ENERGY STAR® Performance Ratings
Technical Methodology for House of Worship

This document presents specific details on the EPA's analytical result and rating methodology for House of Worship. 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).

Model Release Date

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Portfolio Manager Definition

House of Worship applies to buildings that are used as places of worship. This includes churches, temples, mosques, synagogues, meetinghouses, or any other buildings that primarily function as a place of religious worship. The rating applies to buildings that function as the primary place of worship and not to other buildings that may be associated with a religious organization, such as living quarters, schools, or buildings used primarily for other community activities. The rating applies to worship facilities that have 4,000 seats or fewer.

Reference Data

The House of Worship regression model is based on data from the Department of Energy, Energy Information Administration's 2003 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 House of Worship model, the rationale behind the filter, and the resulting number of observations after the filter is applied. After all filters are applied, the remaining data set has 269 observations.

The reasons for applying filters on the use and quantity of propane are worthy of additional discussion. In CBECS, major fuel use is reported in exact quantities of consumption. However, if a building uses propane, the amount of propane is reported according to the variable PRAMT8, which uses ranges rather than exact quantities (e.g. less than 100 gallons, 100 to 500 gallons, etc). Therefore, the quantity must be estimated within the range. To limit error associated with this estimation, EPA applies two limits to the propane quantity.

1. The quantity of propane expressed by PRAMT8 must be 1000 gallons or smaller.
2. The value of propane cannot account for more than 10% of the total source energy use. Because the exact quantity of propane is not reported, this cap ensures that the quantity of propane entered will not introduce undue error into the calculation of total energy consumption. In order to apply this 10% limitation, the value at the high end of the propane category is employed (e.g. for the category of less than 100, a value of 99 is used). If the 10% cap is not exceeded, then EPA will use the value at the middle of the range to calculate total energy use (e.g. for the category of less than 100, a value of 50 is used).

Table 1
Summary of House of Worship Model Filters

Condition for Including an Observation in the Analysis	Rationale	Number Remaining
PBAPLUS8 = 21	Building Type Filter – CBECS defines building types according to the variable "PBAPLUS8." Religious Worship is coded as PBAPBLUS= 21.	311
Must operate for at least 10 months per year	EPA Program Filter – Baseline condition for being a full time House of Worship.	302
A single activity must characterize more than 50% of the floor space[1]	EPA Program Filter – In order to be considered part of the House of Worship peer group, more than 50% of the building must be Religious Worship.	297
If propane is used, the amount category (PRAMTC8) must equal 1, 2, or 3	Data Limitation Filter – Cannot estimate propane use if it is "greater than 1000" or unknown.	285
If propane is used, the maximum estimated propane amount must be 10% or less of the total source energy	Data Limitation Filter – Because propane values are estimated from a range, propane is restricted to 10% of the total source energy.	274
Must not use chilled water	Data Limitation Filter – CBECS does not collect quantities of chilled water.	273
Must have Source EUI less than or equal to 300 kBtu/ft^2	Analytical Filter – Values determined to be statistical outliers.	269

Dependent Variable

The dependent variable in the House of Worship analysis is source energy use intensity (source EUI). This is equal to the total source energy use of the facility divided by the gross floor area. By setting source EUI as the dependent variable, the regressions analyze the key drivers of source EUI – those factors that explain the variation in source energy per square foot in a House of Worship.

[1] This filter is applied by a set of screens. If the variable ONEACT8=1, then one activity occupies 75% or more of the building. If the variable ONEACT8=2, then the activities in the building are defined by ACT18, ACT28, and ACT38. One of these activities must be coded as religious worship (PBAX8=17), with a corresponding percent (ACT1PCT8, ACT2PCT8, ACT3PCT8) that is greater than 50.

Independent Variables

General Overview:
The CBECS data contain numerous building operation questions that EPA identified as potentially important for Houses of Worship. Based on a review of the available variables in the CBECS data, in accordance with the EPA criteria for inclusion[2], EPA analyzed the following variables[3]:

