ENERGY STAR Hotel Benchmarking Methodology
Technical Details on 2009 Model Updates
May 2009

Overview

EPA's energy performance ratings are designed to assess actual as-billed energy data to create a whole building indicator of energy performance and compare a building to its national peer group. EPA analyzes national survey data, develops regression models to predict energy use for specific space types based on operation, compares actual energy use with the model prediction, and assigns a 1-to-100 rating to a building. Each point on the performance scale represents one percentile of buildings. A full overview of this process is available online[1]. At the same link, there is a specific document outlining the hotel benchmarking methodology and supporting analysis, including data filters applied, descriptive statics, and the final regression model. This regression model was released into Portfolio Manager on February 23, 2009. It represents a revised approach that incorporates more recent and robust market data as well as an improved methodology.

The purpose of this document is to supplement existing resources by presenting additional technical information on the analysis of the Hotel model and the evaluation of its performance for Portfolio Manager buildings. The information presented herein supports the purpose and validity of the model with respect to the population of hotels in both the Commercial Building Energy Consumption Survey (CBECS) and the ENERGY STAR rating tool, Portfolio Manager.

Hotel Rating Example

The energy performance rating is based on an evaluation of source energy use per square foot, or Source Energy Use Intensity (EUI). Each building's energy use per square foot is evaluated and placed into the distribution *accounting for its specific operational parameters*. Because the rating regression model adjusts for characteristics like the presence of cooking and the number of rooms, two different hotels could use the same energy per square foot, but achieve different ratings.

For example, the characteristics for Hotel A and Hotel B are summarized in Table 1. Hotel A is a smaller, limited service hotel. It has a small total floor area, and has a high number of rooms per 1,000 square foot. Hotel A does not have a restaurant or commercial cooking, nor does it have extended services such as spas or conference facilities that may require additional workers. Hotel B is a larger full service hotel. The room size is larger and there are more common areas such as banquet spaces, so the number of rooms per square foot is much lower than in Hotel A. Hotel B has on-site restaurants, and a large number of employees to attend to guests, conference facilities, spas, and other amenities.

Although Hotels A and B have the exact same energy use, Hotel B earns a much higher performance rating because it offers more services, and therefore requires more energy. The adjustments in the model account for this difference in service level. In this way, the rating is based on Source EUI, while accounting for the hotel service level.

[1] http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager_model_tech_desc.

Table 1 Example Hotel Performance Characteristics		
	Hotel A	**Hotel B**
Gross Floor Area	65,000	750,000
Number of Rooms	170	1,000
Rooms per 1,000 Square Foot	2.62	1.33
Presence of Food Preparation	No	Yes
Number of Commercial Refrigeration Cases	1	20
Commercial Cases per 1,000 Square Foot	0.015	0.026
Number of Workers	15	555
Workers per 1,000 Square Foot	0.23	0.74
Predicted Source EUI (kBtu/square foot)	195	245
Actual Source EUI (kBtu/square foot)	***180***	***180***
Rating	***52***	***74***
Note: Hotels are assumed to be in the same climate so this does not impact their ratings		

Specific Hotel Variable Details

As the preceding example shows, the model evaluates energy consumption while accounting for the level of service at the hotel. The level of service is captured through some basic hotel characteristics. The adjustment associated with each of these characteristics is based on its statistical correlation with energy use. The regression technique enables simultaneous adjustments for each of the operating characteristics.

Because the adjustments are based on statistical correlations, the regression coefficients ***do not*** represent the specific power requirement of a piece of equipment. The adjustment for commercial refrigeration units or for rooms per 1,000 square foot is not an estimate of the energy use per refrigerator or per room Rather, it is the correlation between that characteristic and energy consumption. This correlation may embody the effects of services like banquet and conference facilities which require food service and refrigeration. Similarly, the coefficient on each operation characteristics will embody the impacts of related hotels services. As another example, hotels that have banquet facilities, spas, and other services will generally require more staff. Hence, the coefficient on worker density is not merely the energy that a worker uses, but it is an adjustment that accounts for that increased service level.

