

Extrapolating CBECS 2012 Data to Estimate Building Type (PBA) by Census Division Cross-Tabulations

Michael MacDonald

Energy Performance Measurement Institute

April 2018



Download from:

<http://epminst.us/commercial/Extrapolating PBA by Census Division cross-tabs.pdf>

Abstract

This paper proposes stretching CBECS data results beyond statistical limits by applying expert knowledge. The example presented is for the principal building activity (PBA) parameter vs Census division (9 currently but likely 10 for the 2018 CBECS). For the 2012 CBECS, this cross-tabulation involves 20 PBA values, for a total of 180 data cells. The parameters presented are number of buildings, total floor area, total energy, and bulk-sum energy use indices (EUIs). Cross-check data methods are presented involving per-capita data and EUI data. The extrapolation method is moved to near-completion here, but not finalized. Users can consider whether final extrapolation efforts for all or some data potentially offer enough value to develop, and also whether to publish final recommended extrapolation values.

Introduction

The Commercial Buildings Energy Consumption Survey (CBECS) is a national sample survey conducted by the Energy Information Administration (EIA) that collects information on most of the stock of U.S. commercial buildings, including energy consumption and expenditures of those buildings and extensive characteristics data for the sample. (<http://www.eia.gov/consumption/commercial/>)

Detailed microdata from the latest CBECS survey for 2012 were released May 2016, and updated August 2016. The detailed data are analyzed and refined by EIA to allow representative estimates of individual parameters or derived parameters for the defined population of commercial buildings represented by the survey sample to be calculated using survey weights. Statistical methods of calculating relative standard errors of the estimates are also possible using an additional set of extensive sampling weights.

The purpose here is not to stay within the confines of statistical survey methods, but to extrapolate the CBECS 2012 data beyond data set limits to estimate (as in engineering estimate) cross-tabulations of limited energy and floor area data by principal building type (parameter PBA in the CBECS set) and Census division geographical unit. The user can gauge reasonableness of results by comparing values of the various cross-tab results, and each user must make such determinations individually (some expertise is needed to find full value here). This report makes no claim to reasonableness of any values presented, although some qualitative assessment is presented for consideration by users. Cells with fewer than four data records are highly suspect.

The results presented, many of which are based on fairly significant sample sizes, are also normalized by population.

CBECS 2012 Data

The 2012 CBECS public use microdata file contains the raw data on individual buildings, together with survey weights and imputation variables. The microdata file contains 6,720 records, with each record corresponding to a single, in-scope, sampled building (some data are manipulated for privacy reasons). Information on methodology and sampling can be found on the EIA website shown above (e.g., detail on sampling: <https://www.eia.gov/consumption/commercial/reports/2012/methodology/sampling.php>).

The first following table is a cross-tabulation of the 6,720 data records showing the number of records for each element of PBA by Census division (Cendiv). Five items (cells) have no data records. Many others have less than 10 data records, so the extent of extrapolation considered here is apparent.

Using the CBECS weights, the estimated number of buildings for each cell can be calculated and these results are shown in the second table following. The estimated national population of commercial buildings for the defined (in-scope) population is 5.557 million buildings for the whole country.

N, CBECS sample size, 2012											
PBA	Principal building activity	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
01	Vacant	13	17	23	22	46	19	48	19	40	247
02	Office	61	168	177	92	306	60	164	91	237	1356
04	Laboratory	7	6	5		6	1	1	3	12	41
05	Nonrefrigerated warehouse	23	75	78	67	148	31	106	47	163	738
06	Food sales	8	12	13	10	28	11	17	8	22	129
07	Public order and safety	7	16	14	7	19	7	13	2	16	101
08	Outpatient health care	7	22	29	25	26	10	22	24	32	197
11	Refrigerated warehouse		3	5	1	6		4		2	21
12	Religious worship	17	36	47	34	74	40	42	20	42	352
13	Public assembly	30	47	65	35	71	33	46	24	63	414
14	Education	34	85	121	62	136	33	106	58	120	755
15	Food service	19	31	41	36	76	31	42	24	61	361
16	Inpatient health care	22	73	58	21	68	31	56	29	51	409
17	Nursing	5	16	17	10	18	4	4	6	14	94
18	Lodging	10	43	24	23	67	20	38	21	49	295
23	Strip shopping mall	13	28	32	18	89	15	28	21	52	296
24	Enclosed mall		5	6	2	8	2	2	4	5	34
25	Retail other than mall	14	47	58	35	67	18	44	23	63	369
26	Service	26	47	73	52	75	25	56	16	54	424
91	Other	3	10	14	7	14	1	13	10	15	87
	Total	319	787	900	559	1348	392	852	450	1113	6720

