ENERGY STAR® Performance Ratings
Technical Methodology for K-12 School

This document presents specific details on the EPA's analytical result and rating methodology for K-12 School. For background on the technical approach to development of the Energy Performance Ratings, refer to *Energy Performance Ratings – Technical Methodology* (http://www.energystar.gov/ia/business/evaluate_performance/General_Overview_tech_methodology.pdf). Please note the general technical methodology listed above reflects changes made to the methodology in 2007. The K-12 School model has not yet been revised in light of these changes; therefore some of the information in this description differs slightly.

Model Release Date[1]

Most Recent Update: January 2004
Original Release Date: April 2000

Portfolio Manager K-12 School Definition

K-12 School applies to facility space used as a school building for Kindergarten through 12th grade students. This does not include college or university classroom facilities and laboratories, or vocational, technical, and trade schools. The total gross floor area should include all supporting functions such as administrative space, conference rooms, kitchens used by staff, lobbies, cafeterias, gymnasiums, auditoria, laboratory classrooms, greenhouses, stairways, atria, elevator shafts, small landscaping sheds, storage areas, etc.

Reference Data

The K-12 School regression model is based on data from the Department of Energy, Energy Information Administration's 1999 Commercial Building Energy Consumption Survey (CBECS). Detailed information on this survey, including complete data files, is publicly available at: http://www.eia.doe.gov/emeu/cbecs/contents.html.

Data Filters

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, EPA Program Filters, Data Limitation Filters, and Analytical Filters. A complete description of each of these categories is provided in Section V of the general technical description document: *Energy Performance Ratings – Technical Methodology*. **Table 1** presents a summary of each filter applied in the development of the K-12 School model and the rationale behind the filter. After all filters are applied, the remaining data set has 400 observations.

[1] Periodic updates to the model occur to reflect the most current available market data. The original model was developed using the CBECS 1995 database. The most recent update of January 2004 reflects the CBECS 1999 database.

Table 1 Summary of K-12 School Model Filters	
Condition for Including an Observation in the Analysis	**Rationale**
PBAPLUS7= 11	Building Filter – CBECS defines building types according to the variable "PBAPLUS7." K-12 Schools are coded as PBAPLUS7= 11.
Must operate for at least 30 hours per week	EPA Program Filter – Baseline condition for being a full time K-12 School.
Must operate for at least 8 months per year	EPA Program Filter – Baseline condition for being a full time K-12 School.
Classroom seating capacity must be less than 10,000	EPA Program Filter – Baseline condition for being a K-12 School.
Must have square foot less than or equal to 1,000,000	Data Limitation Filter – CBECS masks actual values above 1,000,000 using regional averages.
Total energy cost per million Btu must be greater than $1.50	Analytical Limitation Filter – Values determined to be statistical outliers.
Source energy use intensity (kBtu/ft^2) must be greater than 37.3 and less than 314.8 kBtu/ft^{2}S	Analytical Limitation Filter – Values determined to be statistical outliers.
Must have at least 5,000 square feet	Analytical Limitation Filter – Analysis could not model behavior for buildings smaller than 5,000ft^2.

Dependent Variable

The dependent variable in the K-12 analysis is natural log of annual source energy use (LN(Source Energy)). By setting LN(Source Energy) as the dependent variable, the regressions analyze the key drivers of the LN(Source Energy) – those factors that explain the variation in the natural log of source energy consumption in a K-12 School.

Independent Variables

General Overview

The CBECS data contain numerous building operation questions that EPA identified as potentially important for K-12 Schools. These include characteristics such as the total square foot, the weekly hours of operation, the number of months in use, the presence and quantity of cooking and refrigeration equipment, the presence and quantity of office equipment such as computers, printers, and copiers, the percent of the building that is heated and cooled, and the number of heating and cooling degree days.

EPA performed 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 * Percent Heated). As part of the analysis, some variables were reformatted to reflect the physical relationships of building components. Based on analytical results and residual plots, variables were also examined using different transformations (such as the natural logarithm). The analysis consisted 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: LN(Source Energy).

