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Wood Stove Use in the End-Use Load and Consumer Assessment Program Residential Base Sample

B. A. LeBaron

November 1988

**Prepared for the
Bonneville Power Administration
under a Related Services Agreement
with the U.S. Department of Energy
Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

NTIS Price Codes
Microfiche A01

Printed Copy

Pages	Price Codes
001-025	A02
026-050	A03
051-075	A04
076-100	A05
101-125	A06
126-150	A07
151-175	A08
176-200	A09
201-225	A10
226-250	A11
251-275	A12
276-300	A13

WOOD STOVE USE IN THE END-USE LOAD AND
CONSUMER ASSESSMENT PROGRAM
RESIDENTIAL BASE SAMPLE

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Pacific Northwest Laboratory
Richland, Washington 99352

EXECUTIVE SUMMARY

This report examines wood heating in the End-Use Load and Consumer Assessment Program (ELCAP) Residential Base Sample during the 1985/1986 heating season. The goals of this study were to assess the frequency of wood burning in homes having wood burning equipment and to estimate the quantity of electrical space heat displaced by its use.

In the ELCAP Residential Base Sample, 43% of the residences had the capability for major wood heating (wood stoves) and an additional 28% had minor wood heating capabilities (fireplaces). However, only 24% of the total sample actually used wood burning equipment as their primary heat source. Throughout this report, the term wood stove will be used to describe both wood stove and fireplace equipment. The use of wood for wood burning is examined from August 18, 1985, through May 31, 1986 (287 days); this time period is defined as the heating season. Not all sites had data for the entire study period; consequently, only the 68 sites that had at least 50% of the possible data were used. This restriction minimizes the chance of seasonal bias.

Wood stove operation and electrical space heating were monitored at each site by a microprocessor-controlled data logger. This allowed precise knowledge of electrical consumption and frequency of wood stove use over short periods of time. For each site, the days are partitioned into two groups: days when wood burning equipment was used and days when it was not. Days containing missing data are not included. This classification permits examination of seasonal patterns of use and comparisons between wood-use and nonwood-use electrical space heating loads.

Patterns of wood stove usage were investigated on both a seasonal level and a daily level. The results permit several main conclusions about the usage of wood stoves in the ELCAP Residential Base sample:

- More than half the households that have wood stoves use them for space heating throughout the heating season. There are, however, wood households in the sample that never use their wood.

- During the coldest months, the frequency of wood use is strongly bimodal, with large groups either burning wood almost every day or quite rarely, and with relatively few homes at intermediate levels of wood-use frequency.
- Diurnal profiles of wood use aggregated across a reasonable number of sites are qualitatively similar to those for other forms of heat and, in particular, for electrical space heat. The principal difference for wood heat is that evening use is larger than morning use; the converse is generally true for electric heat.
- The dispersion in usage behavior across the sample of sites studied is quite large for all hours of the day.

Quantifying the affect of wood use on residential space heating is very important to thermal performance analysis. An investigation of the amount of electrical space heating displaced by wood use was made for both individual sites and for the sample as a whole. The results of this examination can be summarized as follows:

- The envelope performance analysis used to assess conservation performance in the Residential Standards Demonstration Program is strongly affected by wood stove use. Daily duration of wood burning is directly related to the amount of electrical space heating displaced.
- Daily electrical heating load shapes show an overall reduction throughout the heating season for days when there is wood heating. In particular, maximum displacement occurs during the morning and evening hours reflecting the periods when wood burning is heaviest.
- The two-parameter regression employed to model heating displacement for individual structures provides site-specific estimates but can only be applied to the light to moderate wood users. Thus, this method's resulting sample mean savings estimate of 1502 kWh/year for the 1985/1986 heating season is correspondingly low.
- Monthly and annual estimates of electrical space heating displacement derived by differencing aggregate load profiles for wood use

and nonwood use provide reasonable sample values. Homes that burned wood in this study displaced an average of 1951 kWh of electrical space heating during the 1985/1986 heating season.

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INTRODUCTION

1.1 BACKGROUND

Wood has been used as a residential heating fuel for thousands of years. Its popularity as a heating fuel in the United States has generally declined since the turn of the century because of the declining price and convenience of electricity and fossil fuels. However, since the mid-1970s, residential wood use has experienced a revival following the surge in conventional heating costs. It has been estimated that approximately 20 million households currently burn wood and, of these, about 30% use wood as their primary heating source (Skog and Watterson 1983).

The Pacific Northwest is no exception to this trend. Surveys have reported that as high as 62% of the homes in this region have the capability to heat with wood (Lane Regional Air Pollution Authority 1984). However, the number that use wood as a primary heating source is much less, approximately 21% (Tonn and White 1986). The percentage of homes that supplement their space heating with wood burning falls somewhere in between. For example, the Oregon Department of Energy's Residential Energy Conservation Survey (Oregon Department of Environmental Quality 1985) estimated that 58% of Oregon's households burned some wood.

This widespread capacity for wood heating indicates that residential space heating in the Northwest is rapidly becoming an electric/wood market with the potential for large swings in the residential demand for electricity because of fuel switching (Tonn and White 1986). For example, if the cost of electricity should rise, more home owners will perceive wood heating to be less expensive and start to increase their use of wood heating. Or the opposite situation, declining electricity prices may result in decreased wood heating and a proportional rise in electrical demand.

The estimation of electrical displacement by residential wood heating in the United States has generally been approached through surveys of firewood cutting on public and private lands. While these data may be readily available, it can only indicate gross regional trends in wood consumption for residential heating. Subsequent efforts to equate the amount of wood burned

to space heating energy displaced are complicated by the wide variation in the heating value of wood and stove combustion efficiency (Sheldon 1983; Modera and Sonderegger 1980; Modera 1985).

Other analyses have used electrical billing data in conjunction with participant surveys of wood use to determine electricity savings from wood space heating. The weakness here is that survey responses to estimated cords of wood consumed are unreliable. Respondent estimated wood usage may represent more of an indicator of the propensity to burn wood than the quantity actually burned (Fels and Stram 1986).

The Northwest Power Planning Council (NWPPC) currently assumes, for purposes of estimating the Pacific Northwest electrical resource needs, that homes built to current construction practice will, on the average, derive 10% of their auxiliary heat from wood stoves (NWPPC 1986). This is an average displacement across all homes, including those without wood stoves.

1.2 END-USE LOAD AND CONSUMER ASSESSMENT PROGRAM

The End-Use Load and Consumer Assessment Program (ELCAP) is operated by Pacific Northwest Laboratory (PNL) under the direction of the Bonneville Power Administration (BPA) for the purpose of improving electrical power load forecasting capabilities. This report summarizes the analysis of wood stove use in this program's Residential Base Sample homes. The goals of this study were to assess the frequency of wood burning in homes equipped with wood burning equipment (i.e., wood stoves and fireplaces) and to estimate the displacement of electrical space heating loads by wood heat.