CBECS 2012 final weight population estimate, # of buildings											
PBA	Principal building activity	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
01	Vacant	11,841	20,134	23,645	27,286	57,662	24,034	68,018	29,809	33,611	296,041
02	Office	54,113	93,914	153,833	75,753	197,605	63,308	129,044	65,494	179,309	1,012,373
04	Laboratory	428	5,258	1,045		2,630	207	654	2,477	2,806	15,505
05	Nonrefrigerated warehouse	27,768	60,657	77,978	83,727	172,494	22,040	124,175	46,187	172,143	787,169
06	Food sales	13,267	13,545	19,988	13,853	39,846	14,833	26,591	10,639	24,178	176,739
07	Public order and safety	5,989	7,635	15,440	3,513	14,599	8,739	15,828	39	12,058	83,841
08	Outpatient health care	3,185	17,334	19,554	22,451	20,813	8,833	19,928	17,290	17,767	147,155
11	Refrigerated warehouse		226	1,405	52	4,453		1,990		374	8,499
12	Religious worship	22,079	28,422	50,169	42,261	79,599	57,463	57,596	22,088	52,123	411,799
13	Public assembly	35,729	29,455	65,163	34,350	45,226	34,099	30,648	16,012	61,331	352,014
14	Education	16,371	28,830	43,692	22,985	86,615	14,319	58,066	23,954	93,827	388,659
15	Food service	25,744	36,319	44,722	32,497	77,982	34,513	47,446	21,607	58,882	379,711
16	Inpatient health care	818	944	960	747	1,865	998	1,415	409	1,423	9,579
17	Nursing	2,591	2,556	4,203	3,256	4,552	3,145	1,343	3,401	4,486	29,535
18	Lodging	4,115	17,862	5,262	10,611	28,579	10,734	20,640	8,652	21,934	128,389
23	Strip shopping mall	13,572	9,323	21,246	5,992	50,144	9,926	13,626	8,782	30,076	162,687
24	Enclosed mall		109	354	77	411	39	47	130	211	1,379
25	Retail other than mall	20,556	54,361	62,096	41,261	91,739	21,295	64,176	22,059	60,717	438,261
26	Service	40,555	67,825	101,930	75,292	99,911	41,050	88,942	25,506	77,533	618,544
91	Other	2,912	9,141	22,562	6,268	14,659	60	15,610	13,909	24,140	109,260
	Total	301,635	503,848	735,248	502,232	1,091,384	369,635	785,784	338,445	928,928	5,557,138

Floor Area Extrapolation

For floor area, the data cells with missing values will be estimated, based on examination of percentages of floor area for each Census division (column percentages). The next table shows the floor area calculated directly from the CBECS data, and the second table shows column percentages. The second table also shows the percentage to be used to estimate values for missing cells.

CBECS 2012 Weighted Floor Area Estimate, millions of square feet											
PBA	Principal building activity	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
01	Vacant	177	211	345	191	548	179	935	276	396	3,257
02	Office	738	3,015	2,416	901	3,175	692	1,629	846	2,596	16,007
04	Laboratory	54	76	79		126	2	17	16	102	471
05	Nonrefrigerated warehouse	521	1,231	1,463	948	2,717	521	1,854	592	2,842	12,689
06	Food sales	110	207	99	75	188	74	137	59	304	1,252
07	Public order and safety	79	261	245	88	301	67	207	8	177	1,434
08	Outpatient health care	106	422	190	176	257	87	204	157	182	1,780
11	Refrigerated warehouse		24	120	10	126		62		99	441
12	Religious worship	284	613	547	378	857	615	540	214	511	4,559
13	Public assembly	350	599	1,215	383	871	330	774	312	698	5,531
14	Education	642	1,415	2,208	969	2,839	469	1,849	782	1,066	12,239
15	Food service	130	162	217	153	396	150	225	104	283	1,819
16	Inpatient health care	169	367	350	134	391	185	302	137	317	2,352
17	Nursing	75	196	275	126	253	82	56	73	139	1,275
18	Lodging	132	598	388	258	966	380	545	376	803	4,447
23	Strip shopping mall	299	431	630	213	1,465	331	500	340	876	5,085
24	Enclosed mall		93	116	37	241	27	66	78	210	869
25	Retail other than mall	163	671	750	394	1,050	380	693	307	1,030	5,437
26	Service	255	523	847	625	741	318	583	116	578	4,587
91	Other	23	125	252	106	450	9	231	106	243	1,543
	Total	4,305	11,242	12,751	6,165	17,957	4,896	11,409	4,900	13,451	87,076

Percent of Floor Area in Region											
PBA	Principal building activity	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
01	Vacant	4.1%	1.9%	2.7%	3.1%	3.0%	3.7%	8.2%	5.6%	2.9%	3.7%
02	Office	17.1%	26.8%	18.9%	14.6%	17.7%	14.1%	14.3%	17.3%	19.3%	18.4%
04	Laboratory	1.2%	0.7%	0.6%	use 0.3%	0.7%	0.1%	0.1%	0.3%	0.8%	0.5%
05	Nonrefrigerated warehouse	12.1%	11.0%	11.5%	15.4%	15.1%	10.6%	16.2%	12.1%	21.1%	14.6%
06	Food sales	2.5%	1.8%	0.8%	1.2%	1.0%	1.5%	1.2%	1.2%	2.3%	1.4%
07	Public order and safety	1.8%	2.3%	1.9%	1.4%	1.7%	1.4%	1.8%	0.2%	1.3%	1.6%
08	Outpatient health care	2.5%	3.8%	1.5%	2.9%	1.4%	1.8%	1.8%	3.2%	1.4%	2.0%
11	Refrigerated warehouse	use 0.2%	0.2%	0.9%	0.2%	0.7%	use 0.5%	0.5%	use 0.5%	0.7%	0.5%
12	Religious worship	6.6%	5.5%	4.3%	6.1%	4.8%	12.6%	4.7%	4.4%	3.8%	5.2%
13	Public assembly	8.1%	5.3%	9.5%	6.2%	4.9%	6.7%	6.8%	6.4%	5.2%	6.4%
14	Education	14.9%	12.6%	17.3%	15.7%	15.8%	9.6%	16.2%	16.0%	7.9%	14.1%
15	Food service	3.0%	1.4%	1.7%	2.5%	2.2%	3.1%	2.0%	2.1%	2.1%	2.1%
16	Inpatient health care	3.9%	3.3%	2.7%	2.2%	2.2%	3.8%	2.7%	2.8%	2.4%	2.7%
17	Nursing	1.7%	1.7%	2.2%	2.0%	1.4%	1.7%	0.5%	1.5%	1.0%	1.5%
18	Lodging	3.1%	5.3%	3.0%	4.2%	5.4%	7.8%	4.8%	7.7%	6.0%	5.1%
23	Strip shopping mall	7.0%	3.8%	4.9%	3.5%	8.2%	6.8%	4.4%	6.9%	6.5%	5.8%
24	Enclosed mall	use 0.5%	0.8%	0.9%	0.6%	1.3%	0.5%	0.6%	1.6%	1.6%	1.0%
25	Retail other than mall	3.8%	6.0%	5.9%	6.4%	5.8%	7.8%	6.1%	6.3%	7.7%	6.2%
26	Service	5.9%	4.7%	6.6%	10.1%	4.1%	6.5%	5.1%	2.4%	4.3%	5.3%
91	Other	0.5%	1.1%	2.0%	1.7%	2.5%	0.2%	2.0%	2.2%	1.8%	1.8%
	Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