To identify each of these characteristics, EPA examines multiple different regression formulations using multiple statistical tests including residual plots, model R2, and individual coefficient significance levels. A diverse set of operating characteristics are reviewed, including the number of rooms and employees, counts of equipment such as printers, copiers, computers and commercial refrigeration, and parameters like pools, laundry facilities[2], cooking facilities.

[2] Because laundry is energy intensive, the potential to include it as an operating characteristic in the Hotel model was examined very closely. However, no statistically significant relationships could be found. Despite the absence of an adjustment, the final model does not show any bias with respect to assessing hotels with laundry. Optional characteristics on the type of laundry (linens or terry) and the annual quantity (e.g. pounds or tons) will be collected

Ultimately, the final equation includes the best combination of operating characteristics that have statistically significant correlations with energy use. For a specific building, each characteristic is entered into the equation, and multiplied by the respective coefficients to yield the predicted source energy use intensity (Source EUI). This predicted value represents the amount of energy the building is expected to use, based on its operating characteristics. A specific discussion of the Hotel regression analysis and model coefficients is available online[3]. The terms in the final model are as follows:

- Energy per square foot
- Rooms per 1,000 square foot
- Workers per 1,000 square foot
- Presence of food preparation
- Commercial refrigeration cases per 1,000 square foot
- Heating degree days times Percent heated
- Cooling degree days times Percent cooled

Two additional items that may influence energy performance at a Hotel are Swimming Pools and Parking Garages. These activities do not appear as unique terms in the regression. However, they are accounted for in Portfolio Manager. The tool assigns engineering estimates to account for lighting and ventilation requirements in a garage, and to account for pumping and heating requirements at a pool. In the performance evaluation, these engineered allowances are subtracted from the Hotel's actual energy use, so that the regression and rating applies to the rest of the hotel, not the pool and/or parking garage.

Comparison of Old and New EPA Methodologies

The revised methodology incorporates several improvements to the original methodology, introduced in April of 2002. The major changes include the use of a new data source and movement away from amenity categories (e.g. Economy, Upscale) to more specific service questions (e.g. number of workers and refrigeration units). In addition, the new model focuses on energy *per square foot* rather than total energy. All of the changes have been pursued to enable a more accurate and inclusive model. The changes are each discussed in more detail below.

Data Source

The original benchmark model was based on data from The Hospitality Research Group's (HRG) Trends in the Hotel Industry® database for the year 1999. Information from this data source was deemed to be the best available at the time of model development. Since that time, the Energy Information Administration (EIA) has released a more recent survey, 2003 Commercial Building Energy Consumption Survey (CBECS), which was released in 2006.

The CBECS survey is the standard basis for all EPA models because it is a random survey of energy consumption across the national population of commercial buildings, and it is freely

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in Portfolio Manager, so that EPA can further explore the relationship between laundry use and energy consumption at hotels.

[3] http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager_model_tech_desc.

available to the general public for review and analysis. EPA has adopted this survey for the Hotel model because the most recent version contains more hotel-specific operating characteristic than its predecessors did. Hence, it can be applied now, where it couldn't in the past. New data elements include more information on cooking, refrigeration, and office equipment like computers, servers, and printers.

The CBECS 2003 survey offers several key advantages, which make it the best survey for the new Hotel rating model. First, the CBECS survey contains actual metered energy consumption. Other industry data typically focuses on cost data, which cannot always be easily translated into energy consumption data. CBECS provides the most reliable source of as-billed energy consumption data at hotels. This includes the energy consumption regardless of how the revenue is structured at the hotel. That is, energy use associated with food preparation areas will be included in CBECS even if the food preparation is out-sourced and therefore not a revenue center.

