ENERGY STAR® PortfolioManager®

Technical Reference

ENERGY STAR Score for Worship Facilities in the United States

OVERVIEW

The ENERGY STAR Score for Worship Facilities applies to churches, temples, mosques, synagogues, meetinghouses, or any other buildings that primarily function as a place of religious worship. The objective of the ENERGY STAR score is to provide a fair assessment of the energy performance of a property relative to its peers, taking into account the climate, weather, and business activities at the property. To identify the aspects of building activity that are significant drivers of energy use and then normalize for those factors, a statistical analysis of the peer building population is performed. The result of this analysis is an equation that will predict the energy use of a property, based on its experienced business activities. The energy use prediction for a building is compared to its actual energy use to yield a 1 to 100 percentile ranking of performance, relative to the national population.

- **Property Types.** The ENERGY STAR score for worship facilities applies to churches, temples, mosques, synagogues, meetinghouses, or any other buildings that primarily function as a place of religious worship. The score applies to individual buildings only and is not available for campuses.
- **Reference Data.** The analysis for worship facilities is based on data from the Department of Energy, Energy Information Administration's 2003 Commercial Building Energy Consumption Survey (CBECS).
- **Adjustments for Weather and Business Activity.** The analysis includes adjustments for:
    - Building Size
    - Number of Seats
    - Hours of Operation per Week
    - Number of Personal Computers
    - Number of Refrigeration Units
    - Whether or not the Building is Open all Five Weekdays
    - Whether or not the Building is used for Commercial Food Preparation
    - Weather and Climate (using Heating and Cooling Degree Days, retrieved based on Zip code)
- **Release Date.** The ENERGY STAR score for worship facilities was released in August 2009.

This document presents details on the development of the 1 - 100 ENERGY STAR score for worship facilities. More information on the overall approach to develop ENERGY STAR scores is covered in our Technical Reference for the ENERGY STAR Score, available at www.energystar.gov/ENERGYSTARScore. The subsequent sections of this document offer specific details on the development of the ENERGY STAR score for worship facilities:

REFERENCE DATA & FILTERS

For the ENERGY STAR score for worship facilities, the reference data used to establish the peer building population in the United States is based on data from the Department of Energy, Energy Information Administration's (EIA) 2003 Commercial Building Energy Consumption Survey (CBECS). Detailed information on this survey, including complete data files, is available at: http://www.eia.doe.gov/emeu/cbecs/contents.html.

To analyze the building energy and operating characteristics in this survey data, 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, Program Filters, Data Limitation Filters, and Analytical Filters. A complete description of each of these categories is provided in our Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore. ***Figure 1*** presents a summary of each filter applied in the development of the ENERGY STAR score for worship facilities, the rationale behind the filter, and the resulting number of properties in the data set after the filter is applied. After all filters are applied, the remaining data set has 269 properties.

Figure 1 – Summary of Filters for the ENERGY STAR Score for Worship Facilities

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 worship facility.	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 worship facility 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

[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.

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. 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 filters related to propane.

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 determine if the 10% cap is exceeded, 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 for the regression analysis (e.g., for the category of less than 100, a value of 50 is used).

Of the filters applied to the reference data, some result in constraints on calculating a score in Portfolio Manager and others do not. Building Type and Program Filters are used to limit the reference data to include only properties that are eligible to receive a score in Portfolio Manager, and are therefore related to eligibility requirements. In contrast, Data Limitation Filters account for limitations in the data availability, but do not apply in Portfolio Manager. Analytical Filters are used to eliminate outlier data points or different subsets of data, and may or may not affect eligibility. In some cases, a subset of the data will have different behavior from the rest of the properties (e.g., office buildings smaller than 5,000 ft^2 do not behave the same way as larger buildings), in which case an Analytical Filter will be used to determine eligibility in Portfolio Manager. In other cases, Analytical Filters exclude a small number of outliers with extreme values that skew the analysis, but do not affect eligibility requirements. A full description of the criteria you must meet to get a score in Portfolio Manager is available at www.energystar.gov/EligibilityCriteria.