This extrapolation falls far short, in that cells with few observations are not adjusted. Users are advised to understand that some adjustment of cells with less than four data records is probably also needed. Cells with more data records may also need adjustment. (Also applicable to number of buildings.)

The percentages are interesting to compare across columns. The percentage of office space in the mid-Atlantic region tends to jump out right away, and appears reflective of the concentration of financial entities and corporate headquarters in that region. The floorspace for religious worship in the East South Central region is also worthy of note. The food service and lodging percentages may be reflective of tourism levels.

The next step in the extrapolation is to multiply the total floor area values for each region by the percentages in the percentage table. Since what is printed here is based on a limited number of decimal places, slightly different results will be obtained if one wanted to do a verification using the values here. The values in the spreadsheet used have more decimal places, but the operation does lead to some slight differences in the calculated totals. The new values for previously blank cells are very small percentages, so their impact on totals is also small. The resulting “adjusted” floor area values are shown in the next table, and the column percentages indicate how the column total compares to the previous total calculated directly from the CBECS data.

ADJUSTED Floor Area, millions sq ft											
PBA	Principal building activity	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
01	Vacant	177	211	345	191	548	179	935	276	396	3,257
02	Office	738	3,015	2,416	901	3,175	692	1,629	846	2,596	16,007
04	Laboratory	54	76	79	18	126	2.5	17	16	102	490
05	Nonrefrigerated warehouse	521	1,231	1,463	948	2,717	521	1,854	592	2,842	12,689
06	Food sales	110	207	99	75	188	74	137	59	304	1,252
07	Public order and safety	79	261	245	88	301	67	207	8.4	177	1,434
08	Outpatient health care	106	422	190	176	257	87	204	157	182	1,780
11	Refrigerated warehouse	8.6	24	120	10	126	24	62	24	99	499
12	Religious worship	284	613	547	378	857	615	540	214	511	4,559
13	Public assembly	350	599	1,215	383	871	330	774	312	698	5,531
14	Education	642	1,415	2,208	969	2,839	469	1,849	782	1,066	12,239
15	Food service	130	162	217	153	396	150	225	104	283	1,819
16	Inpatient health care	169	367	350	134	391	185	302	137	317	2,352
17	Nursing	75	196	275	126	253	82	56	73	139	1,275
18	Lodging	132	598	388	258	966	380	545	376	803	4,447
23	Strip shopping mall	299	431	630	213	1,465	331	500	340	876	5,085
24	Enclosed mall	22	93	116	37	241	27	66	78	210	890
25	Retail other than mall	163	671	750	394	1,050	380	693	307	1,030	5,437
26	Service	255	523	847	625	741	318	583	116	578	4,587
91	Other	23	125	252	106	450	8.5	231	106	243	1,543
	Total	4,335	11,242	12,751	6,183	17,957	4,921	11,409	4,924	13,451	87,174
	Percent of CBECS total	100.70%	100.00%	100.00%	100.30%	100.00%	100.50%	100.00%	100.50%	100.00%	100.11%

Adding this small amount of floor area is not considered important here, since CBECS overall does not represent the entire commercial sector (see related EPMI report, for example, *Understanding Commercial and Service Sector Energy Use*, <http://epminst.us/commercial/commercial.htm>), and may not capture some building types adequately, e.g., the Education “type” may be missing some educational floor area and does not represent overall college facilities.

The next table presents the values of floor area per capita for these values of adjusted floor area. As with the percentages, comparisons among regions can be interesting. Again, cells based on less than four data records, such as several enclosed mall and refrigerated warehouse cells, are highly suspect and probably also need adjustment. Cells with “adjusted” values may also need more adjustment. The floor area per capita values, possibly in conjunction with the percentage values in a previous table, may offer the best hope of scoping and selecting “best-estimate” final values.

As an example of scoping potential additional needed changes, consider public order and safety facilities in the Mountain region, which only had two data records. Comparison across the row suggests there should be at least 3–3.5 sq ft per capita in this region, which is almost an order of magnitude larger than the value calculated using the limited number of CBECS data records.