In the ELCAP Residential Base Sample from which this study draws its sample, 24% of the residences were heated primarily with wood (Figure 1). Forty-three percent had the capability for major wood heating (wood stoves), and an additional 28% had minor wood heating capabilities (fireplaces). Throughout the remainder of this report, the term wood stove will be used to define both wood stoves and fireplaces. These percentages were obtained from an onsite inspection as part of the Residential Building Characteristics Survey (BPA 1985).

FIGURE 1. Distribution of ELCAP Residential Base Sample Sites for Primary Heating Devices

In the ELCAP study, electric end-use monitoring by a microprocessor-controlled data logger (Schuster and Tomich 1985) allowed a precise knowledge of the electrical consumption of the heating system in each residence over short intervals of time. The same equipment also tracked the duration and frequency of wood burning. This report covers the analysis of the data from a large number of wood burning houses that provided some new insights into the role wood heating plays in residential energy use. Sections 2.0 and 3.0 discuss site-selection and the wood stove sensor. Sections 4.0 and 5.0 discuss the results and conclusions for usage patterns and displacement of electric space heating.

FIGURE 1. Distribution of Energy Consumption by Building System for Prototype Low-Rise Office Building

In the life cycle study, electric and gas consumption by a microprocessor-controlled data logger (Schlumberger, Inc., 1985) allowed a detailed knowledge of the electrical consumption of the heating system in each residence over short intervals of time. The same equipment also tracked the hot water and hot water heating system. This report covers the analysis of the data from a data logger of hot water heating that provided new data for the life cycle study. The report also provides energy use, Section 4.0 and 5.0, discuss the selection and the wood stove system, Section 4.0 and 5.0, discuss the results and conclusions for major systems and the amount of electric space heating.

2.0 SITE SELECTION

The wood stove study encompassed a data base of 98 sites taken from 184 ELCAP Residential Base Sample (Bonneville Power Administration 1985) sites having major wood burning capabilities. These sites were carefully selected from 143 sites equipped with wood burning sensors to be those providing reliable data for a reasonable fraction of the 1985/1986 heating season (Appendix A). Table 1 indicates that although only half of the possible sites were used, a proportional number were located in each of the NWPPC-defined (Hadley and Pincus 1985) climate zones. Climate Zone 1 is the mildest while Climate Zone 3 is the most severe.

Each site had one sensor monitoring a wood burning device. It was assumed that at sites having more than one heating device (both a wood stove and a fireplace) the sensor was installed in the chimney of the major wood heat source. Figure 2 shows the distribution of the sample by type of wood burning device (Bonneville Power Administration 1985). In this report, references to wood stove usage include the few fireplaces in the sample.

Frequency of wood stove use was examined from August 8, 1985, through May 31, 1986 (287 days). Not all sites have data for the entire period. Statistics on the usage across the full heating season were based on data from only the 68 sites having at least 50% of the possible data. This restriction minimizes the chance of biasing the results to a particular portion of the heating season.

TABLE 1. Number of ELCAP Residential Base Sample Sites and Wood Stove Sample Sites Located in the NWPPC Climate Zone

<u>Climate Zone</u>	<u>Base Sample</u>	<u>Study Sample</u>
1	101	52
2	57	31
3	<u>26</u>	<u>15</u>
Total	184	98

FIGURE 2. Distribution of the Wood Burning Study Sites by Type of Wood Burning Device

3.0 MEASUREMENT

The sensor used to monitor wood stove use consisted of a thermocouple with a floating temperature reference junction. One junction of the thermocouple was positioned inside the chimney approximately 3 ft from the top. The connection to these wires was made with copper wire outside the chimney. This created two more junctions in which temperatures following ambient conditions created a floating junction. Therefore, the output of the sensor was directly related to the difference between the temperature in the chimney and the temperature of the outside (ambient) air.

Nine days of typical time-series data from a wood stove sensor are given in Figure 3. The vertical lines represent midnight for each 24-h period. It is possible to identify periods of wood use because the magnitude of the signal generated when the wood burning-device was in use was much larger than the diurnal background signal variation. This background signal variation is the result of variation in the outside temperature. By carefully choosing a

FIGURE 3. Nine Days of Typical Time Series Data from a Thermocouple Wood Stove Sensor

threshold value just above the background variation, it is possible to distinguish between days when the wood stove was in use and days when it was not, indicating the frequency of wood use.

The procedure for determining the frequency of wood use is illustrated in Figure 4. This site exhibits only modest temperature dependence in the baseline signal. The maximum value of the background signal occurred around November 25, 1985 (the coldest part of the 1985/1986 heating season). The threshold value of the wood stove signal was set slightly higher than this maximum background signal. Note that at this threshold level, some wood-use days are not included, particularly in the warmer season when the background signal was low; for example, around May 4, 1986. Although the threshold process is not perfect in separating wood-use from nonwood-use days, there is only a modest contribution from the wood stove based on the low level of the signal on the few days that were missed by this procedure.

FIGURE 4. Typical Time Series Data for August 18, 1985, to May 31, 1986, from a Thermocouple Wood Stove Sensor

For each sample site examined, a threshold was chosen and the days of the heating season partitioned into wood-use and nonwood-use days. Days were assigned to the wood-use category if for any hour of the day the sensor output was above the threshold value. Otherwise, days were assigned to the nonwood-use category. In this analysis, a day was classified as missing even if 1 h of data was not recorded.

For each study site examined, a threshold was chosen and the days of the heating season identified into wood-use and nonwood-use days. Days were assigned to the wood-use category if for any hour of the day the temperature was above the threshold. Otherwise, days were assigned to the nonwood-use category. In this analysis, a day was classified as missing even if 1 hour of data was not recorded.

4.0 USAGE PATTERNS

4.1 SEASONAL PATTERNS

This section describes the variation of wood stove usage throughout the heating season and classifies the results for each site into two groups: the days that wood burning equipment was used and the days that it was not. This classification permits examination of seasonal usage patterns but does not retain information about quantity of use.

Figure 5 shows the sorted distribution of frequency of use for 68 wood stove sites during the heating season; it also indicates the sample sites that used wood burning equipment every day and sites that did not use it at all. Figure 6 summarizes these results in the form of a bar graph; data used to generate the figure are ratios of days on which wood stoves were used to days for which data are available. Judging by frequency of use, most sites appear to burn wood intensively, with 40 out of 68 burning wood at least 50% of the days.

Figure 7 shows the distribution, by month, of wood burning intensity, as measured by fraction of days, when wood was burned. For each month, sites with two-thirds or more of available data were included. The data show a gradual transition from infrequent to frequent use during the fall, a bimodal distribution during the coldest part of winter, and a return from intensive to occasional use during spring. The distribution during the cold months indicates that the sample divides into frequent wood users and occasional wood users; there are few intermediate cases. Figure 8 shows a combined distribution for the December to February period. This figure exhibits the strong bimodal nature of the distribution quite clearly.

