ENERGY STAR® Performance Ratings
Technical Methodology for Medical Office Building

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

Model Release Date
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Portfolio Manager Medical Office Building Definition
Medical Office Building applies to facility space used to provide diagnosis and treatment for medical, dental, or psychiatric outpatient care. The total gross floor area should include all supporting functions such as kitchens used by staff, laboratories, lobbies, atria, conference rooms and auditoria, fitness areas for staff, storage areas, stairways, elevator shafts, etc.

Reference Data
The Medical Office Building 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 Medical Office Building model and the rationale behind the filter. The 1999 CBECS dataset includes a total of 93 observations that can be defined as Medical Office Buildings. After all filters are applied, the remaining dataset has 82 records.

Table 1 Summary of Medical Office Building Model Filters	
Condition for Including an Observation in the Analysis	**Rationale**
PBAPLUS7= 8	Building Filter – CBECS defines building types according to the variable "PBAPLUS7." Medical Office Buildings are coded as PBAPLUS7= 8.
Must operate for at least 30 hours per week	EPA Program Filter – Baseline condition for being a full time Medical Office Building.
Must have at least 1 worker	EPA Program Filter – Baseline condition for being a full time Medical Office Building.
Source energy use intensity (kBtu/ft^2-yr) must be greater than 38 and less than 575 kBtu/ft^2-yr	Analytical Limitation Filter – Values determined to be statistical outliers.
Must have square foot of at least 5,000	Analytical Limitation Filter – Analysis could not model behavior for buildings smaller than 5,000 ft^2.

Dependent Variable

The dependent variable in the Medical Office Building analysis is the 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 LN(Source Energy) – those factors that explain the variation in the source energy consumption in a Medical Office Buildings.

Independent Variables

The CBECS data contain numerous building operation questions that EPA identified as potentially important for Medical Office Buildings. These include characteristics such as the total square foot, the weekly hours of operation, the number of workers, 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 Medical Office Building regression analysis, the following five characteristics were identified as key explanatory variables that can be used to estimate the expected LN(Source Energy) in a Medical Office Buildings:

- Natural log of gross square foot
- Natural log of number of workers
- Natural log of weekly operating hours
- Heating degree days times Percent of the building that is heated
- Cooling degree days times Percent of the building that is cooled

Regression Modeling Results

The final regression is an ordinary least squares regression across the filtered data set of 82 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 0.93, indicating that this model explains 93% of the variance in LN(Source Energy) for Medical Office Buildings. This is an excellent result for a statistically based energy model.

Most variables were found to be statistically significant at the 95% confidence level or better, as shown by the significance levels (a p-level of less than 0.05 indicates 95% confidence). However, weekly operating hours and HDD times Percent Heated both have slightly lower levels of significance. Given the relationships between weekly operating hours and energy consumption and HDD and energy consumption, this result was considered acceptable given the model framework, and therefore both worker hours and HDD times Percent Heated were retained in the analysis.

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	14.919	11.344	18.878
LnSqft	Natural Log of Square Foot	9.856	6.908	13.122
LNWker	Natural Log of Number of Workers	3.840	0.693	7.718
LNWkhrs	Natural Log of Weekly Operating Hours	3.937	3.555	4.820
HDDxheatp	Heating Degree Days x Percent Heated	3692	0	8176
CDDxcoolp	Cooling Degree Days x Percent Cooled	1253	54	4143

Note: Statistics are computed over the filtered data set (n=82 observations)

Table 3 Final Regression Modeling Results				
Dependent Variable		LN(Source Energy)		
Number of Observations in Analysis		82		
Model R^2 value		0.9336		
Model F Statistic		213.6		
Model Significance (p-level)		<.0001		
	Unstandardized Coefficients	**Standard Error**	**T value**	**Significance (p-level)**
(Constant)	2.78889	1.19393	2.34	0.0221
LnSqft	0.91433	0.09998	9.14	0.0001
LNwker	0.21568	0.09332	2.31	0.0235
LNWkhrs	0.46768	0.29816	1.57	0.1209
HDDxheatp	0.00005321	0.00003712	1.43	0.1558
CDDxcoolp	0.00020111	0.00007429	2.71	0.0084
Note: Full variable names and definitions are presented in Table 2				

Medical Office Building 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 * 14.919

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 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.

[1] The mean value of LN(Source) is determined by the dataset and is presented in Table 2. It is 14.919.

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 13.885, the rating for that building should be 100. If the normalized LN(Source Energy) value is greater than or equal to 13.885 and less than 13.943, the rating for the building should be 99, etc.

