Technical Description for the Warehouse Model **07/04/2003**

Data Source

Energy consumption and building characteristics data for the analysis of both refrigerated and non-refrigerated warehouses 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

From the 1999 CBECS data set, a total of 722 warehouse records were available. Basic filters were applied to both data sets for the purpose of obtaining a more homogenous data set 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 and < 1,000,000
Weekly Hours of Use	WKHRS	> 35
Months in Use during 1999	MONUSE	>10
Principal Building Activity	PBA	= 5(nonrefrig.) or 11(refrig.)
Principal Building Activity PLUS	PBAPLUS	=23(nonrefrig.) or 37(refrig.)
Electricity Used	ELUSED	>0

Applying the filters above resulted in 597 records from the 1999 CBECS data set. The building area filters, SQFT > 4,999 and <1,000,000, resulted in the removal of the majority of records. Records with floor area greater than 1,000,000 ft^2 were eliminated due to a high degree of manipulation of the actual data within CBECS to mask the identity of the building.

Dependent Variable

The basis of the regression, that is, the dependent variable chosen for the regression was the annual source energy use intensity, Source EUI, where annual source energy was measured in kBtu/year. Energy intensity, typically Site not Source, is a commonly used and understood means to characterize and compare building energy performance amongst groups of buildings. Thus, it was determined that results would be provided to the users in terms of the more common site energy intensity by simply converting the Source EUI to Site EUI using the building's fuel mix and standard Site-Source conversion factors. A more detailed description is provided in the section on Assessing Performance near the end of this document.

Independent Variables

After examining the correlation of hundreds of CBECS variables to source energy intensity, 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.

REFRIGWH	refrigerated or non-refrigerated warehouse
NUMWIREF	total number of walk-in refrigerators
SQFOOTAGE	gross building square footage
HDDHEATPER	heating degree days x heating percentage
CDDCOOLPER	cooling degree days x cooling percentage
WKHRS	total weekly operating hours
NWKERS	total employees on main shift
SUMHID_HALOPER	sum of percentages lit by high intensity discharge and halogen lights

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 Warehouse regression modeling.

Source Energy

The analysis relied upon source energy consumption versus the site energy consumption provided in CBECS. 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

Regression Results

The objective of the analysis was to determine the significant drivers or building characteristics of Source EUI. Prior to undertaking this analysis, the explanatory power of the simple relationship of annual source energy consumption to gross building area was examined.

A regression model was examined with annual source energy consumption. The natural log of source energy is the dependent variable revealing an R-squared of slightly more than 0.80.

Table-1 presents the results of the regression analysis. The independent variables used were REFRIGWH, NUMWIREF, HDDHEATP, CDDCOOLP, LOG (WKHRS), LOG (NWKER), AND SUMHID_HALOPER. Each variable was found to be significant by the standard statistical definition where the T-statistic is greater than +/- 2.0.

Table-1 Regression Model Results

Dependent Variable: LOG(SOURCE)
Method: Least Squares
Sample(adjusted): 1 484
Included observations: 484 after adjusting endpoints
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.293	0.464	9.259	7.0848e-19
REFRIGWH	0.785	0.128	6.154	1.6039e-09
NUMWIREF	0.087	0.027	3.290	0.0011
LOG(SQFOOTAGE)	0.714	0.036	19.876	2.0128e-64
HDDHEATP	1.288e-06	1.661e-07	7.757	5.3661e-14
CDDCOOLP	1.978e-06	4.009e-07	4.933	1.1208e-06
LOG(WKHRS)	0.357	0.099	3.615	0.0003
LOG(NWKER)	0.286	0.0292	9.804	8.6547e-21
SUMHID_HALOPER	0.002	0.001	1.848	0.0653

R-squared	0.8038	Mean dependent var	14.8874
Adjusted R-squared	0.8005	S.D. dependent var	1.5607
S.E. of regression	0.6970	F-statistic	243.3291
		Prob(F-statistic)	0

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

	REFRIG WH	NUM WIREF	SQ FOOTAGE	HDD HEATP	CDD COOLP	HDD65	CDD65	WKHRS	NWKER	SUMHID HALO PER
Mean	0.0744	0.2438	10682	230262.78	41828.66	3633.46	1518.41	67.583	56.845	31.004
Median	0	0	50000	122800	16822.5	3274	1101	50	20	0
Max.	1	11	950000	822300	414300	8223	4143	168	4000	105
Min.	0	0	5000	0	0	97	54	40	1	0
Std. Dev.	0.2626	1.0683	148205.41	243587.89	70222.67	2112.73	1063.78	37.058	194.97	39.947

Look-Up Table

Table-4 in the Appendix is the look-up table of EPRs from 1 to 100 and Source EUI values. The column of Actual Source EUI represents the simple adjusted Source EUI values obtained in applying the regression model to the CBECS filtered data sets. Thus, these values represent the normalized Source EUI values on a percentile basis. The column of Fitted Source EUI takes the normalized Source EUI values and fits them to a gamma distribution. The purpose of fitting the Source EUI values to a gamma distribution is to reduce the likelihood of "clustering" of Source EUI values about various EPRs In fitting the Actual Source EUI 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 EUI column corresponding to the EPRs of 1 to 100 now represent the nominal look-up table used to assess an individual building's performance.

