

# Additions and Corrections

The following presents additional information and technical errors found between June 15, 2019, and October 7, 2022, in the SI editions of the 2019, 2020, and 2021 *ASHRAE Handbook* volumes. (As of this date, we have not received errata for the 2020 or 2022 editions.) Occasional typographical errors and nonstandard symbol labels will be corrected in future volumes. The most current list of Handbook additions and corrections is on the ASHRAE web site ([www.ashrae.org](http://www.ashrae.org)).

The authors and editor encourage you to notify them if you find other technical errors. Please send corrections to: Handbook Editor, ASHRAE, 180 Technology Parkway, Peachtree Corners, GA, 30092, or e-mail [hkennedy@ashrae.org](mailto:hkennedy@ashrae.org).

## 2019 HVAC Applications

**First page of Contributors.** Charles Gullledge's employer should be listed as Environmental Air Systems, LLC.

**p. 11.14, Fig. 13.** Source year should be 2000, rather than 2007.

**p. 19.2, Table 1.** Source note should be "©ISO. This material is reproduced from ISO 14644-1:2015, with permission of the American National Standards Institute (ANSI) on behalf of the International Organization for Standardization. All rights reserved."

**Chapter 37, Tables 2 to 5.** The data in these tables have been updated for greater accuracy. Replacement tables are provided on pages A.2 to A.5.

**p. 51.21, Example 6, Solution.** In the line for 60 lavatories, change 46 L/h to 456 L/h. For storage tank capacity, remove "/s" from the units.

**p. 61.3, Fig. 2.** Bottom line of figure cut off. The figure in its entirety is as appears in the opposite column.

**End papers.** Title for Chapter 59 should be listed as "Indoor Air-flow Modeling," and Chapter 60 should be "Integrated Project Delivery and Building Design."

Consultant(s)
<ul style="list-style-type: none"> <li>• None</li> <li>• In-house security management</li> <li>• Outside security consultant</li> <li>• Government security (at time of design; confidential)</li> <li>• Government security (at time of construction; highly confidential)</li> </ul>
Risk Evaluation Status (see risk evaluation document for more detail)
<ul style="list-style-type: none"> <li>• Baseline: No specialized operations, tenants may be relocated, long-term nonoccupancy presents minimal challenge</li> <li>• Enhanced: Specialized or unique operations, larger facilities with high populations, long-term nonoccupancy undesirable</li> <li>• Critical: Highly specialized or unique operations, high importance or visibility, long-term nonoccupancy unacceptable</li> </ul>
Design Features: HVAC Security
<ul style="list-style-type: none"> <li>• List Features</li> </ul>
Design Features: Environmental Health and Safety
<ul style="list-style-type: none"> <li>• List systems with enhanced air filtration and MERV rating</li> <li>• List systems with enhanced safeties and alarms and types of devices used</li> <li>• List zoning application</li> <li>• List air intake minimum height above grade requirements</li> <li>• List equipment to be located above exterior historical flood level data</li> <li>• List systems to be on emergency power</li> </ul>
Commissioning, Operation, Maintenance, and Recommissioning
<ul style="list-style-type: none"> <li>• Commission beginning in design phase through construction phase</li> <li>• Continuous commissioning in warranty phase</li> <li>• Operation training and documentation beginning in design phase</li> <li>• Preventive maintenance work order ready to implement in construction/commissioning phase</li> <li>• Predictive maintenance features</li> <li>• Mode of operation: evacuation, shelter-in-place, uninterrupted operation (list systems by one of these three categories)</li> <li>• Recommissioning every (X) years by _____</li> </ul>

**Fig. 2 HVAC Security and Environmental Health and Safety Basis of Design Segment**  
(from 2019 Applications, p. 61.3)

## 2021 Fundamentals

**Chapter Updates.** Please go to [technologyportal.ashrae.org](http://technologyportal.ashrae.org) and log in to download updates to Chapters 1, 2, 5, 6, 13, 14, 16, 17, 18, 19, 20, 23, 24, 31, 34, 35, and 38. ASHRAE members should use their member login; nonmembers should contact ASHRAE customer service at [cservice@ashrae.org](mailto:cservice@ashrae.org) if they do not have a login.