- SQFT8 – Square footage
- RWSEAT8 – Religious worship seating capacity
- WKHRS8 – Weekly hours of operation
- OPNWE8 – Open weekends (yes/no)
- OPNMF8 – Open during week (1 – all five weekdays, 2 – some weekdays, 3 – no weekdays)
- NWKER8 – Number of employees during main shift
- PCNUM8 – Number of computers
- SRVNUM8 – Number of servers
- PRNTRN8 – Number of printers
- COPRN8 – Number of photocopiers
- SRVFRM8 – Server farm (yes/no)
- COOK8 – Energy used for cooking (yes/no)
- FDRM8 – Commercial food preparation area (yes/no)
- SNACK8 – Snack bar (yes/no)
- CAF8 – Cafeteria or large restaurant (yes/no)
- RFGWIN8 – Number of walk-in refrigeration units
- RFGOPN8 – Number of open refrigerated cases
- RFGRSN8 – Number of residential refrigerators
- RFGCLN8 – Number of closed refrigerated cases
- RFGVNN8 – Number of refrigerated vending machines
- ELEVTR8 – Elevators (yes/no)
- NELVTR8 – Number of elevators
- NFLOOR8 – Number of floors
- HEATP8 – Percent heated
- COOLP8 – Percent cooled
- HDD658 - Heating degree days (base 65)
- CDD658 - Cooling degree days (base 65)

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. For example, the number of personal computers is typically evaluated in a density format. The number of personal computers *per square foot* (not the gross number of computers) is expected to be

[2] For a complete explanation of these criteria, refer to *Energy Performance Ratings – Technical Methodology* (http://www.energystar.gov/ia/business/evaluate_performance/General_Overview_tech_methodology.pdf).
[3] Note that the 8 at the end of all variables indicates that the 2003 CBECS survey is the eighth survey conducted by the Energy Information Administration.

correlated with the energy use per square foot. In addition, based on analytical results and residual plots, variables were 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: source EUI.

Based on the House of Worship regression analysis, the following seven characteristics were identified as key explanatory variables that can be used to estimate the expected average source EUI (kBtu/ft^2) in a House of Worship:

- Number of religious worship seats per 1,000 square feet
- Open all five weekdays (1 = open all five weekdays, 0 = open less than five weekdays)
- Weekly operating hours
- Number of personal computers per 1,000 square feet
- Commercial food preparation area (yes/no)
- Number of commercial refrigeration units[4] per 1,000 square feet
- Heating Degree Days
- Cooling Degree Days

Model Testing:
In addition to the analysis of CBECS data, EPA performed subsequent testing on supplemental data shared with EPA for 40 Houses of Worship. The results of testing and analysis of this dataset showed a broad range of ratings along the 1-to-100 scale. The analysis provided a second level of confirmation that the final regression model provides a fair assessment of Houses of Worship and is unbiased with respect to key operational characteristics such as building size, seating density, operating hours, and heating and cooling degree days.

It is important to reiterate that the final regression model is based on the nationally representative CBECS data, not the supplemental data collected by EPA. The supplemental data served to verify that the CBECS-based regression model provides a valid assessment of energy performance across a variety of Houses of Worship.

Regression Modeling Results
The final regression is a weighted ordinary least squares regression across the filtered data set of 269 observations. The dependent variable is source EUI. Each independent variable is centered relative to the mean value, presented 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 adjusted R^2 value of 0.3660, indicating that this model explains 36.6% of the variance in source EUI for Houses of Worship. Because the final model is structured with energy per square foot as the dependent variable, the explanatory power of square foot is not included in the R^2 value, thus

[4] Commercial refrigeration is defined as the sum of open units (RFGOPN8), closed units (RFGCLN8), and walk-in units (RFGWIN8).

this value appears artificially low. Re-computing the R^2 value in units of source energy[5], demonstrates that the model actually explains 83.87% of the variation of source energy of Houses of Worship. This is an excellent result for a statistically based energy model.

Detailed information on the ordinary least squares regression approach, the methodology for performing weather adjustments, and the independent variable centering technique 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
SrcEUI	Source Energy per Square Foot	86.26	13.11	290.2
SeatDen	Number of Religious Worship Seats per 1000 ft^2	38.81	2.500	150.0
Open_MonFri	Open all five weekdays (yes/no)	0.3932	0.000	1.000
WkHrs	Weekly operating hours	33.28	2.000	168.0
PCDen	Number of Computers per 1000 ft^2	0.2036	0.000	1.960
FDRM	Presence of a Commercial Food Preparation area (yes/no)	0.3047	0.000	1.000
RfgCommDen	Number of Commercial Refrigeration Units per 1000 ft^2	0.0183	0.000	0.4286
HDD	Heating Degree Days	4523	146.0	9716
CDD	Cooling Degree Days	1313	146.0	4824

Note:
- *Statistics are computed over the filtered data set (n=269 observations).*
- *Values are weighted by the CBECS variable ADJWT8.*
- *The mean values are used to center variables for the regression.*
- *Commercial refrigeration is defined as the sum of open units (RFGOPN8), closed units (RFGCLN8), and walk-in units (RFGWIN8).*

[5] The R^2 value in Source Energy is calculated as: 1 – (Residual Variation of Y) / (Total Variation of Y). The residual variation is sum of (Actual Source $Energy_i$ – Predicted Source $Energy_i)^2$ across all observations. The Total variation of Y is the sum of (Actual Source $Energy_i$ – Mean Source Energy)^2 across all observations.

