ENERGY STAR® PortfolioManager® Technical Reference

ENERGY STAR Score for K-12 Schools in Canada

OVERVIEW

The ENERGY STAR Score for Kindergarten through grade 12 (K-12) schools applies to both primary and secondary schools. This score is not applicable to college, cégep, or university classroom facilities and laboratories; vocational, technical or trade schools; or preschool or day care buildings. The objective of the ENERGY STAR score is to provide an unbiased 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. A statistical analysis of the peer building population is performed to identify the aspects of building activity that are significant drivers of energy use and then to normalize for those factors. The result of this analysis is an equation that predicts the energy use of a property based on its 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 schools applies to primary and secondary schools, from kindergarten to grade 12. The score applies to an entire school whether it is a single building or a campus of buildings. Individual buildings that are part of larger K-12 campuses cannot receive their own score.
- **Reference data.** The analysis for schools 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, and represents the energy consumption year 2014.
- **Adjustments for weather and business.** The analysis includes adjustments for:
  - Number of workers on the main shift
  - Percentage of space dedicated to food preparation
  - Weather and climate (using heating degree days and cooling degree days, retrieved based on postal code)
  - Percentage of building that is cooled
- **Release date.** This is the second release of the ENERGY STAR score for K-12 schools in Canada. The ENERGY STAR score for schools is updated periodically as more recent data becomes available:
  - Most recent update: March 2019
  - Original release: July 2013

This document presents details on the development of the 1 - 100 ENERGY STAR score for K-12 school 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 http://www.energystar.gov/ENERGYSTARScore. The subsequent sections of this document offer specific details on the development of the ENERGY STAR score for K-12 schools:

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REFERENCE DATA & FILTERS

The ENERGY STAR score for K-12 schools in Canada applies to primary and secondary schools, from kindergarten to grade 12. The reference data used to establish the peer building population is based on data from the Survey on Commercial and Institutional Energy Use (SCIEU), which was commissioned by Natural Resources Canada and carried out by Statistics Canada in late 2015 and early 2016. The consumption data for the survey was from the calendar year 2014. The raw collected data file for this survey is not publicly available, but a report providing summary results is available on Natural Resources Canada's website, at http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/scieu/2014/tables.cfm

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 K-12 schools and the rationale behind the filter. After all filters are applied, the remaining data set has 277 observations. Due to the confidentiality of the survey data, we are not able to identify the number of cases after each filter.

Figure 1 – Summary of Filters for the ENERGY STAR Score for K-12 Schools

Condition for Including an Observation in the Analysis	Rationale
Defined as category 3 in SCIEU – Kindergarten to Grade 12 Schools	The SCIEU survey covered the commercial and institutional sector and included buildings of all types. For this model, only the observations identified as primarily K-12 schools are used.
Must have electricity consumption data	Program Filter – K-12 schools that do not use electric energy are rare or non-existent and may indicate an omission in energy data. Electricity can be grid-purchased or produced on site.
Building must be at least 50% K-12 School	Building Type Filter – To be considered part of the K-12 school peer group, the facility must have a minimum K-12 school space.
Excludes educational buildings that are "Other Only"	Building Type Filter – Buildings that consist of only 'Other' school type do not meet the definition of a school.
Building area must be at least 92.9 m²	Program Filter – The analysis could not model behaviours for buildings smaller than 92.9 m² (1,000 ft²).
Must operate at least 30 hours per week	Program Filter – Basic requirement to be considered as full-time operation.
Must operate at least 8 months per year	Program Filter – Basic requirement to be considered as full-time operation.
Must have at least 1 employee and 2 students	Program Filter – Basic requirement for a functioning school. It must be occupied.
Must be built in 2013 or earlier	Data Limitation Filter – The survey reported the consumption for calendar year 2014. Therefore, if the building was being built in 2014, a full year of consumption data would not be available.
Must not include energy supplied to other buildings	Data Limitation Filter – The survey asked whether the energy 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 observations were removed.