Table 2 2012 Commercial Sector Floor Area and EUI Percentiles

Building Use	Calculated, Weighted			Calculated, Weighted Energy Use Index (EUI) Values Site Energy, MJ/yr per gross square metre					
	Number of Buildings, Thousand	Floor Area, 10 <sup>9</sup> m <sup>2</sup>	Actual Number of Buildings, N	Percentiles					
				10th	25th	50th	75th	90th	Mean
Administrative/professional office	558	0.84	766	218	361	588	828	1390	728
Bank/other financial	91	0.08	79	516	673	1002	1299	1723	1059
Bar/pub/lounge	71	0.03	60	493	772	1435	2618	3791	1909
Clinic/other health	87	0.12	135	279	497	718	1049	1726	900
College/university*	27	0.17	104	299	656	998	1449	1811	1231
Convenience store	79	0.03	47	707	1289	2486	4048	5154	2769
Convenience store with gas station	52	0.02	32	1402	2469	2802	3981	5287	3261
Courthouse/probation office	6	0.04	26	598	836	1056	1190	1461	1049
Distribution/shipping center	151	0.53	307	80	181	328	514	811	403
Dormitory/fraternity/sorority*	25	0.07	48	116	270	657	966	1379	681
Elementary/middle school	189	0.57	397	233	342	528	801	1238	647
Enclosed mall	1	0.08	34	306	489	707	805	1045	671
Entertainment/culture*	51	0.12	89	56	263	506	832	1362	682
Fast food	92	0.03	94	1088	2219	4671	7842	9585	5127
Fire station/police station	69	0.05	53	235	364	642	966	1591	746
Government office	113	0.25	205	243	450	654	927	1487	778
Grocery store/food market	45	0.07	48	1176	1518	2253	2657	3418	2219
High school	43	0.28	142	265	481	721	1048	1428	828
Hospital/inpatient health*	10	0.22	409	1075	1829	2348	3107	3622	2430
Hotel	30	0.24	159	482	645	747	1203	1876	1017
Laboratory*	16	0.04	41	507	841	1771	2924	7118	2425
Library*	24	0.07	37	321	509	793	972	1122	787
Medical office (diagnostic)	60	0.05	62	203	381	643	847	1164	692
Medical office (non-diagnostic)	50	0.03	42	262	337	580	725	1021	600
Mixed-use office	125	0.25	212	161	287	519	785	1305	635
Motel or inn	61	0.06	61	502	562	677	1313	1552	898
Non-refrigerated warehouse	427	0.50	350	23	72	197	452	849	305
Nursing home/assisted living	30	0.12	94	573	889	1255	1800	2196	1448
Other	109	0.14	87	14	186	450	1366	2641	1122
Other classroom education	62	0.07	62	157	267	446	1002	1311	646
Other food sales	1	0.00	2	2075	2470	2470	2470	2470	2381
Other food service	37	0.01	27	56	479	1155	2578	3649	1597
Other lodging	13	0.04	27	426	637	808	1446	1804	978
Other office	74	0.04	52	137	276	493	893	1484	684
Other public assembly	41	0.06	63	221	431	637	889	2083	848
Other public safety	9	0.04	22	855	1207	1345	1625	1625	1321
Other retail	59	0.03	41	265	451	807	1443	1912	951
Other service	114	0.06	83	154	276	545	1274	3887	1507
Post office/postal	30	0.04	26	337	515	717	878	1008	698
Preschool/daycare	68	0.04	50	320	441	736	1024	1387	844
Recreation	100	0.18	127	199	287	577	1114	1814	793
Refrigerated warehouse	8	0.04	21	285	401	955	2623	3446	1454
Religious worship	412	0.42	352	99	191	319	576	933	493
Repair shop	84	0.05	53	94	162	387	849	1315	566
Restaurant/cafeteria	179	0.10	180	680	1414	3218	5442	7391	3665
Retail store	336	0.42	294	126	259	574	939	1428	689
Self-storage	209	0.15	81	23	44	143	383	789	327
Social/meeting	135	0.09	98	90	201	418	1002	1400	630
Strip shopping mall	163	0.47	296	440	672	1175	2004	3011	1596
Vacant	296	0.30	247	8	45	127	343	573	240
Vehicle dealership/showroom	43	0.05	34	246	393	693	1143	1615	869
Vehicle service/repair	214	0.15	149	128	246	505	1011	1832	810
Vehicle storage/maintenance	176	0.12	113	64	188	368	836	1507	697
SUM or Mean for sector	5557	8.09	6720	101	262	563	1046	2182	982

Source: Oak Ridge National Laboratory, T. R. Sharp, calculated from U.S. DOE/EIA 2012 CBECS microdata.

\* District chilled water use and cost are not reflected in building EUIs and cost metrics because they were not reported in the CBECS public database. Analysis showed there was potential this could significantly impact some EUIs for these building use types: college/university, dormitory/fraternity/sorority, entertainment/culture, library, hospital/inpatient health, and laboratory. Commentary in this chapter will explain the impact of chilled water systems on these categories.

