Technical Description for the Grocery Store/Supermarket Model

12/11/2001

Data Source

Energy consumption and building characteristics data for the analysis of grocery stores/supermarkets, hereafter referred to as supermarkets, were obtained from the 1992 and 1995 CBECS (Commercial Buildings Expenditures and Consumption Survey, EIA).

Data Set and Basic Filters

To yield a dataset as large as possible, the 1995 CBECS dataset was combined with the 1992 dataset . Basic filters were applied to both datasets for the purpose of obtaining a more homogenous dataset and are presented below. Those data records that did not meet any of these criteria were removed from the analysis.

Data Filters

Description	CBECS Variable	Criteria
Gross Building or Facility Area (ft^2)	SQFT	> 4,999
Gross Building or Facility Area (ft^2)	SQFT	< 1,000,000
Weekly Hours of Use	WKHRS	> 29
# of Months in Use out of past 12	MONUSE	> 10
Annual Electricity Consumption (Btu)	ELBTU	> 0
Annual Electricity Consumption (Btu)	ELBTU	< 10,000,000,000,000
HDD + CDD	HDD65, CDD65	> 0
Food Sales Percentage	FDSLSP	> 89
Principal Building Activity	PBA	= 6 (Food Sales)

Applying the filters above resulted in 45 of the 91 records in the 1995 CBECS dataset and 43 of the 103 records in the 1992 CBECS dataset, for a total of 88 data records. The building area filter, SQFT < 4,999, resulted in the removal of the majority of records. Previous analysis identified this group of records as being more closely aligned with convenience stores and statistically different from the group whose building areas were greater than 4,999 ft^2.

Dependent Variable

The basis of the regression, that is, the dependent variable chosen for the regression was the natural logarithm of annual source energy use (LnSource) where annual source energy was measured in kBtu/year. Since energy intensity is a commonly used and understood means to characterize and compare building energy performance amongst groups of buildings, it was determined that user results would be provided in terms of energy intensity by simply requiring the user to enter building size, then modifying the output accordingly. A more detailed description is provided in the section on Assessing Performance near the end of this document.

Independent Variables

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
DD	total heating and cooling degree days
COOLP	percentage of the gross floor area that is mechanically cooled
HEATP	percentage of the gross floor area that heated
PCTRM	number of personal computers (PCs) or electronic cash registers
PCDens	number of PCs or electronic cash registers per 1,000 ft^2
SQFT	gross building square footage

COOL	presence (Y/N) of mechanical cooling equipment in the facility
FDRM	presence (Y/N) of an area dedicated to cooking and serving food
WKHRS	average weekly hours when building is at least 50% occupied
MONUSE	number of months the building was in use during previous 12 months
NWKER	number of workers during the main occupancy of the building
OccDens	number of workers per 1,000 ft^2 during the main occupancy of the building
FLOORS	number of levels in the tallest section of the building
RFGWIN	number of walk-in freezers and refrigerators
RFGOPN	number of open refrigeration cases
RFGCLN	number of closed refrigeration cases
TotalRef	total number of refrigeration cases and walk-in units
ATTWLS	number of exterior walls that touch or are attached to another structure
HWTRM	presence of space within building requiring large amounts of hot water

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 1995). 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 of the Food Sales regression modeling.

Source Energy

The analysis relied upon source energy consumption versus the site energy consumption provided in CBECS 1995. 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 obtain source energy consumption from the site energy consumption:

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 the analysis was to determine the significant drivers or building characteristics of LnSource, or more directly annual source energy consumption. Prior to undertaking this analysis, the explanatory power of the simple relationship of annual source energy consumption to gross building area was examined.

A simple regression model was examined with LnSource as the dependent variable and the natural log of gross building area as the independent variable. The analysis revealed a R-squared for this simple model to be 0.63. Thus the inclusion of other variables in the model effectively means that the regression model is attempting to explain the remaining 37% ([1-0.63]*100) since the square foot term is already explaining 63% of the variability in source energy use.

Table-1 presents the results of the regression analysis. The independent variables used were LnAREA, LnHours, LnWorkers, LnCDD, LnHDD, LnFloors, FDRM, PCs, and LnTotalRef. While not showing to be significant by the standard statistical definition where the T-stat is greater than +/- 2.0, weekly hours (LnHours), LnCDD, LnHDD, FDRM, and PCS were left in the model since beta test results of an earlier model indicated a strong preference by users to keep the variables in.

