

APPENDIX M. DERIVATION OF HEATING LOAD HOURS

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APPENDIX M: DERIVATION OF HEATING LOAD HOURS

M.1 Purpose of using Heating Load Hours (HLH) in LCC Analysis

Using HLH permits a more accurate calculation of the electricity contribution to the house heating load (HHL). The calculation of the HHL for the existing household in the LCC spreadsheet is shown in Eq. M-1:

$$HHL = Q_{in,RECS} * AFUE_{ex} + BE_{ex} * \left[BOH_{ex} + N * HLH * \left(\frac{t^+ - t^-}{3600} \right) \right] \text{Eq. M-1}$$

where,

$Q_{YR,RECS}$	=	fuel used for heating per year of the existing household, (BTU/h),
$AFUE_{ex}$	=	AFUE for existing household (see Chapter 7 Section 7.4.3 for household assignment), (%)
3.412	=	constant to convert kW to kBtu/hr,
BE_{ex}	=	calculation of baseline BE for the household (see Chapter 7 Section 7.5.3 for the calculation of BE for the baseline furnaces; the power consumption of boilers circulating pump motor is 62 watts for the baseline model design ¹), (kW),
BOH_{ex}	=	$Q_{YR,RECS}$ divided by input capacity (see Chapter 7 Section 7.6), (h),
N	=	number of cycles per hour (set equal to 5 for furnaces and 2 for boilers) ² , (cycles/h),
HLH	=	heating load hours (as defined in section M.2), (h),
t^+	=	off delay (see Chapter 7 Section 7.2.7 for values used), (min), and
t^-	=	on delay (see Chapter 7 Section 7.2.7 for values used) (min).

M.2 Derivation of Heating Load Hours (HLH)

The heating load hours (HLH) is defined in Eq. M-2 as³:

$$HLH = \frac{24 * HDD}{65 - ODT} \text{Eq. M-2}$$

where,

24	=	number of hours in one day (h/d),
HDD	=	heating degree days, (d),
ODT	=	outdoor design temperature, (F°) and
65	=	typical average outdoor temperature at which a furnace or boiler starts operating, (F°).

M.2.1 HLH Calculation Methodology

The Energy Information Administration (EIA)'s Residential Energy Consumption Survey of 2001 (RECS 2001)⁴ data include heating degree days (HDD) for individual households, but does not calculate outdoor design temperature (ODT). To calculate HLH, DOE gathered HDD, cooling degree days (CDD), and ODT data for individual cities in the U.S. and matched RECS 2001 data using household's location defined by its census division and four large state designation, CDD, and HDD. Due to confidentiality issues with the RECS 2001 data HDD and CDD are averaged for a number of households over their census division or large state designation. Therefore, there are only 255 individual HDD and CDD combinations for the 4822 individual households. DOE matched ODT data to these 255 individual combinations, not to individual households.

DOE gathered HDD and CDD data for over 5000 cities using U.S. climate data^{5,6}. We used the 1993 ASHRAE Handbook Fundamentals⁷ to gather ODT data for 753 cities and the 97.5 percent ODT used by NIST³ to calculate HLH. From these sources, DOE matched 660 cities that had both ODT, HDD, and CDD data. See Figures M.2.1 and M.2.2 to see the relationship between ODT and HDD and between ODT and CDD.

