Technical Description for the K-12 Model

July 31, 2003

Data Source

Energy consumption and building characteristics data for the analysis of K-12 schools 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 481 observations. These data represent the specific building activity defined as "Elementary/Middle/High School" as defined in the 1999 survey (PBAPLUS value of 11). Basic filters were applied for the purpose of obtaining a more homogenous data set and are presented below. The basic filters that were applied are presented below. Those data records that did not meet these criteria were removed from the analysis.

Basic Filters

Description	CBECS Variable	Criteria
Gross Building or Facility Area (ft^2)	SQFT	> 4,999; <900000
Weekly Hours of Use	WKHRS	> 30; <168
# of Months in Use out of past 12	MONUSE	> 8
Total energy cost per MMBtu	None (calculated)	> $1.5
Classroom Seating Capacity	EDSEAT	< 10000
Source energy use intensity (kBtu/sqft-yr)	None (calculated)	>37.3 and <314.8

Application of these screens eliminated 81 observations from the analysis data set. Approximately 30% each of the 81 were screened out by the energy use intensity and floor area screens and an additional 20% were screened out by the months in use screen. The remaining analysis data set consisted of 400 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.

HDD	heating degree days
CDD	cooling degree days
COOLP	percentage of the gross floor area that is mechanically cooled
HEATP	percentage of the gross floor area that is heated
PCNUM	number of personal computers (PCs)
SQFT	gross building square footage
EDSEAT	number of students that can be seated in all of the classrooms in the building
COOK	presence (Y/N) of an area dedicated to cooking and serving food
WKHRS	average weekly hours when building is at least 50% occupied
MONUSE12	a defined variable equal to 1 (for 12 months use) and 0 otherwise
VENT	a defined variable indicating the presence of mechanical ventilation

Mechanical ventilation was defined to not exist (VENT=0) when heating-air furnaces, space heaters, district heating systems, or internal boilers were used for space heating in combination with no space cooling or the use of window or residential-type air conditioners. One variance from this definition was that mechanical ventilation was defined to exist (VENT=1) when variable-air-volume (VAV) systems or economizers were present regardless of the type of space heating or cooling system or the presence of space cooling. Buildings with other space heating and cooling system types were defined as ventilated (VENT=1).

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 (kBtu)	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 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 consumption, Source EU, as the dependent variable and the natural logarithm of gross building area as the independent variable. The analysis revealed a R-squared for this simple model to be 0.85. Thus, the inclusion of other variables in the model effectively means that the expanded regression model is attempting to explain the remaining 15% ([1-0.85]*100) of the variation in source energy use since building area alone explains 85%.

Table-1 presents the results of the regression analysis. The independent variables used were SQFT, EDSEAT, PCNUM, and WKHRS all in a natural logarithm form and VENT, HDDxHEATP, CDDxCOOLP, MONUSE12, and COOK. While not showing to be statistically significant by the standard statistical definition where the T-stat is greater than +/- 2.0, weekly hours (WKHRS) and 12 months use (MONUSE12) were left in the model since beta test results of an earlier model indicated a strong preference by users to keep the variables in. Principally, the rationale centered around the fact that a significant number of schools – especially those in more rural areas – were used by the local community after school hours and often during the summer break or for year-round school. The COOK variable was kept in the model because it was believed that the presence of cafeterias influence the Source EU of schools. The addition of these three variables did not adversely affect the model. The R-squared of the expanded Source EU model was found to be 0.87. 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: 481				
Included observations: 400				
White Heteroskedasticity-Consistent Standard Errors & Covariance				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Intercept	4.45046	0.33956	13.11	<.0001
Lsqft	0.84274	0.04095	20.58	<.0001
Ledseat	0.12269	0.04019	3.05	0.0024
Vent	0.14911	0.04911	3.04	0.0026
Lpcnum	0.07955	0.02368	3.36	0.0009
HDDxheatp	0.00006155	0.00001748	3.52	0.0005
CDDxcoolp	0.00014839	0.00003392	4.38	<.0001
Lwkhrs	0.06271	0.07188	0.87	0.3835
Monuse12	0.05659	0.04107	1.38	0.169
Cook	0.0983	0.05269	1.87	0.0628
R-squared	0.8775	Mean dependent var		15.719
Adjusted R-squared	0.8746	S.D. dependent var		1.072
S.E. of regression		F-statistic		310.3
		Prob (F-statistic)		<0.0001

Table-2 Basic Statistics, Model Variables

Variable	Obs	Mean	Std Dev	Minimum	Maximum
Ln Source kBtu	400	15.719	1.072	12.484	18.211
Lsqft	400	11.023	0.937	8.517	13.218
Ledseat	400	6.338	0.783	3.401	8.294
Vent*	400	0.758	0.429	0	1
Lpcnum	400	4.189	1.142	0	7.057
HDDxheatp	400	4330.700	1859.1	0.97	8223
CDDxcoolp	400	853.253	945.5	0	4143
Lwkhrs	400	3.978	0.292	3.555	4.942
Monuse12	400	0.640	0.481	0	1
Cook7	400	0.775	0.418	0	1

Look-Up Table

Table-3 is used to compute the Energy Performance Rating (EPR) on a 1 to 100 scale seen by the user. The column of Actual Source EU is the simple adjusted source energy use, in kBtu/yr, obtained in applying the regression model to the CBECS records. Thus, these values represent a normalized Source EU values based on a percentile basis. The column of Fitted Source EU takes the normalized Source EU values and fits them to a gamma distribution. In fitting the Actual 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 Source EU values about various EPRs.