NOTE: Metrics will not exactly match those in CBECS Table PBA3 as shown on the CBECS website due to including propane and wood as energy sources and because EIA uses a database to generate Table PBA3 that is slightly different from the database they make available to the public.

Table 3 2012 Commercial Sector Floor Area and Source EUI Percentiles

Building Use	Calculated, Weighted		Actual Number of Buildings, N	Calculated, Weighted Energy Use Index (EUI) Values					
	Number of Buildings, Thousand	Floor Area, 10 <sup>9</sup> m <sup>2</sup>		Source Energy, MJ/yr per gross square metre					
				Percentiles					
				10th	25th	50th	75th	90th	Mean
Administrative/professional office	558	0.84	766	554	880	1395	2061	3517	1797
Bank/other financial	91	0.08	79	1285	1663	2653	3409	4193	2708
Bar/pub/lounge	71	0.03	60	1228	1920	3454	6073	7906	4274
Clinic/other health	87	0.12	135	742	1207	1785	2622	4703	2233
College/university	27	0.17	104	886	1582	2436	2981	4349	2824
Convenience store	79	0.03	47	2120	3924	7469	12750	15798	8143
Convenience store with gas station	52	0.02	32	3797	7396	8692	12091	16134	9365
Courthouse/probation office	6	0.04	26	1483	1822	2532	2757	3622	2442
Distribution/shipping center	151	0.53	307	207	431	797	1315	1822	928
Dormitory/fraternity/sorority	25	0.07	48	365	801	1341	2189	2370	1529
Elementary/middle school	189	0.57	397	612	907	1263	1758	2683	1514
Enclosed mall	1	0.08	34	404	1479	2121	2438	3030	1887
Entertainment/culture	51	0.12	89	170	550	893	1961	3604	1641
Fast food	92	0.03	94	2732	6277	11451	17338	21630	12082
Fire station/police station	69	0.05	53	510	731	1263	2236	2861	1621
Government office	113	0.25	205	653	1159	1755	2631	3337	1976
Grocery store/food market	45	0.07	48	3092	4749	5627	7478	8789	6002
High school	43	0.28	142	756	1095	1701	2340	3258	1899
Hospital/inpatient health	10	0.22	409	2560	3977	5533	6720	7790	5358
Hotel	30	0.24	159	1207	1472	2060	2623	4362	2452
Laboratory	16	0.04	41	1488	2040	4066	5857	13045	5872
Library	24	0.07	37	1012	1602	1861	2436	2562	1952
Medical office (diagnostic)	60	0.05	62	431	912	1541	2295	2871	1793
Medical office (non-diagnostic)	50	0.03	42	711	989	1524	1832	2259	1532
Mixed-use office	125	0.25	212	391	735	1316	1978	2858	1549
Motel or inn	61	0.06	61	1007	1531	1841	2952	4311	2310
Non-refrigerated warehouse	427	0.50	350	67	215	538	1102	1737	739
Nursing home/assisted living	30	0.12	94	1109	1902	2667	4321	5488	3106
Other	109	0.14	87	44	548	1017	2686	6977	2461
Other classroom education	62	0.07	62	447	669	1033	1858	2332	1316
Other food sales	1	0.00	2	5123	5976	5976	5976	5976	5784
Other food service	37	0.01	27	177	1425	3114	7032	11496	4493
Other lodging	13	0.04	27	925	990	1791	3051	3947	2011
Other office	74	0.04	52	433	758	1155	2138	2891	1537
Other public assembly	41	0.06	63	689	912	1201	1807	3805	1838
Other public safety	9	0.04	22	1879	2771	3464	4183	4786	3523
Other retail	59	0.03	41	427	1047	2040	3433	5314	2477
Other service	114	0.06	83	388	707	1273	2387	8343	2745
Post office/postal	30	0.04	26	724	1279	1644	1835	2231	1587
Preschool/daycare	68	0.04	50	802	1115	1606	2351	3269	2077
Recreation	100	0.18	127	453	654	1357	2507	4117	1887
Refrigerated warehouse	8	0.04	21	541	1264	3009	5597	10856	4389
Religious worship	412	0.42	352	224	431	667	1073	1849	938
Repair shop	84	0.05	53	298	447	932	1794	2676	1164
Restaurant/cafeteria	179	0.10	180	1875	3174	6698	11094	14522	7691
Retail store	336	0.42	294	385	654	1478	2447	3750	1755
Self-storage	209	0.15	81	71	137	449	1035	2486	981
Social/meeting	135	0.09	98	319	581	1195	1945	3740	1508
Strip shopping mall	163	0.47	296	1171	1934	2947	4726	6053	3678
Vacant	296	0.30	247	26	114	274	711	1251	545
Vehicle dealership/showroom	43	0.05	34	516	1009	1522	2963	3990	2081
Vehicle service/repair	214	0.15	149	350	675	1247	2069	3361	1617
Vehicle storage/maintenance	176	0.12	113	182	471	861	1416	3278	1485
SUM or Mean for sector	5557	8.09	6720	300	669	1351	2536	5225	2336