A different view of these data is provided in Figure 9, where the mean percent of wood-use days is plotted by month. Again, the monthly means are taken for sites that have at least two-thirds of the data available for a particular month. The pattern shows a steady increase in wood usage from September through December, with a subsequent decline. The rate of change in frequency of wood use is large at the beginning and end of the heating

FIGURE 5. Sorted Frequency of Wood Use for 68 Sites Over the Period from August 18, 1985, Through May 31, 1986

FIGURE 6. Frequency Distribution of Wood Use for 68 Sites

FIGURE 7. Evolution Over Time of the Frequency Distribution of Wood Heat Use

FIGURE 8. Bimodal Nature of the Frequency Distribution of Wood Use December to February

FIGURE 9. Mean Percent Wood Use by Month

season, but was slow during the coldest months. It is possible that the high use in November was associated with the early arrival of cold weather in much of the region during the 1985 heating season.

The frequency of wood use does not appear to depend on the climate zone. Figure 10 shows box plots indicating the frequency-of-use distributions for the sample partitioned by the basis of the climate zones defined by the NWPPC (Hadley and Pincus 1985). Climate Zone 1 is the mildest and includes the bulk of single-family homes in the region, while Climate Zone 3 is the most severe. The box contains the interquartiles, the dividing line is the median, and the lines extending from the ends of the box approximate the range of the sites. This figure provides no basis for asserting a strong dependence of climatic location on the tendency to use wood.

4.2 DAILY PATTERNS

This section characterizes the hourly usage patterns for the wood stove sample of ELCAP homes, disaggregated by weekday and weekend. For the purpose

FIGURE 10. Box Plot Showing the Range in Frequency of Wood Use for Sites Located in Each of the Three NWPPC Climate Zones

of this work, a wood stove is considered "on" for a full hour if the wood stove sensor gives a value above the on/off threshold, even though the stove may be cooling off. Percent-on time for each individual site serves as the basic data for this study, with each day's available data weighted equally.

Figures 11 and 12 provide box plot summaries of the weekday and weekend profiles, respectively. For each hour, the box plot summarizes the percent-on time data through the heating season for the sites in the sample. The box contains the interquartiles, the dividing line is the median, and the lines extending from the ends of the box approximate the range of the sites. Diurnal patterns are evident in both figures, with maxima at 7:00 to 9:00 am and 8:00 to 10:00 pm. Roughly speaking, the data are reminiscent of typical load shapes for electric space heating, except that the relative magnitude of morning and evening peaks is reversed. That is, wood usage appears to be more intense in the evening than in the morning.

The spread in intensity of use, as measured by the interquartile range (shown on the figure as the height of the box), is substantial at all hours, and there does appear to be significant heating from wood even during the early morning hours for some households. Comparison of the weekday and weekend figures suggests that, just as is regularly observed in electrical space heating profiles, the weekend schedule is shifted toward later hours.

A different view of these data is presented in Figure 13, where mean percent-on time across the sample is plotted as a function of hour on a slightly expanded scale. This figure emphasizes the diurnal pattern and the comparison of the weekday and weekend profiles. Again, wood is burned more frequently during evening hours rather than morning hours, and the difference in burning times during weekdays and weekends (with less morning use and more afternoon use on the weekends) is evident. Note that if these figures had reflected wood stove usage across only the coldest months, mean usage would have been larger for all hours.

Figure 14 is a scatter plot showing the correlation of frequency of wood burning days to the duration of wood burning during those days. The ratio of the number of days that wood was used for heat to the total number of days available is plotted against the mean daily fraction of wood burning for each

FIGURE 11. Weekday Distribution by Hour of Percent Wood Use for the 68 Sampled Sites

FIGURE 12. Weekday Distribution by Hour of Percent Wood Use for the 68 Sites

site. One would expect a relatively tight relationship; however, the figure shows a lot of scatter. A regression line drawn through the data points indicates a positive trend, although there is a large associated error.

FIGURE 13. Display of Weekday and Weekend Diurnal Patterns in Frequency of Wood Stove Use

FIGURE 14. Relationship Between Frequency of Wood Burning Days and the Duration of Wood Burning During Those Days

Occupants who burn wood on a large number of days during the heating season tend to also burn wood for a greater fraction of the hours during those days. The relationship is strongest for the heavy wood users; they are the occupants who use wood as their primary heat source and, therefore, burn it more frequently and for a larger fraction of the day.

4.3 CONCLUSIONS

The results of our investigations permit several observations about the seasonal usage of wood stoves in the random sample of the ELCAP Residential Base Sample participants:

- More than half the households that have wood stoves use them for space heating throughout the heating season. There are, however, wood sites in the sample that never use their wood stoves.
- The seasonal pattern in frequency of wood use across the sample shows a rapid increase at the beginning and a rapid decrease at the end of the heating season, with little variation over the coldest month. In these data, the peak in frequency comes in December.
- During the coldest months, the population of wood users is strongly bimodal with respect to frequency of wood heating. Households with wood stoves either heat with wood almost every day or quite rarely, with relatively few homes at intermediate levels of wood use frequency.
- These summary results suggest that, given that wood burning equipment is available, climatic region does not seem to be a strong determinant of frequency of use.

Analysis of daily patterns of wood stove usage can be summarized in the following:

- Diurnal profiles of wood use aggregated across a reasonable number of sites are qualitatively similar to those for other forms of heat and, in particular, for electrical space heat. The principal difference for wood heat is that evening use is more frequent than morning use; the converse is generally true for electric heat.

Consequently (to the extent that wood users are qualitatively similar to nonwood users in their use of electrical space heat), it may be expected that wood use increases the ratio of morning residential peak in electric loads to an average load.

- The differences between weekday and weekend profiles of wood use intensity are similar to differences between weekday and weekend profiles for space heating and other electrical end-uses. That is, schedules are shifted somewhat later for weekends as opposed to weekdays, and there is more afternoon use on weekends.
- The variability in usage behavior across the sample studied here is quite large for all hours of the day.
- Occupants who burn wood frequently during the heating season tend (with a large associated error) to also burn wood for a greater fraction of the hours during those days.

5.0 DISPLACEMENT OF ELECTRICAL SPACE HEAT

5.1 APPROACH

Probably the most important impact of wood heating on residential electricity use is the amount of electrical heating energy it displaces. Estimates of displacement in aggregate are important to the understanding of the absolute effects of wood burning on the power demand. Site-specific displacement estimates are the first step in developing correlations with structure characteristics data.

Utilities are also interested in the effects of wood heating on daily load demands. If wood use tends to occur during the hours of peak demand (typically early morning) its potential as a load reduction measure is greatly increased. A simple indicator of power grid efficiency can be defined as the ratio of peak load to mean load (referred to as the load factor). Ideally, power utilities would like to supply electricity to a grid such that this ratio has a value close to unity, indicating efficient use of generating and transmission resources at all times. Because this is seldom the case, an examination of wood heating effects on hourly load profiles is important to future planning.

