freezer units
- Area of walk-in refrigeration
- Number of vending machines
- Months in operation in 2014
- Number of commercial appliances
- Number of domestic appliances
- Area of commercial food preparation
- Number of computers
- Number of cash registers
- Number of televisions/electronic displays/LCDs
- Year of construction
- Area of conference space
- Number of rooms
- Presence of an onsite laundry
- Percentage of floor space that is a pool
- Percentage of floor space that is a gym

NRCan, with the advice of the Environmental Protection Agency (EPA), performed an extensive review of these operational characteristics individually and in combination with each other (e.g. heating degree days times percentage of floor space that is heated). As part of the analysis, some variables were reformatted to reflect the physical relationships of building components. For example, the number of rooms can be evaluated in a density format: rooms per 100 m^2. The room density (as opposed to the gross number of rooms) is more closely related to the EUI. In addition, using analytical results and residual plots, variables were assessed by using different transformations (such as the natural logarithm, abbreviated as Ln).The analysis consists of multiple regression formulations structured to find the combination of statistically significant operating characteristics that explained the greatest amount of variance in the dependent variable: source EUI.

The final regression equation includes the following variables:

- Percentage of floor space that is used for food preparation (food preparation percentage)
- Percentage of the building that is cooled times the number of cooling degree days (percentage cooled x CDD)
- Percentage of the building that is heated times the number of heating degree days (percentage heated x HDD)
- Number of rooms per 100 m^2, with a floor at 2 (room density)
- Number of workers divided by the number of rooms (worker to room ratio)

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 characteristics. The predicted source EUI is the mean energy for buildings that operate like your building.

Room Density

Room density is an important variable used to account for the various room and space configurations used in different hotel types. The positive relationship between energy use and room density was primarily observed in hotels with a room density greater than 2 rooms per 100 m^2. Therefore, a floor was applied to room density at 2. Following this practice, a hotel with a room density lower than 2 will be scored as if it had a room density of 2.

Worker to Room Ratio

The ratio of workers to rooms is a strong driver of hotel energy use and may account for hotel service level. Hotels with a higher number of workers per room showed increased energy use. Worker to room ratio and worker density were compared, and the worker to room ratio resulted in a stronger model with more equitable scoring across different hotel types. Therefore, the number of workers divided by the number of rooms was included in the model.

Testing

NRCan further analyzed the regression equation by using actual data entered in Portfolio Manager. In addition to the SCIEU data, this analysis provided another set of buildings for examination of the ENERGY STAR scores and distributions to assess the impacts and adjustments. The analysis also confirmed that there are minimal biases in fundamental operational characteristics such as room density or percentage of floor area heated. Analysis also showed that there was no regional bias or bias for the type of energy used for heating.

It is important to reiterate that the final regression equation is based on the nationally representative reference data from SCIEU 2014, not on 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 118 observations. The dependent variable is source EUI. Each independent variable is centred relative to the weighted mean value, presented in **Figure 2**. The final equation is presented in **Figure 3**. All variables in the regression equation are considered significant at a 90% confidence level or better, as shown by their respective significance levels.

The regression equation has a coefficient of determination (R^2) value of 0.4891, indicating that this equation explains 48.91% of the variance in source EUI for hotels. The explanatory power of the area is not included in the R^2 value because the final equation is structured with energy per unit area as the dependent variable. Consequently, this value appears artificially low. Re-computing the R^2 value in units of source energy[2] demonstrates that the equation actually explains 85.02% of the variation in total source energy of hotels. It is an excellent result for a statistically based energy model.

For detailed information on the ordinary least squares regression approach, see the *Portfolio Manager Technical Reference: ENERGY STAR Score* at www.energystar.gov/ENERGYSTARscore.

Figure 2 – Descriptive Statistics for Variables in a Final Regression Equation

Variable	Minimum	Median	Maximum	Mean
Source energy per square metre (GJ/m^2)	0.4015	1.710	4.997	2.013
Room Density*	2.000	2.000	5.517	2.505
Worker to Room Ratio	8.108E-02	0.2500	0.9597	0.3162
Percent That Can Be Cooled x CDD	0	84.67	337.4	82.21
Percent That Can Be Heated x HDD	1423	4685	6897	4543
Percent Food Preparation	0	0	6.525E-02	1.077E-02

**Room Density is floored at 2.*

[2] The R^2 value in source energy is calculated as 1 – (residual variation of Y) / (total variation of Y). The residual variation is the sum of [weight*(actual source energy$_i$ – predicted source energy$_i$)]^2 across all observations. The total variation of Y is the sum of [weight*(actual source energy$_i$ – weighted mean source energy)]^2 across all observations.