2012 ADJUSTED Floor Area, sq ft per capita											
PBA	Principal building activity	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
01	Vacant	12.1	5.1	7.4	9.2	8.9	9.6	25.0	12.2	7.8	10.4
02	Office	50.6	73.0	51.9	43.4	51.9	37.2	43.5	37.4	51.0	51.0
04	Laboratory	3.7	1.8	1.7	0.9	2.1	0.1	0.4	0.7	2.0	1.6
05	Nonrefrigerated warehouse	35.7	29.8	31.4	45.7	44.4	28.0	49.5	26.2	55.8	40.4
06	Food sales	7.5	5.0	2.1	3.6	3.1	3.9	3.7	2.6	6.0	4.0
07	Public order and safety	5.4	6.3	5.3	4.2	4.9	3.6	5.5	0.4	3.5	4.6
08	Outpatient health care	7.2	10.2	4.1	8.5	4.2	4.7	5.4	6.9	3.6	5.7
11	Refrigerated warehouse	0.6	0.6	2.6	0.5	2.1	1.3	1.7	1.1	1.9	1.6
12	Religious worship	19.5	14.9	11.8	18.2	14.0	33.0	14.4	9.5	10.0	14.5
13	Public assembly	24.0	14.5	26.1	18.5	14.2	17.7	20.7	13.8	13.7	17.6
14	Education	44.0	34.3	47.4	46.7	46.4	25.2	49.4	34.6	20.9	39.0
15	Food service	8.9	3.9	4.7	7.4	6.5	8.1	6.0	4.6	5.5	5.8
16	Inpatient health care	11.6	8.9	7.5	6.5	6.4	9.9	8.1	6.1	6.2	7.5
17	Nursing	5.1	4.7	5.9	6.1	4.1	4.4	1.5	3.2	2.7	4.1
18	Lodging	9.1	14.5	8.3	12.5	15.8	20.4	14.5	16.7	15.8	14.2
23	Strip shopping mall	20.5	10.5	13.5	10.3	23.9	17.7	13.3	15.1	17.2	16.2
24	Enclosed mall	1.5	2.3	2.5	1.8	3.9	1.4	1.8	3.5	4.1	2.8
25	Retail other than mall	11.1	16.3	16.1	19.0	17.2	20.4	18.5	13.6	20.2	17.3
26	Service	17.5	12.7	18.2	30.1	12.1	17.1	15.6	5.1	11.4	14.6
91	Other	1.6	3.0	5.4	5.1	7.3	0.5	6.2	4.7	4.8	4.9
	Total	297	272	274	298	293	264	305	218	264	278

Relative to the CBECS-defined population and the actual US commercial sector population, previous work by EPMI has indicated that total floor area per capita for the entire commercial sector is about 310 sq ft per capita (313 in 2012), and has been at this level for two decades or more (see *Understanding Commercial and Service Sector Energy Use*, pp 44–46, <http://epminst.us/commercial/commercial.htm>).

Site Energy Extrapolation

A similar process is used for total site energy used for each cell. Site energy includes estimates of propane use inferred from CBECS data. Rather than show the intermediate tables, only the percent values, “adjusted” totals, and the site energy used per capita in each cell will be presented in the next three tables. As with the floor area results, users must be aware that additional adjustments are likely to be needed for many cells, especially those with less than four data records.

Percent of Site Energy in Region											
PBA	Principal building activity	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
01	Vacant	1.0%	0.1%	0.6%	1.0%	0.6%	0.5%	0.3%	1.5%	0.7%	0.6%
02	Office	16.5%	28.2%	18.3%	13.9%	14.7%	14.8%	13.5%	14.3%	18.5%	17.8%
04	Laboratory	3.7%	1.1%	1.9%	use 0.5%	2.2%	0.2%	0.5%	1.6%	3.0%	1.7%
05	Nonrefrigerated warehouse	6.4%	3.3%	5.0%	6.2%	5.1%	3.7%	8.3%	5.2%	5.6%	5.3%
06	Food sales	6.2%	4.5%	2.0%	3.2%	2.8%	4.2%	4.0%	3.4%	5.4%	3.8%
07	Public order and safety	2.0%	2.8%	1.6%	2.6%	2.1%	0.9%	2.2%	0.1%	1.6%	1.9%
08	Outpatient health care	2.3%	4.0%	1.6%	5.1%	1.6%	1.7%	2.3%	4.0%	1.4%	2.4%
11	Refrigerated warehouse	use 0.2%	0.3%	0.8%	0.3%	1.1%	use 0.3%	1.1%	use 0.3%	2.2%	0.8%
12	Religious worship	2.4%	2.6%	2.7%	2.7%	2.6%	5.0%	1.8%	1.7%	2.1%	2.5%
13	Public assembly	6.7%	6.2%	9.1%	8.1%	5.9%	5.1%	9.2%	6.6%	4.8%	6.9%
14	Education	12.1%	11.4%	14.2%	17.3%	13.1%	9.2%	13.1%	11.7%	7.0%	12.1%
15	Food service	7.0%	4.3%	6.3%	7.5%	8.9%	9.6%	9.6%	5.9%	8.0%	7.4%
16	Inpatient health care	10.9%	7.7%	7.4%	6.9%	6.3%	13.0%	8.6%	6.8%	8.1%	7.9%
17	Nursing	2.6%	2.0%	2.9%	3.0%	2.1%	5.2%	0.6%	1.9%	1.8%	2.2%
18	Lodging	3.8%	4.9%	3.1%	5.9%	6.1%	7.1%	5.0%	18.0%	5.8%	5.9%
23	Strip shopping mall	6.6%	6.1%	8.2%	4.9%	11.6%	7.0%	6.9%	7.5%	11.7%	8.5%
24	Enclosed mall	use 0.4%	0.6%	0.7%	0.6%	1.2%	0.5%	0.6%	1.0%	1.1%	0.8%
25	Retail other than mall	2.9%	4.1%	6.3%	3.3%	4.5%	7.4%	5.3%	6.1%	6.7%	5.2%
26	Service	3.9%	3.2%	5.1%	6.8%	4.1%	5.0%	3.4%	1.3%	2.9%	3.9%
91	Other	3.1%	2.5%	2.2%	0.7%	3.6%	0.0%	3.9%	1.4%	1.6%	2.4%
	Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