In this section, the annual electrical heating displacement for both the individual structure and the study in aggregate is estimated. Two techniques, a regression model and a load shape model, are employed. These techniques provide two independent estimates that can then be compared. Additional comparisons are made with displacement estimates reported by other investigators.

5.2 SINGLE-STRUCTURE DISPLACEMENT

The dramatic impact wood burning has on electrical space heating can be observed by plotting daily electrical heating load versus outside air temperature for a wood burning residence. This impact is illustrated in Figure 15 where the dots (●) show electrical space heating consumption for homes that did not burn wood, and the triangles (Δ) represent the same for homes that did burn. This plot is similar to those plots used in the

FIGURE 15. Relationship Between Outside Temperature and Space Heating Loads for Nonwood-Use (●) and Wood-Use (Δ) Days

envelope performance analysis for assessing the value of conservation measures in the Residential Standards Demonstration Program (RSDP) (Stokes and Pearson 1985). The outside air temperature was used rather than the inside/outside temperature difference, because the inside temperature in a wood-heated home may rise well above the thermostat setting. This would yield a temperature difference that would predict an erroneously high energy savings.

The line in Figure 15 represents a least-squares fit to the days when no wood heating occurred (points marked with dots). It is clear by the way the wood heating days fall below this line, that wood stove use displaces electrical space heating requirements. The magnitude of this displacement is dependent on the fraction of the day the wood stove was used.

A model similar to that used to calculate the thermal efficiency of homes in the ELCAP RSDP study was developed for examining site-specific electrical space heating displacement. A daily fractional wood use term was added to account for wood stove effects. The result is a two-parameter regression model represented by the following equation:

$$Q_h = a + b(OAT) - c(WSV)$$

The electrical space heating energy required, Q_h , is obtained from the daily mean hourly heating load. Outside air temperature (OAT) is taken from the daily mean outside air temperature. The daily fractional wood use (WSV) is calculated from the ratio of the number of hours of burning to 24 h in a day; a, b, and c are the coefficients of the regression. The third coefficient, c, multiplied by the daily fractional use can be considered the wood stove contribution to the homes internal gains; this can also be equated to the electrical space heating displaced by wood stove use.

Analysis was made of all 98 sites in the sample regardless of their available wood stove data. The site number, total number of days of available wood stove data, number of wood-use days, mean fractional wood use on wood-use days, correlation statistics, and mean hourly electrical displacement on wood use days are listed in Table 2. Results were obtained for only 76 of the 98 sites since 11 sites did not use wood during the number of days available for analysis and an additional 11 sites lacked either the electrical space heating or outside air temperature information necessary for the regression. Many of the sites had too few number of days to be representative of the entire 287-day heating season. In addition, many of the sites had poor correlation statistics ($t < \pm 2$) indicating that the coefficients are not significant. Figure 16 is a bar graph of the estimated annual electrical space heating savings for the 35 sites that had significant coefficients and at least 100 days of data (this represents a compromise between reducing seasonal bias and retaining enough sites for meaningful analysis) or 35% of available data. The 35 sites have a mean displacement of 14 kWh per wood use day and a mean annual displacement of 1502 kWh, based on electrical heating and wood stove usage in the 1985/1986 heating season.

It was found that the two-parameter regression used to predict site-specific displacement gives statistically insignificant results for heavy wood-use sites. This is because the electrical heating for these sites is displaced to such an extent that a statistically meaningful correlation is not possible. Hence, the estimate of mean annual savings based on this method will be biased to the light and moderate wood stove users and will underestimate the wood stove savings for the total study.

TABLE 2. Site-Specific Electrical Space Heating Displacement for the Wood Stove Sites

Count	Site Number	Total Days	Wood Days	Fraction of Use	Correlation Statistic			Displacement (Wh)
					T1	T2	T3	
1	30	141	137	0.953	7.53	-7.62	-2.20	7
2	31	122	114	0.860	5.73	-5.61	-3.94	1171
3	33	61	44	0.577	0.17	-0.02	1.49	-8
4	50	106	1	0.125	18.56	-17.73	-0.45	224
5	61	143	143	0.605	9.21	-9.56	-1.58	11
6	66	244	202	0.609	-5.02	5.28	1.00	-32
7	69	210	146	0.695	3.43	-3.31	-3.94	385
8	72	153	15	0.508	6.94	-6.65	0.44	-52
9	85	144	80	0.520	12.45	-11.82	-9.07	515
10	125	95	65	0.752	18.53	-17.75	-11.52	1709
11	129	63	48	0.497	0.85	-0.79	-1.21	48
12	134	142	45	0.428	10.99	-10.31	-4.23	444
13	136	212	176	0.655	6.08	-5.97	-5.31	376
14	138	154	64	0.893	23.14	-22.04	-20.78	1834
15	144	153	144	0.836	1.99	-1.92	-2.42	12
16	147	228	139	0.751	10.65	-10.30	-18.49	1315
17	163	65	44	0.702	6.86	-6.75	0.51	-31
18	165	243	168	0.817	21.39	-21.15	-7.66	588
19	177	232	115	0.718	13.76	-13.31	-18.77	1536
20	203	155	126	0.757	14.32	-13.87	-12.23	954
21	204	82	63	0.436	2.13	-2.11	1.14	-39
22	211	247	59	0.355	23.93	-23.14	-8.67	619
23	216	252	64	0.286	25.93	-25.21	-4.40	310
24	224	218	177	0.578	8.24	-8.04	-4.76	212
25	227	76	31	0.792	8.75	-8.58	-4.30	405
26	237	91	15	0.183	15.52	-15.08	-1.53	10
27	243	196	138	0.390	5.82	-5.52	1.18	-53
28	245	200	90	0.369	10.94	-10.73	-3.45	86
29	246	178	146	0.557	3.73	-3.79	4.77	-614
30	249	196	164	0.760	12.08	-11.61	-1.70	214
31	256	30	10	0.096	1.83	-1.74	-0.47	55
32	259	171	100	0.870	7.74	-7.49	-7.44	3022
33	261	251	238	0.695	3.32	-3.34	-0.88	2
34	262	129	6	0.153	-1.72	1.97	0.93	-176
35	271	167	156	0.843	3.16	-2.79	-6.50	252
36	276	175	124	0.475	-2.97	3.04	1.63	-76
37	317	134	128	0.693	9.56	-9.47	-2.00	176
38	343	93	48	0.543	8.15	-7.82	-1.04	248

TABLE 2. (contd)