Figure 3 – Final Regression Results

Summary				
Dependent variable		Source energy use intensity (GJ/m²)		
Number of observations in the analysis		118		
R^2 value		0.4891		
Adjusted R^2 value		0.4663		
F statistic		21.45		
Significance (p-level)		< 0.0001		
	Unstandardized Coefficients	**Standard Error**	**T Value**	**Significance (p-level)**
Constant	2.013	6.481E-02	31.06	<.0001
Room Density*	0.6646	8.310E-02	7.998	<.0001
Worker to Room Ratio	0.9282	0.3672	2.528	0.0129
Percent That Can Be Cooled x CDD	3.699E-03	1.130E-03	3.271	0.0014
Percent That Can Be Heated x HDD	9.834E-05	5.820E-05	1.690	0.0938
Percent Food Preparation	13.79	4.517	3.052	0.0028

Notes:
- *Room Density is floored at 2.
- The regression is a weighted ordinary least squares regression, weighted by the SCIEU variable "SWEIGHT."
- All model variables are centred. The centred variable is equal to the difference between the actual value and the observed mean. The observed mean values are presented in Figure 2.
- Heating and cooling degree days are sourced from Canadian weather stations included in the U.S. National Climatic Data Center system.

ENERGY STAR SCORE LOOKUP TABLE

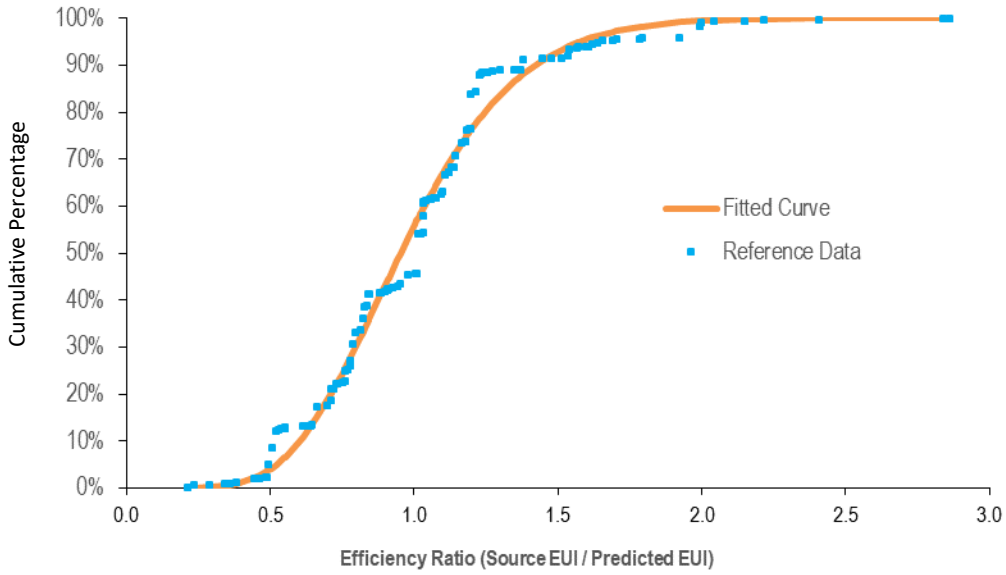
The final regression equation (presented in **Figure 3**) gives a prediction of source EUI based on a building's operating characteristics. Some buildings in the SCIEU data sample use more energy than predicted by the regression equation, while others use less. The *actual* source EUI of each reference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

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

An energy efficiency ratio lower than 1 indicates that a building uses less energy than predicted and, consequently, is more efficient. An energy efficiency ratio above 1 indicates the opposite.

The energy efficiency ratios are sorted from smallest to largest, and the cumulative percentage of the population at each ratio is calculated by 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 to minimize the sum of squared differences between each building's actual percentage rank in the population and each building's percentage rank with the gamma solution. The final fit for the gamma curve gives a shape parameter (alpha) of 9.306 and a scale parameter (beta) of 0.1063. The sum of the squared error for this fit is 0.4605.

Figure 4 – Distribution for Hotels



The final gamma shape and scale parameters are used to calculate the energy 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 registers such a small or even smaller ratio. The ratio on the gamma curve at the value of 25% corresponds to the ratio for a score of 75; only 25% of the population has a ratio this small or smaller. **Figure 5** shows the complete score lookup table.