ADJUSTED 2012 Site Energy Use, TBtu											
PBA	Principal building activity	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
01	Vacant	3.5	1.4	6.3	4.4	8.8	1.7	2.8	6.3	6.5	41.7
02	Office	60.7	308.0	206.3	60.8	200.4	54.6	112.9	59.8	176.8	1,240.4
04	Laboratory	13.8	12.4	21.6	1.3	29.7	0.7	4.3	6.6	28.5	119.0
05	Nonrefrigerated warehouse	23.5	36.1	56.2	27.1	68.9	13.8	69.4	21.9	53.7	370.4
06	Food sales	22.8	49.3	23.1	14.0	38.6	15.4	33.2	14.2	52.0	262.5
07	Public order and safety	7.4	30.0	18.0	11.5	28.0	3.4	18.5	0.6	15.8	133.1
08	Outpatient health care	8.4	43.7	18.1	22.3	21.2	6.2	19.3	16.5	13.3	168.9
11	Refrigerated warehouse	0.7	3.4	8.7	1.2	14.6	1.8	9.4	2.1	21.2	63.2
12	Religious worship	9.0	28.4	31.1	11.6	34.7	18.5	14.9	7.1	19.6	174.8
13	Public assembly	24.7	68.0	103.0	35.4	80.4	18.9	77.2	27.6	45.6	480.7
14	Education	44.7	124.1	160.1	75.3	177.8	34.1	109.9	49.0	67.0	841.9
15	Food service	26.0	46.8	71.6	32.9	120.6	35.6	80.5	24.6	76.6	515.1
16	Inpatient health care	40.0	83.8	83.6	30.1	85.7	48.0	71.9	28.4	77.3	548.8
17	Nursing	9.4	21.7	33.0	13.1	27.9	19.1	5.2	8.0	17.1	154.3
18	Lodging	14.2	53.4	35.6	25.7	83.2	26.2	41.6	75.2	55.2	410.3
23	Strip shopping mall	24.1	67.0	92.5	21.5	158.0	25.8	57.6	31.4	111.9	589.7
24	Enclosed mall	1.8	6.5	7.7	2.7	15.9	1.7	5.1	4.2	10.4	56.0
25	Retail other than mall	10.6	45.1	71.7	14.3	61.5	27.4	44.3	25.3	63.9	364.2
26	Service	14.3	34.8	58.1	29.5	55.1	18.5	28.3	5.6	28.1	272.4
91	Other	11.4	27.0	24.5	3.0	48.3	0.1	32.9	5.9	14.9	167.9
	Total	371.0	1,091.0	1,130.5	437.5	1,359.2	371.4	839.2	420.1	955.3	6,975.3
	Percent of CBECs total	100.6946%	99.9991%	100.0000%	100.2977%	100.0007%	100.5027%	99.9976%	100.5000%	100.003%	100.1120%

For the energy data, some slight percentage differences are introduced by not retaining more significant figures from the CBECs tabulations.

2012 ADJUSTED Site Energy, Btu per capita											
PBA	Principal building activity	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
01	Vacant	241	34	136	210	144	90	73	278	128	133
02	Office	4,164	7,463	4,431	2,932	3,273	2,932	3,015	2,645	3,472	3,950
04	Laboratory	945	301	463	63	485	39	115	293	560	379
05	Nonrefrigerated warehouse	1,610	874	1,206	1,308	1,125	739	1,853	967	1,054	1,180
06	Food sales	1,561	1,194	496	672	630	825	887	630	1,020	836
07	Public order and safety	509	727	386	556	457	183	493	24	309	424
08	Outpatient health care	573	1,058	388	1,076	347	332	516	732	260	538
11	Refrigerated warehouse	51	83	188	56	239	99	250	93	416	201
12	Religious worship	618	687	667	560	567	993	397	312	385	557
13	Public assembly	1,691	1,648	2,211	1,707	1,313	1,012	2,062	1,220	896	1,531
14	Education	3,063	3,006	3,437	3,629	2,905	1,830	2,934	2,169	1,316	2,681
15	Food service	1,779	1,133	1,536	1,584	1,970	1,912	2,151	1,089	1,504	1,640
16	Inpatient health care	2,742	2,031	1,795	1,452	1,400	2,576	1,921	1,255	1,519	1,748
17	Nursing	646	526	709	629	455	1,024	138	354	335	491
18	Lodging	971	1,294	765	1,239	1,359	1,405	1,111	3,329	1,084	1,307
23	Strip shopping mall	1,655	1,624	1,986	1,034	2,581	1,383	1,538	1,389	2,196	1,878
24	Enclosed mall	126	158	164	131	260	92	136	185	204	178
25	Retail other than mall	730	1,093	1,540	687	1,005	1,471	1,183	1,120	1,256	1,160
26	Service	980	843	1,248	1,422	900	994	757	249	552	868
91	Other	784	654	526	144	788	4	880	261	292	535
	Total	25,440	26,432	24,276	21,087	22,204	19,935	22,411	18,594	18,758	22,215

As with previous data, cells based on less than four data records almost certainly need additional adjustment, and cells with “adjusted” values also likely need more adjustment. Public order and safety facilities in the Mountain region again provide an example of possibly major change needed, and many, if not most, refrigerated warehouse values are likely too low. Enclosed mall values are also an example where additional changes appear needed. The per-capita (and percentage) values may offer the best hope of scoping and selecting final preferred estimated values.

The most site energy per capita is in the office sector, which matches the high total floor area in office buildings. Next highest is education buildings, although if overall retail includes both mall categories and retail other than mall, retail would be the next highest.

Source Energy Extrapolation

Following the same process used for total site energy to calculate source energy values, the next three tables present the source energy results. Again, users must be aware that additional adjustments are likely needed for many cells.

Source energy is calculated using national constant multipliers applied to site energy: 3.01 for electricity, 1.05 for natural gas, 1.01 for fuel oil and propane, and 1.20 for district heat. Propane use is inferred from CBECS data.

The next table shows the percentage values. The major impact of office buildings on source energy is notable, as is the impact of education and retail facilities, with all three of these subsectors combined accounting for a total of over 45% of sectoral source energy use.