Count	Site Number	Total Days	Wood Days	Fraction of Use	Correlation Statistic			Displacement (Wh)
					T1	T2	T3	
39	347	195	65	0.171	0.35	-0.28	-0.87	4
40	350	193	6	0.778	39.09	-37.37	1.27	-557
41	352	209	38	0.148	28.49	-27.52	-5.68	639
42	357	98	89	0.663	10.93	-10.36	-4.82	475
43	363	224	164	0.729	3.60	-3.56	-0.65	17
44	369	176	154	0.661	13.25	-12.70	-15.11	1300
45	371	169	165	0.683	4.38	-4.16	-5.09	289
46	374	163	115	0.862	21.23	-20.83	-4.96	669
47	376	221	96	0.213	4.72	-4.06	-1.68	21
48	379	181	166	0.906	15.03	-15.13	-2.62	265
49	380	203	163	0.870	10.90	-10.90	-3.38	139
50	382	13	13	0.231	--	--	--	--
51	384	209	40	0.191	32.91	-31.79	-7.70	487
52	392	209	141	0.653	6.56	-6.25	-2.52	155
53	399	175	147	0.615	10.61	-10.23	-9.77	972
54	400	125	44	0.063	24.94	-23.11	1.30	-118
55	406	188	145	0.666	15.82	-15.48	-4.27	404
56	418	82	73	0.303	12.14	-11.89	-5.39	443
57	425	79	18	0.442	5.10	-4.96	-2.62	137
58	429	231	136	0.337	11.14	-10.92	3.48	-146
59	433	80	13	0.737	1.93	-1.89	-0.68	36
60	434	125	15	0.261	15.14	-14.41	-3.09	919
61	436	189	60	0.496	19.70	-19.19	-1.68	224
62	438	109	104	0.782	6.71	-6.63	1.00	-78
63	461	162	10	0.463	15.69	-15.24	-0.34	68
64	462	210	74	0.130	26.78	-25.43	-6.40	296
65	463	214	180	0.344	2.75	-1.93	3.99	-145
66	468	80	59	0.270	3.84	-3.80	-0.98	54
67	469	158	87	0.446	9.13	-8.83	-0.53	56
68	473	200	143	0.334	20.38	-19.75	-7.05	502
69	490	76	61	0.324	11.35	-11.11	-4.88	372
70	491	203	18	0.623	2.62	-2.51	-1.40	37
71	493	53	20	0.623	8.03	-7.87	-7.93	1658
72	496	73	20	0.260	9.58	-9.30	-1.12	77
73	507	163	140	0.994	8.34	-8.35	-2.21	126
74	512	26	3	0.597	8.15	-7.87	-6.64	718
75	513	98	7	0.833	20.26	-19.72	-3.89	1441
76	514	139	110	0.521	14.23	-14.03	-4.55	332

FIGURE 16. Distribution of Estimated Annual Electrical Space Heating Displacement for 35 Wood Burning Homes

5.3 EFFECTS ON LOAD SHAPE

This subsection examines the effects of wood burning on hourly load demands. A sample of 68 wood burning homes with enough data to be representative (50%) of the entire heating season were used. Hourly electrical heating values were grouped as to wood-use or nonwood-use days for each month (September through May) for each site. The data from each group was then folded into a single day and the mean taken across sites. The result was a mean wood-use day and a mean nonwood-use day for each month.

Figure 17 contains the resulting monthly plots of hourly electrical heating load for the 68 sites. The curve marked with circles represents the hourly load when there was no wood burning. The second curve, marked with triangles, is the corresponding wood burning hourly load profile. Because of the method of binning, data for a site typically appears as a component of both curves.

Not surprisingly, the load profiles generally increase from fall to mid-winter and then decrease. The wood burning profiles in each month fall below those for nonwood burning indicating the level of electrical displacement.

FIGURE 17. Mean Hourly Electrical Space Heating Load Profile for Nonwood-Use (O) and Wood-Use (Δ) Days from September Through May

The amount of displacement, represented as the area between the two curves, is not constant from month to month, but is approximately proportional to the load.

As discussed in the previous section on wood stove usage patterns, the daily use profile has two peaks: one peak in the morning and a second larger peak in the evening. This pattern is reflected in these plots as mean hourly displacement. Large displacement, as measured by the distance between the two curves, occurs at the times of maximum wood burning. Note that in the evening, when the highest peak in burning frequency occurs, electrical heating load is displaced to the minimum nighttime level for most months.

Figure 18 is a stacked bar graph summarizing the hourly displacements for all months indicating the periods during which the greatest savings are achieved. The load displacements peak in the morning and evening hours, complementing the daily patterns of usage findings that these are the hours of peak burning.

FIGURE 18. Stacked Hourly Electrical Space Heating Displacements from September Through May

Because electrical utilities are concerned with the impact of wood stove use on power system efficiency, an examination of load factors was made based on the use of electrical space heating on wood-use and nonwood-use days. The load factor is calculated according to the equation:

$$LF = \bar{x} / x_{\text{peak}}$$

where LF is the load factor and $\bar{x}$ and x_{peak} are the mean and peak electrical space heating loads, respectively.

Table 3 shows the load factors derived from the peak monthly heating load relative to the mean load during the heating season for wood- and nonwood-use days across the sample. Comparison of the monthly load factors suggest that wood stove use significantly reduces the month-to-month variation in the load factor. This translates to a positive impact on the monthly grid system efficiencies.

In this discussion, the effect of wood heating on the electrical space heating load factor is based on comparisons of load factors for days when there is no wood burning to days when wood burning occurs daily. This is analogous to homes that either heat with wood daily or never heat with wood.

TABLE 3. The Mean Seasonal Heating Load (Wh), Monthly Peak Heating Load (Wh), and Associated Load Factor

Month	Nonwood Use		Wood Use	
	Peak	Load Factor	Peak	Load Factor
Sep	479	2.0292	371	1.3989
Oct	1006	0.9662	769	0.6749
Nov	1832	0.5306	1438	0.3609
Dec	2738	0.3550	1406	0.3691
Jan	2387	0.4072	1094	0.4744
Feb	1657	0.5866	1018	0.5098
Mar	1243	0.7820	847	0.6128
Apr	1108	0.8773	969	0.5356
May	665	1.4617	680	0.7632
Mean Seasonal	972		519	

The population of wood stove users in actuality provides some combination of both wood-use and nonwood-use days and ideally, the wood user load factor should be derived from this combination.

