Technical Description for the Medical Office Building Model

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Data Source

Energy consumption and building characteristics data for the analysis of medical 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 93 observations. These data represent the specific building activity defined as "Doctor/Dentist Office" as defined in the 1999 survey (PBAPLUS value of 8). 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
Weekly Hours of Use	WKHRS	> 30; <168
Number of workers	NWKER	> 1
Source energy use intensity (kBtu/sqft-yr)	None (calculated)	>38 and <575

Application of these screens eliminated 11 observations from the analysis data set. Ten observations were screened out from the weekly hours of use and source energy use intensity criteria. An additional observation was eliminated by the number of workers screen. The remaining analysis data set consisted of 82 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
WKHRS	average weekly hours when building is at least 50% occupied
NWKER	number of workers

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 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 revealed an R-squared for this simple model to be 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 building area alone explains 91%.

Table-1 presents the basic statistics – mean/median, minimum/maximum, and standard deviation – for each of the model variables. Table-2 presents the results of the regression analysis. The independent variables used were SQFT, NWKER, and WKHRS all in a natural logarithm form, HDDxHEATP (the product of HDD and heated percent), and CDDxCOOLP (the product of CDD and cooled percent). The variables SQFT, NWKER, 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, WKHRS and HDDxHEATP were left in the model since previous analyses for other building types show that they are typically drivers of energy use in buildings. The expanded model provided a marginal improvement in model fit. The R-squared of the expanded Source EU model was found to be 0.93.

Table-1 Basic Statistics, Model Variables

Variable	Obs	Mean	Std Dev	Minimum	Maximum
Ln Source kBtu	82	14.919	1.774	11.344	18.878
LSqft	82	9.856	1.459	6.908	13.122
LNwker	82	3.840	1.541	0.693	7.718
LWkhrs	82	3.937	0.214	3.555	4.820
HDDxheatp	82	3692	1953	0	8176
CDDxcoolp	82	1253	946.6	54	4143

Table-2 Regression Model Results

Dependent Variable: LN SOURCE_EU (kBtu)				
Method: Least Squares				
Sample: 93				
Included observations: 82				
White Heteroskedasticity-Consistent Standard Errors & Covariance				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Intercept	2.78889	1.19393	2.34	<.0221
LSqft	0.91433	0.09998	9.14	<.0001
LNwker	0.21568	0.09332	2.31	0.0235
LWkhrs	0.46768	0.29816	1.57	0.1209
HDDxheatp	0.00005321	0.00003712	1.43	0.1558
CDDxcoolp	0.00020111	0.00007429	2.71	<.0084
R-squared	0.9336	Mean dependent var		14.9195
Adjusted R-squared	0.9292	S.D. dependent var		1.7745
S.E. of regression	238	F-statistic		213.6
		Prob (F-statistic)		<0.0001

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 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, Predicted Source EU, and Fitted Source EU

EPR	Predicted LnSource (kBtu)	Fitted LnSource (kBtu)		EPR	Predicted LnSource (kBtu)	Fitted LnSource (kBtu)
100	13.708	13.801		50	14.998	15.033
99	13.893	13.859		49	15.005	15.045
98	13.997	13.915		48	15.006	15.056
97	14.013	13.967		47	15.019	15.067
96	14.066	14.017		46	15.032	15.077
95	14.066	14.064		45	15.032	15.088
94	14.128	14.108		44	15.064	15.098
93	14.135	14.150		43	15.094	15.107
92	14.183	14.190		42	15.131	15.117
91	14.250	14.227		41	15.135	15.126
90	14.264	14.263		40	15.144	15.134
89	14.264	14.297		39	15.144	15.143
88	14.277	14.330		38	15.156	15.151
87	14.304	14.361		37	15.170	15.159
86	14.336	14.390		36	15.189	15.166
85	14.347	14.419		35	15.190	15.174
84	14.347	14.446		34	15.190	15.181
83	14.384	14.472		33	15.198	15.188
82	14.491	14.497		32	15.211	15.195
81	14.534	14.521		31	15.212	15.202
80	14.547	14.544		30	15.231	15.209
79	14.576	14.567		29	15.238	15.216
78	14.576	14.588		28	15.238	15.223
77	14.662	14.610		27	15.250	15.230
76	14.686	14.630		26	15.251	15.238
75	14.723	14.650		25	15.255	15.245
74	14.729	14.669		24	15.266	15.253
73	14.729	14.688		23	15.266	15.261
72	14.777	14.707		22	15.270	15.270
71	14.778	14.725		21	15.283	15.280
70	14.782	14.742		20	15.330	15.290
69	14.797	14.760		19	15.334	15.301
68	14.814	14.777		18	15.350	15.313
67	14.814	14.793		17	15.350	15.325
66	14.820	14.810		16	15.370	15.339
65	14.832	14.826		15	15.374	15.355
64	14.837	14.841		14	15.381	15.371
63	14.860	14.857		13	15.396	15.390
62	14.860	14.872		12	15.396	15.410
61	14.870	14.887		11	15.397	15.431
60	14.879	14.902		10	15.422	15.455
59	14.881	14.916		9	15.430	15.482
58	14.904	14.930		8	15.462	15.510
57	14.963	14.944		7	15.486	15.541
56	14.963	14.958		6	15.486	15.576
55	14.964	14.971		5	15.528	15.613
54	14.971	14.984		4	15.529	15.653
53	14.992	14.997		3	15.792	15.697

52	14.993	15.009		2	15.879	15.745
51	14.995	15.021		1	15.879	15.797

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 14.506 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 Medical Office Building

Area (Sqft)	=	14,000 ft^2	CDDxcoolp	=	1200
Nwker	=	25	HDDxheatp	=	4200
Wkhrs	=	50			

Source EU = 1,660,400 kBtu/yr
Weather Norm. Source EU = 1,612,000 kBtu/yr

Ln Weather Norm. Source EU = 14.293 kBtu/yr

Regression Equation

Ln Predicted Source EU = $C_0 + C_1(\text{Ln(Sqft)}) + C_2(\text{Ln(Nwker)}) + C_3(\text{Ln(Wkhrs)}) + C_4(\text{HDDxheatp}) + C_5(\text{CDDxcoolp})$

Ln Predicted Source EU = 14.506 kBtu/yr
Ln Mean Source EU = 14.715 kBtu/yr

Adjustment Factor = (14.506 kBtu/yr / 14.715 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 medical office building, 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	13.801	0.986	13.608
99	13.859	0.986	13.665
98	13.915	0.986	13.720
…	…	…	…
…	…	…	…
…	…	…	…
83	14.472	0.986	14.269
82	14.497	0.986	14.294
81	14.521	0.986	14.318
…	…	…	…
…	…	…	…
…	…	…	…
1	15.797	0.986	15.576