Residential Wood Combustion Survey Report

Minnesota Pollution Control Agency

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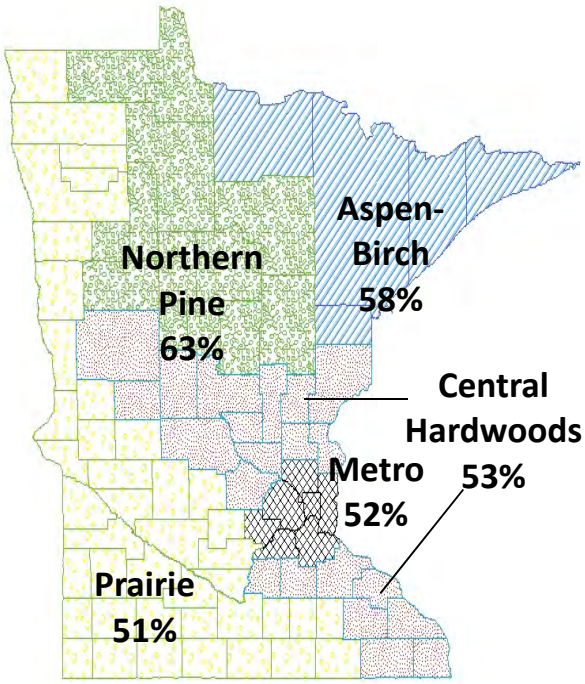
Summary

In 2012, the Minnesota Pollution Control Agency (MPCA) conducted a statewide survey to find out how much wood is harvested and burned annually for heat or pleasure in Minnesota. This survey has been conducted in one form or another every few years since 1960. Historically, the survey was conducted by the Minnesota Department of Natural Resources (MDNR) and the US Forest Service. The survey data has been used by a variety of state and federal agencies as well as trade organizations to manage forests, to inform policy makers and scientists, and to assist the hearth and fireplace industry by examining trends in wood burning.

The MPCA conducted this latest survey to gather additional information about wood combustion practices. Due to the levels of fine particles (PM2.5) in ambient air, it is important to have accurate information about the sources of this pollutant. While wood combustion is not the largest source of fine particle concentrations in the air, residential wood combustion is an important source of fine particle emissions. This survey provides an improved understanding of the residential wood burning in Minnesota, by type of equipment, by purpose for burning, by source of wood fuel, and by region of the state.

During the summer and fall of 2012, the MPCA sent out nearly 7,000 surveys to households throughout the state. After receiving nearly 2,400 responses, the survey was closed and the data analyzed.

For purposes of data collection and analysis, the state was divided into five regions. The figure shows the estimated percentage of households in each region that burned wood during the survey period. These regions (Aspen-Birch, Northern Pine, Prairie, Central Hardwoods and Metro) were also used in several previous surveys.



Percent of households in each region that burn wood.

The general findings of the survey show that Minnesotans burned approximately 1.3 million cords of wood between July 1, 2011 and June 30, 2012. This suggests the amount of residential wood burning is on the rise. However, due to changes to improve the survey design and methodology, comparisons across surveys to identify trends should be done with caution.

Much of the apparent increase seems to be due to more households burning wood for pleasure, predominantly in outdoor recreational burning equipment. The amount of wood burned per household does not seem to have drastically changed, but what has changed is the number of households burning wood, largely due to the increasing popularity of backyard recreational burning. The survey estimate of 1.3 million cords reflects all wood burned by residents in the state from backyard summer fire pits to winter home heating.

The overall data from this survey will inform the state's air pollutant emission inventory. The MPCA completes an inventory of all air emission sources every three years for planning and air quality analysis. The survey will provide a more complete picture of the overall impact of wood burning on air quality across the state.

This survey, along with other data on wood burning collected by the MPCA and other agencies, is an important tool to help Minnesota policy planners make informed policy and decisions regarding overall forestry management and environmental strategies in the state.

Introduction

Project purpose

During the summer and fall of 2012, the MPCA, assisted by the MDNR, US Forest Service and the Hearth, Patio and Barbecue Association, surveyed the state to determine the volume of residential wood burned during a year including the 2011-2012 heating season. Similar surveys were conducted for the 1960, 1969-1970, 1979-1980, 1984-1985, 1988-1989, 1995-1996, 2002-2003 and 2007-2008 heating seasons. These surveys are part of a long-term effort to monitor trends in the use and harvesting of Minnesota's wood supply by Minnesota households.

In addition to the trend and use information, these surveys offer useful data for Minnesota's emission inventories which are assessed every three years by the MPCA. The MPCA estimates the statewide emissions of air pollutants including fine particles, volatile organic compounds and other pollutants released from factories, traffic, residential wood combustion and other activities. These statewide emission inventories offer valuable information about the activities that contribute to fine particles, ozone and other air pollutants. Some of the fine particles in the air we breathe are directly released from combustion processes and some are formed by chemical reactions between other gaseous pollutants in the air. In recent years, Minnesota's emission inventory has indicated that residential wood combustion is an important source of the directly emitted fine particle emissions from combustion processes.

Furthermore, ambient air monitoring shows that parts of the state are at risk of violating U.S. Environmental Protection Agency's fine particulate standards, particularly in the metro area. This survey will help continue to identify and characterize Minnesota residential wood harvesting and burning activities and provide information that can be used to better understand how residential wood burning contributes to air pollution.

Survey objective

This survey has seven objectives. These objectives were framed by the MPCA, MDNR, and U.S. Forest Service to maximize the information that could be extrapolated from the survey results, ensuring that the information gathered would fulfill the primary needs of each of the partners involved.

Objectives:

1. Estimate the total volume and species of wood harvested and consumed between July 1, 2011-June 30, 2012.
2. Determine the geographic distribution of households burning wood by: type of usage (e.g.: primary heating source, secondary heating source, and pleasure), type of wood, and type of wood-burning appliance used.
3. Identify wood burning trends.
4. Determine the temporal allocation of wood burning over a year.
5. Understand the reason(s) wood is burned in order to inform air pollution reduction strategies.
6. Estimate the volume of wood burned from the following wood supply categories: live and/or dead trees, logging residue, land clearing, yard/boulevard trees, mill residues, lumber scraps, salvage of wood pallets, and commercial fuel products such as wood and paper pellets and manufactured fireplace logs.
7. Estimate the volume of fuel wood harvested from land owned by different entities (state, federal, county, forest industry, and private lands)

Survey questionnaire

The survey consisted of a 10 page multiple choice and fill in the blank type questionnaire. Most pages related to a specific type of wood burning appliance, and survey takers were asked to skip over pages if they did not own that type of appliance. The resulting questionnaire was relatively simple to fill out, and only took a few minutes for most survey participants. A copy of the questionnaire is included in this report as Appendix D.

Households were asked about the type of wood burning appliance used, the species of wood burned, whether they purchased or cut their own wood, ownership of the land on which wood was harvested, where wood was used (primary or secondary residence or while camping), and the source of wood harvested (woodland or non-woodland). Woodland included live and dead trees, and logging residue. Non-woodland consisted of fence rows, windbreaks, rural and agricultural land clearing, rural yard trees, and trees inside city limits.

Limitations

This survey was constrained by budget, time, and human resources. The limited budget did not allow us to do a random phone survey which may have yielded additional information; however, we were able to increase the number of participants compared to previous surveys. Additionally, the 2011-2012 winter weather throughout the state was unseasonably warm. This warmer than average winter may have reduced the overall wood consumed compared to an "average" winter, however we chose not to try to "correct" for temperature variations since these survey results will be used and compared to previous surveys, and those surveys also did not attempt to account for warmer or colder than average winters. In spite of these constraints, the survey results contain an abundance of information that can and will be used by a variety of interested parties.

Survey redesign

We significantly redesigned the 2012 survey to increase the overall response rate and to increase our confidence in Twin Cities Metropolitan (Metro) area results. We did so by simplifying the survey format and increasing the sample size for the Metro region. In redesigning the survey questions we also attempted to maintain the ability to compare data from previous surveys with results from this survey. While comparisons of trends based on surveys conducted at different times contain inherent uncertainties, these uncertainties are further exacerbated by 2012 survey changes to improve design and methodology. The redesigned survey was slightly longer, but required respondents to fill out fewer tables. Respondents also had the option of completing an electronic survey on-line. Most respondents chose to respond using the paper survey. The overall response rate of 35% was substantially higher than previous years, giving us a much larger data set to analyze and greater confidence in the results.