5.4 SAMPLE DISPLACEMENT

The aggregated heating values found in Tables 4 and 5 offer a method of calculating monthly and annual wood stove displacement for the sample. Because the sample is binned for wood-use and nonwood-use days, many of the structure-characteristic effects inherent in comparisons of samples composed of different sites can be ignored. Based on findings discussed earlier in

TABLE 4. Electrical Heating Values When
No Wood Burning Occurred (Wh)

<u>Hour</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec/85</u>	<u>Jan/86</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>
1	131	469	1233	1630	1279	979	495	570	203
2	138	516	1254	1830	1367	1049	533	542	241
3	192	588	1338	1941	1390	1146	587	648	278
4	175	649	1471	2040	1569	1239	650	771	328
5	255	730	1518	2054	1576	1320	726	794	488
6	350	897	1486	2192	1901	1387	814	964	665
7	479	1006	1832	2577	2194	1657	1189	1108	609
8	360	932	1815	2738	2369	1652	1243	1030	515
9	226	821	1695	2473	2387	1516	1094	799	381
10	188	606	1778	2363	2067	1367	836	668	321
11	150	530	1625	2145	1956	1119	725	552	283
12	124	377	1539	1942	1549	956	513	459	239
13	85	370	1464	1705	1515	946	508	413	234
14	74	304	1317	1972	1436	932	411	409	210
15	58	294	1476	2030	1516	882	412	371	218
16	68	276	1476	2013	1558	922	384	389	226
17	83	375	1499	2214	1651	922	428	424	303
18	84	354	1591	2132	2052	1131	491	508	294
19	65	445	1557	2489	1835	1104	540	574	308
20	87	485	1467	2209	1865	1129	525	592	318
21	72	506	1490	2328	1724	1162	596	595	301
22	65	500	1439	2367	1573	1165	612	578	230
23	85	506	1338	1829	1510	1052	602	546	212
24	83	522	1138	1616	1240	936	509	530	188
Daily	3675	13055	35837	50827	41077	27671	15422	14834	7596
Annual Heat	6300 kWh								

TABLE 5. Electrical Heating Values When Wood Burning Was Used (Wh)

<u>Hour</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec/85</u>	<u>Jan/86</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>
1	68	267	792	736	535	418	267	358	171
2	70	311	823	792	537	429	265	403	213
3	88	320	890	826	596	466	338	485	250
4	106	385	988	916	616	534	403	537	289
5	84	463	1038	1002	656	557	420	602	442
6	317	581	1186	1160	778	749	577	795	601
7	286	769	1308	1342	1045	967	847	969	680
8	371	575	1438	1406	1094	1018	741	822	502
9	171	456	1296	1396	1020	998	697	761	455
10	218	402	1078	1196	826	783	503	441	330
11	179	310	906	1041	661	671	408	369	376
12	118	245	835	951	662	625	338	320	227
13	66	200	789	905	598	591	290	227	243
14	52	200	716	851	548	493	269	261	237
15	34	159	729	810	562	432	222	224	270
16	33	171	791	837	618	427	217	271	263
17	60	233	956	935	608	598	251	230	255
18	136	195	918	877	589	582	281	264	256
19	82	208	863	864	586	625	360	295	268
20	84	172	823	859	524	514	335	296	347
21	88	167	777	859	510	535	308	297	241
22	79	204	761	755	446	428	300	248	186
23	75	230	812	751	490	465	289	258	188
24	<u>74</u>	<u>236</u>	<u>827</u>	<u>704</u>	<u>480</u>	<u>432</u>	<u>237</u>	<u>252</u>	<u>181</u>
Daily	2937	7456	22340	22771	15584	14337	9165	9985	7470

Annual Heat 3361 kWh

this report that there is no evidence that wood users in the different climate zones have different usage frequencies, estimates should be representative study wide.

The mean daily displacement for each month is calculated by differencing the hourly values for nonwood use (Table 4) and the hourly values for wood use (Table 5) and summing them. These differences and sums can be found in Table 6 and are represented graphically in Figure 18. These sums represent the mean displacement for those days of the month when the wood stove was actually used. To estimate the monthly savings, the mean number of days of wood use by month (Figure 7) must be factored in. The last

TABLE 6. Electrical Space Heating Displaced
by Wood Stove Use (Wh)

<u>Hour</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec/85</u>	<u>Jan/86</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>
1	63	202	442	893	745	561	229	211	32
2	68	205	431	1038	829	620	268	139	28
3	104	268	448	1115	794	680	249	163	28
4	69	264	483	1125	952	705	247	235	39
5	171	267	480	1052	920	763	305	192	46
6	33	316	300	1032	1123	638	237	169	64
7	194	237	525	1235	1150	690	342	140	-71
8	-11	358	377	1332	1275	634	501	209	13
9	55	365	398	1077	1367	518	398	38	-73
10	-30	203	700	1167	1241	585	333	227	-8
11	-29	220	719	1103	1295	448	318	183	-94
12	6	132	704	991	887	331	176	139	12
13	19	170	675	800	917	355	218	186	-9
14	22	103	601	1121	888	439	142	148	-26
15	25	135	747	1219	954	450	190	147	-51
16	35	105	685	1176	940	495	167	118	-37
17	23	142	543	1280	1043	324	176	193	48
18	-52	158	673	1255	1462	549	210	244	38
19	-17	237	694	1624	1249	480	180	279	40
20	3	313	644	1349	1341	615	190	296	-30
21	-16	339	713	1469	1214	627	288	298	61
22	-14	296	678	1611	1127	737	312	330	44
23	10	276	526	1077	1019	586	313	288	24
24	<u>8</u>	<u>286</u>	<u>311</u>	<u>912</u>	<u>760</u>	<u>504</u>	<u>271</u>	<u>278</u>	<u>7</u>
Daily	738	5599	13496	28055	25494	13334	6258	4850	126
Days of Wood Use	<u>10</u>	<u>17</u>	<u>21</u>	<u>22</u>	<u>21</u>	<u>18</u>	<u>16</u>	<u>15</u>	<u>9</u>
Savings	7	95	283	617	535	240	100	73	1
Annual Savings 1951 kWh									

row of Table 6 gives the resulting estimate of mean monthly savings in kilowatt hours. Also listed is the mean annual savings for a wood burning site.

5.5 ESTIMATE COMPARISONS

In this study, wood stove displacement was calculated using two alternative methods; this allows a useful comparison. The load shape model estimated a mean annual savings of 1951 kWh for residences heating with wood.

This is 23% larger than the 1502-kWh mean savings estimate derived from the two-parameter regression model. This difference can be explained by the limitation of the regression model; while providing a site-specific method for estimating displacement for light and moderate wood users, it is not accurate for sites with heavy wood use. Thus, an aggregate mean annual savings calculated from the resulting estimates would be biased toward low.

Estimates reported by other investigators of electrical heating load displacement by wood stove use in the Pacific Northwest are not common. One study, Residential Wood-Use in the Pacific Northwest: 1979-1985 (Tonn and White 1986), estimated very roughly that homes heated primarily with wood displaced about 6000 kWh per year, or approximately 23% of their annual electricity demand. This estimate was derived through an examination of data from evaluations of Bonneville Power Administration (BPA) conservation programs to track differences between homes that were heated primarily with electricity or with wood. Considering that the study dealt with that portion of the wood burning population that burned wood the most heavily (those homes that use wood as the primary heating source), while the estimate presented here examined all those having the ability to heat with wood, their higher estimate is understandable.

