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:

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

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 as[3]:

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

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 Fundamentals[7] to gather ODT data for 753 cities and the 97.5 percent ODT used by NIST[3] 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.

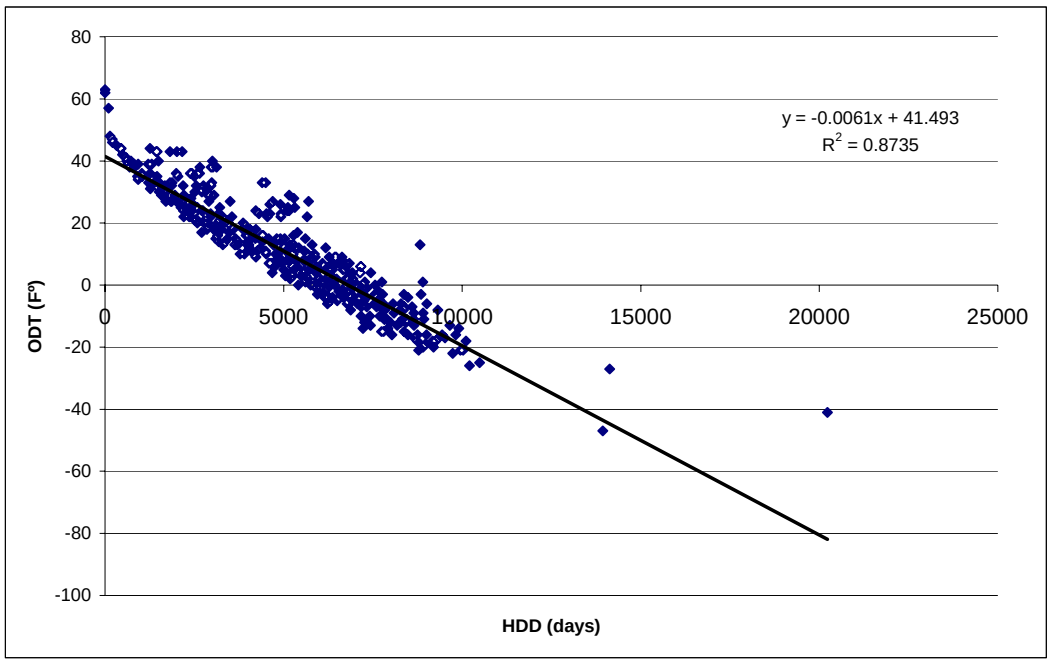

Figure M.2.1 Heating Degree Days (HDD) vs. Outdoor Design Temperature (ODT)

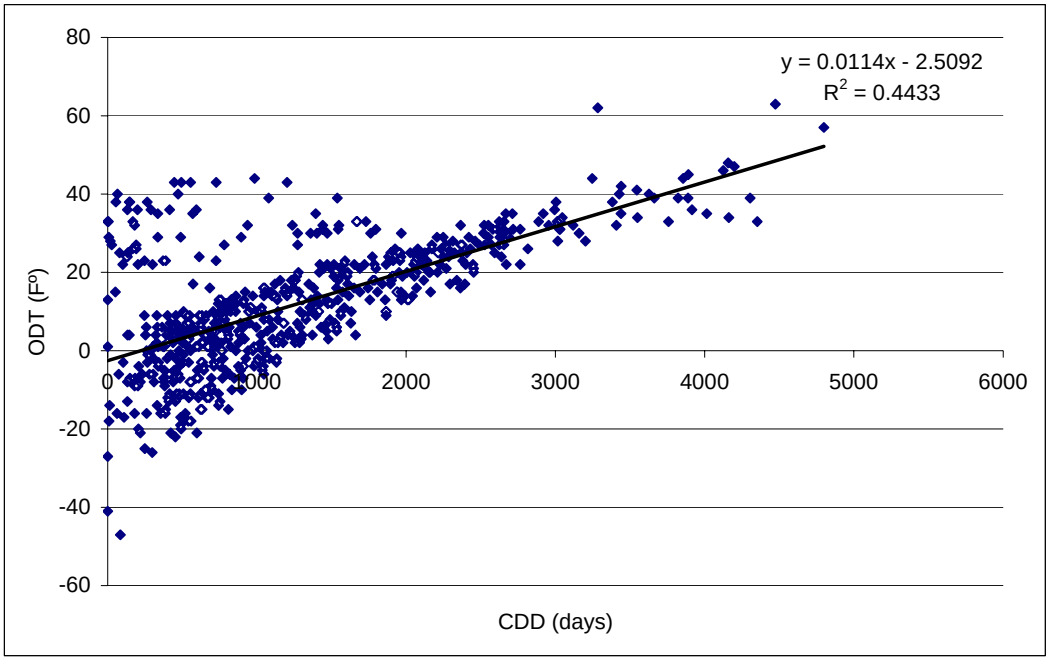

Figure M.2.2 Cooling Degree Days (CDD) vs. Outdoor Design Temperature (ODT)

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:

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

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.