Wood burning by region of state

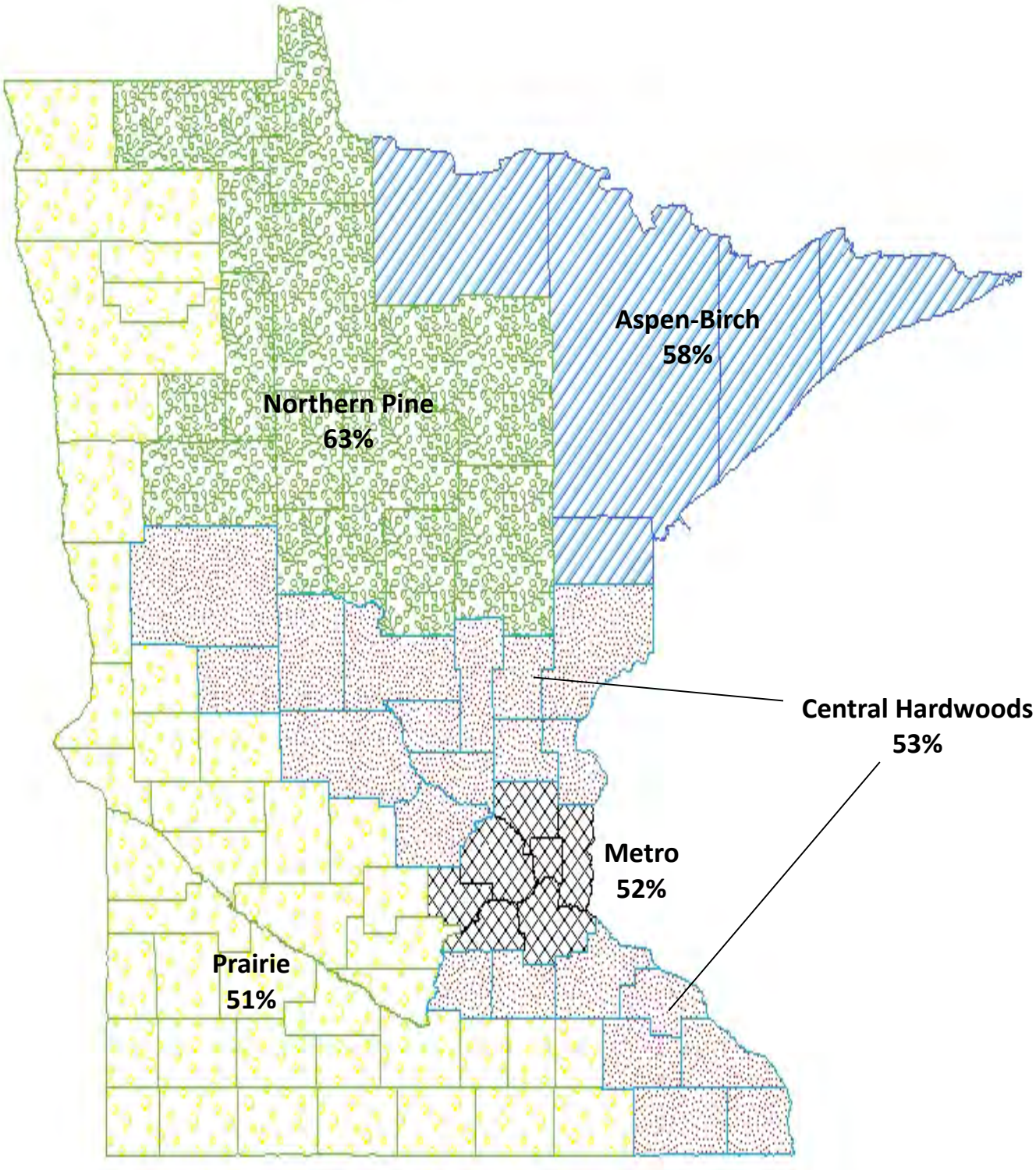


Figure 1. Percent of households in each survey region that burn wood

Methods

Survey methods

Background

During the time in which the residential fuel wood surveys have been conducted, the objectives and designs have changed. The 2012 survey design was substantially changed to try to increase the response rate, increase the accuracy of the results in the Metro area and to increase our confidence in the Metro region results by increasing the sample size for the Metro survey region.

Researchers developed a draft of the questionnaire based on questions used successfully in previous surveys, including a survey developed by John Gulland of Gulland and Associates from Killaloe, Ontario, Canada. The questionnaire was developed with help from Rob Daves, principle of Daves and Associates Research, a public opinion research consultancy.

In an attempt to increase response rates and meet the objectives, the survey structure was changed substantially. Most tables were replaced with sequential questions and lists of equipment and types of wood were simplified. Graphics depicting equipment and measurements showing sizes of a bundle, face cord and full cord of wood were included with appropriate questions. More demographic questions were added. (See Appendix D for a copy of the 2012 survey.)

The MPCA tested a draft using MPCA and MDNR volunteer staff and members of the public. Based on results, questions were reworded and reordered to improve clarity and mitigate question-order effects. Cognitive interviewing was used to develop additional response categories for open-ended questions. Formatting, readability and ease of navigating the survey were considered.

Sample selection

Survey Sampling, Inc. (SSI), a company specializing in sampling services, provided 7,000 addresses selected at random from valid Minnesota residential addresses based on a U.S. postal service list of residential addresses. All households in Minnesota were included in the sampling frame using a *disproportionate stratified sampling* design. This means that the number of surveys sent to each region was not in direct proportion to the population of the region. For example, even though the Northern Pine region comprises less than 6% of the state household population, we sent about a sixth (about 17%) of all surveys to this region. While we sent about twice as many surveys to the Metro region as we sent to any other region, the Metro region comprises a much larger proportion of the state household population (about 54%) than any other region. The rationale for the *disproportionate stratified sampling* design was two-fold. First of all, we wanted to ensure that we had enough respondents in the less populated survey regions to analyze, which was particularly important because we expected that many of the wood-burning behaviors we were trying to measure were likely to be more prevalent in less populous areas. Secondly, more surveys were sent to the Metro area than in prior surveys because more than half of the households in Minnesota are in the Metro area, because relatively small amounts of wood burning by many people in the relatively small Metro area had been estimated to result in relatively larger air quality impacts, and because we expected that wood-burning may be relatively less pertinent to Metro region residents and we wanted to ensure that we had enough returned surveys from the Metro region for analysis.

Respondent selection

There were no within-household respondent selection quotas. Presumably, the household member who was willing or who knew the most about the household's wood burning practices completed the survey.

On August 15th, 2012, all addresses in the sample were mailed a postcard briefly explaining the purpose of the survey and advising the residents to watch for the survey in the mail. We used returned postcards to eliminate invalid addresses. After removing 378 invalid addresses, 6,622 surveys were mailed, making the pool of potential respondents for this survey 6,622.

Households receiving the survey could choose the method they used to complete it. They could either complete the paper version and return it in a postage-paid envelope or complete an electronic version. SNAP survey software was used to develop the electronic survey so those choosing that response method were required to type a short URL printed on the first page of the paper survey. Accessing a computer and typing in the URL appeared to be a disincentive to taking the survey on-line, since only about 10 percent of respondents completed the survey electronically.

The initial survey was mailed out on August 29th, 2012. Each survey had a unique number printed in the upper right hand corner that corresponded to an address in the sample. Respondents using the electronic format were required to provide that number as part of their response. As surveys were completed, the unique survey numbers were checked off a master list. By September, 2012, approximately 1,600 surveys had been returned. On October 12th, 4,950 surveys with a new sequence of unique numbers were mailed to those who had not yet responded. The new numbers allowed researchers to distinguish the second mailing from the first. An additional 700 surveys were returned from the second round mailing, and the survey was closed on December 12th, 2012. A total of 2,360 valid surveys were returned[1], 212 electronically and 2,148 by mail.

Paper survey results were entered into the SNAP electronic form so all the data could be compared easily in an Excel database. Once all responses were entered and checked for quality, the unique numbers were disassociated from the addresses to maintain privacy of the respondents and prevent associating responses with a specific mailing address. The data could still be tracked by city, county, zip code and survey region.

Data analysis methods

The design of the survey distinguished between seven different types of wood burning, based on the wood-burning equipment used:

1. Conventional fireplaces
2. Fireplace inserts
3. Wood stoves
4. Wood (or corn) pellet stoves
5. Wood burning furnaces
6. Wood burning boilers
7. Outdoor recreational burning equipment including fire rings, chimeneas and fire pits

(The survey questionnaire is included in Appendix D.)

[1] Slightly more surveys were returned (roughly 2400) but some surveys were culled from the sample due to either being returned completely blank or not having a valid survey number so that there was no way to track the location of the residence.

For each type of wood-burning, respondents provided how many pieces of the equipment they have; the quantity of wood (if any) burned between July 2011 and June 2012; the months during that period in which the equipment was used; and the main purpose for which the equipment was used: pleasure, primary heat or secondary heat. Information was requested about the type of location in which the burning activity took place, whether primary residence, secondary residence or camping.
For each equipment type, a separate section was devoted to primary and secondary residences. A separate section on campfire burning appeared at the beginning of the survey where respondents provided quantities of wood burned at campsites during the survey year as well as a list of (up to four) Minnesota counties in which campfire burning took place. (All campfires were assumed to be located in fire rings and fire pits. So, all camping burning was included in the equipment type number seven: outdoor recreational burning equipment including fire rings, chimeneas and fire pits.) Questions at the end of the survey requested additional information from households that reported burning wood, including characteristics of the heating systems of the primary and secondary residences, a tree species breakdown for all wood that was burned, and sources and species of all harvested firewood. Finally, at the end of the survey, all respondents (wood-burners and non-wood-burners) were asked to provide basic demographic information about household income and housing type.

The basic methodology for using the survey responses to estimate population-wide wood burning for the survey year – for each of the five survey regions and for the entire state – involved the following main steps, each of which is explained in detail below:

1. **Prepare data for analysis**: record survey responses in a spreadsheet, review responses for quality, and recode responses into formats appropriate for analysis.
2. **Correct missing, invalid or contradictory responses**.
3. **Aggregate survey responses to get wood burning totals for survey regions for survey sample**: assign wood burning activities to specific locations, convert responses to common units, and find totals for each wood burning activity.
4. **Extrapolate survey sample totals to population-wide estimates**: find estimates for each of the five survey regions and for the state of Minnesota for each of the different wood-burning activities. Population and demographic weights were calculated and applied to correct for unequal probabilities of selection.

Prepare data for analysis

To assure data quality, manually entered data was rechecked to make any necessary corrections. Additional review of the spreadsheet was done to ensure data validity and to discard any unusable surveys. Discarded surveys included those with duplicate entries, those returned blank, and those with invalid survey numbers (rendering it impossible to determine the location of their reported activities or to assure that they were not duplicate surveys). Once the data were checked and quality assured, the resulting total survey sample was 2,360 responses.

Preparing the data for analysis involved recoding responses into numerical values. For example, all yes/no responses were recoded into ones and zeros, respectively. All categorical responses, in which the responder answers a question by choosing from a set of options, were recoded into numerical values. The recoding and assumptions that were made during the process were documented in a code book available on the MPCA website:
http://www.pca.state.mn.us/index.php/air/air-quality-and-pollutants/general-air-quality/wood-smoke/index.html.

Correct missing, invalid or contradictory responses

Dealing with missing, invalid, and contradictory responses was a lengthy process that involved a combination of inference, imputation, and common sense. Many of the key assumptions that were made are documented below. Throughout this process any seemingly incredulous responses were

checked with the actual paper surveys to ensure that there was not incorrect data entry into the spreadsheet. If a response was verified to have been entered correctly but still defied credibility, it was reclassified as invalid and a replacement value for the response was imputed based on the assumptions and methods listed below. An example of this type of response is a reported wood-burning quantity several standard deviations above the mean of other responses for that type of wood-burning equipment and deemed not physically possible for the equipment type.