Early beta tests with the public indicated that this phenomena – 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, Adjusted Source EU, and Fitted Source EU

EPR	Actual Ln Source EU (kBtu/yr)	Fitted Ln Source EU (kBtu/yr)		**EPR**	Actual Ln Source EU (kBtu/yr)	Fitted Ln Source EU (kBtu/yr)
100	14.6914	13.1764		50	15.7491	15.7887
99	14.9429	13.3361		49	15.754	15.7943
98	14.9913	13.5249		48	15.7587	15.804
97	15.0147	13.6895		47	15.7697	15.8179
96	15.0536	13.8372		46	15.7737	15.8323
95	15.0745	13.9066		45	15.7757	15.8509
94	15.1022	14.053		44	15.779	15.8861
93	15.1664	14.1446		43	15.7855	15.9065
92	15.2028	14.3426		42	15.793	15.9329
91	15.2444	14.4643		41	15.801	15.9428
90	15.2641	14.5054		40	15.808	15.9844
89	15.2792	14.6383		39	15.8164	16.0048
88	15.2944	14.6734		38	15.8281	16.0449
87	15.3244	14.7197		37	15.8357	16.0634
86	15.3382	14.7472		36	15.8421	16.0914
85	15.3491	14.7756		35	15.8514	16.1269
84	15.3862	14.8526		34	15.8569	16.1401
83	15.4059	14.8772		33	15.8718	16.1589
82	15.431	14.906		32	15.8761	16.2173
81	15.4372	14.9651		31	15.8795	16.2369
80	15.4492	14.9899		30	15.8892	16.283
79	15.4586	15.0279		29	15.9017	16.2972
78	15.4717	15.0427		28	15.9091	16.3165
77	15.4901	15.0809		27	15.9224	16.3376
76	15.5007	15.11		26	15.9351	16.3713
75	15.5137	15.1566		25	15.9419	16.4243
74	15.5267	15.2157		24	15.956	16.4667
73	15.5367	15.2318		23	15.9755	16.5018
72	15.5445	15.2515		22	15.9842	16.5246
71	15.5554	15.2835		21	15.9936	16.608
70	15.566	15.3125		20	16.0086	16.6691
69	15.5842	15.331		19	16.0275	16.7035
68	15.589	15.349		18	16.0355	16.7429
67	15.6061	15.3746		17	16.0449	16.7575
66	15.6132	15.3866		16	16.0635	16.7883
65	15.6226	15.406		15	16.077	16.8346
64	15.6314	15.432		14	16.0993	16.8858
63	15.6386	15.4704		13	16.1265	16.9295
62	15.6502	15.4886		12	16.1385	16.9802
61	15.655	15.5342		11	16.1692	17.0179
60	15.6614	15.5707		10	16.1979	17.0788
59	15.6641	15.5852		9	16.2421	17.1076
58	15.6729	15.6205		8	16.2716	17.1667
57	15.6848	15.653		7	16.3281	17.2512
56	15.6896	15.6805		6	16.3807	17.3022
55	15.6984	15.6906		5	16.4456	17.3847
54	15.7052	15.7117		4	16.529	17.4748
53	15.7152	15.7206		3	16.599	17.5914
52	15.7307	15.7444		2	16.7145	17.7644
51	15.7439	15.7696		1	16.8347	18.0767

Assessing Performance

To assess the performance of a building via the Energy Performance Rating 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 energy use, in kBtu/yr, is weather normalized to reflect the annual source energy use 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. To calculate the EPR of the building, the building's weather normalized Source EU is compared to Customized Source EU values.

Table-4 is intended for use with the following example to illustrate how a EPR is determined for a given building. In this example, the actual 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.

Example School Building

Area (Sqft)	=	50,000 ft^2	CDDxcoolp	=	1250
Edseat	=	400	Wkhrs	=	45
Vent	=	1 (yes)	Monuse12	=	0
PCnum	=	40	Cook	=	1 (yes)
HDDxheatp	=	3800			

Actual Source EU = 3,820,000 kBtu/yr
Actual Ln Source EU = 15.156 kBtu/yr

Weather Norm. Ln Source EU = 15.125 kBtu/yr

Regression Equation

Ln Source EU = $C_0 + C_1(\mathrm{Ln}(\mathrm{Sqft})) + C_2(\mathrm{Ln}(\mathrm{Edseat})) + C_3(\mathrm{Vent}) + C_4(\mathrm{Ln}(\mathrm{PCnum})) + C_5(\mathrm{HDDxheatp}) + C_6(\mathrm{CDDxcoolp}) + C_7(\mathrm{Ln}(\mathrm{Wkhrs})) + C_8(\mathrm{Monuse12}) + C_9(\mathrm{Cook})$

Predicted Ln Source EU = 15.503 kBtu/yr
Mean Ln Source EU = 15.719 kBtu/yr

Adjustment Factor = (15.503 kBtu/yr / 15.719 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 the building having K-12 space, 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	Fitted Ln Source EU (kBtu/yr)	Adjustment Factor	Customized Ln Source EU (kBtu/yr)
100	13.18	0.986	13.36
99	13.33	0.986	13.51
98	13.52	0.986	13.71
…	…	…	…
…	…	…	…
…	…	…	…
83	14.87	0.986	15.08
82	14.91	0.986	15.12
81	14.96	0.986	15.17
…	…	…	…
…	…	…	…
…	…	…	…
1	18.07	0.986	18.32