ENERGY STAR® Performance Ratings
Technical Methodology for Residence Hall/Dormitory

This document presents specific details on the EPA's analytical result and rating methodology for Residence Hall/Dormitory. 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 Residence Hall/Dormitory model has not yet been revised in light of these changes; therefore some of the information in this description differs slightly.

Model Release Date
January 2004

Portfolio Manager Residence Hall/Dormitory Definition
Residence Hall/Dormitory applies to buildings associated with educational institutions or military facilities which offer multiple accommodations for long-term residents. The total gross floor area should include all supporting functions such as food service facilities, laundry facilities, meeting spaces, exercise rooms, health club/spas, lobbies, elevator shafts, storage areas stairways, etc.

Reference Data
The Residence Hall/Dormitory 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 Residence Hall/Dormitory model and the rationale behind the filter. The 1999 CBECS dataset includes a total of 81 Residence Hall/Dormitory records. After all filters are applied, the remaining dataset has 79 records.

Table 1 Summary of Residence Hall/Dormitory Model Filters	
Condition for Including an Observation in the Analysis	**Rationale**
PBAPLUS7= 9	Building Filter – CBECS defines building types according to the variable "PBAPLUS7." Residence Hall/Dormitory buildings are coded as PBAPLUS7= 9.
Source energy use intensity (kBtu/ft^2-yr) must be greater than 40 and less than 425 kBtu/ft^2-yr	Analytical Limitation Filter – Values determined to be statistical outliers.

Dependent Variable

The dependent variable in the Residence Hall/Dormitory 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 Residence Hall/Dormitories.

Independent Variables

General Overview

The CBECS data contain numerous building operation questions that EPA identified as potentially important for Residence Hall/Dormitories. These include characteristics such as the total square footage, the number of guest/occupant rooms, the percent of the building that is heated and cooled, and the number of heating and cooling degree days.

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 Residence Hall/Dormitory regression analysis, the following four characteristics were identified as key explanatory variables that can be used to estimate the expected LN(Source Energy) in a Residence Hall/Dormitory:

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

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 Residence Hall/Dormitory 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 95% or better, as indicated by a p-level of 0.05 or lower. The majority of independent variables pass this test. However, one additional variable, with slightly lower significance, *number of guest/occupant rooms*, was also retained in the model. This variable has a strong individual correlation with dormitory energy use and was determined to be important to retain in the model.

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.

Regression Modeling Results
The final regression is an ordinary least squares regression across the filtered data set of 79 observations. The dependent variable is LN(Source Energy). Basic statistics for 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 0.8834, indicating that this model explains 88% of the variance in LN(Source Energy) for Residence Hall/Dormitory buildings. This is an excellent result for a statistically based energy model.

Detailed information on the ordinary least squares regression approach 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	15.717	12.584	18.699
LnSqft	Natural Log of Square foot	10.705	8.161	13.653
LnLodgrm	Natural Log of Rooms	4.417	1.386	6.397
HDDxheatp	Heating Degree Days x Percent Heated	4575	116.2	7339
CDDxcoolp	Cooling Degree Days x Percent Cooled	510.3	0	3162

Note: Statistics are computed over the filtered data set (n=79 observations)

Table 3 Final Regression Modeling Results				
Dependent Variable	LN(Source Energy)			
Number of Observations in Analysis	79			
Model R^2 value	0.8834			
Model F Statistic	140.1			
Model Significance (p-level)	0.000			
	Unstandardized Coefficients	**Standard Error**	**T value**	**Significance (p-level)**
(Constant)	4.99455	0.5671	8.81	<.0001
LnSqft	0.91308	0.07724	11.82	<.0001
LnLodgrm	0.09455	0.08141	1.16	0.2492
HDDxheatp	0.00009774	0.00003297	2.96	0.0041
CDDxcoolp	0.00016279	0.08141	2.14	0.0357
Note: Full variable names and definitions are presented in Table 2				

Residence Hall/Dormitory 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) [1]:

Normalized LN(Source Energy) = Energy Efficiency Ratio * 15.717

The normalized LN(Source Energy) values are sorted from smallest to largest and the cumulative percent of the population at each energy value is computed. A smooth curve is fitted to the data using a two parameter gamma distribution. The fit is performed in order to minimize the sum of square 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.

[1] The mean value of LN(Source) is determined by the dataset and is presented in Table 2. It is 15.717.

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 14.704 the rating for that building should be 100. If the normalized LN(Source Energy) value is greater than or equal to 14.704 and less than 14.769, the rating for the building should be 99, etc.

Example Calculation

Below are the five steps to compute a rating for a hypothetical Residence Hall/Dormitory. 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 Residence Hall/Dormitory model has not yet been revised in light of these changes (departures from the current methodology are described in footnotes).