Table 3 Final Regression Modeling Results				
Dependent Variable	Source Energy Intensity (kBtu/ft^2)			
Number of Observations in Analysis	269			
Model R^2 value	0.3660			
Model F Statistic	20.34			
Model Significance (p-level)	0.0000			
	Unstandardized Coefficients	**Standard Error**	**T value**	**Significance (p-level)**
(Constant)	73.91	4.257	17.36	0.0000
C_SeatDen	0.6532	0.0930	7.022	0.0000
Open_MonFri	19.14	7.852	2.438	0.0154
C_WKHRS	0.2717	0.1090	2.492	0.0133
C_PCDen	26.55	9.644	2.753	0.0063
FDRM	15.83	6.159	2.571	0.0107
C_RfgCommDen	113.1	40.78	2.773	0.0060
C_HDD	0.0081	0.0020	4.133	0.0000
C_CDD	0.0141	0.0050	2.841	0.0049

Note:
- *The regression is a weighted ordinary least squares regression, weighted by the CBECS variable "ADJWT8".*
- *The prefix "C_" on each variable indicates that it is centered. The centered variable is equal to the difference between the actual value and the observed mean. The observed mean values are presented in **Table 2**.*
- *Unlike other variables, the yes/no variables FDRM and Open_MonFri are not centered. The coefficient adjustments represent the adjustment for Houses of Worship that have these characteristics.*
- *Full variable names and definitions are presented in **Table 2.***

House of Worship Lookup Table

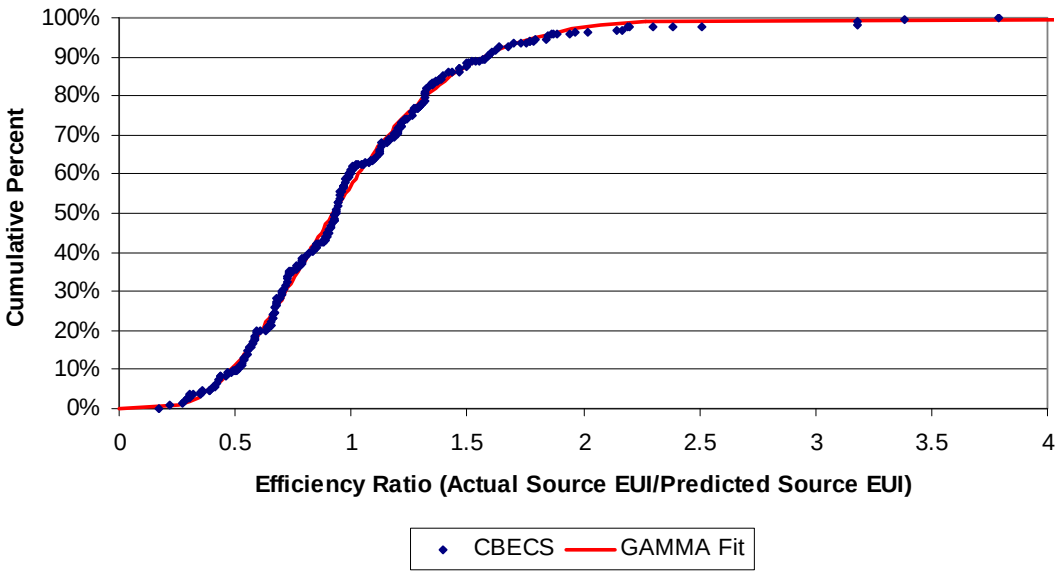
The final regression model (presented in **Table 3**) yields a prediction of source EUI based on a building's operating constraints. Some buildings in the CBECS data sample use more energy than predicted by the regression equation, while others use less. The *actual* source EUI of each CBECS observation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

Energy Efficiency Ratio = Actual Source EUI / Predicted Source EUI

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.

The efficiency ratios are sorted from smallest to largest and the cumulative percent of the population at each ratio is computed using the individual observation weights from the CBECS dataset. **Figure 1** presents a plot of this cumulative distribution. A smooth curve (shown in red) 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 final fit for the gamma curve yielded a shape parameter (alpha) of 5.097 and a scale parameter (beta) of 0.1933. For this fit, the sum of the squared error is 0.0786.