Percent of Source Energy in Region											
PBA	Principal building activity	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
01	Vacant	1.0%	0.1%	0.6%	1.0%	0.6%	0.5%	0.4%	1.7%	0.7%	0.6%
02	Office	16.9%	30.3%	20.1%	15.5%	15.9%	15.8%	15.1%	14.9%	20.9%	19.2%
04	Laboratory	4.0%	1.3%	1.9%	use 1.0%	2.0%	0.2%	0.5%	2.0%	2.3%	1.6%
05	Nonrefrigerated warehouse	5.2%	3.3%	4.7%	6.8%	5.1%	4.0%	9.3%	4.4%	6.2%	5.5%
06	Food sales	7.3%	5.1%	2.6%	3.7%	3.3%	5.0%	4.2%	4.3%	6.2%	4.4%
07	Public order and safety	2.1%	2.6%	1.4%	2.2%	1.9%	1.1%	2.4%	0.2%	1.4%	1.8%
08	Outpatient health care	2.6%	4.3%	1.8%	5.1%	1.8%	1.9%	2.5%	3.6%	1.4%	2.6%
11	Refrigerated warehouse	use 0.2%	0.4%	1.1%	0.3%	1.3%	use 1.0%	1.4%	use 1.0%	1.7%	0.9%
12	Religious worship	1.9%	2.3%	2.2%	2.2%	2.3%	4.7%	1.8%	1.5%	1.7%	2.2%
13	Public assembly	7.3%	5.9%	9.1%	7.5%	5.9%	4.9%	8.4%	7.2%	4.7%	6.7%
14	Education	10.4%	9.7%	12.9%	17.1%	12.8%	9.4%	13.2%	11.8%	6.5%	11.4%
15	Food service	7.7%	4.3%	6.1%	7.4%	7.8%	9.1%	8.1%	5.7%	7.4%	6.9%
16	Inpatient health care	9.9%	6.7%	6.7%	6.1%	5.3%	10.9%	7.5%	6.2%	7.1%	6.9%
17	Nursing	2.5%	1.8%	2.7%	3.0%	2.0%	4.6%	0.6%	1.7%	1.5%	2.0%
18	Lodging	4.4%	4.7%	3.1%	5.8%	5.9%	6.6%	4.7%	15.3%	5.3%	5.6%
23	Strip shopping mall	7.3%	6.1%	8.4%	5.1%	12.0%	7.3%	6.7%	8.6%	10.9%	8.7%
24	Enclosed mall	use 0.5%	0.8%	0.8%	0.8%	1.4%	0.6%	0.7%	1.3%	1.3%	1.0%
25	Retail other than mall	3.3%	4.6%	6.9%	3.5%	5.1%	9.0%	6.0%	7.3%	7.8%	6.0%
26	Service	3.6%	2.7%	4.4%	6.1%	3.5%	4.4%	2.7%	1.2%	3.0%	3.4%
91	Other	2.7%	3.0%	2.5%	0.7%	4.1%	0.0%	4.0%	1.1%	1.8%	2.7%
	Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

ADJUSTED 2012 Source Energy Use, TBtu											
PBA	Principal building activity	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
01	Vacant	7.6	2.1	13.1	10.0	20.4	4.3	7.6	15.5	14.9	95
02	Office	123	694	474	149	533	136	308	133	456	3,007
04	Laboratory	29	31	44	2.9	68	1.7	9.9	18	51	254
05	Nonrefrigerated warehouse	38	76	110	66	172	35	190	39	135	860
06	Food sales	53	118	62	36	112	44	87	39	135	683
07	Public order and safety	15	60	33	22	65	9.4	49	1.4	31	286
08	Outpatient health care	19	98	43	49	62	16	51	32	32	401
11	Refrigerated warehouse	1.5	8.8	25	2.6	44	4.3	28	4.5	38	157
12	Religious worship	14	52	51	21	76	41	36	14	37	342
13	Public assembly	53	136	215	72	196	42	171	64	103	1,052
14	Education	76	221	304	164	428	81	269	105	141	1,790
15	Food service	56	99	144	71	261	78	165	50	162	1,088
16	Inpatient health care	72	154	159	59	177	94	154	55	155	1,078
17	Nursing	18	40	64	29	66	40	11	15	34	318
18	Lodging	32	109	74	56	199	57	96	136	117	875
23	Strip shopping mall	53	141	197	49	403	63	137	77	237	1,356
24	Enclosed mall	3.6	18	19	7.3	46	4.9	14	12	29	154
25	Retail other than mall	24	105	164	34	170	78	123	65	170	932
26	Service	26	61	104	58	116	38	56	10.4	66	536
91	Other	19	68	60	6.7	136	0.2	82	9.7	40	421
	Total	733	2,291	2,357	966	3,351	868	2,043	895	2,183	15,688
	Percent of CBECS total	100.70%	100.00%	100.0004%	100.30%	100.00%	100.50%	100.00%	100.50%	100.00%	100.1069%