Assessing Performance

To assess the performance of a building via the Energy Performance Rating, 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 Source EUI value based on the operating characteristics entered by the user. This Predicted Source EUI is then divided by the Mean Source EUI of the regression model, which yields an adjustment factor. The adjustment factor is then multiplied to each of the Fitted Source EUI values corresponding to EPRs from 1 to 100 to provide a range of Customized Source EUI values. Finally, to calculate the EPR, 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 Warehouse

Ref Warehouse	=	0 (no)
Number of Walk-in Refs	=	0
Area	=	200,000 ft^2
HEATPER	=	100
COOLPER	=	50
HDD	=	7084
CDD	=	385
Weekly Hours	=	40
Number of Workers	=	12
Percent HID & Halo	=	0

Actual Ln Source = 14.492 kBtu/ft^2-yr

Weather Norm. Source EUI = 14.782 kBtu/ft^2-yr 

Regression Equation

Source (kBtu/year) = C_0 + C_1 RefWH + C_2 Walk-InRefs + C_3 Ln (Area) + C_4 HDDxHeatPer + C_5 CDDxCool Per + C_6 Ln (Hours) +C_7 Ln (Workers) + C_8 SumHID&Halo

Source (kBtu/year) = 4.229 +0.775(RefWH) + 0.088(Walk-InRefs) + 0.709 Ln (Area) +1.273e-06 (HDDxHeatPer) + 1.936e-06(CDDxCoolPer) + 0.393 Ln (Hours) + 0.281 Ln (Workers) + 0.002 (SumHID&Halo)

Predicted Ln Source = 15.04 kBtu/ft^2-yr

Mean Ln Source = 14.897 kBtu/ft^2-yr

Adjustment Factor = (15.04/14.897)
= 1.01

Table-3 Determining Energy Performance Rating

EPR	Fitted Source EUI (kBtu/ft^2-yr)	Adjustment Factor	Customized Source EUI (kBtu/ft^2-yr)
100	13.408	1.01	13.541
99	13.523	1.01	13.663
98	13.628	1.01	13.764
…	…	…	…
…	…	…	…
…	…	…	…
85	14.329	1.01	14.472
84	14.352	1.01	14.495
83	14.373	1.01	14.517
…	…	…	…
…	…	…	…
…	…	…	…
1	18.035	1.01	18.215

Appendix

Table-4 Energy Performance Rating, Adjusted Source EUI, and Fitted Source EUI

EPR	Adjusted Source EUI (kBtu/ft^2-yr)	Fitted Source EUI (kBtu/ft^2-yr)	EPR	Adjusted Source EUI (kBtu/ft^2-yr)	Fitted Source EUI (kBtu/ft^2-yr)
100	13.449	13.408	50	14.865	14.892
99	13.532	13.523	49	14.880	14.909
98	13.592	13.628	48	14.893	14.925
97	13.699	13.722	47	14.901	14.941
96	13.853	13.807	46	14.921	14.957
95	13.914	13.884	45	14.929	14.972
94	13.992	13.954	44	14.943	14.986
93	14.023	14.016	43	14.958	15.000
92	14.097	14.072	42	14.965	15.014
91	14.113	14.121	41	14.978	15.027
90	14.141	14.166	40	15.000	15.039
89	14.178	14.206	39	15.011	15.051
88	14.208	14.242	38	15.018	15.062
87	14.230	14.274	37	15.029	15.074
86	14.256	14.303	36	15.039	15.084
85	14.266	14.329	35	15.054	15.095
84	14.308	14.352	34	15.091	15.105
83	14.331	14.373	33	15.109	15.115
82	14.367	14.392	32	15.127	15.126
81	14.420	14.410	31	15.143	15.137
80	14.430	14.426	30	15.150	15.148
79	14.446	14.441	29	15.159	15.160
78	14.451	14.456	28	15.176	15.172
77	14.461	14.470	27	15.208	15.186
76	14.478	14.483	26	15.239	15.201
75	**14.499**	**14.496**	25	15.265	15.218
74	14.537	14.509	24	15.299	15.236
73	14.560	14.522	23	15.317	15.257
72	14.570	14.535	22	15.347	15.281
71	14.584	14.548	21	15.378	15.308
70	14.594	14.562	20	15.397	15.338
69	14.605	14.576	19	15.437	15.373
68	14.627	14.590	18	15.528	15.411
67	14.640	14.604	17	15.559	15.455
66	14.650	14.619	16	15.584	15.504
65	14.659	14.635	15	15.622	15.559
64	14.674	14.650	14	15.681	15.621
63	14.699	14.666	13	15.732	15.691
62	14.702	14.683	12	15.795	15.768
61	14.712	14.700	11	15.850	15.855
60	14.738	14.717	10	15.918	15.951
59	14.765	14.734	9	15.973	16.057
58	14.781	14.752	8	16.077	16.174
57	14.791	14.769	7	16.126	16.304
56	14.801	14.787	6	16.164	16.447

55	14.816	14.805	5	16.359	16.604
54	14.824	14.823	4	16.460	16.775
53	14.838	14.840	3	16.903	16.963
52	14.840	14.858	2	17.226	17.169
51	14.840	14.875	1	18.035	17.392