Another benefit of CBECS is that it contains measures of gross square foot, a key building descriptor that is required along with energy use. It is important to know both the gross square foot and the number of rooms, as the relationship between the two will shed light on the amount of common space, such as conference facilities. Because CBECS offers gross floor area, gross energy use, and total number of rooms, the relationship among all three can be characterized more accurately.

In addition to floor area, CBECS also offers many specific operational variables including counts of employees, types of food service, and counts of equipment such as computer, printers, copiers, refrigerators, and vending machines. In contrast, the old benchmark model had fewer such specific variables and instead broader amenity categories. From feedback of existing ENERGY STAR partners, it was determined that these amenity categories were not clear. Many hotels did not know whether to designate their operations as Upscale or Upper Upscale, for example, or as Economy or Mid-Scale. As such, it was determined that the CBECS survey offered better resolution of specific characteristics that differ depending on the level of service.

Finally, one of the most important benefits of the CBECS data set is that the micro data are free and available to the public; anyone interested can replicate the model to explore the energy performance in greater detail[4].

Amenity Categories

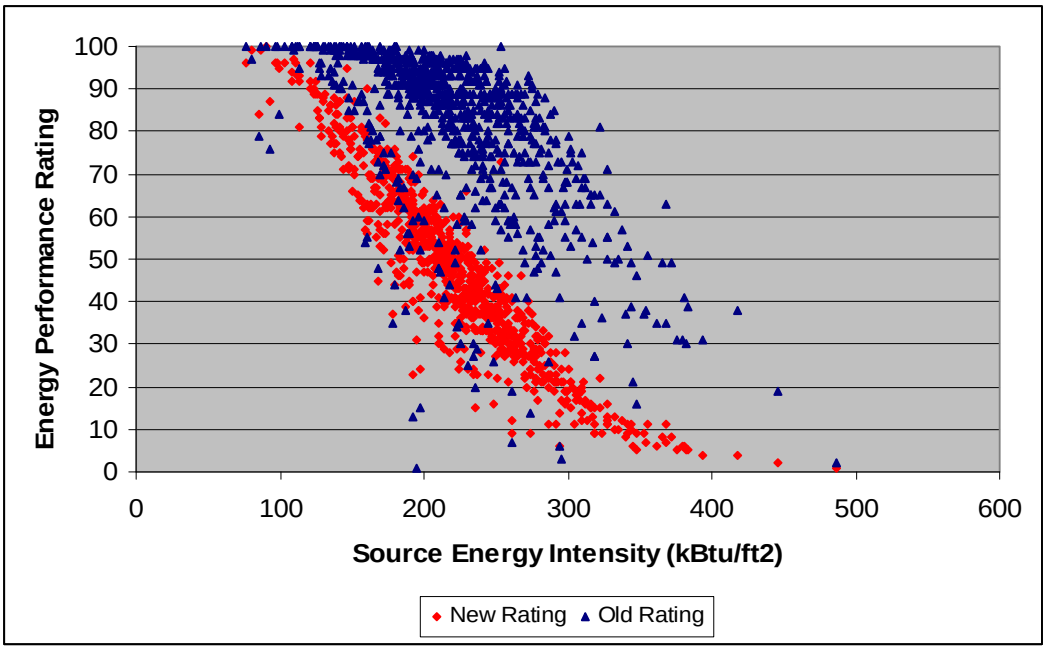
As the discussion of data suggests, the use of specific characteristics (e.g. workers, refrigeration units) offers the most accurate assessment of energy use across hotel amenity categories. These measures are easier to quantify and are less subject to interpretation. In fact, a review of the rating results for the 3,203 hotels in Portfolio Manager shows that the distribution of ratings across these categories is more equitable under the new model.