Condition for Including an Observation in the Analysis	Rationale
Must not use any "other" fuels for which the consumption is not reported	Data Limitation Filter – The survey asked whether fuels other than purchased electricity, on-site generated electricity from renewable sources, natural gas, light fuel oil, diesel, kerosene, propane, district steam, district hot water or district chilled water were consumed in the facility. Either the type of energy was not defined, or in the case of wood, the energy was not easily convertible; therefore, the energy content of these fuels could not be directly compared. In these occurrences, these observations were removed from the analysis.
Must have at least 50% heated floor space	Analytical Filter – Observations less than or equal to 50% were not deemed realistic for the Canadian climate, which generally exceeds 2,000 HDD.
Must have Source EUI that is less than or equal to 3.2 GJ/m²	Analytical Filter – Values determined to be outliers based on analysis of the data. Outliers are typically clearly outside normal operating parameters for a building of this type.
Must have a worker density (workers per 100 m²) that is less than or equal to 2.9	Analytical Filter – Values determined to be outliers based on analysis of the data. Outliers are typically clearly outside normal operating parameters for a building of this type.
Must have a student seating capacity density (students per 100 m²) that is greater than or equal to 2.2 and less than or equal to 30	Analytical Filter – Values determined to be outliers based on analysis of the data. Outliers are typically clearly outside normal operating parameters for a building of this type.

Of the filters applied to the reference data, some are also eligibility requirements for calculating a score in Portfolio Manager. 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 has a different behaviour from the rest of the properties (e.g. office buildings smaller than 465 m² do not behave the same way as larger buildings), in which 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 get a score in Portfolio Manager is available at www.nrcan.gc.ca/energy/efficiency/buildings/energy-benchmarking/faq/3787#faq292.

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. The ENERGY STAR score applies to an entire K-12 school, whether it is a single building or a campus of buildings. Schools may have multiple buildings that are all integral to the primary activity. One building might contain classes, a second, the gymnasium, and another might be a portable. In this case, the campus can get an ENERGY STAR score as long as the energy for all the buildings is metered and reported. For cases where all the activities are contained within one building, that school can get a building ENERGY STAR score.

VARIABLES ANALYZED

To normalize for differences in business activity, we 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, which evaluated energy use relative to business activity (e.g. operating hours per week, number of workers, floor area, and climate). This linear regression yielded 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 K-12 schools in Canada.

Dependent Variable

The dependent variable is what we try to predict with the regression equation. For the K-12 school 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, including portables supplied by the main building. The regression analyzes the key drivers of source EUI—those factors that explain the variation in source energy use per square metre in K-12 schools. The units for source EUI in the Canadian model are gigajoules per square metre (GJ/m²).

Independent Variables

The SCIEU data contains numerous questions on building property operation which NRCan identified as potentially important for K-12 schools. Based on a review of the available variables in the SCIEU data, in accordance with the criteria for inclusion in Portfolio Manager,[1] NRCan initially analyzed the following variables in the regression analysis:

- Gross building area (m²)
- Heating degree days (HDD)
- Cooling degree days (CDD)
- Percentage of heated floor space
- Percentage of cooled floor space
- Floor space dedicated to food preparation
- Percentage of space dedicated to food preparation
- Presence of a gymnasium (Y/N)
- Floor space dedicated to gymnasium (m²)
- Presence of portable classroom(s) (Y/N)
- Presence of an indoor pool (Y/N)
- Weekend/After hours operation
- Weekly hours of operation
- Number of months in operation in 2014
- Number of workers on the main shift
- Number of registered students
- Number of occupants in the building
- Presence of a daycare (Y/N)

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

- Number of vending machines
- Whether the school is only a primary school
- Whether the school is a secondary school (a.k.a. high school)

NRCan, with the advice of the Environmental Protection Agency (EPA), performed an extensive review on all of these operational characteristics. In addition to reviewing each characteristic individually, characteristics were reviewed in combination with each other (e.g. Heating Degree Days times Percent Heated). As part of the analysis, some variables were reformatted to reflect the physical relationships of building components. For example, the number of workers on the main shift can be evaluated in a density format. The number of workers per square metre (as opposed to the gross number of workers) could be expected to be correlated with the energy use per square metre. Also, based on analytical results and residual plots, variables were examined using different transformations (such as the natural logarithm, abbreviated as Ln). The analysis consists of multiple regression formulations. These analyses were 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:

- Worker Density
- Percentage of Area Used for Food Preparation
- Heating Degree Days (HDD)
- Cooling Degree Days times Percent Cooled

These variables are used together to compute the predicted source EUI for K-12 schools. The predicted source EUI is the mean EUI for a hypothetical population of buildings that share the same values for each of these characteristics. That is, the mean energy for buildings that operate like your building.