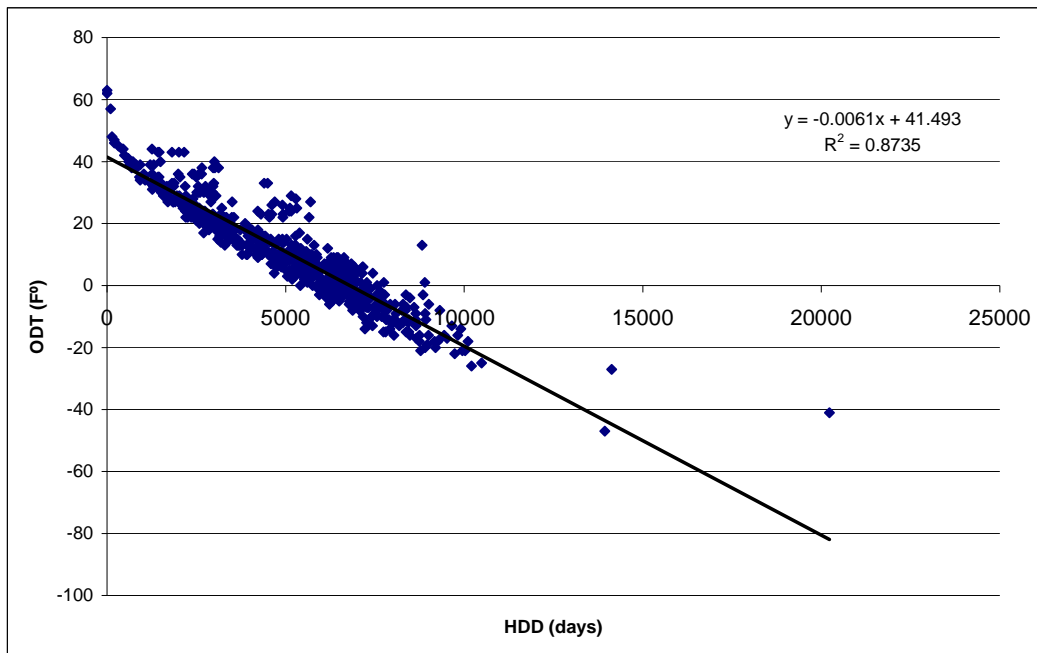


Figure M.2.1 Heating Degree Days (HDD) vs. Outdoor Design Temperature (ODT)

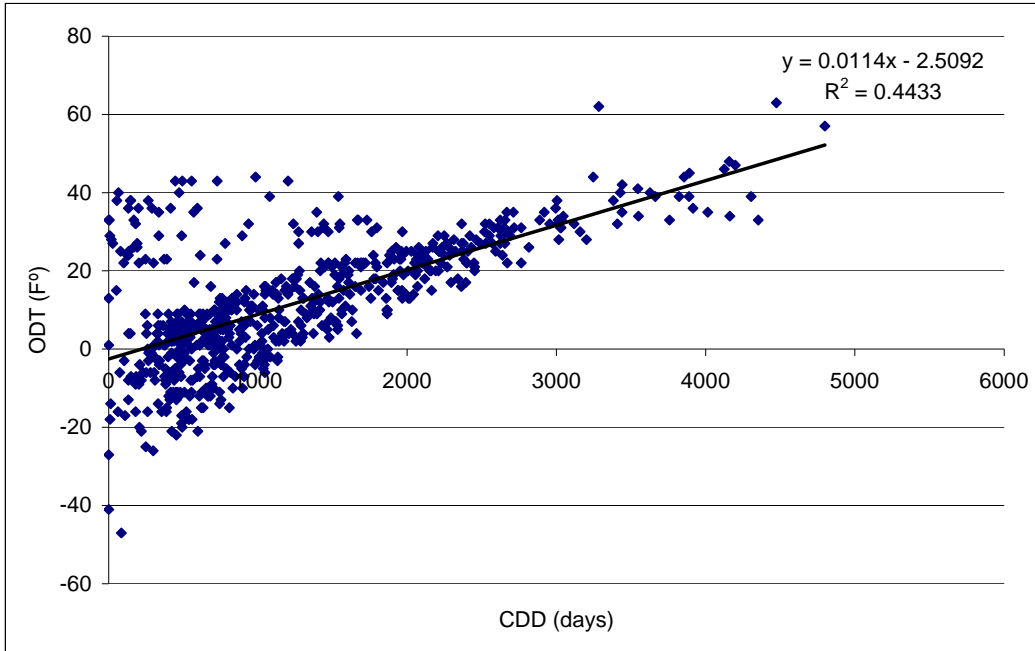


Figure M.2.2 Cooling Degree Days (CDD) vs. Outdoor Design Temperature (ODT)

M.2.1.1 ODT Imputation Method

To calculate ODT, DOE matched the RECS 2001 combinations (255 individual combinations of census divisions plus 4 large states, HDD, and CDD) to U.S. weather data. DOE used the U.S. weather station closest (or with minimum “distance”) from the RECS 2001 data combination. Eq. M-3 calculates the “distance” between the U.S. weather data and RECS 2001 data:

$$\text{"Distance"} = \sqrt{(HDD_2 - HDD_1)^2 + (CDD_2 - CDD_1)^2} \quad \text{Eq. M-3}$$

where,

- HDD_1 = heating degree days from U.S. weather data,
- HDD_2 = heating degree days from RECS 2001 data,
- CDD_1 = cooling degree days from U.S. weather data, and
- CDD_2 = cooling degree days from RECS 2001 data.