Figure 1:
House of Worship Energy Efficiency Ratio Distribution



The final gamma shape and scale parameters are then used to calculate the efficiency ratio at each percentile (1 to 100) along the curve. For example, the ratio on the gamma curve at 1% corresponds to a rating of 99; only 1% of the population has a ratio this small or smaller. The ratio on the gamma curve at the value of 25% will correspond to the ratio for a rating of 75; only 25% of the population has ratios 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 ratio is less than 0.2564 the rating for that building should be 100. If the ratio is greater than or equal to 0.2564 and less than 0.3058 the rating for the building should be 99, etc.

Example Calculation

As detailed in the document *Energy Performance Ratings – Technical Methodology*, there are five steps to compute a rating. The following is a specific example with the House of Worship model:

Step 1 – User enters building data into Portfolio Manager

For the purposes of this example, sample data is provided

- Energy data
  - Total annual electricity = 85,000 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) = 20,000
- Seating Capacity = 300
- Number of Weekdays Open = 5
  - Yes for open all five weekdays, Open_MonFri
- Operating Hours = 40
- Number of Personal Computers = 10
- Commercial Food Preparation = No
- Number of Commercial Refrigeration Units = 0
- HDD (provided by Portfolio Manager, based on zip code) = 3558
- CDD (provided by Portfolio Manager, based on zip code) = 1325

Step 2 – Portfolio Manager computes the Actual Source Energy Use Intensity

In order to compute actual source EUI, 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: (85,000 kWh)*(3.412kBtu/kWh) = 290,020 kBtu Site
  - Natural gas: (2,000 therms)*(100kBtu/therm) = 200,000 kBtu Site
- Apply the source-site ratios to compute the source energy
  - Electricity:
    290,020 Site kBtu*(3.34 Source kBtu/Site kBtu) = 968,667 kBtu Source
  - Natural Gas:
    200,000 Site kBtu *(1.047 Source kBtu/Site kBtu) = 209,400 kBtu Source
- Combine source kBtu across all fuels
  - 968,667 kBtu + 209,400 kBtu = 1,178,067 kBtu
- Divide total source energy by gross floor area
  - Source EUI = 1,178,067 kBtu/20,000 ft^2 = 58.90 kBtu/ft^2

Step 3 – Portfolio Manager computes the Predicted Source Energy Intensity

Portfolio Manager uses the building data entered under Step 1 to compute centered values for each operating parameter. These centered values are entered into the House of Worship regression equation to obtain a predicted source EUI.

- Calculate centered variables
  - Use the operating characteristic values to compute each variable in the model. (e.g. SeatDen = 300 / 20,000 * 1000 = 15)
  - Subtract the reference centering value from calculated variable (e.g. SeatDen – 38.81 = 15 – 38.81 = -23.81).
  - These calculations are summarized in **Table 4**
- Compute predicted source energy use intensity
  - Multiply each centered variable by the corresponding coefficient in the model (e.g. Coefficient*CenteredSeatDen = 0.6532*-23.81 = -15.55)
  - Take the sum of these products (i.e. coefficient*CenteredVariable) and add to the constant (this yields a predicted Source EUI of 77.48 kBtu/ft^2)
  - This calculation is summarized in **Table 5**

Step 4 – Portfolio Manager computes the energy efficiency ratio
The energy efficiency ratio is equal to: Actual Source EUI/ Predicted Source EUI

- Ratio = 58.90/77.48 = 0.7602

Step 5 – Portfolio Manager looks up the efficiency ratio 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.

- A ratio of 0.7602 is less than 0.7693 (requirement for 66) but greater than 0.7593 (requirement for 67)
- ***The rating is 66***

Table 4 Example Calculation – Computing Building Centered Variables				
Operating Characteristic	Formula to Compute Variable	Building Variable Value	Reference Centering Value	Building Centered Variable (Variable Value - Center Value)
SeatDen	#Seats/ft^2*1000	15.00	38.81	-23.81
Open_MonFri	Open_MonFri	1.000	NA	1.000
WkHrs	Weekly Operating Hours	40.00	33.28	6.720
PCDen	#PCs/ft^2*1000	0.5000	0.2036	0.2964
FDRM	FDRM	0.0000	NA	0.0000
RfgCommDen	#Refrigerators/ft^2*1000	0.0000	0.0183	-0.0183
HDD	HDD – from zip code	3558	4523	-965
CDD	CDD – from zip code	1325	1313	12

Note
- *Densities are always expressed as the number per 1,000 square feet.*
- *The center reference values are the weighted mean values from the CBECS population, shown in **Table 2**.*
- *FDRM and Open_MonFri are binary (yes/no) variables and are not centered.*

Table 5 Example Calculation – Computing predicted Source EUI			
Operating Characteristic	Centered Variable	Coefficient	Coefficient * Centered Variable
Constant	NA	73.91	73.91
SeatDen	-23.81	0.6532	-15.55
Open_MonFri	1.000	19.14	19.14
WkHrs	6.720	0.2717	1.826
PCDen	0.2964	26.55	7.869
FDRM	0.0000	15.83	0.0000
RfgCommDen	-0.0183	113.1	-2.070
HDD	-965	0.0081	-7.817
CDD	12	0.0141	0.1692
Predicted Source EUI ($kBtu/ft^2$)			***77.48***

Attachment

Table 6 lists the energy efficiency ratio cut-off point for each rating, from 1 to 100.