Secondary School Variable

In the previous model based on 2009 data, identifying as Secondary School (as opposed to a Primary School) contributed to a higher EUI, and was statistically significant in the model. In the current model based on 2014 data, the relationship between Secondary Schools and higher EUI is much less pronounced, and the relationship is not statistically significant. Analysis indicates that between 2009 and 2014, the difference in the energy intensity between Primary Schools and Secondary Schools narrowed; Primary Schools increased in energy intensity while Secondary Schools remained similar to 2009 values.

Worker, Student, and Computer Density Analysis

All three variables were analyzed to determine their suitability as predictors for building EUI, and all three showed a positive correlation. However, worker density was chosen as the predictor due to its strong correlation and ability to explain variances in student density and computer density.

Testing

Finally, NRCan further analyzed the regression equation using actual schools that have been entered in Portfolio Manager. This provided another set of buildings to examine, in addition to the SCIEU data, to see the average ENERGY STAR scores and distributions, and to assess the corresponding impacts and adjustments. This analysis on a separate data set provided a second level of verification to ensure that there was a homogenous distribution of scores with regard to region or to 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, 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 277 observations. The dependent variable is source EUI. Each independent variable is centred 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.

The regression equation has a coefficient of determination (R^2) value of 0.251, indicating that this equation explains 25.1% of the variance in source EUI for K-12 school buildings. Because the final equation is structured with energy per unit area as the dependent variable, the explanatory power of the area is not included in the R^2 value, and thus this value appears artificially low. Re-computing the R^2 value in units of source energy[2] demonstrates that the equation actually explains 92.3% of the variation in total source energy of K-12 schools. This is a good 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	Minimum	Median	Maximum	Mean
Source Energy per Square Metre (GJ/m^2)	0.3508	1.0888	3.1974	1.1273
Worker Density	0.2024	0.8536	2.8026	0.9045
Percentage of Area Used for Food Preparation	0	0	0.1371	0.00295
Heating Degree Days (HDD)	2718	4616	7053	4735
Cooling Degree Days times Percent Cooled	0	26.31	344.1	72.4

[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 Intensity (GJ/m²)		
Number of observations in analysis		277		
R^2 value		0.2510		
Adjusted R^2 value		0.24		
F statistic		22.78		
Significance (p-level)		<0.0001		
	Unstandardized Coefficients	**Standard Error**	**T Value**	**Significance (p level)**
Constant	1.1273	0.02084	54.09	<.0001
Worker Density	0.0987	0.05108	1.93	0.0543
Percentage of Area Used for Food Preparation	8.5142	1.803	4.72	<.0001
Heating Degree Days (HDD)	1.885E-04	2.24E-05	8.42	<.0001
Cooling Degree Days times Percent Cooled	6.128E-04	2.285E-04	2.68	0.0078

Notes:

- *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.*
- *The adjustment for the percentage of space dedicated to food preparation is capped at a value of 0.15 or 15%.*
- *The heating degree days and cooling degree days are sourced from the U.S. National Climatic Data Center.*