Missing location information

A first step in the data analysis was to determine the location, by survey region, of every reported wood-burning activity. Wood burning could occur in three essential location types: primary residence, secondary residence and camping. For respondents who filled out the survey completely and accurately, geographic locations for all of these activities were provided. However, in some instances this information was missing or incomplete. In all cases in which respondents did not provide the location of their primary residence, it was assumed that the primary residence was the address to which the survey was mailed. In most cases where respondents *did* provide the location of their primary residence, it matched our information on where the survey was mailed. In the few cases where there was not a match, the location in the survey response overrode the survey region where the survey was mailed.

When respondents indicated wood burning at a secondary residence, but did not provide location information for a secondary residence, its location was inferred based on probabilities for all respondents who did provide secondary residence information. For example, if, for all residents who provided secondary residence information, their primary residence was located in the Northern Pine region, data showed that a household with a secondary residence whose primary residence was in the Northern Pine region, had the following probabilities for the location of its secondary residence (hypothetical example here with made up numbers):

Primary residence:	Northern Pine
Secondary residence:	Northern Pine: 70%
	Aspen-Birch: 10%
	Prairie: 5%
	Metro Area: 0%
	Central Hardwoods: 15%

Then, for all households with primary residence in the Northern Pine region that did not provide location of secondary residence, their secondary residence location was randomly chosen according to the indicated probabilities.

The final location type for wood burning was camping. Survey respondents were instructed to list all of the counties in Minnesota in which they burned wood in campfires. When respondents indicated more than one camping location, the total wood burned while camping was allocated equally to all counties listed in the survey in which campfire burning took place. In cases where respondents did not provide camping locations, then the camping location was inferred based on the modal response of all other responses from households with primary residences in the survey region. For example, if among all households with a primary residence in the Metro survey region the most common camping location was in the Aspen-Birch survey region, then all respondents from the Metro region that did not provide camping locations were assumed to have camped in the Aspen-Birch region.

Missing or invalid wood-burning quantities

In each section of the survey, there were many instances of respondents indicating that they had particular wood-burning equipment (or, in the case of camping, a response that the household did engage in campfire burning), but they entered no wood-burning quantities. In the case of campfire burning, when respondents reported burning but did not provide the quantity, the median campfire burning amount for all respondents who did provide campfire burning quantities was assumed.

For missing wood burning quantities for other types of wood burning equipment, quantities were inferred or imputed in the following ways. In the majority of cases a missing quantity was inferred to indicate that the respondent did not use the particular wood burning equipment. Only in cases where other responses made it clear that the household did indeed burn wood were missing quantities inferred or imputed. Such responses included indicating the months of the year in which the particular equipment was used. In these cases where responses to other questions indicated that a particular type of wood burning equipment was used, simple regression models were used to impute missing quantities based on all those that did provide quantities for using the particular equipment. For all households, indexed by *i*, that did provide burning quantities for use of equipment *j*, their reported number of pieces of equipment type *j* and the number of months in which they used equipment j were used to estimate the following regression equation:

$$Quantity\ Burned_{i,j} = \propto + \beta_1 Number\ of\ Equipment_j + \beta_2 Number\ of\ Months\ Equipment\ Used_j$$

Thus, using the responses of all other households that did provide burning quantities, the coefficients in the above equation (α, β_1, β_2) were estimated and used to impute the amount of wood burned by any household that did not provide quantities based on the number of pieces of equipment the household reported to have[2] and the number of months for which burning activity was reported. Note that a separate version of the equation above was estimated and applied for each different type of equipment, and separate equations were estimated for primary and secondary residences. This method was just used to determine the number of cords of wood (round wood/logs and split wood) that were burned; it was assumed that households that did not provide burning quantities did not burn any alternative wood types, such as wax logs, slabs or pallets.

In some cases respondents provided invalid responses to quantities of wood burned. For example, some responses consisted of an "x" instead of a number for the amount of a specific unit type (full cords, face cords, bundles, etc.). For these responses the median for all other households that did enter a quantity for that specific unit type was assumed. When entering burning quantities for each wood burning activity, respondents were given the option to answer "Other" and then to provide a specific answer. In the case of outdoor wood burning in fire pits, chimeneas or fire rings, many respondents did not provide a quantity burned but instead indicated "Other". Many of these "Other" responses indicated light use (for example, "sticks", "branches", "scrap", "brush", etc.). For these households, it was assumed that the equivalent of one bundle of wood was burned for each month that the equipment was used. If such a respondent did not indicate any months in which the equipment was burned, no wood burning was assumed.

Other missing information (number of pieces of equipment, purpose for burning, etc.)

In several cases, respondents indicated having and using wood burning equipment but did not give complete information. For example, some respondents failed to indicate how many pieces of a particular type of equipment they had in their residence; others failed to give their main purpose for using the equipment. In the first case, it was assumed that the household had only one piece of equipment (which was the modal response for all the equipment types for the households that did provide this information). In the case of missing main purpose for burning, then the most typical burning purpose of a particular equipment type was assumed -- pleasure for conventional fireplaces and secondary heat source for wood stoves and fireplace inserts.

[2] Throughout the survey, if a household indicated having a particular type of wood-burning equipment but did not indicate how many pieces of the equipment it had, it was assumed that it had one piece, which was the modal response for all equipment types for all households who did indicate number of equipment pieces.

To reduce the length, the main purpose for burning question (primary heat, secondary heat or pleasure) was not included on the survey questionnaire for central heating equipment (boilers and furnaces), pellet stoves or outdoor recreational equipment. The following assumptions were categorically made to impute the purpose for burning for these types of equipment. To ascertain whether pellet stoves and wood burning furnaces and boilers were used as a primary or secondary heat source, the survey question asking for the percent of heat provided by each potential heat source (electricity, natural gas, oil, wood, etc.) was considered. For all households that indicated wood provided 50% or more of their heat, it was assumed that the equipment provided primary heat; for all other households, secondary heat was assumed.[3] All outdoor recreational equipment for backyard recreational burning or camping were assumed to be used for pleasure.

Other responses revealed clear contradictions that suggested that respondents either did not thoroughly understand the survey or did not know the specific type of equipment that they had. For example, in the section on wood burning furnaces and boilers, some respondents indicated that they had wood furnaces as defined in the questionnaire (not boilers) but also indicated that the equipment's function was to heat water, which is clearly a characteristic of a wood boiler (not a furnace). In cases of obvious contradictions such as this, corrections were made to most accurately reflect the true behaviors of responding households.

Concurrent to the completion of analysis for this report, the quality-assured data with all the inferences and imputations described above is being transferred into a relational database, which at the time of publication of this report is still under development. It will be publicly available when it is complete.

Aggregate survey responses to obtain wood burning totals for survey regions and extrapolate to population-wide estimates

Based on locations of primary and secondary residences and provided (or inferred) locations for campsite burning, every burning activity reported in the survey was assigned to one of the five survey regions. All wood burning quantities were converted into common units of cords. Some survey units (full cords, face cords and bundles) were converted based on standard conversion factors.[4] Other wood burning units (wax logs, pallets, pounds of pellets) were converted into cord-equivalents using the conversion factors listed in Appendix B.

Once all wood burning activities were assigned a location (by survey region) and were converted into a common unit (cords), the wood burned by households in each region was tallied. Additionally, wood burning by equipment type as well as wood burning by each wood burning purpose was totaled for each survey region.

Estimates of the total wood burned, as well as subtotals by equipment type and by burning purpose, for the survey sample were extrapolated to determine approximate wood burning amounts for the entire population for each survey region. This extrapolation was based on the number of households in each survey region, according to the 2011 U.S. Census American Community Survey. For example, there were 706 survey responses from the Metro region, and 1,127,600 households in the region. Thus Metro region totals for the survey sample were scaled up by a factor of $\frac{1{,}127{,}600}{706} = 1{,}597$[5] to estimate total burning activities for the region. This process yielded estimates for total wood burning (in cords), as well

[3] Note that the 2011-12 survey posed the question of burning purpose in a different manner than in previous surveys, making a quantitative identification of trends in changing purposes for burning across survey years difficult.

[4] One full cord equals three face cords equals 64 bundles.

[5] This is equivalent to saying that each household responding to the survey from the Metro region represents 1,597 households in the population as a whole.

as estimates for total wood burned in each equipment type and for each burning purpose for each of the five survey regions. Scaling survey region-wide estimates in this manner corrects for the unequal probability of selection caused by *disproportionate stratified sampling* (i.e. the fact that the proportion of completed surveys from any individual survey region was unequal to that region's proportion of the total state household population).

Statewide total wood-burning activities were estimated by summing the estimates for the five survey regions. The accuracy of this estimate is predicated on initially unbiased estimates for each region and does not correct for any response bias or any sampling error.

Additional weighting steps were tried to account for differential response across demographic groups. These steps along with the impact on results are described in Appendix C.

Uncertainty and Confidence Intervals

We assigned a confidence interval to the estimate of the total cords of wood households burned statewide. This indicates where we expect the true statewide amount burned to be with a 95% level of confidence. This reflects the inherent variability in how much wood different households burn and the fact that all population level-estimates derived from survey responses have an inherent degree of uncertainty. This uncertainty arises from many causes, including the survey sampling method, selection bias in who responds to the survey, and errors and ambiguities in survey responses.

Uncertainty can be particularly severe with small survey sample sizes. For the 2011-2012 Residential Wood Fuel Survey, the sample size was quite large (2,360 total responses), but sub-samples for specific wood-burning behaviors in specific wood burning equipment in specific survey regions can be quite small. For example, the estimate of wood fuel consumption in pellet stoves in the Metro survey region was based on a single positive response of wood burning in pellet stoves from the region. Although it is a small contributor to the total wood burned, the extrapolation of this single response to an estimate for all wood fuel consumed in pellet stoves for all the households in the Metro region is fraught with uncertainty. Similarly, other wood-burning equipment types in other regions had similarly small samples of positive responses. With such small incidence rates (i.e., number of positive responses relative to all responses), small numbers of outlying responses can have a large impact on population-wide estimates.