Figure M.2.3 shows the relationship between the imputed ODT values and the RECS 2001 HDD values.

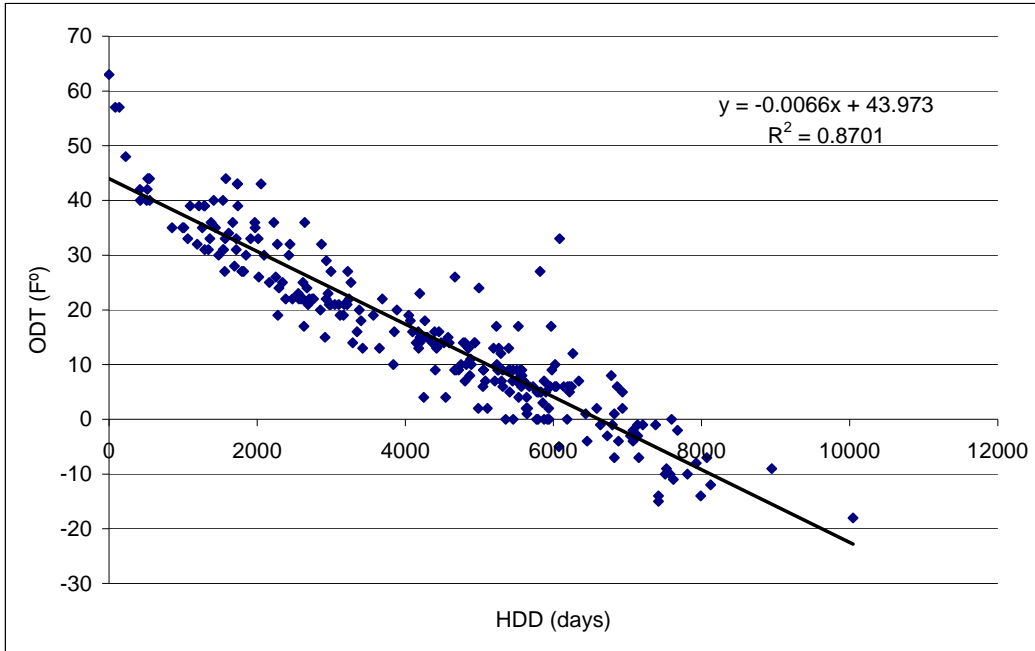


Figure M.2.3 Heating Degree Days (HDD) vs. Imputed Outdoor Design Temperature (ODT) Values

Table M.2.1 shows the imputation results.

Table M.2.1 Imputation Results

Division + 4	HDD65	CDD65	ODT
1	5053	903	9
1	5247	820	9
1	5256	613	9
1	5312	777	9
1	5397	760	9
1	5415	753	9
1	5455	583	9
1	5456	887	0
1	5549	769	9
1	5791	781	0
1	5872	711	0
1	5914	696	0
1	5939	708	0
1	5978	671	9
1	6183	761	0
1	6433	590	1
1	6822	447	-7
1	8072	416	-7
1	8948	191	-9
2	4148	1225	14
2	4168	1404	14
2	4398	1271	14
2	4484	1070	14
2	4781	1045	14
2	4807	1027	14
2	4850	961	13
2	4880	983	11
2	4931	1083	14
2	4940	1027	14
2	5190	743	13
2	5235	801	10
2	5263	704	13
2	5289	881	12
2	5395	719	13
2	5508	596	9
2	5560	714	8
2	5573	589	9
2	5631	714	2
2	5651	722	2
2	5826	608	5