Figure 1 presents the energy performance ratings and Source EUI values for the Economy hotels in Portfolio Manager. Looking at this figure, it is expected that hotels with higher energy should

[4] Complete information on the CBECS survey, including the public microdata is available at: http://www.eia.doe.gov/emeu/cbecs/contents.html

have lower ratings, while those with lower energy will have higher ratings. Hotels in the middle range may be expected to have a variety of ratings, depending on their specific service level.

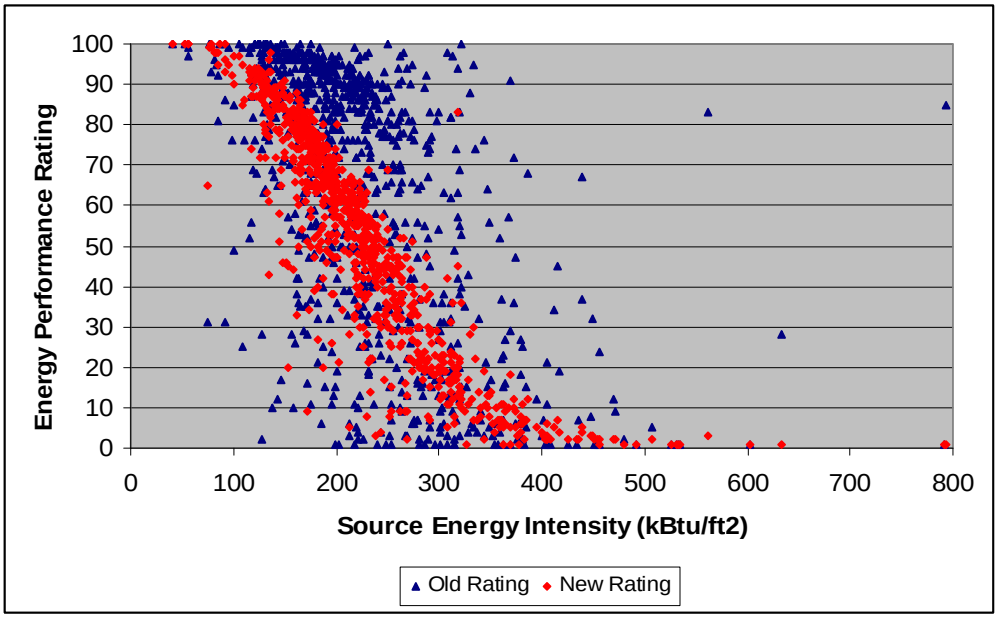
Figure 1 - Energy Performance Rating Comparison for Economy Hotels



Looking at **Figure 1**, it is apparent that under the old model (blue triangles), Economy hotels tended to rate very well. A disproportionate number of economy hotels earned high ratings, with the average above 80. As shown on **Figure 1**, even Economy hotels with very high EUI values (e.g. 350 kBtu/ft^2) rated well under the old model. The new rating model produces a more expected relationship between EUI and rating (in red diamonds), with the more intensive buildings earning lower ratings. Under the new model the distribution of ratings is more equitable showing a relatively flat distribution, with an average rating of 46 and 17% of hotels qualifying for ENERGY STAR.

Similar evaluations can be made across all amenity categories. **Figure 2** presents the same comparison for the Upscale amenity category. As shown thereon, the older model produced more varied results. Some upscale hotels with very low energy intensities received very low ratings (unexpected), while others with above average energy use received high ratings (also unexpected). In general, the relationship between energy intensity and the rating appears more stable under the new model. Under the new model, the Upscale Hotels have an average rating of 52 points, and 24% qualify for ENERGY STAR. This is an excellent result and suggests that the model is appropriate and unbiased for the Hotels in Portfolio Manager.

