Technical Description for the Residence Hall/Dormitory Building Model

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Data Source

Energy consumption and building characteristics data for the analysis of residence hall/dormitory buildings were obtained from the U.S. Department of Energy, Energy Information Administration's (EIA) 1999 Commercial Buildings Expenditures and Consumption Survey (CBECS).

Data Set and Basic Filters

The subset of data extracted from the 1999 CBECS survey to create this model provided an initial data set for analysis of 81 observations. These data represent the specific building activity of "Dormitory/Fraternity/Sorority" as defined in the 1999 survey (PBAPLUS value of 9) and are representative of the U.S. population of these building types. A single filter was applied for the purpose of obtaining a more homogenous data set and is presented below. Those data records that did not meet this criterion were removed from the analysis.

Basic Filter:

Description	CBECS Variable	Criteria
Source energy use intensity (kBtu/sqft-yr)	None (calculated)	>40 and <425

Application of this screen eliminated two observations from the analysis data set. The remaining analysis data set consisted of 79 observations.

Dependent Variable

The basis of the regression, that is, the dependent variable chosen for the regression was annual source energy use, Source EU, expressed in kBtu. Site energy use of each fuel was converted to its source equivalent using standard site-source energy conversion factors and then summed to yield annual total source energy use for each building.

Independent Variables

After examining the correlation of many CBECS variables to source energy use, the following independent variables were examined for their significance and correlation with the dependent variable as well as with the other independent variables.

HDD65	heating degree days
CDD65	cooling degree days
COOLP	percentage of the gross floor area that is mechanically cooled
HEATP	percentage of the gross floor area that is heated
SQFT	gross building square footage
LODGRM	number of guest/occupant rooms

Weighting Factors

The stated purpose of CBECS is to develop and publish estimates of population values. Thus, the CBECS sample is designed so that survey responses can be used to estimate characteristics of the entire stock of commercial buildings in the United States (EIA, CBECS 1999). CBECS calculates basic sampling weights that relate sampled buildings to the entire stock of commercial buildings. While sampling weights – or weighting factors – are necessary to estimate characteristics of the entire stock of U.S. commercial buildings, they are not necessary to perform meaningful regression analyses. Thus, the CBECS weighting factors were not used in the analysis.

Source Energy

The analysis relied upon source energy consumption. A one-page discussion regarding the use of the source energy convention versus the site energy convention can be viewed and

downloaded via www.energystar.gov. The following conversion factors were used to calculate source energy consumptions from the CBECS site energy values:

Fuel Type	Site Site (kBtu)	Source Source (kBtu)
Electricity	1	3.013
Natural Gas	1	1.024
Fuel Oil	1	1
Steam	1	1.38
Hot Water	1	1

Regression Results

The objective of this analysis was to determine the significant drivers of building energy use on a source energy use (Source EU) basis. Prior to undertaking this analysis, the explanatory power of the simple relationship of annual source energy consumption to the primary driver of energy use in buildings, gross building area, was examined.

A simple regression model was examined with the natural logarithm of annual source energy use (expressed Ln Source EU) as the dependent variable and the natural logarithm of gross building area as the independent variable. Using the natural logarithm basis for each variable produced a much more normal distribution for the statistical analysis, a stronger correlation between the variables, and significantly less error in the resulting model. The analysis indicated the R-squared for this simple model to be 0.86. Thus, the inclusion of other variables in the model effectively means that the expanded regression model is attempting to explain the remaining 14% ([1-0.86]*100) of the variation in source energy use since building area alone explains 86%.

Table-1 presents the results of the regression analysis. The independent variables used were SQFT and LODGRM in natural logarithm form, HDDxHEATP (the product of HDD and heated percent), and CDDxCOOLP (the product of CDD and cooled percent). The variables SQFT, HDDxHEATP product, and the CDDxCOOLP product were all found to be statistically significant by the standard statistical definition where the T-statistic is greater than +/- 2.0. While not showing to be statistically significant, LODGRM was left in the model because of its strong independent correlation to dormitory energy use (R-squared = 0.62) and its resulting potential for influencing dormitory energy use in the expanded model. The expanded model provided a marginal improvement in model fit. The R-squared of the expanded Source EU model was found to be 0.88. Table-2 presents the basic statistics – mean/median, minimum/maximum, and standard deviation – for each of the model variables.