Source: Oak Ridge National Laboratory, T. R. Sharp, calculated from U.S. DOE/EIA 2012 CBECS microdata.

\* District chilled water use and cost are not reflected in building EUIs and cost metrics because they were not reported in the CBECS public database. Analysis showed there was potential this could significantly impact some EUIs for these building use types: college/university, dormitory/fraternity/sorority, entertainment/culture, library, hospital/inpatient health, and laboratory. Commentary in this chapter will explain the impact of chilled water systems on these categories.

Table 4 Electricity Index Percentiles from 2012 Commercial Survey

Building Use	Weighted Electricity Use Index Values, kWh/yr per gross square metre					
	Percentiles					
	10th	25th	50th	75th	90th	Mean
Administrative/professional office	35	59	104	164	264	135
Bank/other financial	94	118	204	260	357	209
Bar/pub/lounge	96	122	272	412	494	294
Clinic/other health	52	77	141	201	329	169
College/university	66	100	158	214	300	189
Convenience store	177	317	531	1119	1301	691
Convenience store with gas station	302	611	735	1021	1233	783
Courthouse/probation office	85	142	185	197	258	172
Distribution/shipping center	11	25	54	90	136	66
Dormitory/fraternity/sorority	32	54	91	139	185	102
Elementary/middle school	47	61	87	127	199	109
Enclosed mall	9	120	174	215	247	155
Entertainment/culture	10	19	72	142	274	120
Fast food	182	463	794	1289	1637	876
Fire station/police station	21	42	84	157	243	108
Government office	51	84	128	182	273	151
Grocery store/food market	244	375	465	588	693	483
High school	43	67	113	168	260	133
Hospital/inpatient health	179	218	347	475	489	356
Hotel	79	102	147	195	313	181
Laboratory	126	152	356	433	713	433
Library	89	113	156	167	195	145
Medical office (diagnostic)	34	51	123	179	247	140
Medical office (non-diagnostic)	43	71	97	155	168	118
Mixed-use office	23	47	93	143	204	115
Motel or inn	61	130	160	228	364	179
Non-refrigerated warehouse	5	15	38	72	126	55
Nursing home/assisted living	55	115	187	296	382	205
Other	3	22	53	180	547	163
Other classroom education	13	28	74	116	159	82
Other food sales	386	443	443	443	443	430
Other food service	16	95	234	612	1014	370
Other lodging	30	33	94	162	267	127
Other office	35	43	80	105	182	106
Other public assembly	39	51	76	135	318	121
Other public safety	111	172	289	366	407	278
Other retail	29	69	153	241	469	194
Other service	23	46	79	165	315	148
Post office/postal	48	80	111	143	153	111
Preschool/daycare	30	83	122	178	256	155
Recreation	16	41	80	193	357	136
Refrigerated warehouse	31	111	265	494	957	378
Religious worship	13	23	38	63	119	54
Repair shop	19	33	56	109	141	72
Restaurant/cafeteria	116	209	414	730	929	493
Retail store	26	48	99	192	291	134
Self-storage	6	12	34	91	219	84
Social/meeting	16	31	68	118	307	105
Strip shopping mall	102	149	215	300	433	261
Vacant	1	9	18	40	101	38
Vehicle dealership/showroom	18	57	95	232	324	151
Vehicle service/repair	21	49	80	125	182	96
Vehicle storage/maintenance	5	22	53	97	214	95
Mean for sector	18	41	94	184	385	168

Source: Oak Ridge National Laboratory, T. R. Sharp, calculated from U.S. DOE/EIA 2012 CBECs microdata.