Figure 2 - Energy Performance Rating Comparison for Upscale Hotels



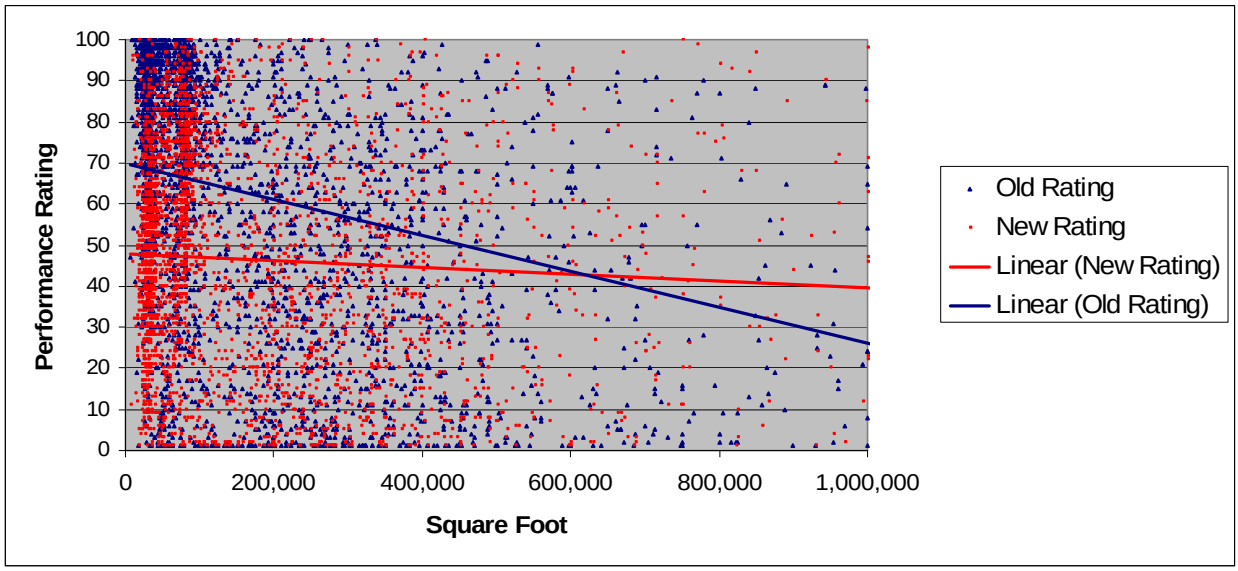
Equivalent evaluations can be made for all amenity categories, but are not included in this document in the interest of simplicity. In general the observations that can be drawn from the Economy and Upscale hotels can be extended to the full set of buildings in Portfolio Manager. The new model produces more equitable results across all categories. No one amenity category performs uniformly better or worse than any other category with the new rating model. Also, the performance is more uniform and is not highly skewed towards high or low ratings. As such, the new methodology appears to be more equitable across the spectrum of hotel amenity categories present in Portfolio Manager.

Hotel Size and Energy Intensity

One reason the economy hotels seem to rate differently under the new model is the use of energy *per square foot* as the unit of analysis. The old model looked at total energy, relative to total number of rooms. While it is obvious that a larger hotel will use more total energy, the more salient question is whether a larger hotel uses more energy *per square foot*. Hence, for a hotel, energy *per square foot* as compared with rooms *per square foot* is a much more appropriate indicator. This allows for the model to better capture the relationship between size, rooms, and energy use.

In fact under the old methodology some ENERGY STAR partners observed that their smaller properties tended to rate more favorably. Analysis and development of the new model confirms that the old model often was generous to small hotels, whereas the new model is more equitable across the spectrum of size. **Figure 3** presents the energy performance ratings as compared with hotel size for both the old and new models. Looking at this graph, the desired result is to see a lot of scatter with a flat trend line. That result would indicate that the rating is unbiased with respect to size. Based on this criteria, the new model presents much better scatter and a much flatter trend line (blue dots and line), as compared with the older model. Hence, the new methodology is more equitable with respect to hotel size.