In A Residential Conservation Data Base For the Pacific Northwest, Usibelli et al. (1983) made theoretical calculations of electrical space heating displacement by wood stoves. For these calculations, they assumed typical conversion energies for Northwest species of wood, numbers of cords burned, efficiencies of wood burning devices, and availability of wood burning devices. The result was that 1000 kWh/year is displaced by wood burning in Climate Zones 1 and 2 and nearly 2000 kWh/year is displaced in Climate Zone 3. This displacement results in a 10 to 20% contribution to internal gains. These estimates appear to be somewhat low in comparison with ours considering that 85% of our sample falls into Climate Zones 1 and 2.

The Bonneville Power Administration (BPA) predicted that by the year 2000, wood burning could displace 4.6% of the electrical heating demand in the Pacific Northwest with an annual savings of 3720×10^6 kWh (Onisko 1980).

This estimate was based on the assumption that 40% of the projected 1,943,700 homes would burn wood. This equates to an average displacement of 4785 kWh per residence burning some wood, which implies a combined increase of about 2.5 times in the wood stove penetration and intensity of use over the estimate presented here. Because the penetration is already 60% with the bulk of these sites burning at least 50% of the time in the ELCAP sample, the estimate of 4.6% displacement by the year 2000 may be somewhat high.

5.6 CONCLUSIONS

The examination of electrical space heating displacement by residential wood stove use can be summarized as follows:

- The envelope performance analysis used to assess conservation performance in the RSDP is strongly affected by wood stove use. Daily duration of wood burning is directly related to the amount of electrical space heating displaced.
- The two-parameter regression employed to model heating displacement for individual structures provided site-specific estimates but can only be applied to the light to moderate wood users. Thus, this method's resulting sample mean savings estimate of 1502 kWh/year for the 1985/1986 heating season is correspondingly low.
- Daily electrical heating load shapes show an overall reduction throughout the heating season for days when there is wood heating. In particular, maximum displacement occurs during the morning and evening hours reflecting the periods when wood burning is heaviest (as established in the section on patterns of usage).
- The monthly electrical space heating displacement, as estimated from load shape examination, increases from the warmer months to the colder months (approximately in proportion to the heating load).
- Wood heating reduces the month to month variation in the power system load factor, as examined for nonwood-use and wood-use samples.

- Estimates of electrical space heating displacement derived from differencing aggregate load profiles for wood use and nonwood use provide reasonable sample values. Homes that burned wood in this study displaced an average of 1951 kWh of electrical space heating during the 1985/1986 heating season.

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APPENDIX A

DISTRIBUTION OF DATA

APPENDIX A

DISTRIBUTION OF DATA

TABLE A.1. Number of Days When the Wood Stove Was Used

<u>Site/Year</u>	<u>SEP</u>	<u>OCT</u>	<u>NOV</u>	<u>DEC</u>	<u>JAN</u>	<u>FEB</u>	<u>MAR</u>	<u>APR</u>	<u>MAY</u>
002685	2	5	11	11	5	3	2	0	0
003085	0	0	10	25	30	17	29	27	16
003185	24	21	30	30	22	27	28	30	18
003385	0	0	0	0	0	15	16	6	10
004485	0	0	0	0	0	0	0	0	0
005085	0	0	0	0	0	0	0	0	1
005585	0	0	17	28	27	16	16	17	9
006185	0	8	27	29	26	8	27	18	12
006685	3	23	25	27	31	21	27	24	21
006785	0	0	0	0	0	0	0	0	0
006885	0	0	0	0	0	0	0	0	0
006985	0	16	22	30	20	23	18	14	3
007285	0	0	0	0	0	0	0	5	11
007585	18	15	0	0	0	0	0	0	0
008585	0	0	23	22	15	22	3	1	3
011985	0	0	0	0	0	0	0	0	0
012585	0	0	12	24	19	18	2	2	4
012885	21	9	0	0	0	0	0	0	0
012985	0	0	0	0	6	26	30	8	0
013485	0	0	0	0	0	0	7	26	22
013685	9	27	11	16	28	17	24	26	18
013885	0	0	21	27	28	0	0	0	0
014485	10	28	16	23	22	16	24	19	21
014785	9	19	29	27	31	16	0	5	25
016385	0	0	0	20	0	0	5	20	3
016585	2	3	14	31	30	27	28	23	19
017785	0	15	30	29	23	14	0	4	0
018085	16	25	19	24	31	20	28	27	9
018685	0	1	0	0	0	0	0	0	0
020385	0	0	12	30	11	28	29	17	13
020485	0	0	0	0	0	21	23	21	13
021185	7	6	10	16	10	3	0	8	4
021685	0	1	15	28	20	1	0	0	0
022385	0	0	0	0	0	0	0	0	0
022485	6	22	29	21	26	21	26	27	12
022785	0	1	10	20	0	0	0	0	0
023785	0	0	0	0	0	4	3	8	4
023985	0	0	0	3	1	4	0	0	0
024385	16	20	6	18	14	24	18	17	14
024585	1	21	5	28	24	10	0	2	0

TABLE A.1. (contd)

Site/Year	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
024685	2	2	10	30	31	23	24	27	12
024985	0	10	22	29	27	27	23	22	12
025685	0	0	0	0	0	0	0	0	0
025985	1	25	28	30	13	0	0	4	3
026185	29	31	29	30	31	25	25	28	17
026285	0	0	0	4	0	0	1	1	2
027185	0	0	21	31	30	26	27	22	13
027685	0	0	12	19	29	23	22	20	11
031785	0	0	0	19	30	27	30	24	14
034385	0	21	29	30	31	22	8	5	1
034785	10	11	8	4	4	12	12	5	0
035085	0	3	3	0	0	0	0	0	0
035185	0	5	21	26	17	18	1	0	0
035285	0	8	7	9	3	4	0	4	5
035785	24	25	23	24	28	27	21	19	17
036385	3	18	27	29	30	27	22	11	11
036585	0	0	0	0	0	0	0	0	0
036985	19	20	27	22	29	27	20	13	14
037185	1	26	16	28	29	28	21	25	5
037485	1	26	28	20	0	0	25	12	12
037685	15	25	3	25	18	12	0	1	0
037985	9	28	27	31	31	27	26	25	14
038085	0	20	29	30	30	28	21	6	3
038285	0	0	0	0	0	0	0	14	18
038485	2	3	16	7	1	0	2	11	2
039285	0	9	26	30	30	24	24	1	4
039585	0	1	21	25	31	26	9	0	0
039985	11	28	25	23	26	25	2	8	10
040085	0	6	10	16	12	6	2	3	6
040685	7	15	27	29	31	23	16	16	7
041885	16	30	15	18	1	1	3	21	22
042585	0	0	0	0	0	0	0	6	12
042985	0	0	0	0	0	0	0	1	0
043385	0	0	0	0	0	0	0	3	11
043485	0	0	0	0	0	6	7	0	2
043585	1	27	29	28	13	26	24	25	18
043685	0	0	10	11	15	11	3	6	4
043885	0	0	0	0	6	26	25	29	18
046185	0	0	2	9	0	0	0	0	0
046285	3	22	12	11	12	9	8	5	6
046385	2	29	30	30	29	25	27	21	13
046585	0	0	0	0	0	0	0	0	0
046885	0	0	0	20	15	25	26	29	11
046985	0	8	21	0	14	19	14	12	5
047285	0	0	0	0	0	0	0	0	0
047385	4	19	25	23	26	16	16	15	12
048985	0	0	0	0	0	0	0	16	12
049085	0	0	0	0	0	0	16	28	17
049185	0	0	12	4	2	0	0	0	0