Table-1 Regression Model Results

Dependent Variable: LN SOURCE_EU (kBtu)				
Method: Least Squares				
Sample: 81				
Included observations: 79				
White Heteroskedasticity-Consistent Standard Errors & Covariance				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Intercept	4.99455	0.5671	8.81	<.0001
LSqft	0.91308	0.07724	11.82	<.0001
HDDxheatp	0.00009774	0.00003297	2.96	0.0041
CDDxcoolp	0.00016279	0.00007609	2.14	0.0357
LLodgrm	0.09455	0.08141	1.16	0.2492
R-squared	0.8834	Mean dependent var		15.717
Adjusted R-squared	0.8771	S.D. dependent var		1.286

S.E. of regression	0.4509	F-statistic	140.1
		Prob (F-statistic)	<0.0001

Table-2 Basic Statistics, Model Variables

Variable	Obs	Mean	Std Dev	Minimum	Maximum
Ln Source kBtu	79	15.717	1.286	12.584	18.699
LSqft	79	10.705	1.166	8.161	13.653
HDDxheatp	79	4575	1859	116.2	7339
CDDxcoolp	79	510.3	775	0	3162
LLodgrm	79	4.417	1.094	1.386	6.397

Look-Up Table

Table-3 is used to determine the Energy Performance Rating (EPR) on a 1 to 100 scale seen by the user. The Predicted Source EU is the adjusted source energy use, in kBtu/yr, obtained by applying the regression model to the CBECS records. Thus, they represent normalized Source EU values based on a percentile basis. The column of Fitted Source EU takes the Predicted (normalized) Source EU values and fits them to a gamma distribution. In fitting Predicted Source EU, the value corresponding to an EPR of 75 – the minimum threshold for ENERGY STAR – is held constant. Once done, the values in the Fitted Source EU column corresponding to the EPRs of 1 to 100 now represent the nominal look-up table used to assess an individual building's performance. The purpose of fitting the Source EU values to a gamma distribution is to reduce the likelihood of "clustering" of Predicted Source EU values about various EPRs. Early beta tests with the public indicated that this phenomenon – where relatively large (2 or 3 points) movements in EPR would occur for small changes in Source EU – was confusing to users.

Table-3 Energy Performance Rating, Predicted Source EU, and Fitted Source EU

EPR	Predicted Source EU (Ln kBtu)	Fitted Source EU (Ln kBtu)		EPR	Predicted Source EU (Ln kBtu)	Fitted Source EU (Ln kBtu)
100	14.5891	14.5000		50	15.7679	15.7497
99	14.6793	14.729		49	15.7768	15.7609
98	14.7738	14.8462		48	15.7769	15.7722
97	14.8885	14.9209		47	15.7772	15.7835
96	14.8886	14.9773		46	15.7809	15.7948
95	14.8899	15.0233		45	15.7928	15.8061
94	14.8954	15.0625		44	15.7993	15.8175
93	14.9015	15.0969		43	15.7994	15.8289
92	15.0196	15.1277		42	15.8259	15.8404
91	15.0197	15.1558		41	15.8447	15.852
90	15.1546	15.1817		40	15.8567	15.8636
89	15.2007	15.2058		39	15.8568	15.8753
88	15.2212	15.2284		38	15.864	15.8871
87	15.2412	15.2498		37	15.884	15.899
86	15.2413	15.27		36	15.9389	15.911
85	15.2515	15.2893		35	15.946	15.9232
84	15.322	15.3078		34	15.9461	15.9355
83	15.3369	15.3255		33	15.9796	15.9479
82	15.3503	15.3426		32	15.9955	15.9604
81	15.3504	15.3591		31	16.0114	15.9732
80	15.358	15.3751		30	16.0142	15.9861
79	15.3845	15.3907		29	16.0143	15.9993
78	15.3883	15.4058		28	16.0172	16.0126
77	15.3884	15.4206		27	16.0497	16.0262
76	15.4233	15.435		26	16.0718	16.0401
75	15.4491	15.449		25	16.0747	16.0542
74	15.477	15.4628		24	16.0748	16.0687
73	15.48	15.4764		23	16.0857	16.0835
72	15.4801	15.4897		22	16.0961	16.0987
71	15.4922	15.5027		21	16.1122	16.1142
70	15.5337	15.5156		20	16.1123	16.1303
69	15.54	15.5283		19	16.1138	16.1468
68	15.5824	15.5408		18	16.1146	16.1639
67	15.5825	15.5532		17	16.1167	16.1816
66	15.5948	15.5654		16	16.1505	16.2
65	15.6007	15.5775		15	16.1506	16.2192
64	15.6228	15.5894		14	16.2158	16.2393
63	15.6391	15.6013		13	16.2218	16.2604
62	15.6392	15.613		12	16.2441	16.2827
61	15.654	15.6247		11	16.2479	16.3064
60	15.6579	15.6363		10	16.248	16.3316
59	15.6632	15.6478		9	16.3314	16.3589
58	15.6633	15.6593		8	16.4025	16.3885
57	15.7034	15.6707		7	16.4503	16.4211
56	15.7096	15.6821		6	16.472	16.4575
55	15.7178	15.6934		5	16.4721	16.4992
54	15.7243	15.7047		4	16.5088	16.5482
53	15.7244	15.7159		3	16.5319	16.6086
52	15.7288	15.7272		2	16.5467	16.6891