2012 ADJUSTED Source Energy, Btu per capita											
PBA	Principal building activity	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
01	Vacant	518	51	282	483	333	229	202	685	293	304
02	Office	8,425	16,825	10,174	7,192	8,705	7,316	8,227	5,892	8,955	9,576
04	Laboratory	1,988	743	938	139	1,106	91	265	790	1,004	811
05	Nonrefrigerated warehouse	2,578	1,838	2,363	3,164	2,815	1,874	5,074	1,722	2,652	2,740
06	Food sales	3,622	2,851	1,327	1,713	1,826	2,336	2,315	1,707	2,645	2,175
07	Public order and safety	1,062	1,464	706	1,038	1,065	506	1,302	62	600	910
08	Outpatient health care	1,280	2,384	926	2,345	1,009	873	1,350	1,435	620	1,278
11	Refrigerated warehouse	100	213	541	123	719	232	750	197	741	499
12	Religious worship	941	1,267	1,101	1,031	1,247	2,183	959	605	730	1,091
13	Public assembly	3,628	3,293	4,611	3,488	3,204	2,275	4,557	2,831	2,020	3,350
14	Education	5,208	5,358	6,528	7,921	6,988	4,339	7,188	4,646	2,777	5,700
15	Food service	3,819	2,396	3,101	3,443	4,269	4,206	4,415	2,231	3,184	3,465
16	Inpatient health care	4,961	3,730	3,405	2,837	2,894	5,039	4,101	2,431	3,034	3,432
17	Nursing	1,260	973	1,374	1,412	1,081	2,137	306	679	664	1,014
18	Lodging	2,183	2,631	1,579	2,708	3,254	3,063	2,568	6,025	2,292	2,788
23	Strip shopping mall	3,645	3,413	4,229	2,364	6,581	3,374	3,649	3,400	4,657	4,320
24	Enclosed mall	250	428	402	352	751	264	385	529	576	490
25	Retail other than mall	1,650	2,537	3,515	1,647	2,779	4,194	3,281	2,871	3,336	2,970
26	Service	1,805	1,474	2,236	2,813	1,892	2,061	1,490	462	1,299	1,708
91	Other	1,332	1,642	1,278	323	2,229	10	2,182	428	779	1,341
	Total	50,256	55,513	50,615	46,535	54,746	46,601	54,566	39,630	42,858	49,962

As with site energy, many cells need more adjustment. Source energy per capita (and percentage) values likely again offer the best hope of scoping and selecting final preferred estimated values.

Extending the Cross-Checks Using EUI

Several cross-check options have been mentioned, and energy use index (EUI) will be added as one additional cross-check point. The next two tables present the bulk-sum ratios of total cell energy divided by total cell floor area to calculate regional-building-type EUIs (kBtu/ft²) for both site energy and source energy. These values allow one more check on potential reasonableness of the cell data, with potential for also scoping additional adjustments that may be needed.

One issue with suspect EUI values is not knowing whether the energy value (numerator) or floor area value (denominator) for the ratio is potentially off. The EUI ratios do provide a limited check on whether the energy and floor area data for an individual cell appear to scale up consistently.

The variability in EUI ratios for the refrigerated warehouse building type indicates the concern that should be present for these values due to the very small sample sizes for most cells. Some of the Laboratory cells appear suspect. The EUI for lodging buildings in the Mountain division appears to be a red flag for suspect data also. The variability for the “Other” building type is also dramatic.

These EUI data provide an additional window onto the limits of the CBECS sampling methodology, but all the data together offer a possible opportunity for taking this extrapolation and developing final recommended cell values that could inform energy evaluations or energy assessments.

2012 Bulk-Sum EUI Ratio based on Adjusted Site Energy Use and Floor Area, kBtu/ft²											
PBA	Principal building activity	New	Middle	East	West	South	East	West			
		England	Atlantic	North Central	North Central	Atlantic	South Central	South Central	Mountain	Pacific	Total
01	Vacant	19.9	6.6	18.4	22.8	16.1	9.4	2.9	22.7	16.5	12.8
02	Office	82.3	102.2	85.4	67.5	63.1	78.9	69.3	70.7	68.1	77.5
04	Laboratory	256.2	163.9	274.6	70.8	236.4	289.2	258.5	410.0	278.9	242.8
05	Nonrefrigerated warehouse	45.1	29.3	38.4	28.6	25.3	26.4	37.4	36.9	18.9	29.2
06	Food sales	207.6	238.7	232.7	186.6	205.5	208.9	241.7	243.0	170.9	209.7
07	Public order and safety	93.4	114.9	73.4	131.6	92.8	51.3	89.0	65.5	89.0	92.8
08	Outpatient health care	79.2	103.3	95.2	126.7	82.6	70.9	94.8	105.3	72.9	94.9
11	Refrigerated warehouse	85.6	144.6	72.6	112.2	116.5	75.5	151.2	85.3	214.3	126.8
12	Religious worship	31.8	46.2	56.7	30.7	40.5	30.1	27.5	33.0	38.4	38.3
13	Public assembly	70.5	113.7	84.8	92.4	92.2	57.2	99.8	88.3	65.4	86.9
14	Education	69.6	87.7	72.5	77.7	62.6	72.7	59.4	62.6	62.9	68.8
15	Food service	200.0	287.9	330.3	215.0	304.4	237.3	358.0	236.3	271.0	283.1
16	Inpatient health care	236.5	228.2	238.9	224.4	219.2	259.8	237.9	206.9	244.2	233.3
17	Nursing	126.2	110.9	119.9	103.3	110.0	233.8	92.5	109.4	122.3	121.0
18	Lodging	106.9	89.3	91.7	99.4	86.1	68.9	76.4	199.9	68.8	92.3
23	Strip shopping mall	80.6	155.4	146.8	100.6	107.9	78.0	115.3	92.3	127.7	116.0
24	Enclosed mall	85.6	70.2	66.1	73.9	65.8	64.2	76.6	53.4	49.4	62.9
25	Retail other than mall	65.4	67.2	95.7	36.2	58.6	72.0	63.9	82.5	62.1	67.0
26	Service	56.1	66.5	68.6	47.2	74.3	58.3	48.6	48.4	48.6	59.4
91	Other	498.9	215.4	97.4	28.2	107.4	8.2	142.7	55.7	61.0	108.8
	Total	85.6	97.0	88.7	70.8	75.7	75.5	73.6	85.3	71.0	80.0