Related to the filters and eligibility criteria described above, another consideration is how Portfolio Manager treats properties that are situated on a campus. The main unit for benchmarking in Portfolio Manager is the property, which may be used to describe either a single building or a campus of buildings. The applicability of the ENERGY STAR score depends on the type of property. For worship facilities, the score is based on individual buildings, because the primary function of the worship facility is contained within a single building and because the properties included in the reference data are single buildings. In cases where multiple facilities are situated together, the ENERGY STAR score for Worship Facilities 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 or schools.

VARIABLES ANALYZED

To normalize for differences in business activity, we perform a statistical analysis to understand what aspects of building activity are significant with respect to energy use. The filtered reference data set described in the previous section is analyzed using a weighted ordinary least squares regression, which evaluates energy use relative to business activity (e.g., operating hours, number of workers, and climate). This linear regression yields an equation that is used to compute energy use (also called the dependent variable) based on a series of characteristics that describe the business activities (also called independent variables). This section details the variables used in the statistical analysis for worship facilities.

Dependent Variable

The dependent variable is what we try to predict with the regression equation. For the worship facility analysis, the dependent variable is energy consumption expressed in source energy use intensity (source EUI). This is equal to

the total source energy use of the property divided by the gross floor area. The regressions analyze the key drivers of source EUI – those factors that explain the variation in source energy use per square foot in worship facilities.

Independent Variables

The reference survey collects numerous property operating characteristics that were identified as potentially important for worship facilities. Based on a review of the available variables in the data, in accordance with the criteria for inclusion in Portfolio Manager[2], the following variables were analyzed:[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)

We perform extensive review on all of these operational characteristics. In addition to reviewing each characteristic individually, characteristics are reviewed in combination with each other (e.g., Heating Degree Days times Percent Heated). As part of the analysis, some variables are 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 correlated with the

[2] For a complete explanation of these criteria, refer to our Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore.

[3] Note that the number 8 at the end of all variables indicates that the 2003 CBECS survey is the eighth survey conducted by the Energy Information Administration.

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, abbreviated as Ln). The analysis consisted of multiple regression formulations. These analyses are structured to find the combination of statistically significant operating characteristics that explain the greatest amount of variance in the dependent variable: source EUI.

The final regression equation includes the following variables:

- 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

These variables are used together to compute the predicted source EUI for worship facilities. The predicted source EUI is the mean EUI for a hypothetical population of buildings that share the same values for each of these variables. That is, the mean energy use for a building that operates just like your building.

Testing

Finally, we test the regression equation using supplemental data, which consisted of energy data and use details for 40 worship facilities shared with EPA. The results of testing and analysis of this dataset showed a broad range of scores along the 1-to-100 scale. The analysis provided a second level of confirmation that the final regression equation produces robust results that are 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 equation is based on the nationally representative CBECS data, not the supplemental data collected by EPA.

REGRESSION EQUATION 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 ***Figure 2***. The final equation is presented in ***Figure 3***. All variables in the regression equation are significant at the 95% confidence level or better, as shown by significant levels (a p-level of less than 0.05 indicates 95% confidence).

The regression equation has a coefficient of determination (R^2) value of 0.3849, indicating that this equation explains 38.49% of the variance in source EUI. Because the final equation 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 this value appears artificially low. Re-computing the R^2 value in units of source energy[5], demonstrates that the equation actually explains 76.2% of the variation of source energy of worship facilities. This is an excellent result for a statistically-based energy model. Detailed information on the ordinary least squares regression approach is available in our Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore.

[4] 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.