Table-1 Regression Model Results

Dependent Variable: LnSource
Method: Least Squares
Date: 07/10/01 Time: 11:59
Sample: 1 88
Included observations: 88
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	6.235193	2.374959	2.625390	0.0104
LnArea	0.530412	0.152526	3.477517	0.0008
LnHours	0.175165	0.224288	0.780982	0.4372
LnWorkers	0.419759	0.108954	3.852641	0.0002
LnCDD	0.089196	0.085115	1.047936	0.2979
LnHDD	0.151034	0.131435	1.149110	0.2540
LnFloors	-0.424754	0.154166	-2.755166	0.0073
FDRM	0.068430	0.165934	0.412393	0.6812
PCS	0.011130	0.008710	1.277830	0.2051
LnTotalRef	0.250377	0.056546	4.427880	0.0000

R-squared	0.811827	Mean dependent var	15.84218
Adjusted R-squared	0.790114	S.D. dependent var	1.224246
S.E. of regression	0.560867	Akaike info criterion	1.787980
Sum squared resid	24.53663	Schwarz criterion	2.069495
Log likelihood	-68.67112	F-statistic	37.39014
Durbin-Watson stat	0.923229	Prob(F-statistic)	0.000000

Table-2 presents the basic statistics – mean/median, minimum/maximum, and standard deviation – for each of the model variables.

Table-2 Basic Statistics, Model Variables

Variable	# of Obs	Min	Mean	Median	Max
LnSource	88	12.65	15.84	16.07	17.67
Area	88	5,000	24,389	19,375	80,000
Workers	88	1	24.7	19	148
CDD	88	74	1169	978	3588
HDD	88	403	4108	4125	9110
Floors	88	1	1.40	1	3
FDRM	88	0	0.57	1	1
PCs	88	0	6.8	2.5	34.5
TotalRef	88	1	23.4	12.5	107

Look-Up Table

Table-4 in the Appendix is the look-up table of benchmarking EPRs from 1 to 100 and associated Ln Source annual energy consumption values. The column of Actual LnSource represents the simple adjusted LnSource energy consumption obtained in applying the regression model to the CBECS filtered data sets. Thus, these values represent a normalized LnSource energy consumption based on the CBECS data sets. The column of Fitted LnSource takes the normalized LnSource values and fits them to a gamma distribution. In fitting the Actual LnSource the value corresponding to an EPR of 75 – the minimum threshold for ENERGY STAR – is held constant. Once done, the values in the Fitted LnSource column corresponding to the benchmarking 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 LnSource values to a gamma distribution is to reduce the likelihood of "clustering" of LnSource 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 source energy consumption – was confusing to the users.

Since the datasets used for the supermarket model contained 88 observations, calculation of the full spectrum of EPRs from 1 to 100 required the resultant blank values corresponding to a given EPR to be "filled" with an interpolated value. With 88 actual observations, required that 12 "blank" values be filled in by taking the average of the value immediately preceding and immediately following the blank value.

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 intensity, in kBtu/ft^2-yr, is weather normalized to reflect the annual source energy intensity 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 LnSource energy consumption value based on the operating characteristics entered by the user. This predicted LnSource energy consumption is then divided by the mean LnSource energy consumption of the regression model, which yields an adjustment factor. The adjustment factor is then multiplied to each of the Fitted LnSource energy consumption values corresponding to EPRs from 1 to 100 to provide a range of Customized LnSource values. Next, the exponential of LnSource values are taken and then divided by the user's actual building area (ft^2) yielding a table of Customized Source EUI values corresponding to EPRs from 1 to 100. Finally, to calculate the EPR of the building, the building's weather normalized Source EUI is compared to the table of Customized Source EUI values.

Table-3 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 EUI 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 Supermarket

Area	=	42,000 ft^2
Weekly Hours	=	168
# of Workers	=	20
CDD	=	3250
HDD	=	1450
# of Floors	=	1
Food Facility	=	yes ("yes" = 1; "no" = 0)
# of PCs	=	7
TotalRefrig	=	80

Actual Source EUI = 499.3 kBtu/ft^2-yr

Weather Norm. Source EUI = 489.5 kBtu/ft^2-yr ⟵

Regression Equation

LnSource (kBtu/year) = $C_0 + C_1$ Ln(Area) + C_2 Ln(Hours) + C_3 Ln(Workers) + C_4 Ln(CDD) + C_5 Ln(HDD) + C_6 Ln(Floors) + C_7 FoodRoom + C_8 PCs + C_9 Ln(TotalRefrig)

