ENERGY STAR® Performance Ratings
Technical Methodology for Hospital (Acute Care/Children's)

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

Model Release Date

November 2001

Portfolio Manager Hospital (Acute Care/Children's) Definition

Hospital applies to facility space used as Acute Care and Children's Hospitals between 20,000 and 5 million square feet in total gross floor area. These facilities provide acute care services intended to treat patients for short periods of time for any brief but severe medical condition, including emergency medical care, physician's office services, diagnostic care, ambulatory care, and surgical care. Acute care hospitals typically discharge patients as soon the patient is deemed healthy and stable. Note: Long-term care hospitals (LTCHs) that are certified as acute care hospitals are not eligible because LTCHs provide patients with acute care for extended inpatient stays, defined by federal statute as an average of 25 days or more.

At least 51% of beds must be licensed and used for acute care services. And at least 51% of the total gross floor area must be used for acute care services. The total floor area should include all supporting functions such as: stairways, connecting corridors between buildings, medical offices, exam rooms, laboratories, lobbies, atria, cafeterias, storage areas, elevator shafts, and any space affiliated with emergency medical care, or diagnostic care. Facilities that use 51% or more of the gross floor area for long-term care, skilled nursing, and/or ambulatory surgical centers are not eligible for a rating at this time but can benchmark within Portfolio Manager using the "Other" space type category.

Reference Data

The Hospital regression model is based on data from the Electric Power Research Institute's (EPRI) Energy Benchmarking Survey completed in 1997. Through careful examination, it was determined that the 1995 CBECS (Commercial Buildings Expenditures and Consumption Survey 1995, EIA) data was not sufficiently robust to fully account for the variation in service found in the healthcare sector. The EPRI data set was determined to be the most robust, representative data set for development of an energy rating model.

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 Hospital model and the rationale behind the filter.

Table 1
Summary of Hospital Building Model Filters

Condition for Including an Observation in the Analysis	Rationale
Building Type = N/A	Building Filter – All observations within the EPRI study were of Hospital complexes thus no building type filter had to be applied.
Must operate for at least 30 hours per week	EPA Program Filter – Baseline condition for being a full time Hospital.
All questions regarding each Hospital observation must contain a full response	Data Limitation Filter – Information for each observation must be complete.
Must have at least 16 licensed beds and no more than 1,510	Analytical Limitation Filter – Analysis could not model behavior for buildings with less than 16 beds and no more than1,510 beds
Must have no more than 40 floors	Analytical Limitation Filter – Analysis could not model behavior for buildings with more than 40 floors.
Must have square foot of at least 20,000	Analytical Limitation Filter – Analysis could not model behavior for buildings smaller than 20,000 ft^2.

The EPRI Energy Benchmarking Survey data (EPRI Data) contains energy consumption and building characteristics data on 701 Hospitals. After all filters are applied, the remaining dataset has 493 records, representing five different categories of Hospitals. Due to the number of observations one analysis was performed across all categories together; refer the Independent Variables section for greater detail. The five EPRI Hospital categories are:

1. Acute Care/Children's Hospitals (415 records)
2. Cancer Centers/Clinics (4 records)
3. Skilled Nursing Facilities (45 records)
4. Psychiatric Hospitals (10 records)
5. Rehabilitations Centers (19 records)

Dependent Variable

The dependent variable in the Hospital 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 Hospital.

Independent Variables

General Overview
The EPRI data contain numerous building operation questions that EPA identified as potentially important for Hospitals. These include characteristics such as the total square footage, the EPRI Hospital category, whether the Hospital provides tertiary care, the number of beds, the number of floors, the presence of an above ground parking structure, 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. 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 Hospital regression analysis, the following seven characteristics were identified as key explanatory variables that can be used to estimate the expected LN(Source Energy) in a Hospital:

- Natural log of gross square foot
- Whether the Hospital is in the Acute Care/Children's Category (1 = yes)
- Whether the Hospital provides tertiary care (1 = yes)
- Natural log of the number of beds
- Natural log of the maximum number of floors
- Presence of an above ground parking facility (1 = yes)
- Sum of heating and cooling degree days

EPA explored the possibility of having yes/no variables for each Hospital category in the EPRI dataset. Due to the limited number of observations, the categories other than Acute Care/Children's were not found to have statistically meaningful differences. EPA also explored the possibility of excluding these other categories from the analysis entirely. This was not shown to have an impact on the result, and as such the full set of 493 observations was retained.