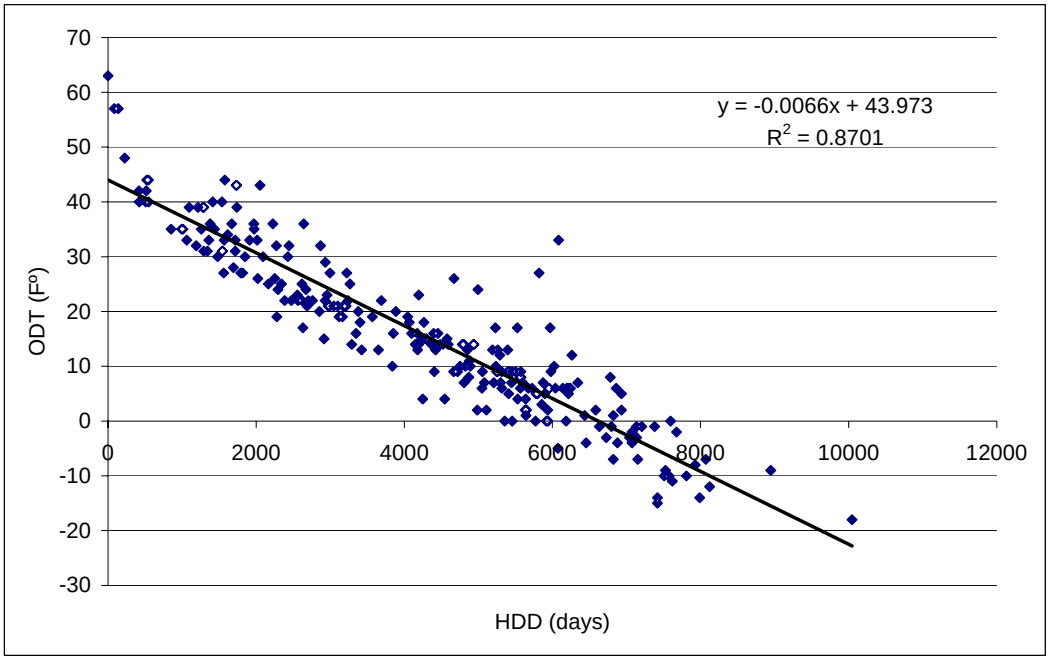

Figure M.2.3 Heating Degree Days (HDD) vs. Imputed Outdoor Design Temperature (ODT) Values

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
2	5831	515	5
2	6340	377	7

Division + 4	HDD65	CDD65	ODT
3	4683	1411	9
3	4752	974	10
3	4806	1231	7
3	4824	1048	10
3	4889	1083	10
3	5046	1149	6
3	5080	902	7
3	5207	847	7
3	5297	740	7
3	5316	1154	6
3	5409	1072	5
3	5501	696	7
3	5513	740	7
3	5530	1064	4
3	5590	715	7
3	5598	697	7
3	5637	863	4
3	5641	973	1
3	5725	606	6
3	5777	802	5
3	5800	735	5
3	5855	931	3
3	5873	673	7
3	5936	849	2
3	6019	537	6
3	6041	746	6
3	6139	516	6
3	6215	620	5
3	6633	729	-1
3	6796	713	-1
3	6877	693	-4
3	6932	642	5
3	7038	567	-3
3	7076	722	-4
3	7137	546	-3
3	7526	653	-9
3	7927	590	-8
4	4174	1419	16
4	4198	1573	15
4	4249	1713	4
4	4404	1377	9
4	4422	1545	13
4	4545	1637	4
4	4665	1294	9
4	4720	1405	9
4	4873	1114	8
4	4984	1270	2
4	5106	1297	2
4	5771	980	0
4	6456	940	-4
4	6727	711	-3
4	7153	922	-7
4	7506	647	-10
4	7574	708	-10
4	7617	738	-11
4	7808	654	-10
4	7988	777	-14
4	8122	711	-12
5	2164	1936	25
5	2251	1902	26
5	2474	1669	22
5	2554	1535	23
5	2592	1648	22
5	2672	1770	24
5	2742	1669	22
5	2932	1643	22
5	2957	1555	23
5	2971	1367	21
5	2992	1352	21
5	2997	1330	27
5	3047	1420	21
5	3100	1479	21
5	3118	1497	19
5	3163	1536	19
5	3175	1422	21
5	3213	1414	21
5	3222	1290	27
5	3241	1463	22
5	3377	1356	20
5	3687	1424	22
5	3885	1301	20
5	4068	1139	18
5	4095	1025	16
5	4263	1125	18
5	4364	1105	14
5	4394	1072	16
5	4454	1030	16
5	4520	837	14
5	4591	1133	14
6	1291	2716	31
6	2384	1955	22
6	2565	1833	22
6	2620	1797	22
6	2760	1907	22
6	3424	1430	13
6	3568	1206	19

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