Confidence intervals were calculated in the following manor. First, all survey responses were weighted to correct for unequal representation across survey regions. For example, 706 households completed surveys (with their primary residence) in the Metro region out of 2,360 total completed surveys. Thus, the percentage of surveys in the total survey sample from the Metro region was $\frac{706}{2{,}360} = 30\%$. The overall number of households in the Metro region is 1,127,600 while there are 2,101,295 households in the state. Thus, the percentage of the state's households in the Metro region is $\frac{1{,}127{,}600}{2{,}101{,}295} = 54\%$. Therefore, Metro region households make up 54% of the state population but only 30% of the survey sample population so the Metro region was under-represented in the survey sample. Similarly, other regions were either under- or over-represented in the survey sample. Because wood burning behaviors may vary across locations of primary residence, giving equal weight to all surveys regardless of residence location could introduce bias in the total estimates for statewide burning. To correct for this, surveys from over-represented survey regions were given weights less than one (i.e., the contribution of their wood burning activities to state totals were scaled down) while under-represented groups were given weights greater than one (their contribution to total estimates were scaled up). Continuing the Metro region example, responses from this region were given weights of $\frac{54\%\ of\ population}{30\%\ of\ survey\ sample} =$ a weight of 1.8. Weights across the five regions ranged from 0.3 in the most over-represented regions (Northern Pine and Aspen-Birch) to 1.8 in the most under-represented region (Metro). These weights are generally termed "post-stratification weights" and their use is fairly common in survey analysis where response rates are not equivalent across different subgroups within the survey sample.

Once all survey responses were weighted in this manner, the mean and standard deviation of the unweighted survey responses were calculated. The standard deviation was divided by the square root of the number of surveys in the sample (2,360) to estimate the standard error (SE) of the sample. For 95% confidence intervals, a critical value (*t**) was obtained from tables of the *t* distribution with a significance level (α) of one minus the confidence level or 0.05. The SE of the sample was multiplied by *t** to obtain a margin of error around the sample mean. Finally, to correct for the *design effect*, which entails greater variance in the data and thus greater uncertainty in population-wide wood burning estimates due to the weighting described above, the following correction was made to the margin of error. The design effect was calculated as: $1 + \left(\frac{\sigma}{\mu}\right)^2$, where σ is the standard deviation of the weight parameter and μ is the mean of the weight parameter across all 2,360 households in the survey sample. The confidence interval was scaled up by the square root of the design effect, which served to widen the confidence interval by roughly 20%. This confidence interval was applied to the weighted survey responses to obtain overall estimates of a 95% confidence interval for statewide wood-burning quantities.

Results

Volume of wood fuel consumed

The total volume of wood burned statewide during the survey year was an estimated 1.29 million cords. As Figure 2 depicts, this is the second consecutive survey that showed a substantial increase in point estimates of wood burning over the previous survey, reflecting what appears to be a steady increase in wood-burning over the past decade. The estimated total from this survey year is similar to previous high estimates for wood-burning in the early- to mid-1980s.

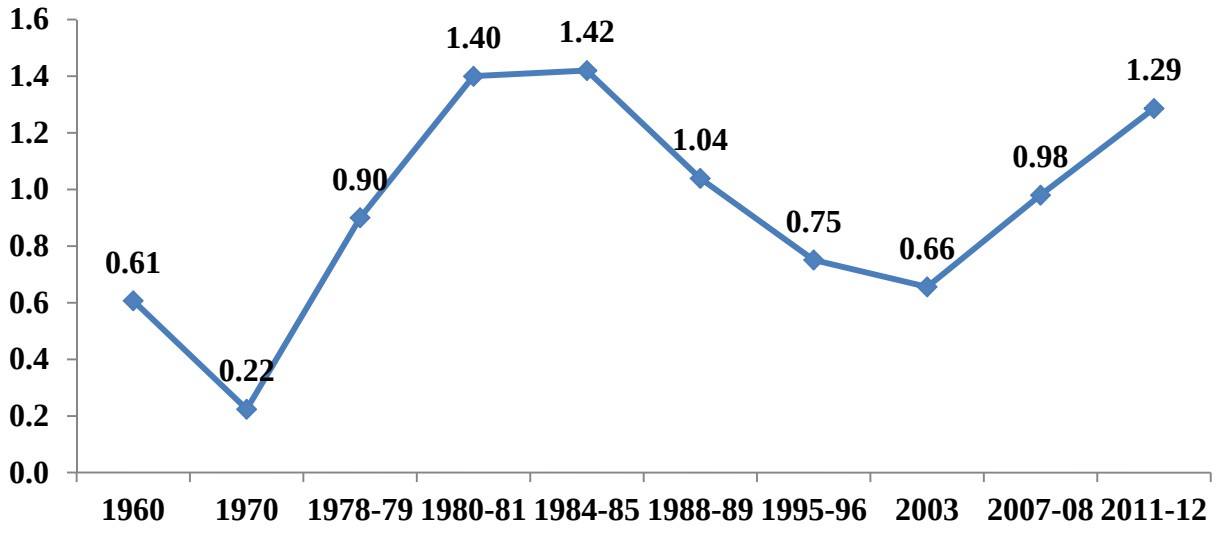


Figure 2. Wood fuel consumption in Minnesota by survey year (Millions of Cords)

Estimation of a 95% confidence interval around this point estimate yields a range of between 1.02 million cords and 1.54 million cords[6]. This means that we can say with 95% confidence that the true statewide level of wood-burning during the survey year was somewhere within this range.[7] Confidence intervals are not available from the statewide wood burning estimates from prior years, but based on these calculations, it does not appear there was a statistically significant increase in statewide wood-burning with a 95% level of confidence.

However, we must stress that given changes in survey design, the survey sampling regime (i.e., how many surveys were sought after and received in each survey region) and changes in survey analysis methodology, comparing across surveys to identify trends is challenging. It is possible that facets of the 2011-2012 survey design (perhaps the perceived length of the survey) led to a higher response rate among wood burners relative to non-burners. (The current survey questionnaire can be seen in Appendix D while previous survey questionnaires are available from the MPCA wood-smoke web site.[8]) This could partially explain the considerable increase in the proportion of households across the state found to be wood burners (see results below) in this survey relative to previous surveys. Thus, although we provide findings on trends in this report, comparisons of trends across surveys contain inherent uncertainties which are further exacerbated by changes in the 2011-2012 survey design and methodology.

There are many exogenous factors that influence wood-burning behaviors, including: weather; general economic conditions in the state; wood fuel prices; substitutes to wood fuel prices and availability (i.e. other heating fuels, including natural gas, oil, and electricity); cultural tastes and preferences; demographic patterns; marketing of wood-burning equipment; technological developments in wood-burning equipment; wood fuel availability due to wind storms and ash borer infestations; and others. Future work could examine how much each of these factors contributes to overall wood-burning behaviors as well as specific types of wood-burning behaviors. The remainder of this section of the report, however, will seek to break down the sources of this total volume of wood burned, by survey region, by type of wood-burning equipment, by wood-burning purpose, by place of wood-burning consumption (primary residence, secondary residence, campsite), by type of species burned, and by source of wood fuel.

Figure 3 depicts the level of wood burning estimated in each of the five survey regions. On an absolute basis, the Northern Pine and the Central Hardwoods survey regions had the highest levels of wood-burning in terms of total cords burned, each with an estimated wood burning total of nearly 350,000 cords. The Northern Pine region had the highest wood-burning per household despite having the second fewest number of households, reflecting considerably higher per household wood burning (for households that burned wood) in that region compared with the rest of the state. On a per household basis the Northern Pine had burning levels of about 2.8 cords per household in the survey region that burned wood. The next highest per-household consumer of fuel wood was the Aspen-Birch region with about 1.7 cords burned per household in the survey region. The Metro Area had the lowest per-household burning total in the region(under 0.2 cords per household that burned wood), but because the population of the Metro Area vastly exceeds any of the other survey regions, the total wood burned in the Metro Area was not much lower than the other survey regions. Note that these wood-burning

[6] This confidence interval includes an adjustment for the design effect as described in the Methods section above.
[7] There were several assumptions made to support the validity of this confidence interval, namely that wood-burning behaviors in the population are normally distributed and that there are no sources of bias in the survey responses, such as response bias and selection bias. It is possible that these assumptions may not be accurate, rendering the true confidence interval wider than is reported here.
[8] http://www.pca.state.mn.us/index.php/air/air-quality-and-pollutants/general-air-quality/wood-smoke/index.html

totals reflect the total wood burning in the survey region even if the wood was burned by households located outside of the survey region (i.e., at a secondary residence or campsite), but the per household totals are based on the actual number of households in the survey region. The distribution of wood burning activities across the state depicted in Figure 3 likely generally reflects the relative abundance and price of wood fuel and price and availability of alternative fuels (natural gas, propane, corn, etc.) in the different regions of the state.