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 Hospitals. Additionally, the beta testing effort helped verify that the final regression model included the appropriate set of variables. The public beta testing of the model provided a sufficient quantity of observations to validate the Hospital model for Acute Care/Children's Hospitals. However, there were not enough records in other categories to provide a sufficient test sample. As such, only Acute Care/Children's Hospitals are eligible for the energy performance rating and the ENERGY STAR label at this time.

It is important to reiterate that the final regression model is based on the nationally representative EPRI data, not data collected during the beta test.

Regression Modeling Results

The final regression is an ordinary least squares regression across the filtered data set of 493 observations. The dependent variable is LN(Source Energy). Basic statistics for the final set of independent variables in the model are provided in **Table 2**. The final model is presented in **Table 3**. All model variables are 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). The model has an R^2 value of 0.8322, indicating that this model explains 83% of the variance in LN(Source Energy) for Hospitals. 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	18.60	15.55	21.58
Ln(SqFt)	Natural Log of Square Footage	12.54	9.97	15.32
Acute	Falls under Acute Care/Children's Category (1 = yes)	0.83	0	1
Tertiary	Provides Tertiary Care (1= yes)	0.32	0	1
Ln(Beds)	Natural Log of Number of Beds	5.18	2.77	7.32
Ln(Floors)	Natural Log of Number of Floors	1.59	0	3.58
A.G. Parking	Presence of an Above Ground Parking Facility (1 = yes)	0.28	0	1
DD	Sum of Heating and Cooling Degree Days	6220	2185	10736

Note: Statistics are computed over the filtered data set (n=493 observations)

Table 3 Final Regression Modeling Results				
Dependent Variable		LN(Source Energy)		
Number of Observations in Analysis		493		
Model R^2 value		0.8322		
	Unstandardized Coefficients	**Standard Error**	**T value**	**Significance (p-level)**
(Constant)	7.50492	0.42164	17.8	<.0001
Ln(Sqft)	0.82798	0.04436	18.66	<.0001
Acute	0.14794	0.05121	2.89	0.004
Tertiary	0.09278	0.04255	2.18	0.0297
Ln(# Beds)	0.10439	0.04015	2.60	0.0096
Ln(Max # Floors)	0.11119	0.05079	2.19	0.0291
A.G. Parking	0.10534	0.04864	2.17	0.0308
DD	-0.00003	0.00001	-2.27	0.0239
Note: Full variable names and definitions are presented in Table 2				

Hospital 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 EPRI data sample use more energy than predicted by the regression equation, while others use less. The *actual* value of LN(Source Energy) for each EPRI 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 * 18.60

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 18.60.

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 17.834 the rating for that building should be 100. If the normalized LN(Source Energy) value is greater than or equal to 17.834 and less than 17.954, the rating for the building should be 99, etc.

Example Calculation

Below are the five steps to compute a rating for a hypothetical Hospital. 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 Hospital 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 = 8,360,000 kWh
  - Total annual natural gas = 180,000 therms
  - Note that this data is actually entered in monthly meter entries
- Operational data
  - Gross floor area (ft^2) = 300,000
  - Acute care = yes (1)
  - Tertiary care = yes (1)
  - Number of beds = 200
  - Number of floors = 5
  - Above ground parking = yes (1)
  - HDD (provided by Portfolio Manager, based on zip code) = 4000
  - CDD (provided by Portfolio Manager, based on zip code) = 2220

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: (8,360,000 kWh)*(3.412 kBtu/kWh) = 28,524,320 kBtu Site
  - Natural gas: (180,000 therms)*(100 kBtu/therm) = 18,000,000 kBtu Site
- Apply the site-to-source conversion factors to compute the source energy
  - Electricity:

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

28,524,320 Site kBtu*(3.34 Source kBtu/ Site kBtu) = 95,271,229 kBtu Source
    - Natural gas:
      18,000,000 Site kBtu*(1.047 Source kBtu/Site kBtu) = 18,846,000 kBtu Source
- Combine source kBtu across all fuels
    - 95,271,229 kBtu + 18,846,000 kBtu = 114,117,229 kBtu
- Take the natural log of total source energy consumption
    - LN (114,117,229 kBtu) = 18.553

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(300,000) = 12.6115
- Multiply each variable by the corresponding coefficient in the model
    - e.g. Coefficient * LN(Square Foot) = 0.827984*12.6115 = 10.442
- Sum each product (i.e. coefficient*variable) from the preceding step and add to the constant
    - This yields a predicted LN(Source Energy) of 18.838
- 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)
    - 18.553/ 18.838 = 0.9849
- 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** = 18.60
    - 0.9849 * 18.60 = 18.319

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 18.319 is less than 18.334 (requirement for 87) but greater than 18.314 (requirement for 88)
- ***The rating is a 87***

[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	7.50492	7.505
Ln(Sqft)	12.6115	0.82798	10.442
DD	6,220	-0.00003	-0.187
Acute	1	0.14794	0.148
Tertiary	1	0.09278	0.093
Ln(# Beds)	5.2983	0.10439	0.553
Ln(Max # Floors)	1.6094	0.11119	0.179
A.G. Parking	1	0.10534	0.105
Predicted LN(Source Energy) (LN(kBtu))			***18.838***

Attachment

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

Table 5 Lookup Table for Hospital Rating						
Rating	**Cumulative Percent**	**Normalized LN(Source Energy)**		**Rating**	**Cumulative Percent**	**Normalized LN(Source Energy)**
100	0%	17.834		50	50%	18.718
99	1%	17.954		49	51%	18.724
98	2%	18.024		48	52%	18.734
97	3%	18.074		47	53%	18.744
96	4%	18.114		46	54%	18.754
95	5%	18.154		45	55%	18.761
94	6%	18.184		44	56%	18.768
93	7%	18.214		43	57%	18.774
92	8%	18.234		42	58%	18.784
91	9%	18.254		41	59%	18.794
90	10%	18.274		40	60%	18.804
89	11%	18.294		39	61%	18.811
88	12%	18.314		38	62%	18.818
87	13%	18.334		37	63%	18.824
86	14%	18.344		36	64%	18.834
85	15%	18.364		35	65%	18.844
84	16%	18.384		34	66%	18.854
83	17%	18.394		33	67%	18.864
82	18%	18.404		32	68%	18.871
81	19%	18.424		31	69%	18.878
80	20%	18.434		30	70%	18.884
79	21%	18.444		29	71%	18.894
78	22%	18.454		28	72%	18.904
77	23%	18.464		27	73%	18.914
76	24%	18.484		26	74%	18.924
75	25%	18.494		25	75%	18.934
74	26%	18.504		24	76%	18.944
73	27%	18.514		23	77%	18.954
72	28%	18.524		22	78%	18.964
71	29%	18.534		21	79%	18.974
70	30%	18.544		20	80%	18.984
69	31%	18.554		19	81%	18.994
68	32%	18.564		18	82%	19.014
67	33%	18.574		17	83%	19.024
66	34%	18.584		16	84%	19.034
65	35%	18.594		15	85%	19.044
64	36%	18.601		14	86%	19.064
63	37%	18.608		13	87%	19.074
62	38%	18.614		12	88%	19.094
61	39%	18.624		11	89%	19.104
60	40%	18.634		10	90%	19.124
59	41%	18.644		9	91%	19.144
58	42%	18.654		8	92%	19.164
57	43%	18.664		7	93%	19.184
56	44%	18.671		6	94%	19.204
55	45%	18.678		5	95%	19.234
54	46%	18.684		4	96%	19.274
53	47%	18.694		3	97%	19.324
52	48%	18.704		2	98%	19.394
51	49%	18.711		1	99%	19.584