Figure 3 – Portfolio Manager Energy Performance Ratings and Hotel Size Using the Old and New Models



Comparison of Populations: CBECS and Portfolio Manager

The Hotel benchmarking model is based on a regression analysis using CBECS data. The model is used to normalize energy consumption with respect to operating characteristics and climate, in order to calculate a 1-to-100 energy performance rating. In addition to reviewing CBECS data, existing Portfolio Manager buildings can be analyzed to understand how the model works and to provide additional verification that the model is appropriate for use by all hotels types. The CBECS data is used as the basis for the regression analysis because it is a nationally representative sample of buildings. The Portfolio Manager data is useful for comparison purposes, but should not be considered nationally representative, as it is subject to self-selection bias, and may be influenced by several large hotel operators that are actively benchmarking building portfolios.

Ideally, the model developed with CBECS data should work well when it is applied to the Portfolio Manager data. When the two populations are compared, the desired result is to see similar average ratings and similar relationships between energy and the performance ratings. If these things are similar for both CBECS and Portfolio Manager, then the CBECS model works for Portfolio Manager. In this way, the Portfolio Manager analysis enables an added level of verification for the model development.

A comparison of the CBECS and Portfolio Manager populations for Hotels reveals some interesting differences, but there are actually more similarities than differences. Although the hotels are different sizes, the energy consumption patterns and performance ratings are similar. Because of these similarities, the CBECS model is determined to be appropriate for the full spectrum of hotel sizes and types found in Portfolio Manager. Even though the Portfolio Manager hotels are generally larger, many of them rate well and nearly 550 have ratings of 75 or higher, which qualify them for the ENERGY STAR.

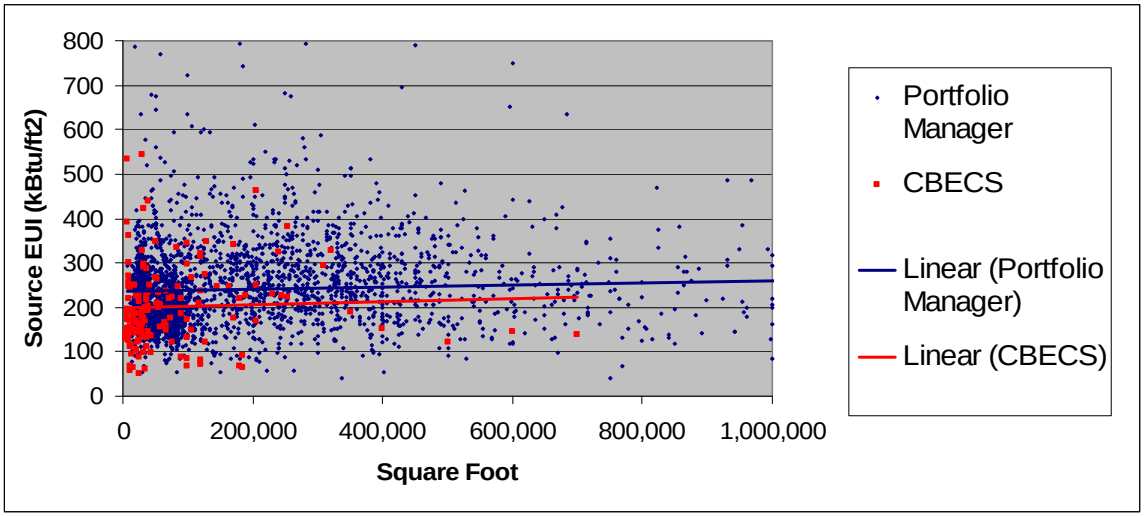
Differences
The main difference between the CBECS and Portfolio Manager data is the hotel size, as summarized in **Table 2**. While the CBECS data does contain hotels representing a wide size range, the average floor area and number of rooms is smaller than the Portfolio Manager buildings.