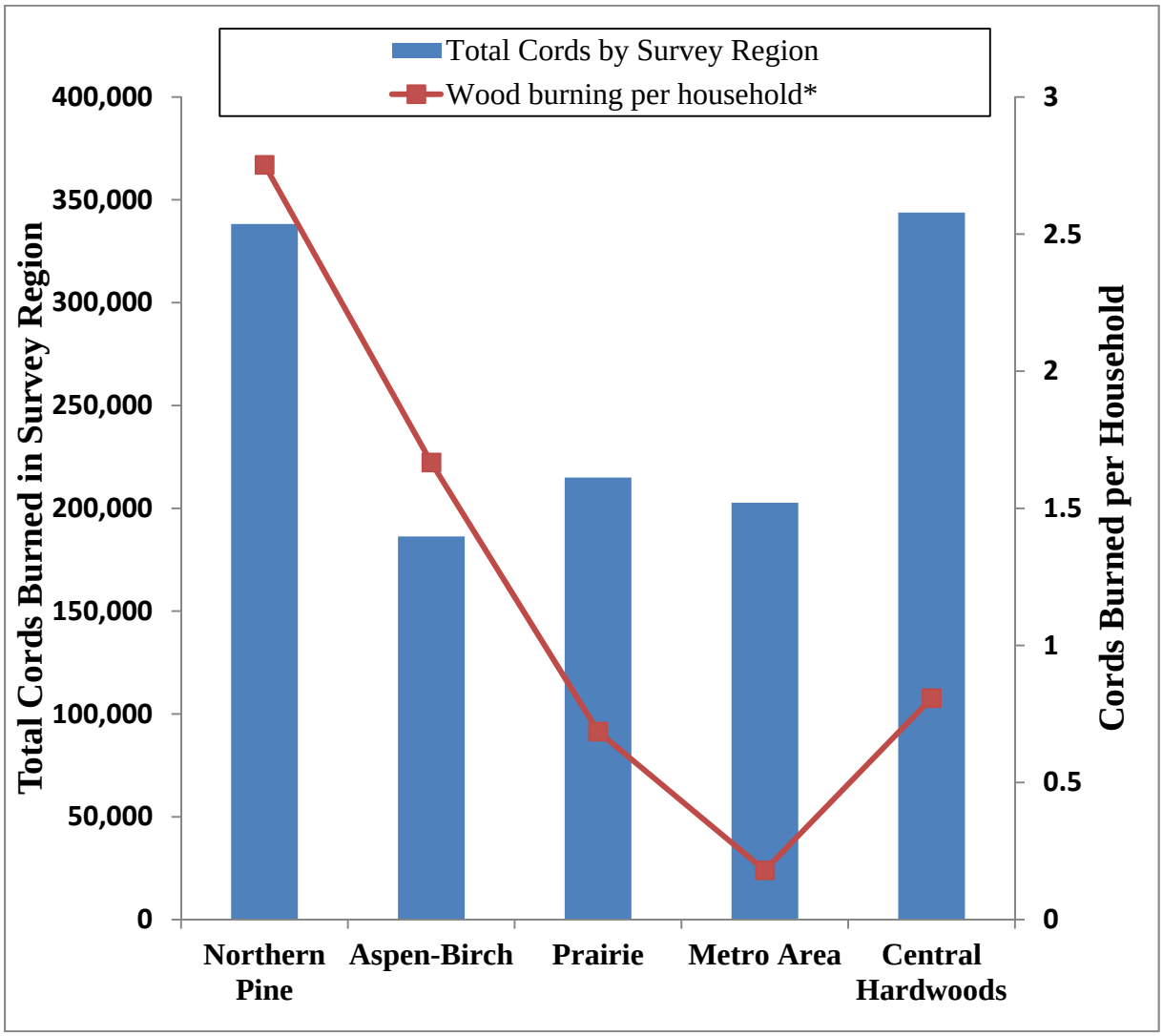


Figure 3. Total and per-household wood fuel consumption by survey region

*Note: wood burning totals are based on all the wood burning that occurred in the survey region even if it was done by households from outside the region while number of households in the region is the actual households physically located within the region.

In examining how wood burning is divided into different types of wood-burning activities, the first breakdown of burning activity that we looked at was based on the different categories of wood-burning equipment. Figure 4 presents survey estimates of wood burning by type of burning equipment in each survey region. (Panel A presents the information in adjacent columns to better illustrate the total wood fuel consumed in each type of equipment in each survey region while Panel B presents the same information in stacked columns so that the total wood fuel consumption in each region can be more easily seen.) As can be seen in Figure 4, the predominant types of equipment used to burn wood vary across the state. For example, burning in outdoor equipment (including camping) is highest in the

Northern Pine, Prairie and Metro regions. In the Aspen-Birch region, however, burning in wood stoves far eclipses other equipment used for wood burning. In the Central Hardwoods, wood boilers were estimated to contribute the largest proportion of wood burning in the region. Wood burning in pellet stoves was relatively low across all regions[9], while the other burning equipment types (conventional fireplaces, fireplace inserts, and wood furnaces) had low to mid burning levels depending on the region.

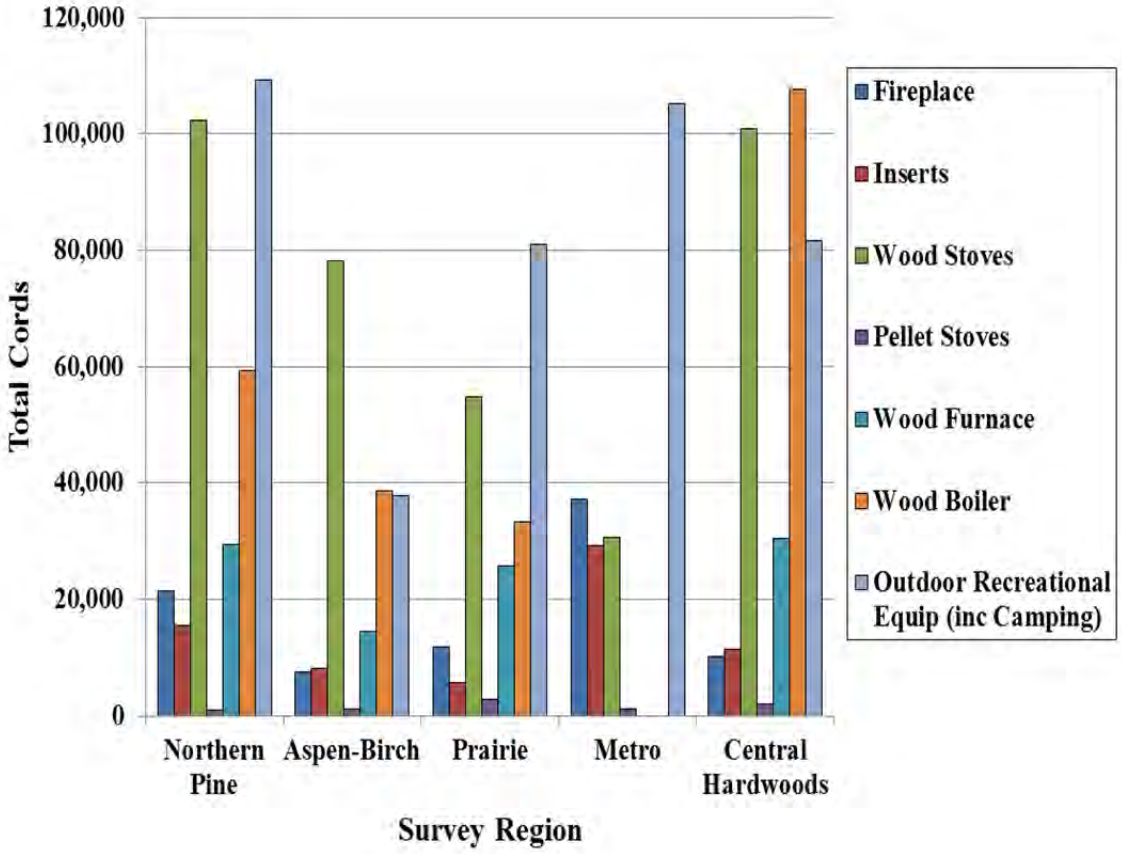


Figure 4A. Total wood fuel burned by survey region and type of wood-burning equipment

[9] Since the objective of this study is to characterize wood burning in Minnesota, we do not include any findings of corn burning in corn pellet stoves, even though this information was asked on the survey. The burning of corn is not generally widespread in Minnesota, but in some areas, particularly in the Prairie survey region, corn-burning to heat homes does occur and may supplant some wood burning activity.

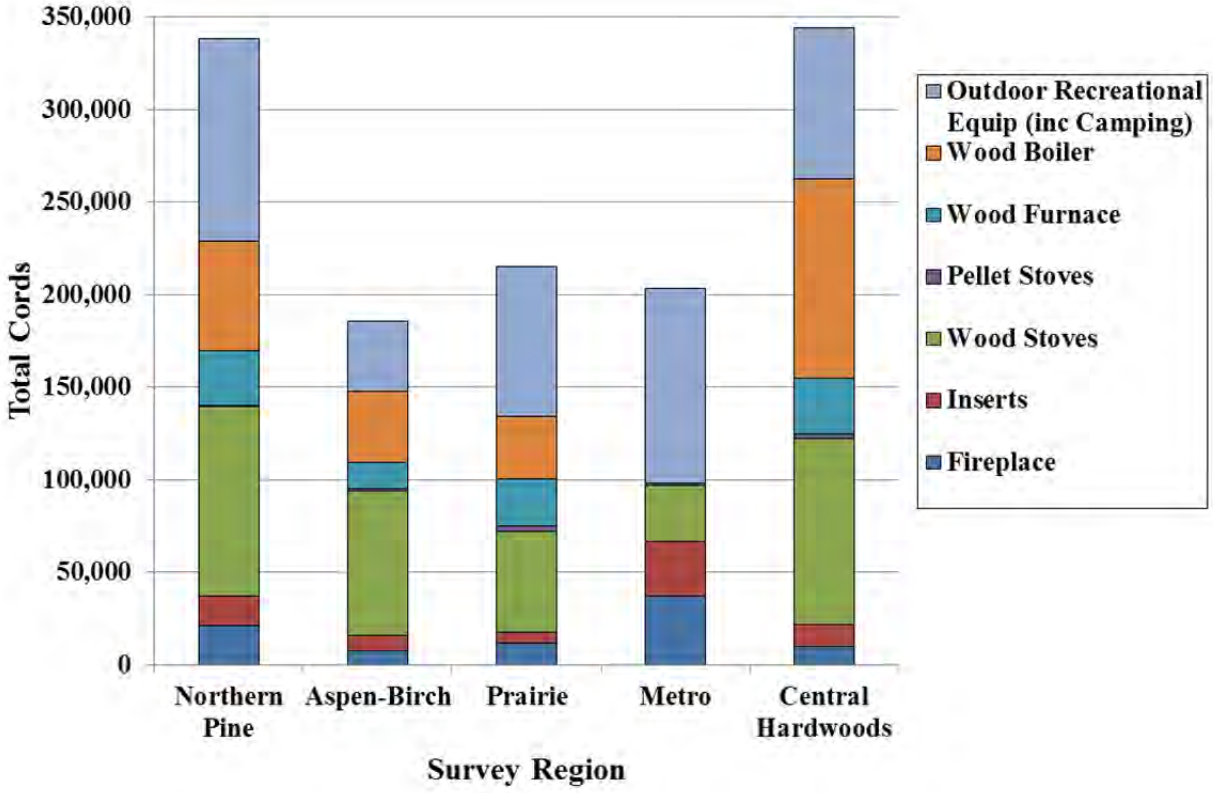


Figure 4B Total wood fuel burned by survey region and type of wood-burning equipment

Table 1 and Figure 5 depict how statewide uses of different wood-burning equipment have changed over the past 10 years, taking results of previous surveys into account. Table 1 shows how proportionate use of different equipment types has changed while Figure 5 depicts how absolute levels of wood burning (both in the aggregate and for each of the different equipment types) has changed over the past decade. Figure 5 illustrates that wood-burning as a whole has seemingly increased substantially[10] and that the greatest contribution to this change has been the increasing use of outdoor recreational equipment (fire pits, chimeneas, fire rings, campfires). In 2002-03 outdoor recreational burning comprised of only 3% (an estimated 17,000 cords) of all wood burned. In 2007-2008 it had risen to 16% (an estimated 160,000 cords). In 2011-2012, it comprised an estimated 32% (an estimated 430,000 cords) of all wood fuel consumed across the state.