Table 5 Energy Cost Percentiles from 2012 Commercial Survey

Building Use	Weighted Energy Cost Values, \$/yr per gross square metre					
	Percentiles					
	10th	25th	50th	75th	90th	Mean
Administrative/professional office	5.70	9.25	14.10	21.30	33.46	17.86
Bank/other financial	10.65	13.88	22.92	32.50	40.35	23.67
Bar/pub/lounge	12.91	17.54	27.65	48.31	87.48	38.09
Clinic/other health	5.60	10.22	19.05	23.67	34.86	20.01
College/university	8.93	12.91	20.55	26.58	45.41	23.03
Convenience store	17.00	30.34	52.19	88.55	170.65	73.92
Convenience store with gas station	34.75	44.22	67.36	98.56	107.71	76.07
Courthouse/probation office	11.19	13.77	26.15	37.98	51.11	28.62
Distribution/shipping center	2.26	3.66	6.99	11.73	18.94	8.82
Dormitory/fraternity/sorority	5.27	6.35	11.94	18.61	25.39	13.02
Elementary/middle school	6.03	8.61	12.16	17.00	24.86	14.31
Enclosed mall	3.23	10.11	16.89	20.98	26.15	15.39
Entertainment/culture	2.04	5.60	11.62	17.86	29.37	15.49
Fast food	31.85	62.73	98.35	139.56	175.28	102.33
Fire station/police station	4.20	5.60	10.33	17.43	28.94	13.99
Government office	5.70	8.82	14.53	22.17	30.99	17.86
Grocery store/food market	23.35	40.03	50.25	69.51	75.54	52.83
High school	6.56	9.58	14.20	19.26	28.08	17.54
Hospital/inpatient health	21.09	29.81	39.27	51.43	67.57	42.39
Hotel	9.25	11.94	15.17	23.03	35.08	20.12
Laboratory	17.97	24.86	36.15	56.38	118.58	52.19
Library	8.72	15.17	17.97	24.32	33.57	19.48
Medical office (diagnostic)	6.78	10.11	16.46	22.27	35.40	18.18
Medical office (non-diagnostic)	6.03	9.04	13.67	17.22	30.34	14.96
Mixed-use office	3.77	7.42	13.45	20.87	30.24	15.60
Motel or inn	6.99	12.27	18.83	23.03	33.03	19.05
Non-refrigerated warehouse	0.75	2.47	5.81	9.79	16.25	7.42
Nursing home/assisted living	10.65	14.31	22.06	37.44	62.52	27.65
Other	0.97	4.84	7.85	23.24	60.47	25.39
Other classroom education	2.37	5.49	10.76	17.32	24.75	11.73
Other food sales	38.20	38.20	38.20	38.20	43.79	39.38
Other food service	1.29	10.01	31.85	82.64	92.97	46.05
Other lodging	8.50	8.72	14.10	20.34	24.53	16.03
Other office	3.55	6.99	12.37	16.89	26.04	15.60
Other public assembly	6.03	8.29	10.65	14.42	31.74	15.60
Other public safety	14.63	18.83	21.95	31.53	31.53	23.03
Other retail	5.49	10.11	16.89	35.40	54.23	24.32
Other service	3.44	6.13	11.19	24.75	59.18	23.03
Post office/postal	7.64	10.11	13.45	17.32	21.74	14.10
Preschool/daycare	9.04	12.05	15.71	21.63	36.26	18.61
Recreation	4.09	7.42	11.94	27.01	46.81	19.15
Refrigerated warehouse	8.18	9.68	25.29	41.00	95.33	37.44
Religious worship	2.15	3.87	6.35	10.11	15.28	8.39
Repair shop	2.37	4.73	9.68	14.31	26.68	11.41
Restaurant/cafeteria	15.17	28.73	53.80	84.04	118.79	61.76
Retail store	4.20	7.32	12.48	21.52	34.11	16.79
Self-storage	0.65	1.40	3.34	8.61	27.44	9.68
Social/meeting	2.80	5.06	9.15	16.03	32.06	12.91
Strip shopping mall	9.58	15.60	24.10	37.66	52.19	30.02
Vacant	0.65	1.40	3.23	7.32	13.34	5.38
Vehicle dealership/showroom	4.30	9.36	13.56	26.36	42.18	20.12
Vehicle service/repair	3.44	7.64	12.48	17.00	35.51	15.92
Vehicle storage/maintenance	1.83	4.52	9.36	17.11	26.68	14.53
Mean for sector	3.12	6.56	12.70	22.92	46.59	21.09

Source: Oak Ridge National Laboratory, T. R. Sharp, calculated from U.S. DOE/EIA 2012 CBECs microdata.

\* District chilled water use and cost are not reflected in building EUIs and cost metrics because they were not reported in the CBECs public database. Analysis showed there was potential this could significantly impact some EUIs for these building use types: college/university, dormitory/fraternity/sorority, entertainment/culture, library, hospital/inpatient health, and laboratory. Commentary in this chapter will explain the impact of chilled water systems on these categories.