Figure 2 - Descriptive Statistics for Variables in Final Regression Equation

Variable	Mean	Minimum	Maximum
Source Energy per ft²	86.26	13.11	290.2
Number of Religious Worship Seats per 1,000 ft²	38.81	2.500	150.0
Open all five weekdays (yes/no)	0.3932	0.000	1.000
Weekly operating hours	33.28	2.000	168.0
Number of Computers per 1000 ft²	0.2036	0.000	1.960
Presence of a Commercial Food Preparation Area (yes/no)	0.3047	0.000	1.000
Number of Commercial Refrigeration Units per 1,000 ft²	0.0183	0.000	0.4286
Heating Degree Days	4,523	146.0	9,716
Cooling Degree Days	1,313	146.0	4,824

Figure 3 - Final Regression Results

Summary				
Dependent Variable	Source Energy Intensity (kBtu/ft²)			
Number of Observations in Analysis	269			
R^2 value	0.3849			
Adjusted R^2 value	0.3660			
F Statistic	20.34			
Significance (p-level)	0.0000			
	Unstandardized Coefficients	**Standard Error**	**T value**	**Significance (p-level)**
(Constant)	73.91	4.257	17.36	0.0000
C_Number of Seats per 1,000 ft²	0.6532	0.0930	7.022	0.0000
C_Open All Five Weekdays	19.14	7.852	2.438	0.0154
C_Weekly Operating Hours	0.2717	0.1090	2.492	0.0133
C_Number of Computers per 1,000 ft²	26.55	9.644	2.753	0.0063
C_Commercial Food Preparation Area (y/n)	15.83	6.159	2.571	0.0107
C_Commercial Refrigeration Units per 1,000 ft²	113.1	40.78	2.773	0.0060
C_Heating Degree Days	0.0081	0.0020	4.133	0.0000
C_Cooling Degree Days	0.0141	0.0050	2.841	0.0049

Notes:

- *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 **Figure 2**.*
- *Unlike other variables, the yes/no variables Commercial Food Preparation Area and Open Five Weekdays are not centered. The coefficient adjustments represent the adjustment for worship facilities that have these characteristics.*

ENERGY STAR SCORE LOOKUP TABLE

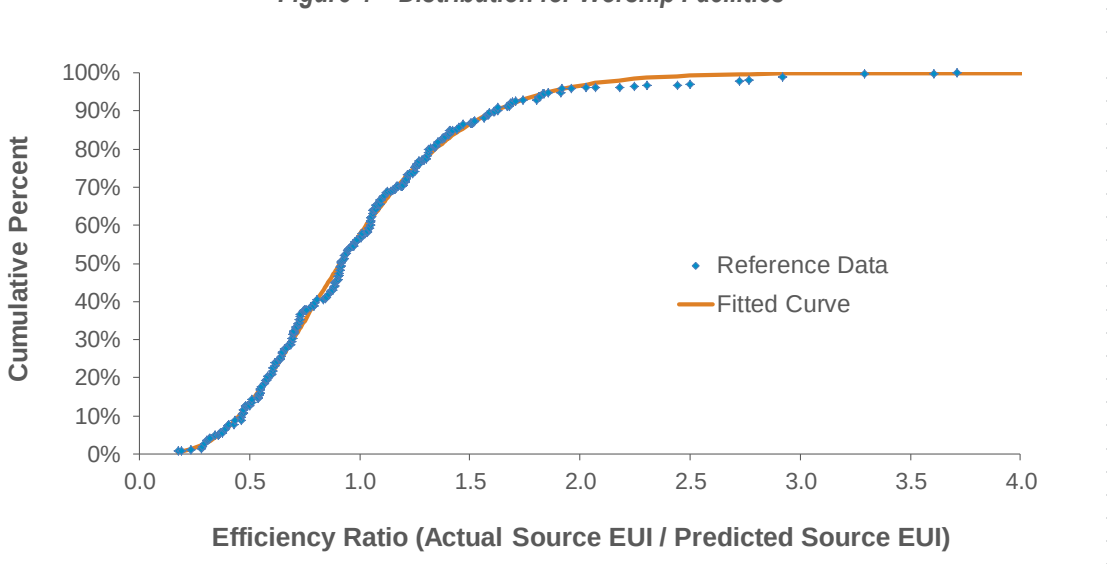
The final regression equation (presented in ***Figure 3***) yields a prediction of source EUI based on a building's operating characteristics. Some buildings in the reference data sample use more energy than predicted by the regression equation, while others use less. The *actual* source EUI of each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

$$Energy\ Efficiency\ Ratio = \frac{Actual\ Source\ EUI}{Predicted\ Source\ EUI}$$