[10] As mentioned above, due to uncertainty in point estimates, claims of "significant" trends must be done cautiously. Note that the low end of the 95% confidence interval for total residential wood burning for the current survey is nearly as low as the point estimate for the 2007-2008 survey. Had confidence intervals been calculated for the 2007-2008 estimate of total residential wood burning, there would surely be overlap of the two confidence intervals for the two surveys. Thus, we cannot claim a "statistically significant" increase over the previous survey; although the difference between the two point estimates suggest that an increase in residential wood burning may be occurring.

Table 1. Percent of Statewide Wood Volume Consumed by Type of Wood-Burning Equipment

Type of Wood-Burning Equipment	Percent of Total		
	2002-03	2007-08	2011-12
Conventional Fireplaces	25%	9%	7%
Fireplace Inserts	13%	8%	5%
Wood Stoves	20%	40%	29%
Pellet Stoves	-	1%	1%
Wood-Burning Furnaces	24%	5%	8%
Wood Boilers	16%	20%	19%
Outdoor Recreational Equipment	3%	16%	32%

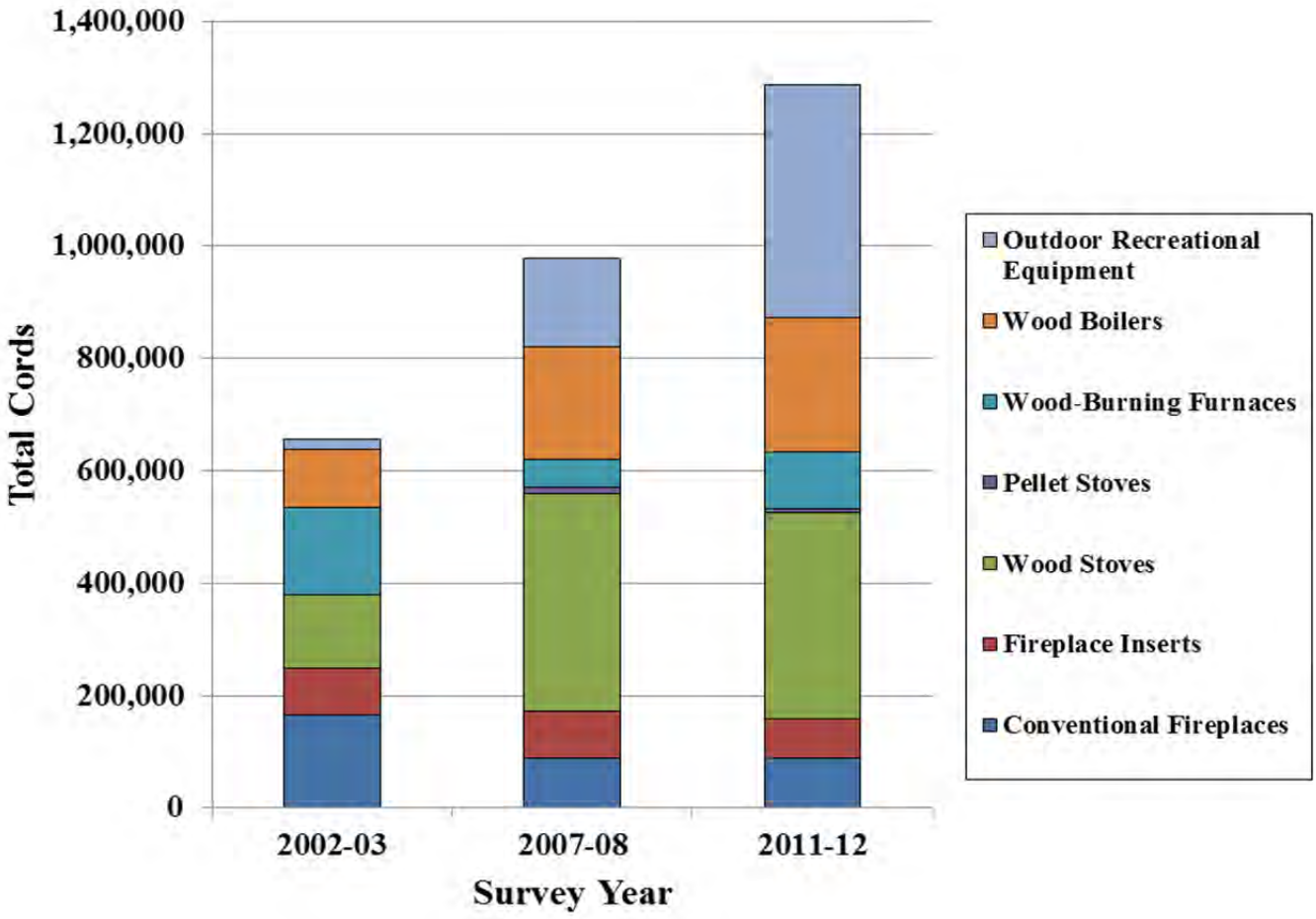


Figure 5. Total wood burned by type of wood burning equipment and year of survey

Figure 6 depicts wood consumption by reason for burning in each survey region. (Again, the two panels, A and B, of Figure 6 show similar information, but in the first panel total amounts of burning for different purposes in each region is clear to see while in the second panel the proportions of each purpose as well as the total wood burned in the region can be more clearly seen.) The survey distinguished between three general reasons for burning: primary heat, secondary heat and pleasure. In areas of greater wood abundance (Northern Pine, Aspen-Birch, Central Hardwoods) consumption of wood as a heating source was relatively higher than in areas with scarcer amounts of wood (Metro, Prairie[11]). These regions of lower wood abundance had relatively high proportions of burning activity for pleasure, largely from outdoor wood burning equipment and camping (see Figure 6). Lesser abundance of wood fuel appears to provide a disincentive for using wood as a heating source but not a strong disincentive towards backyard recreational burning and campfires for pleasure. [12]

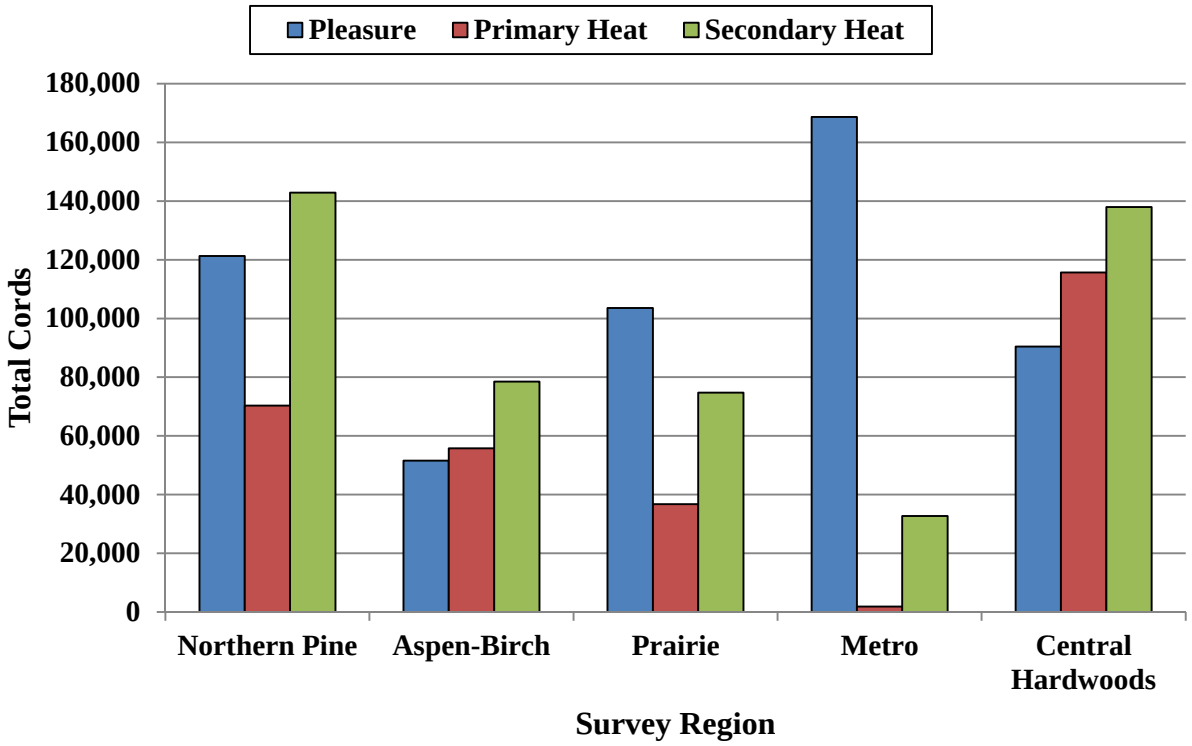


Figure 6A. Total wood burned by survey region and reason for burning

[11] Again, corn burning in the Prairie region is not considered in this report. The majority of corn-burning that was reported in the survey occurred in the Prairie survey region.

