Technical Description for the Office, Bank, Financial Center, and Courthouse Model

July 31, 2003

Data Source

Energy consumption and building characteristics data for the analysis of office 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 1,125 observations. These data represent the specific building activities defined as "Administrative/Professional", "Bank/Financial", "Government", and "Other Office" office and "Courthouse" building types as defined in the 1999 survey (PBAPLUS values of 1, 4, 7, 15, and 29). The "Bank/Financial" building observations were divided into "Banks" (building gross floor areas <= 20 ksf) and "Financial Centers" (building gross floor areas > 20 ksf). Basic filters were applied for the purpose of obtaining a more homogenous data set and are presented below. Those data records that did not meet these criteria were removed from the analysis.

Data Filters

Description	CBECS Variable	Criteria
Gross Building or Facility Area (ft^2)	SQFT	>= 1000 (banks only) >= 5000 (all others)
Weekly Hours of Use	WKHRS	> 30
# of Months in Use out of past 12	MONUSE	> 10
Occupant Density	NWKER/(SQFTx1000)	> 0.3 and < 10.0
# of Personal Computers	PCNUM	>= 0
Source energy use intensity (kBtu/sqft)	None (calculated)	>42.67 and <731.2

Applying the filters above resulted in 910 observations for the analysis. The building area filter, SQFT >= 5,000, resulted in the removal of the majority of records.

Dependent Variable

The basis of the regression, that is, the dependent variable chosen for the regression was the 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 more closely 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
Nwker	total employees during main shift
PCNum	number of computers used
SQFT	square footage
Wkhrs	total weekly operating hours
Bank	defined variable indicating bank
Finctr	defined variable indicating financial center
Courthse	defined variable indicating courthouse

Weighting Factors

The stated purpose of CBECS is to develop and publish estimates of population values. The CBECS survey 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). Basic sampling weights that relate sampled buildings to the entire stock of commercial buildings are calculated for the CBECS sample. 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	3.0129
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 an exceptionally-high R-squared for this simple model of 0.91. Thus, the inclusion of other variables in the model effectively means that the expanded regression model is attempting to explain the remaining 9% ([1-0.91]*100) of the variation in source energy use since the building area alone explains 91%.

Table-1 presents the results of the regression analysis. The independent variables used were SqFt, PCs, WkHrs, and Workers all in a natural logarithm form, and HDD, CDD, and the defined Bank, Financial Center, and Courthouse variables. Each variable was found to be significant by the standard statistical definition where the T-statistic is greater than +/- 2.0. The R-squared of the expanded Source energy use model was found to be 0.93. Table-2 presents the basic statistics – mean/median, minimum/maximum, and standard deviation – for each of the model variables.

Look-Up Table

Table-3 is the look-up table of EPRs from 1 to 100 and Source EU values. The column of Actual Source EU represents the simple adjusted Source EU values obtained in applying the regression model to the CBECS filtered data sets. Thus, these values represent the normalized Source EU values on a percentile basis. The column of Fitted Source EU takes the normalized Source EU values and fits them to a gamma distribution. 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. 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.

Table-1 Regression Model Results

Dependent Variable: LN Source Energy Use (kBtu)				
Method: Least Squares				
Sample: 1125				
Included Observations: 910				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Intercept	5.39567	0.25005	21.58	<.0001
LnSqft	0.75867	0.02914	26.04	<.0001
LnPCs	0.15362	0.02776	5.53	<.0001
LnWkHrs	0.19426	0.03975	4.89	<.0001
LnWorkers	0.1532	0.03687	4.15	<.0001
HDD	2.24E-05	1.11E-05	2.02	0.044
CDD	6.96E-05	2.42E-05	2.88	0.0041
Bank	0.44884	0.07886	5.69	<.0001
FinCtr	0.17658	0.07789	2.27	0.0236
Courthse	0.2148	0.10852	1.98	0.0481
R-squared	0.9338	Mean dependent var		16.63
Adjusted R-squared	0.9331	S.D. dependent var		2.85
S.E. of regression		F-statistic		1409.5
		Prob (F-statistic)		<0.0001

Table-2 Basic Statistics, Model Variable

Variable	Obs	Mean	Std Dev	Minimum	Maximum
LnSource	910	16.63	1.84	12.11	20.93
LnSqft	910	11.37	1.64	7.13	14.40
LnPCs	910	5.12	1.86	0.00	9.62
LnWkHrs	910	4.16	0.43	3.56	5.12
LnWorkers	910	5.25	1.80	0.69	9.02
HDD	910	4107	1968	97	11665
CDD	910	1217	905	1	4143
Bank	910	0.049	0.217	0	1
FinCtr	910	0.044	0.205	0	1
Courthse	910	0.022	0.147	0	1

Assessing Performance

To assess the performance of a building via the national energy performance rating system, two calculations are made upon the user entering in the requisite data. First, 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 energy use value based on the operating characteristics entered by the user. This Predicted Source energy use is then divided by the Mean Source energy use of the regression model, which yields an adjustment factor. The adjustment factor is then multiplied by each of the Fitted Source energy use values corresponding to EPRs from 1 to 100 to provide a range of Customized Source

energy use values. Finally, to calculate the EPR, the building's weather normalized Source energy use is compared to the table of Customized Source energy use values.