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 reference data set. ***Figure 4*** presents a plot of this cumulative distribution. A smooth curve (shown in orange) 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 4 – Distribution for Worship Facilities



The final gamma shape and scale parameters are 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 score 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 score of 75; only 25% of the population has ratios this small or smaller. The complete score lookup table is presented in ***Figure 5***.

Figure 5 – ENERGY STAR Score Lookup Table for Worship Facilities

ENERGY STAR Score	Cumulative Percent	Energy Efficiency Ratio > =	Energy Efficiency Ratio <
100	0%	0.0000	0.2418
99	1%	0.2418	0.2884
98	2%	0.2884	0.3212
97	3%	0.3212	0.3476
96	4%	0.3476	0.3702
95	5%	0.3702	0.3903
94	6%	0.3903	0.4085
93	7%	0.4085	0.4254
92	8%	0.4254	0.4410
91	9%	0.4410	0.4559
90	10%	0.4559	0.4700
89	11%	0.4700	0.4835
88	12%	0.4835	0.4965
87	13%	0.4965	0.5090
86	14%	0.5090	0.5211
85	15%	0.5211	0.5329
84	16%	0.5329	0.5444
83	17%	0.5444	0.5556
82	18%	0.5556	0.5666
81	19%	0.5666	0.5774
80	20%	0.5774	0.5881
79	21%	0.5881	0.5984
78	22%	0.5984	0.6087
77	23%	0.6087	0.6189
76	24%	0.6189	0.6290
75	25%	0.6290	0.6389
74	26%	0.6389	0.6488
73	27%	0.6488	0.6585
72	28%	0.6585	0.6682
71	29%	0.6682	0.6778
70	30%	0.6778	0.6874
69	31%	0.6874	0.6970
68	32%	0.6970	0.7065
67	33%	0.7065	0.7160
66	34%	0.7160	0.7254
65	35%	0.7254	0.7349
64	36%	0.7349	0.7443
63	37%	0.7443	0.7538
62	38%	0.7538	0.7633
61	39%	0.7633	0.7727
60	40%	0.7727	0.7821
59	41%	0.7821	0.7916
58	42%	0.7916	0.8012
57	43%	0.8012	0.8107
56	44%	0.8107	0.8203
55	45%	0.8203	0.8299
54	46%	0.8299	0.8396
53	47%	0.8396	0.8494
52	48%	0.8494	0.8592
51	49%	0.8592	0.8691

ENERGY STAR Score	Cumulative Percent	Energy Efficiency Ratio >=	Energy Efficiency Ratio <
50	50%	0.8691	0.8791
49	51%	0.8791	0.8891
48	52%	0.8891	0.8992
47	53%	0.8992	0.9094
46	54%	0.9094	0.9198
45	55%	0.9198	0.9302
44	56%	0.9302	0.9407
43	57%	0.9407	0.9515
42	58%	0.9515	0.9622
41	59%	0.9622	0.9733
40	60%	0.9733	0.9844
39	61%	0.9844	0.9956
38	62%	0.9956	1.0071
37	63%	1.0071	1.0188
36	64%	1.0188	1.0306
35	65%	1.0306	1.0428
34	66%	1.0428	1.0550
33	67%	1.0550	1.0676
32	68%	1.0676	1.0804
31	69%	1.0804	1.0935
30	70%	1.0935	1.1069
29	71%	1.1069	1.1207
28	72%	1.1207	1.1348
27	73%	1.1348	1.1492
26	74%	1.1492	1.1641
25	75%	1.1641	1.1795
24	76%	1.1795	1.1953
23	77%	1.1953	1.2117
22	78%	1.2117	1.2286
21	79%	1.2286	1.2462
20	80%	1.2462	1.2645
19	81%	1.2645	1.2836
18	82%	1.2836	1.3035
17	83%	1.3035	1.3244
16	84%	1.3244	1.3465
15	85%	1.3465	1.3698
14	86%	1.3698	1.3945
13	87%	1.3945	1.4209
12	88%	1.4209	1.4493
11	89%	1.4493	1.4799
10	90%	1.4799	1.5134
9	91%	1.5134	1.5503
8	92%	1.5503	1.5915
7	93%	1.5915	1.6384
6	94%	1.6384	1.6929
5	95%	1.6929	1.7583
4	96%	1.7583	1.8409
3	97%	1.8409	1.9546
2	98%	1.9546	2.1423
1	99%	2.1423	>2.1423