Division + 4	HDD65	CDD65	ODT				
2	5831	515	5	4	4984	1270	2
2	6340	377	7	4	5106	1297	2
3	4683	1411	9	4	5771	980	0
3	4752	974	10	4	6456	940	-4
3	4806	1231	7	4	6727	711	-3
3	4824	1048	10	4	7153	922	-7
3	4889	1083	10	4	7506	647	-10
3	5046	1149	6	4	7574	708	-10
3	5080	902	7	4	7617	738	-11
3	5207	847	7	4	7808	654	-10
3	5297	740	7	4	7988	777	-14
3	5316	1154	6	4	8122	711	-12
3	5409	1072	5	5	2164	1936	25
3	5501	696	7	5	2251	1902	26
3	5513	740	7	5	2474	1669	22
3	5530	1064	4	5	2554	1535	23
3	5590	715	7	5	2592	1648	22
3	5598	697	7	5	2672	1770	24
3	5637	863	4	5	2742	1669	22
3	5641	973	1	5	2932	1643	22
3	5725	606	6	5	2957	1555	23
3	5777	802	5	5	2971	1367	21
3	5800	735	5	5	2992	1352	21
3	5855	931	3	5	2997	1330	27
3	5873	673	7	5	3047	1420	21
3	5936	849	2	5	3100	1479	21
3	6019	537	6	5	3118	1497	19
3	6041	746	6	5	3163	1536	19
3	6139	516	6	5	3175	1422	21
3	6215	620	5	5	3213	1414	21
3	6633	729	-1	5	3222	1290	27
3	6796	713	-1	5	3241	1463	22
3	6877	693	-4	5	3377	1356	20
3	6932	642	5	5	3687	1424	22
3	7038	567	-3	5	3885	1301	20
3	7076	722	-4	5	4068	1139	18
3	7137	546	-3	5	4095	1025	16
3	7526	653	-9	5	4263	1125	18
3	7927	590	-8	5	4364	1105	14
4	4174	1419	16	5	4394	1072	16
4	4198	1573	15	5	4454	1030	16
4	4249	1713	4	5	4520	837	14
4	4404	1377	9	5	4591	1133	14
4	4422	1545	13	6	1291	2716	31
4	4545	1637	4	6	2384	1955	22
4	4665	1294	9	6	2565	1833	22
4	4720	1405	9	6	2620	1797	22
4	4873	1114	8	6	2760	1907	22
				6	3424	1430	13

Division + 4	HDD65	CDD65	ODT				
6	3568	1206	19	10	4575	1029	15
6	3649	1315	13	10	5947	789	6
6	3836	1626	10	10	5957	638	6
6	3851	1074	16	10	6191	684	6
6	4047	1269	19	10	6217	653	6
6	4193	981	14	10	6243	571	6
7	1437	2704	35	10	6820	325	1
7	1562	2502	27	10	6932	400	2
7	1718	2604	31	10	7675	145	-2
7	1816	2578	27	11	1258	1314	35
7	2629	2490	17	11	1281	1058	39
7	2915	2115	15	11	1290	1050	39
7	3287	2078	14	11	1359	1704	33
7	3348	2374	16	11	1413	544	40
8	1093	5161	39	11	1539	446	40
8	1212	4612	39	11	1576	960	44
8	1615	3949	34	11	1669	311	36
8	1692	3509	28	11	1718	3745	33
8	2277	2067	19	11	1730	646	43
8	2686	2255	21	11	1734	1137	43
8	3266	1911	25	11	1737	1066	39
8	5356	1018	0	11	1849	2041	30
8	5447	1109	7	11	1912	1856	33
8	5566	905	6	11	1967	152	36
8	5576	663	8	11	1971	579	35
8	5675	912	6	11	2013	1787	33
8	6022	789	10	11	2050	1107	43
8	6074	592	-5	11	2094	1820	30
8	6262	703	12	11	2223	234	36
8	6583	426	2	11	2273	1528	32
8	6781	1037	8	11	2427	1522	30
8	7075	859	-2	11	2443	828	32
8	7134	431	-1	11	2642	135	36
8	7205	235	-1	11	2705	1676	22
8	7379	298	-1	11	2869	2256	32
8	7418	346	-14	11	2935	290	29
8	7419	790	-15	11	5228	310	17
8	7594	538	0	11	5524	256	17
9	0	4912	63	11	5968	463	17
9	4195	357	23	11	6083	106	33
9	4670	106	26	12	1189	3086	32
9	4993	71	24	12	1342	2806	31
9	5821	35	27	12	1376	2947	36
9	5897	531	5	12	1542	2995	31
9	6860	357	6	12	1545	2521	31
9	10045	0	-18	12	1568	2875	33
10	4242	1251	15	12	1791	2510	27
10	4298	1216	15	12	2022	2916	26
				12	2294	2642	24

Division + 4	HDD65	CDD65	ODT
12	2340	2580	25
12	2619	2574	25
12	2852	2242	20
12	3402	1937	18
12	4180	1622	13
12	4280	1828	15
13	83	4553	57
13	138	4546	57
13	224	4151	48
13	416	3458	42
13	421	3675	40
13	508	3665	40
13	516	3494	42
13	522	3308	44
13	545	3294	44
13	550	3661	40
13	849	2806	35
13	992	2726	35
13	1010	2723	35
13	1061	2628	33
13	1480	2225	30

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