[12] Note that the delineation of the different survey regions is based on fairly stark differences in forest cover as well as tree species type. Generally speaking, the Northern Pine and Aspen-Birch regions are heavily forested. Comparatively little forest coverage is present in the Prairie and Metro regions. In the Central Hardwoods region, there is a mid-range moderate level of forest coverage.

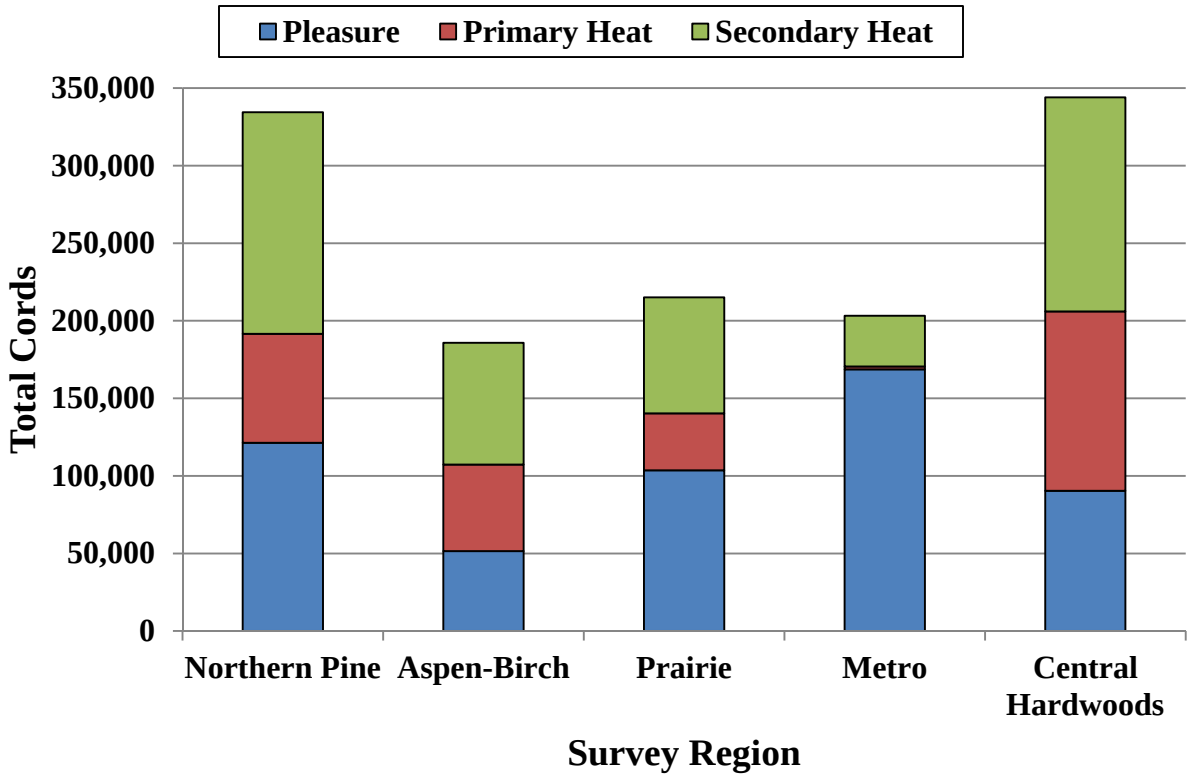


Figure 6B. Total wood burned by survey region and reason for burning

Figure 7 depicts how statewide estimates for wood-burning by reason for burning have changed through time. It appears that burning for pleasure has increased substantially while burning for primary heating purposes has decreased substantially. In 2011-2012, the percent of all wood burned for pleasure (including camping) was over 41% (just over 550,000 cords), while in 2007-2008 it was only 30% and in previous years it was even lower. Percentage of wood burned for primary heat in 2011-2012 was 23% (310,000 cords), down from 45% in 2007-2008. As has been stated above, however, these trends should be interpreted cautiously due to the many changes to improve survey design and survey analysis methodology. One of the more stark changes has been in the way the survey asks why people burn wood. In the 2011-2012 survey, purpose for burning was asked separately for each type of burning equipment used (with exceptions noted in the Methods section above where the purpose was assumed). In the 2007-2008 and prior surveys, however, purpose for burning was asked just once and applied to all wood consumed by the respondent. While the changes give us greater confidence in understanding the purpose for wood burning in the 2011-2012 results, these changes introduce a significant source of bias in estimating trends. Nonetheless, these results do likely reflect a general trend of increased burning for pleasure relative to home heating.

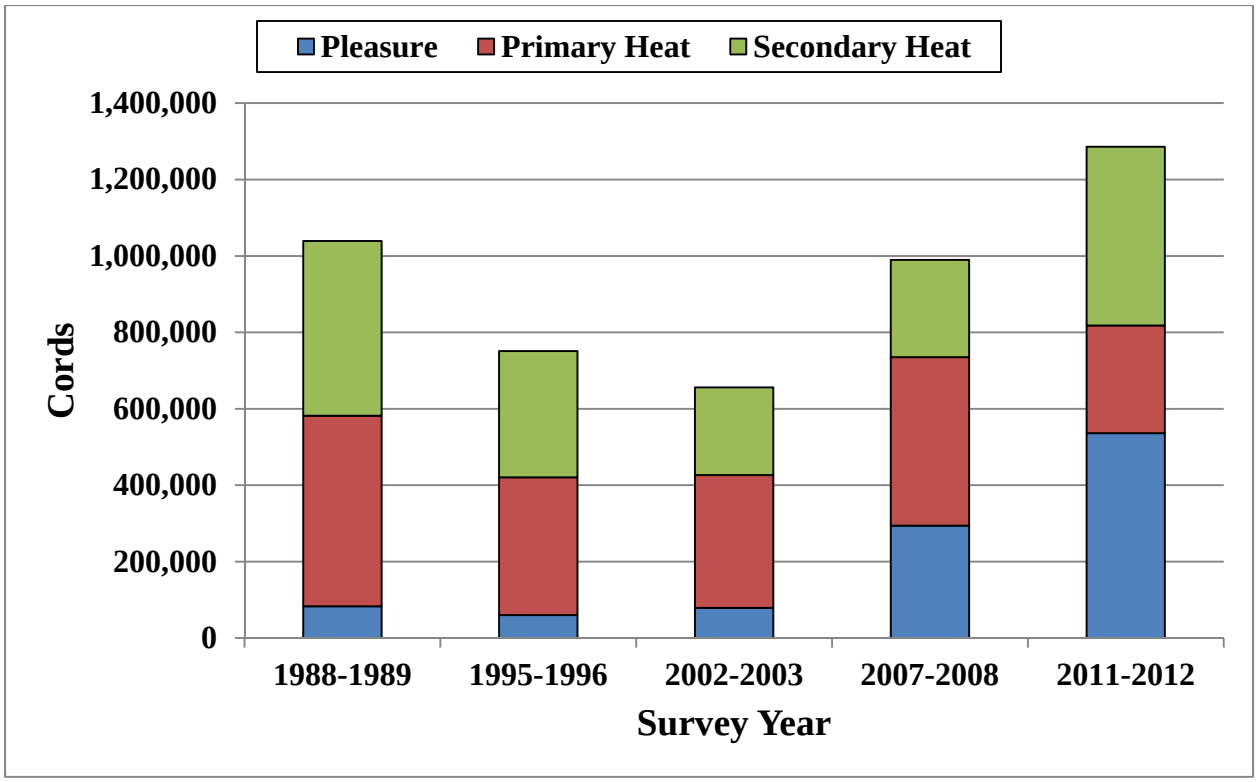


Figure 7. Volume of wood burned by reason for burning by survey year

Table 2 shows that of the estimated statewide total of 1.29 million cords of wood fuel burned, 77% (0.99 million cords) was burned at primary residences, 16% (0.21 million cords) was burned at secondary residences and 7% (0.09 million cords) was burned at campsites. These relative proportions for the different places of wood consumption are similar to the 2007-08 survey results although comparisons are difficult, again due to changes in the way that burning locations were asked in the two surveys. The Central Hardwoods region consumed the most wood at primary residences while the Aspen-Birch region reported the lowest volume of wood fuel burned at primary residences. Burning at secondary residences was highest in the Northern Pine region, which is unsurprising given that many Minnesotans from across the state have secondary residences in the Northern Pine region of the state. Similarly, wood burned for camping was also highest in the Northern Pine region.

The number of wood-burning equipment column shown in Table 2 includes all seven types of wood burning equipment listed above but does not include campsites. As by far the most populous survey region, the Metro Area has the highest numbers of wood burning equipment. Relative to the population size, however, the Northern Pine has the highest numbers of wood burning equipment.

Table 2. Number of cords burned by survey region and place of consumption

Survey Unit	Number of Wood-Burning Households*	Number of Wood-Burning Equipment	Total Volume (Cords)	Place of Wood Consumption		
				Primary Residence (Cords)	Secondary Residence (Cords)	Camping (Cords)
Northern Pine	77,896	305,519	338,248	204,617	102,714	30,917
Aspen-Birch	65,362	175,003	186,331	139,337	34,046	12,948
Prairie	158,879	220,099	214,942	182,370	14,341	18,231
Metro Area	589,355	926,866	202,729	184,552	7,135	11,042
Central Hardwoods	225,223	390,419	343,811	276,368	47,942	19,502
Statewide	**1,115,715**	**2,017,905**	**1,286,062**	**987,244**	**206,178**	**92,640**

*Based on location of primary residence

Figure 3 showed the average wood burned per household for all wood burning households in each survey region. Figure 8 shows how per-household average volume of wood burned across the state varied by burning purpose. The average volume burned by households using wood fuel as a primary heat source was 3.5 cords over the course of the 2011-2012 survey year. Wood burned per household for secondary heat was 3.6 cords and wood burned for pleasure was 0.6 cords[13]. The per-household wood consumption for pleasure is virtually unchanged since the previous survey, so the overall increase in wood consumption for pleasure (See Figure 7) is because many more households are burning wood for pleasure and not to the amount of wood burned per household increasing. As can be seen in Figure 8, the per household wood consumed for primary heat decreased considerably compared to previous years while the wood consumed per household for secondary heat increased. This may be due in part to different survey design and different survey analysis methodology in the way that burning purposes were assumed when not explicitly stated in the survey (see explanation in Methods section above). The overall wood burned per household for wood burners in 2011-2012 was estimated at just over 1.2 cords per household. This is slightly less than the per-household wood burning estimated from the 2007-08 survey (approximately 1.6 cords per wood-burning household). This makes sense given the proportionate increase in recreational burning for pleasure relative to other wood-burning purposes and the fact that burning for pleasure generally involves lower quantities of wood that burning as a heating source.