TABLE A.1. (contd)

<u>Site/Year</u>	<u>SEP</u>	<u>OCT</u>	<u>NOV</u>	<u>DEC</u>	<u>JAN</u>	<u>FEB</u>	<u>MAR</u>	<u>APR</u>	<u>MAY</u>
049385	0	0	0	0	2	21	0	0	0
049685	0	0	0	0	2	11	7	4	0
050785	0	4	23	29	12	15	30	29	6
051285	0	0	0	0	0	0	0	0	3
051385	0	0	17	1	0	0	0	0	0
051485	0	0	11	29	31	27	28	23	4

TABLE A.2. Number of Days When the Wood Stove Was Not Used

<u>Site/Year</u>	<u>SEP</u>	<u>OCT</u>	<u>NOV</u>	<u>DEC</u>	<u>JAN</u>	<u>FEB</u>	<u>MAR</u>	<u>APR</u>	<u>MAY</u>
002685	28	24	16	10	26	23	25	30	30
003085	0	0	0	0	0	0	2	2	6
003185	4	3	0	0	0	0	0	0	8
003385	0	0	0	0	0	0	6	4	16
004485	22	16	30	28	25	26	31	25	26
005085	0	0	0	0	0	4	27	29	28
005585	0	0	1	1	4	11	15	12	21
006185	0	0	0	0	0	0	0	0	10
006685	6	0	3	1	0	4	2	4	10
006785	0	0	0	0	0	0	0	0	0
006885	0	8	15	29	19	27	14	6	22
006985	0	6	3	0	0	3	11	16	26
007285	0	0	0	0	0	0	0	0	7
007585	1	0	0	0	0	0	0	0	0
008585	0	5	7	3	5	4	10	17	21
011985	0	15	30	30	17	0	0	0	0
012585	0	0	7	0	0	6	29	24	27
012885	9	1	0	0	0	0	0	0	0
012985	0	0	0	0	0	0	1	9	0
013485	0	0	0	0	0	0	2	0	2
013685	7	2	1	0	0	1	4	3	12
013885	0	8	3	0	2	28	19	18	28
014485	0	2	0	0	0	0	0	0	5
014785	18	12	1	0	0	12	28	11	5
016385	4	0	0	0	0	0	8	9	28
016585	14	28	14	0	0	0	2	4	10
017785	25	16	0	0	7	14	29	26	29
018085	5	5	0	0	0	0	0	2	11
018685	20	28	29	31	29	28	31	28	30
020385	0	0	0	1	17	0	0	13	0
020485	0	0	0	0	0	3	8	8	18
021185	23	24	20	15	20	23	30	21	24
021685	30	30	15	3	11	26	31	30	30
022385	0	0	0	0	0	0	0	0	0

TABLE A.2. (contd)

Site/Year	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
022485	14	0	1	0	1	5	5	2	17
022785	0	0	0	0	0	0	26	20	27
023785	0	0	0	0	0	20	26	21	26
023985	0	0	0	16	29	23	31	29	29
024385	14	7	3	1	2	2	11	10	16
024585	27	10	1	0	6	18	17	19	31
024685	8	0	0	0	0	3	6	1	11
024985	0	1	0	0	1	1	7	7	18
025685	19	0	0	0	0	0	0	0	0
025985	26	4	0	0	18	18	0	2	27
026185	1	0	0	0	0	3	6	2	13
026285	0	0	0	21	25	24	28	28	28
027185	0	0	0	0	0	1	2	8	11
027685	20	30	2	0	0	1	7	8	19
031785	0	0	0	0	0	0	1	5	16
034385	14	7	0	0	0	0	8	24	14
034785	17	18	8	25	1	15	17	15	3
035085	29	25	25	30	31	20	27	25	28
035185	19	25	5	5	12	10	23	1	0
035285	2	14	21	18	25	23	31	25	26
035785	1	3	0	0	0	0	1	10	13
036385	25	10	1	0	0	1	6	14	18
036585	0	0	0	0	0	0	16	29	25
036985	7	10	1	0	2	0	6	12	11
037185	0	0	0	0	0	0	2	0	2
037485	20	0	0	0	0	0	0	8	14
037685	13	5	19	6	11	16	26	21	30
037985	0	0	0	0	0	0	0	0	16
038085	10	9	0	0	0	0	5	17	16
038285	0	0	0	0	0	0	0	0	10
038485	26	25	13	23	30	26	25	17	28
039285	30	20	1	0	1	1	6	28	26
039585	30	28	9	0	0	1	16	23	24
039985	13	2	1	0	4	3	1	5	20
040085	4	23	19	15	18	22	28	22	25
040685	12	14	3	1	0	3	14	14	23
041885	14	1	0	0	0	0	0	7	9
042585	0	0	0	0	0	0	0	0	18
042985	0	0	0	0	0	0	0	11	30
043385	0	0	0	0	0	0	0	0	0
043485	0	0	0	0	5	19	12	3	26
043585	5	0	0	0	0	0	1	3	9
043685	0	0	11	18	13	15	26	21	26
043885	0	0	0	0	0	0	5	0	0
046185	0	2	16	21	19	27	31	29	27
046285	3	9	17	18	18	18	23	25	24
046385	4	2	0	1	1	2	4	9	17
046585	5	29	30	29	31	26	27	29	31
046885	0	0	0	0	0	2	0	0	9

TABLE A.2. (contd)

<u>Site/Year</u>	<u>SEP</u>	<u>OCT</u>	<u>NOV</u>	<u>DEC</u>	<u>JAN</u>	<u>FEB</u>	<u>MAR</u>	<u>APR</u>	<u>MAY</u>
046985	5	21	1	0	4	8	16	17	24
047285	5	29	28	29	30	28	29	28	30
047385	2	11	1	1	5	9	15	15	18
048985	0	0	0	0	0	0	0	4	17
049085	0	0	0	0	0	0	2	1	13
049185	0	0	15	26	28	27	30	30	30
049385	0	0	0	0	0	1	0	4	30
049685	0	0	0	0	0	17	20	24	30
050785	0	0	0	0	0	0	0	0	25
051285	0	0	0	0	0	0	0	0	24
051385	0	0	1	14	22	28	29	19	29
051485	0	0	0	1	0	0	2	7	25

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