Based on the K-12 School regression analysis, the following nine characteristics were identified as key explanatory variables that can be used to estimate the expected LN(Source Energy) in a K-12 School:

- Natural log of gross square foot
- Natural log of weekly operating hours
- Natural log of number of personal computers
- Natural log of the student seating capacity
- Presence of mechanical ventilation[2]
- Months of use during the year (this variable is set to 1 if the K-12 School is open for 12 months of the year and zero otherwise)
- Presence of cooking
- Heating degree days times Percent of the building that is heated
- Cooling degree days times Percent of the building that is cooled

Model Testing

EPA engaged a variety of ENERGY STAR Partners to test the final regression model as compared with interim model alternatives. These tests helped provide a superior understanding of the physical relationship between each variable and energy use at K-12 School buildings. Additionally, the beta testing effort helped verify that the final regression model included the appropriate set of variables.

The primary criterion for including an independent variable in the regression model was statistical significance at a confidence level of 90% or better, as indicated by a p-level of 0.10 or lower. The majority of independent variables pass this test. However, based on the beta testing efforts, two additional variables were retained in the model in spite of lower confidence levels: *weekly operating hours* and *month of use during the year*. The beta test included a variety of participants, including schools that operated on different schedules, such as those with extensive after-hour community activities and year-round operation. The results of the beta test support the hypothesis that *weekly operating hours* and *months of use* are correlated with energy use. There was a strong preference among ENERGY STAR partners to retain these variables in the final regression in order to obtain the most meaningful result.

It is important to reiterate that the final regression model is based on the nationally representative CBECS data, not data collected during the beta test or data previously entered into EPA's Portfolio Manager.

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[2] Mechanical ventilation was defined to not exist (VENT = 0) when heating-air furnaces, space heaters, district heating systems, or internal boilers were used for space heating in combination with no space cooling or the use of window or residential-type air conditioners. One variance from this definition was that the mechanical ventilation was defined to exist (VENT =1) when variable-air-volume (VAV) systems or economizers were present regardless of the type of space heating or cooling system or the presence of space cooling. Building with other space heating and cooling system types were defined as ventilated (VENT=1).

Regression Modeling Results

The final regression is an ordinary least squares regression across the filtered data set of 400 observations. The dependent variable is LN(Source Energy). Basic statistics of the final set of independent variables left in the model are provided in **Table 2**. The final model is presented in **Table 3**. The model has an R^2 value of 0.8775, indicating that this model explains 88% of the variance in LN(Source Energy) for K-12 Schools. This is an excellent result for a statistically based energy model.

Detailed information on the ordinary least squares regression approach and the methodology for performing weather adjustments is available in the technical document: *Energy Performance Ratings – Technical Methodology*.

Table 2
Descriptive Statistics for Variables in Final Regression Model

Variable	Full Name	Mean	Minimum	Maximum
LnSource	Natural Log of Total Source Energy Use	15.719	12.484	18.211
LnSqft	Natural Log of Square foot	11.023	8.517	13.218
LnEdseat	Natural Log of Student Seating Capacity	6.338	3.401	8.294
Vent	Presence of Ventilation	0.758	0	1
LnPcnum	Natural Log of Number of Personal Computers	4.189	0	7.057
LnWkhrs	Natural Log of Weekly Operating Hours	3.978	3.555	4.942
Monuse12	Months of Use	0.640	0	1
Cook7	Presence of Cooking	0.775	0	1
HDDxheatp	Heating Degree Days x Percent Heated	4330.7	0.97	8223
CDDxcoolp	Cooling Degree Days x Percent Cooled	853.3	0	4143

Note: Statistics are computed over the filtered data set (n=400 observations)

Table 3
Final Regression Modeling Results

Dependent Variable	LN(Source Energy)
Number of Observations in Analysis	400
Model R^2 value	0.8775
Model F Statistic	310.3
Model Significance (p-level)	0.001

	Unstandardized Coefficients	Standard Error	T value	Significance (p-level)
(Constant)	4.45046	0.33956	13.11	<0.0001
LnSqft	0.84274	0.04095	20.58	<0.0001
LnEdseat	0.12269	0.04019	3.05	0.0024
Vent	0.14911	0.04911	3.04	0.0026
LnPcnum	0.07955	0.02368	3.36	0.0009
LnWkhrs	0.06271	0.07188	0.87	0.3835
Monuse12	0.05659	0.04107	1.38	0.169
Cook7	0.0983	0.05269	1.87	0.0628
HDDxheatp	0.00006155	0.00001748	3.52	0.0005
CDDxcoolp	0.00014839	0.00003392	4.38	<0.0001

Note: Full variable names and definitions are presented in Table 2

K-12 School Lookup Table

The final regression model (presented in **Table 3**) yields a prediction of LN(Source Energy) based on a building's operating constraints. Some buildings in the CBECS data sample use more energy than predicted by the regression equation, while others use less. The *actual* value of LN(Source Energy) for each CBECS observation is divided by its *predicted* value for LN(Source Energy) to calculate an energy efficiency ratio:

Energy Efficiency Ratio = Actual LN(Source Energy) / 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) [3]:

Normalized LN(Source Energy) = Energy Efficiency Ratio * 15.719

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 fit 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 fit is performed with the constraint that the gamma value of LN(Source Energy) at a rating 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 rating 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 rating of 75; only 25% of the population has normalized LN(Source Energy) values this small or smaller. The complete lookup table is presented at the end of the document. In order to read this lookup table, note that if the normalized LN(Source Energy) value is less than 14.8923 the rating for that building should be 100. If the normalized LN(Source Energy) value is greater than or equal to 14.8923 and less than 14.9563, the rating for the building should be 99, etc.

Example Calculation

Below are the five steps to compute a rating for a hypothetical K-12 School. Note that these steps are slightly different than those outlined in the document *Energy Performance Ratings – Technical Methodology*, which reflects changes made to the methodology in 2007. The K-12 School model has not yet been revised in light of these changes (departures from the current methodology are described in footnotes).

[3] The mean value of LN(Source) is determined by the dataset and is presented in Table 2. It is 15.719.

Step 1 – User enters building data into Portfolio Manager

For the purpose of this example, sample data is provided.

- Energy data
  - Total annual electricity = 400,000 kWh
  - Total annual natural gas = 180 therms
  - Note that this data is actually entered in monthly meter entries
- Operational data
  - Gross floor area (ft^2) = 50,000
  - Weekly operating hours = 70
  - Student seating capacity = 400
  - Number of personal computers = 40
  - Months of the year in use[4] = 10
  - Percent of the building that is heated = 50%
  - Percent of the building that is cooled = 50%
  - Presence of on-site cooking facilities = yes (1)
  - Presence of mechanical ventilation = yes (1)
  - HDD (provided by Portfolio Manager, based on zip code) = 3800
  - CDD (provided by Portfolio Manager, based on zip code) = 2300

Step 2 – Portfolio Manager computes the actual value for the natural log of Source Energy Use[5]

In order to compute actual Source Energy Use, Portfolio Manager must convert each fuel from the specified units (e.g. kWh) into Site kBtu, and must convert from Site kBtu to Source kBtu.

- Convert the meter data entries into site kBtu
  - Electricity: (400,000kWh)*(3.412 kBtu/kWh) = 1,364,800 kBtu Site
  - Natural gas: (180 therms)*(100 kBtu/therm) = 18,000 kBtu Site
- Apply the site-to-source conversion factors to compute the source energy
  - Electricity:
    1,364,800 Site kBtu*(3.34 Source kBtu/ Site kBtu) = 4,558,432 kBtu Source
  - Natural gas:
    18,000 Site kBtu*(1.047 Source kBtu/Site kBtu) = 18,846 kBtu Source
- Combine source kBtu across all fuels
  - 4,558,432 kBtu + 18,846 kBtu = 4,577,278 kBtu
- Take the natural log of total source energy consumption
  - LN (4,577,278 kBtu) = 15.33661

Step 3 – Portfolio Manager computes the predicted natural log of Source Energy Use[6]

Portfolio Manager uses the building data entered in Step 1 to compute the predicted energy consumption of the building with the given operational constraints.

- Compute each variable in the model

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[4] Because the building is not open for 12 months of the year, it receives a value of 0 for MONUSE12

[5] Note that for models revised in 2007 or later, this step computes the actual source energy use intensity.

[6] Note that for models revised in 2007 or later, this step computes the predicted source energy use intensity.

- Use the operating characteristic values to compute each variable in the model. e.g. LN(Square Foot) = LN(50,000) = 10.819
- Multiply each variable by the corresponding coefficient in the model
  - e.g. Coefficient * LN(Square Foot) = 0.84274*10.819 = 9.118
- Sum each product (i.e. coefficient*variable) from the preceding step and add to the constant
  - This yields a predicted LN(Source Energy) of 15.397
- This calculation is summarized in **Table 4**

Step 4 – Portfolio Manager computes the normalized LN(Source Energy) value[7]

The actual and predicted values for LN(Source Energy) are used to compute the energy efficiency ratio, which is converted into a normalized LN(Source Energy).