ENERGY STAR SCORE LOOKUP TABLE

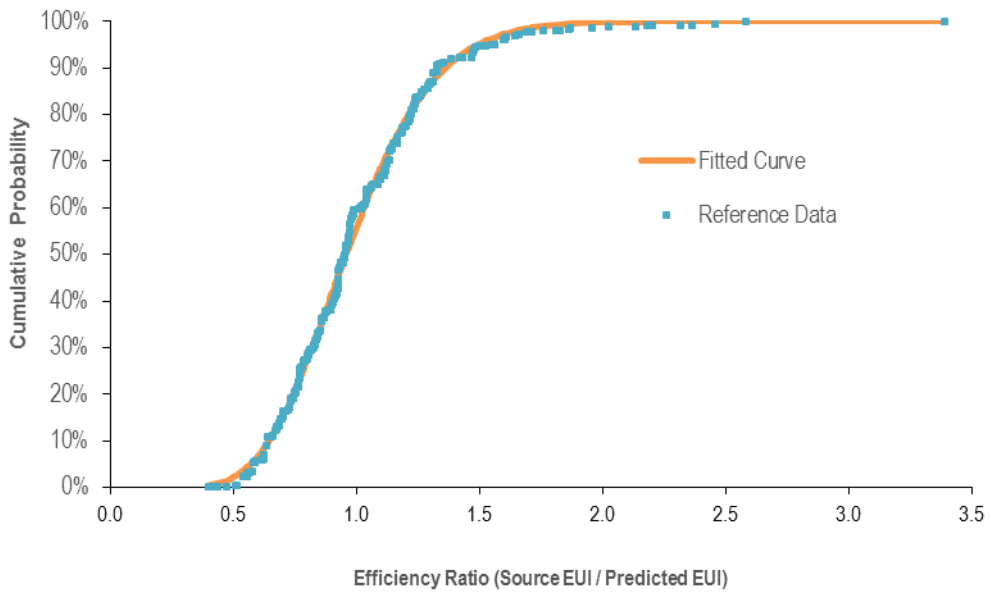
The final regression equation (presented in ***Figure 3***) yields a prediction of source EUI based on a building's operating characteristics. Some buildings in the SCIEU data sample use more energy than predicted by the regression equation, while others use less. The actual source EUI of each reference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

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

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 12.1105 and a scale parameter (beta) of 0.08139. For this fit, the sum of the squared error is 0.06565.

Figure 4 – Distribution for K-12 Schools



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% corresponds to the ratio for a score of 75; only 25% of the population has a ratio this small or smaller. The complete score lookup table is presented in ***Figure 5***.

Figure 5 – ENERGY STAR Score Lookup Table for K-12 Schools

ENERGY STAR Score	Cumulative Percent	Energy Efficiency Ratio > =	Energy Efficiency Ratio <
100	0%	0.0000	0.4478
99	1%	0.4478	0.4943
98	2%	0.4943	0.5256
97	3%	0.5256	0.5500
96	4%	0.5500	0.5704
95	5%	0.5704	0.5882
94	6%	0.5882	0.6041
93	7%	0.6041	0.6186
92	8%	0.6186	0.6320
91	9%	0.6320	0.6445
90	10%	0.6445	0.6563
89	11%	0.6563	0.6675
88	12%	0.6675	0.6781
87	13%	0.6781	0.6883
86	14%	0.6883	0.6982
85	15%	0.6982	0.7076
84	16%	0.7076	0.7168
83	17%	0.7168	0.7257
82	18%	0.7257	0.7344
81	19%	0.7344	0.7429
80	20%	0.7429	0.7512
79	21%	0.7512	0.7593
78	22%	0.7593	0.7673
77	23%	0.7673	0.7751
76	24%	0.7751	0.7828
75	25%	0.7828	0.7904
74	26%	0.7904	0.7979
73	27%	0.7979	0.8053
72	28%	0.8053	0.8126
71	29%	0.8126	0.8199
70	30%	0.8199	0.8271
69	31%	0.8271	0.8342
68	32%	0.8342	0.8413
67	33%	0.8413	0.8483
66	34%	0.8483	0.8553
65	35%	0.8553	0.8622
64	36%	0.8622	0.8691
63	37%	0.8691	0.8760
62	38%	0.8760	0.8829
61	39%	0.8829	0.8898
60	40%	0.8898	0.8966
59	41%	0.8966	0.9035
58	42%	0.9035	0.9103
57	43%	0.9103	0.9172
56	44%	0.9172	0.9241
55	45%	0.9241	0.9309
54	46%	0.9309	0.9378
53	47%	0.9378	0.9447
52	48%	0.9447	0.9517
51	49%	0.9517	0.9587