Step 1 – User enters building data into Portfolio Manager

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

- Energy data
  - Total annual electricity = 271,500 kWh
  - Total annual natural gas = 5,900 therms
  - Note that this data is actually entered in monthly meter entries
- Operational data
  - Gross floor area (ft^2) = 44,000
  - Number of rooms = 80
  - Percent of the building that is heated = 100%
  - Percent of the building that is cooled = 50%
  - HDD (provided by Portfolio Manager, based on zip code) = 4500
  - CDD (provided by Portfolio Manager, based on zip code) = 1000

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

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: (271,500 kWh)*(3.412 kBtu/kWh) = 926,358 kBtu Site
  - Natural gas: (5,900 therms)*(100 kBtu/therm) = 590,000 kBtu Site
- Apply the site-to-source conversion factors to compute the source energy
  - Electricity:
    926,358 Site kBtu*(3.34 Source kBtu/ Site kBtu) = 3,094,036 kBtu Source
  - Natural gas:

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

590,000 Site kBtu*(1.047 Source kBtu/Site kBtu) = 617,730 kBtu Source

- Combine source kBtu across all fuels
  - 3,094,036 kBtu + 617,730 kBtu = 3,711,766 kBtu
- Take the natural log of total source energy consumption
  - LN (3,711,766 kBtu) = 15.127

Step 3 – Portfolio Manager computes the predicted natural log of Source Energy Use[3]
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
  - Use the operating characteristic values to compute each variable in the model. e.g. LN(Square Foot) = LN(44,000) = 10.6919
- Multiply each variable by the corresponding coefficient in the model
  - e.g. Coefficient * LN(Square Foot) = 0.91308*10.6919 = 9.763
- Sum each product (i.e. coefficient*variable) from the preceding step and add to the constant
  - This yields a predicted LN(Source Energy) of 15.693
- This calculation is summarized in **Table 4**

Step 4 – Portfolio Manager computes the normalized LN(Source Energy) value[4]
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)
  - 15.127 / 15.693 = 0.9639
- 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** = 15.717
  - 0.9639 * 15.717 = 15.149

Step 5 – Portfolio Manager looks up the normalized LN(Source Energy) in the Lookup Table[5]
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 15.149 is less than 15.162 (requirement for 91) but greater than 15.123 (requirement for 92)
- ***The rating is a 91***

[3] Note that for models revised in 2007 or later, this step computes the predicted source energy use intensity.
[4] Note that for models revised in 2007 or later, this step computes the energy efficiency ratio.
[5] 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	4.99455	4.995
LnSqft	10.6919	0.91308	9.763
LnLodgrm	4.382	0.09455	0.414
HDDxheatp	4500	0.00009774	0.440
CDDxcoolp	500	0.00016279	0.081
Predicted LN(Source Energy) (LN(kBtu))			***15.693***

Attachment

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

Table 5 Lookup Table for Residence Hall/Dormitory Rating						
Rating	**Cumulative Percent**	**Normalized LN(Source Energy)**		**Rating**	**Cumulative Percent**	**Normalized LN(Source Energy)**
100	0%	14.704		50	50%	15.844
99	1%	14.769		49	51%	15.855
98	2%	14.830		48	52%	15.867
97	3%	14.887		47	53%	15.878
96	4%	14.941		46	54%	15.889
95	5%	14.991		45	55%	15.900
94	6%	15.038		44	56%	15.911
93	7%	15.082		43	57%	15.923
92	8%	15.123		42	58%	15.934
91	9%	15.162		41	59%	15.945
90	10%	15.198		40	60%	15.956
89	11%	15.232		39	61%	15.967
88	12%	15.264		38	62%	15.979
87	13%	15.294		37	63%	15.990
86	14%	15.322		36	64%	16.001
85	15%	15.348		35	65%	16.012
84	16%	15.373		34	66%	16.024
83	17%	15.397		33	67%	16.035
82	18%	15.419		32	68%	16.047
81	19%	15.440		31	69%	16.058
80	20%	15.459		30	70%	16.070
79	21%	15.478		29	71%	16.082
78	22%	15.496		28	72%	16.094
77	23%	15.513		27	73%	16.106
76	24%	15.529		26	74%	16.118
75	25%	15.545		25	75%	16.131
74	26%	15.560		24	76%	16.144
73	27%	15.574		23	77%	16.158
72	28%	15.588		22	78%	16.171
71	29%	15.601		21	79%	16.185
70	30%	15.614		20	80%	16.200
69	31%	15.627		19	81%	16.215
68	32%	15.640		18	82%	16.231
67	33%	15.652		17	83%	16.248
66	34%	15.664		16	84%	16.265
65	35%	15.676		15	85%	16.283
64	36%	15.687		14	86%	16.302
63	37%	15.699		13	87%	16.322
62	38%	15.710		12	88%	16.344
61	39%	15.722		11	89%	16.366
60	40%	15.733		10	90%	16.390
59	41%	15.744		9	91%	16.415
58	42%	15.755		8	92%	16.442
57	43%	15.766		7	93%	16.471
56	44%	15.778		6	94%	16.501
55	45%	15.789		5	95%	16.533
54	46%	15.800		4	96%	16.568
53	47%	15.811		3	97%	16.604
52	48%	15.822		2	98%	16.644
51	49%	15.833		1	99%	16.685