2012 Bulk-Sum EUI Ratio based on Adjusted Source Energy Use and Floor Area, kBtu/ft²											
PBA	Principal building activity	New	Middle	East	West	South	East	West			
		England	Atlantic	North Central	North Central	Atlantic	South Central	South Central	Mountain	Pacific	Total
01	Vacant	42.8	10.0	38.0	52.4	37.3	23.8	8.1	56.0	37.7	29.3
02	Office	166.5	230.3	196.1	165.6	167.9	196.9	189.1	157.5	175.7	187.8
04	Laboratory	539.2	404.0	555.8	156.2	538.7	678.7	595.1	1,107	499.9	519.4
05	Nonrefrigerated warehouse	72.2	61.6	75.2	69.2	63.4	67.0	102.5	65.8	47.5	67.8
06	Food sales	481.7	569.9	622.9	475.4	595.2	591.5	630.7	657.9	443.1	545.8
07	Public order and safety	194.9	231.1	134.1	245.8	216.4	141.8	235.0	167.9	172.4	199.1
08	Outpatient health care	177.0	232.9	227.4	276.2	240.3	186.5	248.3	206.6	173.6	225.5
11	Refrigerated warehouse	169.1	370.6	209.5	244.5	350.2	176.4	452.9	181.8	381.6	314.1
12	Religious worship	48.4	85.3	93.7	56.6	89.1	66.1	66.5	64.0	72.7	75.1
13	Public assembly	151.3	227.1	176.8	189.0	225.1	128.5	220.5	204.9	147.5	190.2
14	Education	118.3	156.2	137.7	169.7	150.7	172.3	145.5	134.2	132.7	146.2
15	Food service	429.4	609.2	666.7	467.5	659.7	522.1	734.8	484.1	573.9	598.0
16	Inpatient health care	428.0	419.2	453.1	438.3	453.1	508.1	507.8	400.9	487.9	458.2
17	Nursing	246.1	205.4	232.4	232.0	261.1	487.7	205.5	210.0	242.4	249.7
18	Lodging	240.4	181.5	189.4	217.4	206.2	150.2	176.5	361.8	145.5	196.9
23	Strip shopping mall	177.6	326.5	312.6	230.0	275.0	190.2	273.4	225.9	270.8	266.7
24	Enclosed mall	169.1	189.7	161.8	199.0	190.3	184.8	216.8	152.4	139.8	172.9
25	Retail other than mall	148.0	156.0	218.3	86.8	162.0	205.3	177.2	211.4	165.0	171.5
26	Service	103.2	116.3	122.9	93.4	156.2	120.8	95.6	89.9	114.4	116.9
91	Other	848.1	540.8	236.6	63.6	303.5	21.1	354.0	91.3	162.9	272.8
	Total	169.1	203.8	184.9	156.2	186.6	176.4	179.1	181.8	162.3	180.0

Internal Data Consistency

EPMI has published multiple reports that document internal consistency issues with CBECS and RECS (the residential sector survey), where calculating certain values can vary considerably, depending on the path chosen for the calculation. In the residential sector, after calculating (weighted) refrigerator energy use per person and the (weighted) total number of people in the country, multiplying kWh per person times number of people leads to total kWh for the country that is 30% higher than the value obtained using the refrigerator energy parameter directly. The opinion of EPMI is that the kWh per person calculation is probably more correct for the country.

Major variations in values of EUI for the commercial sector have shown up in previous CBECS data, but the 2012 data have been fairly consistent at the national level. Consistency is determined by comparing bulk-sum ratio EUIs to EUIs determined statistically from the entire sample using the sampling weights, where only minor differences between weighted-sample results and bulk-sum ratios should be found if the data are reasonably consistent internally. The practice of floor area masking, where buildings from one-half to one million square feet are put in categories (100,000 sq ft increments), and buildings larger than one million square feet are assigned a more obscure value, causes some issues. EPMI recommends using bulk-sum ratios, as reported in the tables above, for the most reliable sectoral EUIs, since EUIs calculated using the weights can vary unreasonably, typically being too high.

Surprisingly here, for office buildings, which have fairly good samples, the weighted EUIs by region are noticeably lower than some of the bulk-sum ratios. The sample sizes for office buildings are among the largest, but the results for the Mid-Atlantic cell may have issues.

Example of Checking Cell Values

The bulk sum EUIs for office buildings in all regions are higher than would be calculated directly using the CBECS weights, although relative standard errors might also be high but are not calculated here. The intent here is to go beyond limits imposed by statistical methods and to offer a starting point for expert knowledge and triangulation of cross-check data to be applied to extrapolate CBECS results. This paper offers a starting point, while others can choose to apply additional effort and knowledge to achieve a more refined extrapolation of some or all of the data.

A comparison of weighted mean CBECS site energy EUIs and bulk sum ratio EUIs for office building Census divisions is shown below. The mid-Atlantic bulk sum value appears suspect.

Comparison of Bulk-sum and CBECS mean weighted office site energy EUIs kBtu/ft²

	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific
Bulk-sum site EUI	82.3	102.2	85.4	67.5	63.1	78.9	69.3	70.7	68.1
CBECS site EUI	65.2	74.9	78.9	54.0	58.4	63.0	61.6	68.9	62.0
CBECS % of bulk-sum	79.2%	73.3%	92.4%	80.0%	92.5%	79.8%	88.9%	97.5%	91.1%

If some organization wished to further evaluate all the cell values presented here, checks such as this could be conducted to develop final recommended values of “average” EUIs or other parameters for each Census division. Other cross-tab extrapolations might also be considered worthwhile to develop.

Conclusion

The extrapolation results here offer an opportunity to develop recommendations on values to be used for individual cells or region columns or building type rows. While such an effort could be conducted here, this option will be left open for others to pursue if the value obtained is deemed worthwhile.

The intent of the effort presented here was to demonstrate the possibilities for pursuing such extrapolations. If studied effort can be directed at developing final recommendations on some or all of the data here, the benefit and usefulness of the CBECS results may be increased.