LnSource (kBtu/year) = 6.235192543 + 0.5304121627*Ln(Area) + 0.1751649881*Ln(Hours) + 0.4197590116*Ln(Workers) + 0.08919559467*Ln(CDD) + 0.1510335536*Ln(HDD) - 0.4247541528*Ln(Floors) + 0.06842991077*FoodRoom + 0.01112991177*PCs + 0.25037737*Ln(TotalRefrig)

Predicted LnSource = 17.15
Mean LnSource = 15.84

Adjustment Factor = (17.15/15.84)
= 1.08

Table-3 Determining Energy Performance Rating

EPR	Fitted LnSource	Adjustment Factor	Customized LnSource	Customized Source EUI (kBtu/ft^2-yr)
100	14.96	1.08	16.20	258.4
99	15.09	1.08	16.34	297.3
98	15.17	1.08	16.42	322.0
…	…	…	…	…
…	…	…	…	…
…	…	…	…	…
85	15.55	1.08	16.83	485.2
84	15.56	1.08	16.85	495.0
83	15.58	1.08	16.87	505.0
…	…	…	…	…
…	…	…	…	…
…	…	…	…	…
1	16.86	1.08	18.25	2007.4

Note that when this 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, K-12 schools, computer rooms, garage space, and parking lots. With the exception of parking lots, these other space types, if used to characterize the building having supermarket 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.

Appendix

Table-4 Benchmarking EPR, Adjusted Source EUI, and Fitted Source EUI

EPR	Actual Source EUI (kBtu/ft^2-yr)	Fitted Source EUI (kBtu/ft^2-yr)		EPR	Actual Source EUI (kBtu/ft^2-yr)	Fitted Source EUI (kBtu/ft^2-yr)
100	14.02	14.96		50	15.92	15.93
99	14.06	15.09		49	15.92	15.94
98	14.08	15.17		48	15.94	15.95
97	14.45	15.23		47	15.94	15.96
96	14.72	15.27		46	15.94	15.97
95	14.99	15.31		45	15.94	15.98
94	15.00	15.35		44	15.95	15.99
93	15.02	15.38		43	15.96	16.00
92	15.13	15.41		42	15.97	16.01
91	15.15	15.43		41	15.99	16.01
90	15.17	15.45		40	16.01	16.02
89	15.27	15.47		39	16.02	16.03
88	15.30	15.49		38	16.02	16.04
87	15.34	15.51		37	16.02	16.05
86	15.35	15.53		36	16.03	16.06
85	15.39	15.55		35	16.04	16.07
84	15.45	15.56		34	16.04	16.08
83	15.46	15.58		33	16.08	16.09
82	15.47	15.59		32	16.09	16.10
81	15.49	15.61		31	16.10	16.11
80	15.51	15.62		30	16.10	16.12
79	15.53	15.64		29	16.10	16.13
78	15.59	15.65		28	16.11	16.14
77	15.64	15.66		27	16.12	16.15
76	15.67	15.67		26	16.13	16.16
75	**15.69**	**15.69**		25	16.15	16.17
74	15.69	15.70		24	16.16	16.18
73	15.69	15.71		23	16.20	16.19
72	15.69	15.72		22	16.24	16.20
71	15.71	15.73		21	16.25	16.21
70	15.74	15.74		20	16.25	16.22
69	15.75	15.75		19	16.27	16.24
68	15.77	15.76		18	16.28	16.25
67	15.79	15.77		17	16.30	16.26
66	15.80	15.78		16	16.31	16.27
65	15.80	15.79		15	16.33	16.29
64	15.80	15.80		14	16.34	16.30
63	15.82	15.81		13	16.35	16.32
62	15.84	15.82		12	16.36	16.33
61	15.84	15.83		11	16.38	16.35
60	15.85	15.84		10	16.46	16.37
59	15.86	15.85		9	16.50	16.39
58	15.87	15.86		8	16.53	16.41
57	15.87	15.87		7	16.57	16.43
56	15.87	15.88		6	16.59	16.46
55	15.88	15.89		5	16.61	16.49
54	15.89	15.90		4	16.64	16.53
53	15.91	15.91		3	16.70	16.58
52	15.92	15.92		2	16.79	16.66
51	15.92	15.93		1	16.79	16.86