Table 6
Lookup Table for House of Worship Rating

Rating	Cumulative Percent	Energy Efficiency Ratio		Rating	Cumulative Percent	Energy Efficiency Ratio	
		> =	<			>=	<
100	0%	0	0.2564	50	50%	0.9216	0.9322
99	1%	0.2564	0.3058	49	51%	0.9322	0.9428
98	2%	0.3058	0.3406	48	52%	0.9428	0.9536
97	3%	0.3406	0.3686	47	53%	0.9536	0.9644
96	4%	0.3686	0.3926	46	54%	0.9644	0.9754
95	5%	0.3926	0.4139	45	55%	0.9754	0.9864
94	6%	0.4139	0.4332	44	56%	0.9864	0.9976
93	7%	0.4332	0.4511	43	57%	0.9976	1.0090
92	8%	0.4511	0.4677	42	58%	1.0090	1.0204
91	9%	0.4677	0.4835	41	59%	1.0204	1.0321
90	10%	0.4835	0.4984	40	60%	1.0321	1.0439
89	11%	0.4984	0.5127	39	61%	1.0439	1.0558
88	12%	0.5127	0.5265	38	62%	1.0558	1.0680
87	13%	0.5265	0.5398	37	63%	1.0680	1.0804
86	14%	0.5398	0.5526	36	64%	1.0804	1.0929
85	15%	0.5526	0.5651	35	65%	1.0929	1.1058
84	16%	0.5651	0.5773	34	66%	1.1058	1.1188
83	17%	0.5773	0.5892	33	67%	1.1188	1.1321
82	18%	0.5892	0.6009	32	68%	1.1321	1.1457
81	19%	0.6009	0.6123	31	69%	1.1457	1.1596
80	20%	0.6123	0.6236	30	70%	1.1596	1.1738
79	21%	0.6236	0.6346	29	71%	1.1738	1.1884
78	22%	0.6346	0.6455	28	72%	1.1884	1.2034
77	23%	0.6455	0.6563	27	73%	1.2034	1.2187
76	24%	0.6563	0.6670	26	74%	1.2187	1.2345
75	25%	0.6670	0.6775	25	75%	1.2345	1.2508
74	26%	0.6775	0.6880	24	76%	1.2508	1.2676
73	27%	0.6880	0.6983	23	77%	1.2676	1.2849
72	28%	0.6983	0.7086	22	78%	1.2849	1.3029
71	29%	0.7086	0.7188	21	79%	1.3029	1.3215
70	30%	0.7188	0.7290	20	80%	1.3215	1.3409
69	31%	0.7290	0.7391	19	81%	1.3409	1.3612
68	32%	0.7391	0.7492	18	82%	1.3612	1.3823
67	33%	0.7492	0.7593	17	83%	1.3823	1.4045
66	34%	0.7593	0.7693	16	84%	1.4045	1.4279
65	35%	0.7693	0.7793	15	85%	1.4279	1.4526
64	36%	0.7793	0.7893	14	86%	1.4526	1.4788
63	37%	0.7893	0.7994	13	87%	1.4788	1.5068
62	38%	0.7994	0.8094	12	88%	1.5068	1.5369
61	39%	0.8094	0.8194	11	89%	1.5369	1.5694
60	40%	0.8194	0.8294	10	90%	1.5694	1.6049
59	41%	0.8294	0.8395	9	91%	1.6049	1.6440
58	42%	0.8395	0.8496	8	92%	1.6440	1.6877
57	43%	0.8496	0.8597	7	93%	1.6877	1.7374
56	44%	0.8597	0.8699	6	94%	1.7374	1.7952
55	45%	0.8699	0.8801	5	95%	1.7952	1.8646
54	46%	0.8801	0.8904	4	96%	1.8646	1.9522
53	47%	0.8904	0.9007	3	97%	1.9522	2.0727
52	48%	0.9007	0.9111	2	98%	2.0727	2.2718
51	49%	0.9111	0.9216	1	99%	2.2718	>2.2718