Example Calculation

Below are the five steps to compute a rating for a hypothetical Medical Office Building. 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 Medical Office Building 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 = 123,400 kWh
  - Total annual natural gas = 2,000 therms
  - Note that this data is actually entered in monthly meter entries
- Operational data
  - Gross floor area (ft^2) = 14,000
  - Number of workers = 25
  - Weekly operating hours = 50
  - Percent heated = 100%
  - Percent cooled = 100%
  - Heating degree days = 4200
  - Cooling degree days = 1200

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: (123,400 kWh)*(3.412 kBtu/kWh) = 421,041 kBtu Site
  - Natural gas: (2,000 therms)*(100 kBtu/therm) = 200,000 kBtu Site
- Apply the site-to-source conversion factors to compute the source energy
  - Electricity:
    421,041 Site kBtu*(3.34 Source kBtu/ Site kBtu) = 1,406,276 kBtu Source

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

- Natural gas:
  200,000 Site kBtu*(1.047 Source kBtu/Site kBtu) = 209,400 kBtu Source
- Combine source kBtu across all fuels
  - 1,406,276 kBtu + 209,400 kBtu = 1,615,676 kBtu
- Take the natural log of total source energy consumption
  - LN (1,615,676 kBtu) = 14.295

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(14,000) = 9.5468
- Multiply each variable by the corresponding coefficient in the model
  - e.g. Coefficient * LN(Square Foot) = 0.91433*9.5468 = 8.729
- Sum each product (i.e. coefficient*variable) from the preceding step and add to the constant
  - This yields a predicted LN(Source Energy) of 14.506
- 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)
  - 14.295 / 14.506 = 0.9855
- 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** = 14.919
  - 0.9855 * 14.919 = 14.703

Step 5 – Portfolio Manager looks up the normalized LN(Source Energy) in the Lookup Table
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 14.703 is less than 14.714 (requirement for 76) but greater than 14.694 (requirement for 77)
- ***The rating is a 76***

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[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.

Table 4 **Example Calculation – Computing predicted LN(Source Energy)**			
Operating Characteristic	Variable Value	Coefficient	Coefficient * Variable
(Constant)	N/A	2.78889	2.789
LnSqft	9.5468	0.91433	8.729
LNwker	3.2189	0.21568	0.694
LNWkhrs	3.912	0.46768	1.830
HDDxheatp	4200	0.00005321	0.223
CDDxcoolp	1200	0.00020111	0.241
		Predicted LN(Source Energy) (LN(kBtu))	***14.506***

Attachment

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

Table 5 Lookup Table for Medical Office Building						
Rating	**Cumulative Percent**	**Normalized LN(Source Energy)**		**Rating**	**Cumulative Percent**	**Normalized LN(Source Energy)**
100	0%	13.885		50	50%	15.117
99	1%	13.943		49	51%	15.129
98	2%	13.999		48	52%	15.140
97	3%	14.051		47	53%	15.151
96	4%	14.101		46	54%	15.161
95	5%	14.148		45	55%	15.172
94	6%	14.192		44	56%	15.182
93	7%	14.234		43	57%	15.191
92	8%	14.274		42	58%	15.201
91	9%	14.311		41	59%	15.210
90	10%	14.347		40	60%	15.218
89	11%	14.381		39	61%	15.227
88	12%	14.414		38	62%	15.235
87	13%	14.445		37	63%	15.243
86	14%	14.474		36	64%	15.250
85	15%	14.503		35	65%	15.258
84	16%	14.530		34	66%	15.265
83	17%	14.556		33	67%	15.272
82	18%	14.581		32	68%	15.279
81	19%	14.605		31	69%	15.286
80	20%	14.628		30	70%	15.293
79	21%	14.651		29	71%	15.300
78	22%	14.672		28	72%	15.307
77	23%	14.694		27	73%	15.314
76	24%	14.714		26	74%	15.322
75	25%	14.734		25	75%	15.329
74	26%	14.753		24	76%	15.337
73	27%	14.772		23	77%	15.345
72	28%	14.791		22	78%	15.354
71	29%	14.809		21	79%	15.364
70	30%	14.826		20	80%	15.374
69	31%	14.844		19	81%	15.385
68	32%	14.861		18	82%	15.397
67	33%	14.877		17	83%	15.409
66	34%	14.894		16	84%	15.423
65	35%	14.910		15	85%	15.439
64	36%	14.925		14	86%	15.455
63	37%	14.941		13	87%	15.474
62	38%	14.956		12	88%	15.494
61	39%	14.971		11	89%	15.515
60	40%	14.986		10	90%	15.539
59	41%	15.000		9	91%	15.566
58	42%	15.014		8	92%	15.594
57	43%	15.028		7	93%	15.625
56	44%	15.042		6	94%	15.660
55	45%	15.055		5	95%	15.697
54	46%	15.068		4	96%	15.737
53	47%	15.081		3	97%	15.781
52	48%	15.093		2	98%	15.829
51	49%	15.105		1	99%	15.881