Table 2
Descriptive Statistics for CBECS and Portfolio Manager

	CBECS	Portfolio Manager
Number of Observations	142	3,203
Hotel Size (ft^2)	40,596	206,832
Number of Rooms	62	262
Number of Rooms per 1,00 square foot	1.95	2.0
Source Energy Intensity ($kBtu/ft^2$)	182.5	204.1

Similarities
Despite the difference in size, the two populations show a similar range of EUI values, with average Source EUI values within approximately 10% of each other. In both datasets, there is not a strong relationship between EUI and size. The EUI range tends to be similar across the full size range, with a relatively flat trend line, as shown in **Figure 4**. Most hotels use between 100 and 400 source $kBtu/ft^2$, with an average around 200 $kBtu/ft^2$.

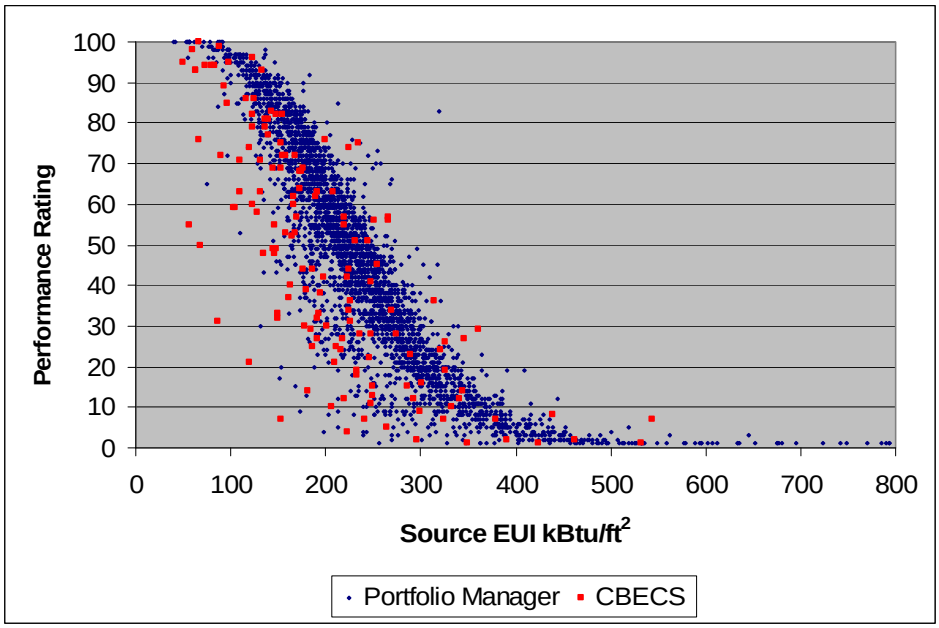
Figure 4: Source Energy Intensity and Size Comparison



Another way to compare the CBECS and Portfolio Manager data is to evaluate the 1-to-100 energy performance rating as it relates to the energy use. **Figure 5** presents this relationship. Both populations exhibit a broad range of Source EUI, with values ranging from below 100 to 800 $kBtu/ft^2$. In both data sets, higher energy use is generally correlated with lower performance ratings. Note that this is not an exact relationship because of the adjustments in the

model. A hotel with EUI less than 50 kBtu/ft^2 will have a high rating and a hotel with EUI over 400 kBtu/ft^2 will have a low rating regardless of adjustments for operating characteristics. However, a building with EUI close to 200 kBtu/ft^2 may have a high rating if it has food preparation facilities, a high density of commercial refrigeration equipment, high worker density, or high heating degree days. Conversely, the building may have a low rating if it is a hotel with more limited services and lower values for key operating characteristics. (See the Rating Example above for details.) Generally this graph shows that the CBECS and Portfolio Manager hotels exhibit similar performance. This similarity confirms that the CBECS model works for Portfolio Manager hotels.