51	15.7342	15.7384		1	16.5468	16.8165

Assessing Performance

To assess the performance of a building via the Energy Performance Rating (EPR) on the 1 to 100 scale, two calculations are made upon the user entering in the requisite data. First, as explained in the Weather Normalization file (downloadable at www.energystar.gov), the user's actual annual Source EU, in kBtu, is weather normalized to reflect the annual Source EU the building would have seen in a normal (i.e. 30-year average) weather year. In the second calculation, the regression model equation is used to calculate a Predicted Source EU value based on the operating characteristics entered by the user. This Predicted Source EU is then divided by the mean Source EU of the regression model, yielding an adjustment factor. The adjustment factor is then applied to each of the Fitted Source EU values corresponding to EPRs from 1 to 100 to provide a range of Customized Source EU values (see Table 4). Finally, to determine the EPR of the building, the building's weather-normalized Source EU is compared to the table of Customized Source EU values.

Table-4 is intended for use with the following example to illustrate how an EPR is determined for a given building. In this example, the buildings Source EU was weather-normalized down approximately 3%; in essence meaning that over the course of the year in which the building's energy consumption was reported the building "experienced" a net 3% more severe weather year than normal. When entered into the model, the building's characteristics yield a Ln Predicted Source EU of 15.692 kBtu/yr (natural logarithm basis). Dividing this value by the Ln Mean Source EU of the model, the adjustment factor is determined to be 0.986 and is applied in Table 4. The EPR of 82 is found in Table 4 where the buildings Weather Norm. Source EU matches the Customized Source EU.

Example Residence Hall/Dormitory

Area (Sqft)	=	44,000 ft^2		CDDxcoolp	=	500
Lodgrm	=	80		HDDxheatp	=	4500

Source EU	=	5,905,000 kBtu/yr
Weather Norm. Source EU	=	5,727,850 kBtu/yr
Ln Weather Norm. Source EU	=	15.561 kBtu/yr

Regression Equation

Ln Predicted Source EU = $C_0 + C_1(\text{Ln(Sqft)}) + C_2(\text{HDDxheatp}) + C_3(\text{CDDxcoolp}) + C_4(\text{Ln(Lodgrm)})$

Ln Predicted Source EU	=	15.692 kBtu/yr
Ln Mean Source EU	=	15.915 kBtu/yr
Adjustment Factor	=	(15.692 kBtu/yr / 15.915 kBtu/yr)
	=	0.986
EPR	=	82 (see Table 4)

Note that when the model is placed onto the production site with the Energy Performance Rating software tool, users can include other space types to further characterize their building. These space types include office, computer rooms, garage space, and parking lots. With the exception of parking lots, these other space types, if used to characterize a dormitory, are incorporated into the Energy Performance Rating by using weighted averages. If defined by the user, the energy impact associated with parking lots is simply added to the customized look up table.

Table-4 Determining Energy Performance Rating

EPR	Ln Fitted Source EU (kBtu/yr)	Adjustment Factor	Ln Customized Source EU (kBtu/yr)
100	14.5000	0.986	14.71
99	14.729	0.986	14.94
98	14.8462	0.986	15.06
…	…	…	…
…	…	…	…
…	…	…	…
83	15.3255	0.986	15.54
82	15.3426	0.986	15.56
81	15.3591	0.986	15.58
…	…	…	…
…	…	…	…
…	…	…	…
1	16.8165	0.986	17.06