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	12.92	13.27		50	16.82	16.67
99	13.14	13.53		49	16.87	16.71
98	13.34	13.62		48	16.97	16.75
97	13.48	13.73		47	17.00	16.81
96	13.61	13.81		46	17.05	16.85
95	13.70	13.88		45	17.08	16.90
94	13.78	14.02		44	17.12	16.93
93	13.89	14.07		43	17.15	16.99
92	13.98	14.15		42	17.22	17.06
91	14.11	14.24		41	17.29	17.11
90	14.23	14.34		40	17.32	17.20
89	14.27	14.41		39	17.38	17.27
88	14.31	14.46		38	17.44	17.32
87	14.37	14.52		37	17.49	17.36
86	14.43	14.60		36	17.56	17.46
85	14.52	14.65		35	17.64	17.55
84	14.65	14.72		34	17.70	17.61
83	14.71	14.83		33	17.77	17.67
82	14.77	14.88		32	17.86	17.76
81	14.83	14.93		31	17.94	17.83
80	14.95	14.99		30	17.98	17.85
79	15.00	15.07		29	18.04	17.91
78	15.06	15.11		28	18.08	17.94
77	15.14	15.15		27	18.15	18.01
76	15.21	15.21		26	18.18	18.07
75	**15.28**	**15.26**		25	18.20	18.12
74	15.32	15.33		24	18.25	18.20
73	15.36	15.38		23	18.28	18.24
72	15.40	15.44		22	18.32	18.30
71	15.45	15.50		21	18.38	18.34
70	15.54	15.56		20	18.43	18.40
69	15.60	15.62		19	18.47	18.52
68	15.67	15.68		18	18.54	18.56
67	15.71	15.72		17	18.61	18.67
66	15.79	15.76		16	18.68	18.72
65	15.85	15.83		15	18.73	18.79
64	15.89	15.89		14	18.78	18.86
63	15.95	15.94		13	18.82	18.90
62	16.02	15.98		12	18.86	18.93
61	16.11	16.04		11	18.92	19.01
60	16.17	16.08		10	19.02	19.08
59	16.22	16.13		9	19.10	19.22
58	16.29	16.19		8	19.23	19.34
57	16.34	16.24		7	19.33	19.49
56	16.41	16.29		6	19.44	19.64
55	16.48	16.34		5	19.53	19.68
54	16.55	16.40		4	19.74	19.79
53	16.65	16.50		3	19.91	19.85

52	16.68	16.53		2	20.12	20.00
51	16.73	16.61		1	20.93	20.36

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 actual Source energy consumption was weather normalized down approximately 2%; in essence meaning that over the course of the year in which the building's energy consumption was reported the building "experienced" a net 2% more severe weather year than normal.

Example - Professional Office Building

Area (Sqft)	=	60,000 ft^2	# of Workers	=	160
No. of PCs	=	140	HDD	=	3850
Weekly Hours	=	60	CDD	=	2708

Actual Source Energy Use = 5,078,000 kBtu or 84.6 kBtu/ft^2-yr

Weather Norm. Source EU = 4,976,440 kBtu
Weather Norm. Ln Source EU = 15.42 kBtu

Regression Equation

Ln Source (kBtu/year) = $C_0 + C_1(Ln(SqFt)) + C_2(Ln(PCs)) + C_3(Ln(WkHrs)) + C_4(Ln(Nwker)) + C_5(HDD) + C_6(CDD5) + C_7(Bank) + C_8(FinCtr) + C_9C(Courthse)$

Ln Source (kBtu/year) = 5.395 + 0.758 Ln(SqFt) + 0.153 Ln(PCs) + 0.194 Ln(WkHrs) + 0.153 Ln(Nwker) + 2.24E-5 HDD + 6.96E-5 CDD + 0.448 Bank + 0.176 FinCtr + 0.214 Courthse

Predicted Ln Source EU = 16.34 kBtu
Mean Ln Source EU = 16.63 kBtu/yr

Adjustment Factor = (16.34/16.63)
= 0.983

EPR = 68 (see Table 4)

Note that when this model is placed onto the production site with the Energy Performance Rating software tool, users can include other building types to further characterize their building.

Table-4 Determining Energy Performance Rating

EPR	Fitted Ln Source EU (kBtu/yr)	Adjustment Factor	Customized Ln Source EU (kBtu/yr)
100	13.27	.983	13.04
99	13.53	.983	13.30
98	13.62	.983	13.39
…	…	…	…
…	…	…	…
…	…	…	…
69	15.62	.983	15.35
68	15.68	.983	15.41
67	15.72	.983	15.45
…	…	…	…
…	…	…	…
…	…	…	…
1	20.36	.983	20.01