- Compute the energy efficiency ratio
  - Energy efficiency ratio =
    Actual LN(Source Energy) / Predicted LN(Source Energy)
  - 15.33661 / 15.397 = 0.9960
- Compute the normalized LN(Source Energy)
  - Normalized LN(Source Energy) =
    Energy Efficiency Ratio * Mean LN(Source Energy)
  - Mean LN(Source Energy) is provided in **Table 2** = 15.719
  - 0.9960 * 15.719 = 15.6561

Step 5 – Portfolio Manager looks up the normalized LN(Source Energy) in the Lookup Table[8]

Starting at 100 and working down, Portfolio Manager searches the lookup table for the first ratio value that is larger than the computed ratio for the building.

- An adjusted value of 15.6561 is less than 15.6643 (requirement for 68) but greater than 15.6553 (requirement for 69)
- ***The rating is a 68***

[7] Note that for models revised in 2007 or later, this step computes the energy efficiency ratio.
[8] Note that for models revised in 2007 or later, this step looks up the energy efficiency ratio in the lookup table.

Table 4 **Example Calculation – Computing predicted LN(Source Energy)**			
Operating Characteristic	Variable Value	Coefficient	Coefficient * Variable
(Constant)	N/A	4.45046	4.450
LnSqft	10.819	0.84274	9.118
LnEdseat	5.991465	0.12269	0.735
Vent	1	0.14911	0.149
LnPcnum	3.688879	0.07955	0.293
HDDxheatp	1900	0.00006155	0.117
CDDxcoolp	1150	0.00014839	0.171
LnWkhrs	4.248495	0.06271	0.266
Monuse12	0	0.05659	0.000
Cook7	1	0.0983	0.098
		Predicted LN(Source Energy) (LN(kBtu))	***15.397***

Attachment

Table 5 lists the normalized LN(Source Energy) cut-off point for each rating, from 1 to 100.

Table 5
Lookup Table for K-12 School Rating

Rating	Cumulative Percent	Normalized LN(Source Energy)		Rating	Cumulative Percent	Normalized LN(Source Energy)
100	0%	14.8923		50	50%	15.8303
99	1%	14.9563		49	51%	15.8393
98	2%	15.0153		48	52%	15.8483
97	3%	15.0703		47	53%	15.8563
96	4%	15.1203		46	54%	15.8643
95	5%	15.1663		45	55%	15.8733
94	6%	15.2083		44	56%	15.8803
93	7%	15.2473		43	57%	15.8883
92	8%	15.2823		42	58%	15.8963
91	9%	15.3153		41	59%	15.9033
90	10%	15.3443		40	60%	15.9103
89	11%	15.3723		39	61%	15.9173
88	12%	15.3973		38	62%	15.9243
87	13%	15.4203		37	63%	15.9303
86	14%	15.4413		36	64%	15.9373
85	15%	15.4613		35	65%	15.9433
84	16%	15.4793		34	66%	15.9493
83	17%	15.4963		33	67%	15.9563
82	18%	15.5113		32	68%	15.9623
81	19%	15.5263		31	69%	15.9683
80	20%	15.5393		30	70%	15.9753
79	21%	15.5523		29	71%	15.9823
78	22%	15.5643		28	72%	15.9893
77	23%	15.5753		27	73%	15.9963
76	24%	15.5863		26	74%	16.0043
75	25%	15.6153		25	75%	16.0123
74	26%	15.6073		24	76%	16.0213
73	27%	15.6173		23	77%	16.0313
72	28%	15.6273		22	78%	16.0423
71	29%	15.6363		21	79%	16.0543
70	30%	15.6463		20	80%	16.0663
69	31%	15.6553		19	81%	16.0823
68	32%	15.6643		18	82%	16.0983
67	33%	15.6733		17	83%	16.1163
66	34%	15.6833		16	84%	16.1363
65	35%	15.6923		15	85%	16.1583
64	36%	15.7013		14	86%	16.1833
63	37%	15.7103		13	87%	16.2103
62	38%	15.7203		12	88%	16.2403
61	39%	15.7293		11	89%	16.2733
60	40%	15.7383		10	90%	16.3103
59	41%	15.7483		9	91%	16.3503
58	42%	15.7573		8	92%	16.3953
57	43%	15.7663		7	93%	16.4443
56	44%	15.7763		6	94%	16.4973
55	45%	15.7853		5	95%	16.5563
54	46%	15.7943		4	96%	16.6203
53	47%	15.8033		3	97%	16.6903
52	48%	15.8133		2	98%	16.7673
51	49%	15.8223		1	99%	16.8503