ENERGY STAR Score	Cumulative Percent	Energy Efficiency Ratio >=	Energy Efficiency Ratio <
50	50%	0.9587	0.9657
49	51%	0.9657	0.9727
48	52%	0.9727	0.9798
47	53%	0.9798	0.9869
46	54%	0.9869	0.9941
45	55%	0.9941	1.0013
44	56%	1.0013	1.0087
43	57%	1.0087	1.0160
42	58%	1.0160	1.0235
41	59%	1.0235	1.0310
40	60%	1.0310	1.0386
39	61%	1.0386	1.0463
38	62%	1.0463	1.0541
37	63%	1.0541	1.0621
36	64%	1.0621	1.0701
35	65%	1.0701	1.0782
34	66%	1.0782	1.0865
33	67%	1.0865	1.0950
32	68%	1.0950	1.1036
31	69%	1.1036	1.1123
30	70%	1.1123	1.1213
29	71%	1.1213	1.1304
28	72%	1.1304	1.1397
27	73%	1.1397	1.1493
26	74%	1.1493	1.1591
25	75%	1.1591	1.1692
24	76%	1.1692	1.1796
23	77%	1.1796	1.1903
22	78%	1.1903	1.2013
21	79%	1.2013	1.2127
20	80%	1.2127	1.2246
19	81%	1.2246	1.2369
18	82%	1.2369	1.2497
17	83%	1.2497	1.2632
16	84%	1.2632	1.2773
15	85%	1.2773	1.2921
14	86%	1.2921	1.3078
13	87%	1.3078	1.3245
12	88%	1.3245	1.3423
11	89%	1.3423	1.3616
10	90%	1.3616	1.3825
9	91%	1.3825	1.4054
8	92%	1.4054	1.4309
7	93%	1.4309	1.4597
6	94%	1.4597	1.4930
5	95%	1.4930	1.5328
4	96%	1.5328	1.5826
3	97%	1.5826	1.6504
2	98%	1.6504	1.7610
1	99%	1.7610	>1.7610

EXAMPLE CALCULATION

As detailed in the 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 K-12 schools:

1 User enters building data into Portfolio Manager

- 12 months of energy use information for all energy types (annual values, provided from monthly meter readings)
- Physical building information (size, location, etc.) and use details describing building activity (hours, etc.)

Energy Data	Value
Electricity	780,000 kWh
Natural gas	12,000 m^3

Property Use Details	Value
Gross Floor Area (m^2)	7,000
Gross Floor Area Used for Food Preparation (m^2)	80
Number of Workers on Main Shift[3]	75
Percent that Can Be Cooled	90
HDD (provided by Portfolio Manager, based on postal code)	3,601
CDD (provided by Portfolio Manager, based on postal code)	322

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 GJ Multiplier	Site GJ	Source Multiplier	Source GJ
Electricity	780,000 kWh	0.0036	2,808	1.96	5,503.68
Natural gas	12,000 m^3	0.03843	461.16	1.01	465.77
				Total Source Energy (GJ)	5,969.45
				Actual Source EUI (GJ/m^2)	**0.8528**

[3] This represents the 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 density as necessary).
- The centering values are subtracted to compute the centred variable for each operating parameter.
- The centred variables are multiplied by the coefficients from the K-12 school regression equation to obtain a predicted source EUI.

Computing Predicted Source EUI

Variable	Actual Building Value	Reference Centering Value	Building Centred Variable	Coefficient	Coefficient x Centred Variable
Constant	-	-	-	1.1273	1.1273
Cooling Degree Days x Percent Cooled	289.8	*72.4031*	*217.3969*	6.128E-04	0.1332
Heating Degree Days	3,601	*4734.7878*	*-1133.7878*	1.885E-04	-0.2137
Worker Density	1.0714	*0.9045*	*0.1669*	0.0987	0.01648
Percent Food Preparation	0.0114	0.003	0.008	8.5142	0.07218
			Predicted Source EUI (GJ/m²)		***1.1355***

4 Portfolio Manager computes the energy efficiency ratio

- The ratio equals the actual source EUI (Step 2) divided by the predicted source EUI (Step 3).
- Ratio = 0.8528 / 1.1355 = **0.7510**.

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 0.7510 is greater than 0.7429 and less than 0.7512.
- ***The ENERGY STAR score is 80.***