Figure 5: Energy Performance Rating Comparison



The performance displayed in the preceding figures can also be evaluated through an examination of the average ratings, and the percent of the population that qualifies for the ENERGY STAR. This information is summarized in **Table 3**, below. The CBECS data has an average rating of 50 with 26% of the population achieving ratings of 75 or higher. This result is expected as the CBECS population is the basis for the rating model. The Portfolio Manager data has an average of 46, with 17% qualifying. This is similar, though not identical performance. Although the Portfolio Manager hotels perform slightly below the average it is important to remember that it is not a random population and that some individual companies may have several hundred hotels. As such, it is not expected to be identical to a random survey. On aggregate though, the hotels in Portfolio Manager exhibit a very broad range of ratings, ranging across the full scale from 1 to 100, and nearly 550 (17%) have ratings of 75 or higher on the rating scale, which is the threshold required for ENERGY STAR.

Table 3 Overall Rating Performance: Portfolio Manager and CBECS		
	CBECS	Portfolio Manager
Energy Performance Rating	50	46
Percent Eligible for ENERGY STAR (Rate 75 or higher)	26 %	17 %

When developing regression models, EPA conducts analysis that goes beyond the simple averages in **Table 3**, to ensure that performance is not biased in favor of any particular subsets of the Hotel population. As an example of this analysis, **Table 4** presents average ratings computed across subsets of the population to explore the performance for large buildings, buildings with laundry, and buildings with cooking. In all of these groupings, the CBECS and Portfolio Manager buildings have similar average. No particular characteristics (i.e. size, cooking, or laundry) are correlated with higher or lower ratings on average.

The most surprising result here is that buildings in CBECS that report having laundry tend to rate higher than those that do not. This result is the reverse of what might be expected. Because laundry is energy intensive, the potential to include it as an operating characteristic in the Hotel model was examined very closely. However, regression analysis did not present any statistically significant results with respect to the presence of laundry. Despite the absence of an adjustment in the model, the CBECS buildings with laundry still rate better than those without, and the Portfolio Manager building averages show virtually no difference with respect to the presence of laundry. As such, it does not seem that the final model presents any problem with respect to assessing hotels with laundry.[5]

Table 4 Average Energy Performance Rating Comparisons			
		CBECS	Portfolio Manager
All Hotels		50	46
Size	500,000 or more ft^2	NA	44
	Less than 500000 ft^2	50	47
Cooking	Yes	47	47
	No	51	45
Laundry	Yes	53	47
	No	41	46
Note: An average cannot be computed for CBECS buildings that are over 500,000 square foot because there are only three buildings in this range.			

Results of Comparison

The Portfolio Manager data presents a sample of over 3,000 buildings which can be evaluated using the CBECS regression. This population was used in comparing CBECS model formulations to ensure that the final model did not exhibit any biases when applied to the hotels in Portfolio Manager. In general the hotels in Portfolio Manager tend to be larger than those in

[5] Optional characteristics on the type of laundry (linens or terry) and the annual quantity (e.g. pounds or tons) are being collected in Portfolio Manager, so that EPA can further explore the relationship between laundry use and energy consumption at Hotels.

CBECS. However, as **Figure 4** shows, larger hotels do not necessarily tend to use more energy than their smaller counterparts. Moreover, the energy performance rating analysis shows that the average rating and the percent of the population that qualify for the ENERGY STAR are comparable between the CBECS and Portfolio Manager data sets. Finally, these averages remain comparable when evaluated over specific segments of the population, such as buildings with laundry and cooking. As such, the analysis shows that the performance rating model provides an equitable and unbiased distribution of ratings for both the CBECS and the Portfolio Manager Hotels.

Summary

In summary, the revised methodology introduced in February 2009 includes several substantial enhancements for the calculation of an energy performance rating. The new methodology relies on a more recent and robust. data source. Analysis shows that it produces more equitable ratings across a diverse set of hotel amenity categories. The final model selection was determined by analyzing the performance with both Portfolio Manager and CEBCS data. Analysis shows that the model produces fair unbiased results for both hotel populations. Subsets of the population were considered to establish that equitable ratings are achieved for all types of operational parameters.