EXAMPLE CALCULATION

As detailed in our Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore, there are five steps to compute a score. The following is a specific example for the score for worship facilities.

1 User enters building data into Portfolio Manager

- 12 months of energy use information for all energy types (annual values, entered in monthly meter entries)
- Physical building information (size, location, etc.) and use details describing building activity (hours, etc.)

Energy Data	Value
Electricity	85,000 kWh
Natural gas	2,000 therms

Property Use Details	Value
Gross floor area (ft²)	20,000
Seating Capacity	300
Open all five weekdays	1 (Yes)
Operating Hours	40
Number of Personal Computers	10
Commercial Food Preparation	0 (No)
Number of Commercial Refrigeration Units	0
HDD (provided by Portfolio Manager, based on Zip code)	3,558
CDD (provided by Portfolio Manager, based on Zip code)	1,325

2 Portfolio Manager computes the actual source EUI

- Total energy consumption for each fuel is converted from billing units into site energy and source energy
- Source energy values are added across all fuel types
- Source energy is divided by gross floor area to determine actual source EUI

Computing Actual Source EUI

Fuel	Billing Units	Site kBtu Multiplier	Site kBtu	Source kBtu Multiplier	Source kBtu
Electricity	85,000 kWh	3.412	290,020	3.14	910,663
Natural gas	2,000 therms	100	200,000	1.05	210,000
				Total Source Energy (kBtu)	1,120,663
				Actual Source EUI (kBtu/ft²)	**56.0**

3 Portfolio Manager computes the predicted source EUI

- Using the property use details from Step 1, Portfolio Manager computes each building variable value in the regression equation (determining the natural log or density as necessary).
- The centering values are subtracted to compute the centered variable for each operating parameter.
- The centered variables are multiplied by the coefficients from the regression equation to obtain a predicted source EUI.

Computing Predicted Source EUI

Variable	Actual Building Value	Reference Centering Value	Building Centered Variable	Coefficient	Coefficient * Centered Variable
Constant	--	--	--	73.91	73.91
Number of Seats per 1,000 ft²	15.00	38.81	-23.81	0.6532	-15.55
Open All Five Weekdays	1.000	--	1.000	19.14	19.14
Weekly Operating Hours	40.00	33.28	6.720	0.2717	1.826
Number of Computers	0.5000	0.2036	0.2964	26.55	7.869
Commercial Food Preparation Area (y/n)	0.0000	--	0.0000	15.83	0.0000
Commercial Refrigeration Units	0.0000	0.0183	-0.0183	113.1	-2.070
Heating Degree Days	3,558	4,523	-965	0.0081	-7.817
Cooling Degree Days	1,325	1,313	12.00	0.0141	0.1692
			Predicted Source EUI (kBtu/ft²)		**77.5**

4 Portfolio Manager computes the energy efficiency ratio

- The ratio equals the actual source EUI (Step 2) divided by predicted source EUI (Step 3)
- Ratio = 56.0/ 77.5 = 0.7226

5 Portfolio Manager uses the efficiency ratio to assign a score via a lookup table

- The ratio from Step 4 is used to identify the score from the lookup table
- A ratio of 0.7226 is greater than 0.7160 and less than 0.7254
- ***The ENERGY STAR score is 66***