Figure 5 – ENERGY STAR Score Lookup Table for Hotels

ENERGY STAR Score	Cumulative Percentage	Energy Efficiency Ratio		ENERGY STAR Score	Cumulative Percentage	Energy Efficiency Ratio	
		> =	<			>=	<
100	0%	0.0000	0.3928	50	50%	0.9537	0.9617
99	1%	0.3928	0.4415	49	51%	0.9617	0.9697
98	2%	0.4415	0.4746	48	52%	0.9697	0.9778
97	3%	0.4746	0.5006	47	53%	0.9778	0.9860
96	4%	0.5006	0.5225	46	54%	0.9860	0.9942
95	5%	0.5225	0.5417	45	55%	0.9942	1.0025
94	6%	0.5417	0.5589	44	56%	1.0025	1.0108
93	7%	0.5589	0.5746	43	57%	1.0108	1.0193
92	8%	0.5746	0.5892	42	58%	1.0193	1.0278
91	9%	0.5892	0.6028	41	59%	1.0278	1.0364
90	10%	0.6028	0.6157	40	60%	1.0364	1.0452
89	11%	0.6157	0.6279	39	61%	1.0452	1.0540
88	12%	0.6279	0.6396	38	62%	1.0540	1.0630
87	13%	0.6396	0.6508	37	63%	1.0630	1.0721
86	14%	0.6508	0.6616	36	64%	1.0721	1.0813
85	15%	0.6616	0.6720	35	65%	1.0813	1.0907
84	16%	0.6720	0.6822	34	66%	1.0907	1.1003
83	17%	0.6822	0.6920	33	67%	1.1003	1.1100
82	18%	0.6920	0.7016	32	68%	1.1100	1.1199
81	19%	0.7016	0.7110	31	69%	1.1199	1.1300
80	20%	0.7110	0.7202	30	70%	1.1300	1.1403
79	21%	0.7202	0.7293	29	71%	1.1403	1.1509
78	22%	0.7293	0.7381	28	72%	1.1509	1.1617
77	23%	0.7381	0.7468	27	73%	1.1617	1.1728
76	24%	0.7468	0.7554	26	74%	1.1728	1.1842
75	25%	0.7554	0.7639	25	75%	1.1842	1.1958
74	26%	0.7639	0.7723	24	76%	1.1958	1.2079
73	27%	0.7723	0.7806	23	77%	1.2079	1.2203
72	28%	0.7806	0.7888	22	78%	1.2203	1.2331
71	29%	0.7888	0.7969	21	79%	1.2331	1.2464
70	30%	0.7969	0.8049	20	80%	1.2464	1.2602
69	31%	0.8049	0.8129	19	81%	1.2602	1.2746
68	32%	0.8129	0.8209	18	82%	1.2746	1.2895
67	33%	0.8209	0.8288	17	83%	1.2895	1.3052
66	34%	0.8288	0.8366	16	84%	1.3052	1.3216
65	35%	0.8366	0.8445	15	85%	1.3216	1.3390
64	36%	0.8445	0.8523	14	86%	1.3390	1.3574
63	37%	0.8523	0.8601	13	87%	1.3574	1.3769
62	38%	0.8601	0.8678	12	88%	1.3769	1.3979
61	39%	0.8678	0.8756	11	89%	1.3979	1.4204
60	40%	0.8756	0.8833	10	90%	1.4204	1.4450
59	41%	0.8833	0.8911	9	91%	1.4450	1.4720
58	42%	0.8911	0.8989	8	92%	1.4720	1.5020
57	43%	0.8989	0.9066	7	93%	1.5020	1.5360
56	44%	0.9066	0.9144	6	94%	1.5360	1.5754
55	45%	0.9144	0.9222	5	95%	1.5754	1.6225
54	46%	0.9222	0.9300	4	96%	1.6225	1.6816
53	47%	0.9300	0.9379	3	97%	1.6816	1.7623
52	48%	0.9379	0.9458	2	98%	1.7623	1.8944
51	49%	0.9458	0.9537	1	99%	1.8944	>1.8944

EXAMPLE CALCULATION

According to the *Portfolio Manager Technical Reference: ENERGY STAR Score* at www.energystar.gov/ENERGYSTARScore, there are five steps in computing a score for hotels. The following is a specific example.

1 User enters the 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	800,000 kWh
Natural gas	310,000 m^3

Property Use Details	Value
Gross Floor Area (m^2)	10,000
Number of Rooms	200
Number of Workers on Main Shift	50
Gross Floor Area Used for Food Preparation (m^2)	100
Percent That Can Be Heated	100%
Percent That Can Be Cooled	100%
HDD (provided by Portfolio Manager, based on postal code)	3,700
CDD (provided by Portfolio Manager, based on postal code)	300

2 Portfolio Manager computes the actual source EUI

- The 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 the actual source EUI.

Computing the Actual Source EUI

Fuel	Billing Units	Site GJ Multiplier	Site GJ	Source Multiplier	Source GJ
Electricity	800,000 kWh	3.600E-03	2,879	1.960	5,644
Natural gas	310,000 m^3	3.843E-02	11,913	1.010	12,032
				Total source energy (GJ)	17,676
				Source EUI (GJ/m^2)	**1.768**

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

Computing Predicted Source EUI

Variable	Actual Building Value	Reference Centring Value	Building Centred Variable	Coefficient	Coefficient x Centred Variable
Constant	-	-	-	2.013	2.013
Room Density*	2.000	2.505	-0.5050	0.6646	-0.3356
Worker to Room Ratio	0.2500	0.3162	-6.620E-02	0.9282	-6.145E-02
Percent Cooled x CDD	300.0	82.21	217.8	3.699E-03	0.8056
Percent Heated x HDD	3700	4543	-843	9.834E-05	-8.290E-02
Percent Food Preparation	1.000E-02	1.077E-02	-7.700E-04	13.79	-1.062E-02
				Predicted source EUI (GJ/m²)	**2.328**

**Room Density is floored at 2.*

4 Portfolio Manager computes the energy efficiency ratio

- The energy efficiency ratio equals the actual source EUI (Step 2) divided by the predicted source EUI (Step 3).
- Ratio = 1.768 / 2.328 = **0.7595**

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 0.7593 is greater than 0.7554 and less than 0.7639.
- ***The ENERGY STAR score is 75.***