[13] We find it hard to explain why the amount wood burned per household was greater for secondary heat than it was for primary heat. This may be due in part to incorrect assumptions in our allocation of burning activities to purposes when the purpose was not explicitly indicated in the survey (see Methods section above).

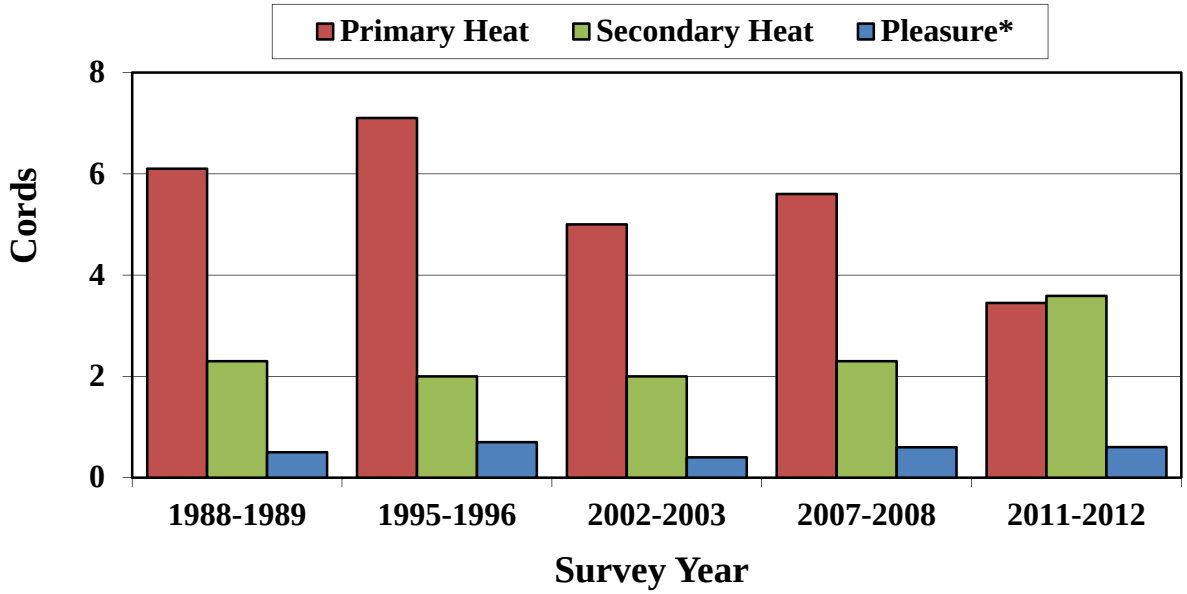


Figure 8. Average number of cords burned per household by reason for burning survey year

*Burning for pleasure includes campfire burning.

Characteristics of wood fuel users

Statewide, the survey results produce the estimate that 53% of Minnesota households burned wood during the survey year, or roughly 1.1 million wood burning households out of 2.1 million households in the state. (See Table 3 and Table 4.) This is a considerable increase from previous surveys. 30% of households in the state were estimated to be wood burners from the 2007-2008 survey, and even fewer from the survey before that. Increased numbers of households burning wood at home in outdoor recreational burning equipment may contribute to the higher percent of households burning wood.

Given changes in survey design, comparing results across surveys may be problematic. For example, in the current survey, the very first questions drew out camping behaviors whereas in the previous survey, campsite burning was embedded later in the survey along with other wood-burning activities. It is possible that respondents that did not carefully read through and fill out the entire survey (i.e., respondents who suffered "survey fatigue") would have nonetheless answered the first question about campfire burning. However, even when camping is excluded from the total, this survey estimated nearly 49% of households burned wood across the state. (See Table 3.)

As shown in Figure 1 and in Table 3, the percent of households burning wood in each survey unit varies from 51% in the Prairie to 63% in the Northern Pine. This general pattern of less wood-burning activity in the Prairie[14], Metro Area and Central Hardwoods and higher activity in the Northern Pine and Aspen-Birch is consistent with findings from previous surveys, but the estimated percentages of burners are significantly higher in every region compared to previous surveys. Again, changes in survey design creating different selection biases make comparisons across survey years difficult. The higher burning activity in the Northern Pine and Aspen-Birch relative to the other regions is likely caused in part by the relative abundance of wood available in those regions.

The way households utilize wood fuel also varies, with an estimated 11.5% of all wood burners using it as a primary heating source, 11.6% as a secondary heat source, 32.8% for camping, and 82.8% for pleasure. The percentage of households burning wood as their primary or secondary heat source is highest in the Aspen-Birch and Northern Pine regions. As can be expected, the Metro area, where wood costs are the highest and availability is the lowest, had by far the lowest percentages of households using wood as a heating source. The vast majority of households that burned wood in the Metro area did so for pleasure. Burning for pleasure was not nearly as high in any of the other regions. This general pattern of different wood fuel uses across the survey regions is consistent with the results of previous surveys. There appears to be a trend of increasing wood burning for pleasure (by percentage of households) relative to heating purposes compared to 2007-2008. However, as has been stated above, due to the changes in survey design analysis methodologies, examining trends across time must again be done with caution.

Table 4 expands upon the information presented in Table 3 to show the number of households within each survey region that burned for each of the burning purposes. The table presents the regional totals for the survey sample as well as estimates for the entire population that are reached by proportionately extrapolating out the sample totals based on the population (by number of households) of the region relative to the number of households from the region in the survey sample. As Table 4 shows the estimated number of wood-burning households in the state (over 1.1 million) is over 80% higher than the estimate for 2007-2008 (616,000 households). This increase seems rather incredulous, and may in part be caused by selection biases in the survey response and other uncontrollable factors in the makeup of the survey sample that were mentioned above.

[14] As noted above, the vast majority of corn burning that was reported in the survey responses were in the Prairie region.

Table 3. Percent of households by survey region of primary residence that burned wood (at primary residence, secondary residence, or camping) during the 2011-2012 heating season

Survey Unit	Percentage of Households Burning Wood	Percentage of Households Burning Wood (Camping Excluded)	Reason for Burning			
			Primary Heat	Secondary Heat	Pleasure	Camping
Northern Pine	63%	59%	27%	26%	70%	33%
Aspen-Birch	58%	54%	33%	26%	71%	34%
Prairie	51%	45%	16%	10%	75%	39%
Metro Area	52%	48%	5%	8%	91%	33%
Central Hardwoods	53%	48%	13%	14%	76%	26%
Statewide	**53%**	**49%**	**12%**	**12%**	**83%**	**33%**

Table 4. Number of households burning wood for each purpose with extrapolations out to population

Survey Unit	Survey Responses					Population Estimates				
	House-holds Burning Wood	Pri-mary Heat	Second-ary Heat	Pleas-ure	Camp-ing	Households Burning Wood	Primary Heat	Second-ary Heat	Pleasure	Camping
Northern Pine	284	77	74	199	93	77,896	21,120	20,297	54,582	25,508
Aspen-Birch	237	79	62	168	80	65,362	21,787	17,099	46,332	22,063
Prairie	216	34	22	162	85	158,879	25,009	16,182	119,159	62,522
Metro Area	369	20	28	334	123	589,355	31,943	44,721	533,454	196,452
Central Hardwoods	197	25	27	150	52	224,223	28,455	30,731	170,728	59,186
Statewide	1,303	235	213	1013	433	1,115,609	128,279	129,002	924,181	365,695

Types of wood and tree species burned as wood fuel

Table 5 shows the breakdown in different types of wood fuel consumed in Minnesota by households. In previous surveys, a distinction was made between roundwood and split wood in the survey questionnaire itself. However, in the 2011-2012 survey, respondents were only asked to report total volumes of wood (in cords, face cords and bundles) and no distinction was made between round wood (or logs) and split wood. Depending on the type of burning equipment, however, respondents did have the opportunity to report on burning of some other types of wood: wood slabs, wood pellets, wax logs, and pallets. As can be seen in Table 5, the vast majority (94.9%) of the reported wood fuel burned in the State was reported as “wood”. Wood slabs (burned in conventional fireplaces, wood furnaces, wood boilers and outdoor burning equipment), accounted for the next largest type of wood at just under 4% of total wood fuel consumed. Other types of wood, wood pellets (burned in pellet stoves), wax logs (burned in conventional fireplaces, fireplace inserts, wood stoves and outdoor burning equipment), and wooden pallets (burned in wood furnaces, wood boilers and outdoor burning equipment) all accounted for much smaller proportions of the total wood consumed.

Table 5. Number of Cords Burned by Fuel Type[15]

Fuel Type	Cords	Percent of Total
Roundwood/logs and Split wood	1,220,446	94.9%
Slabs	49,699	3.9%
Wood pellets	8,603	0.7%
Wax logs	1,458	0.1%
Pallets	5,857	0.5%
Total	1,286,062	100%

Oak continues to be the preferred wood fuel species. (See Table 6.) At 38% of all wood burned, it is the single most important tree species utilized. This result is consistent with past surveys. Other species were reported in smaller proportions compared to 2007-2008 but this may be due to "Mixed" as a new species choice on the 2011-2012 survey. Mixed was the next most popular choice after oak and respondents indicated that 26% of all wood consumed was mixed species. The next most popular single species for wood fuel is ash, comprising of 9% of total wood consumed.

Table 6. Percent of wood burned by species and survey year

Species	Survey Year				
	1988-89	1995-96	2002-03	2007-08	2011-12
Oak	32	27	38	29	38
Birch	13	14	13	9	6
Ash	8	4	10	17	9
Elm	14	3	5	9	2
Maple	8	4	8	10	4
Aspen	7	10	8	12	5
Basswood	N/A	N/A	N/A	N/A	< 1
Pine	N/A	N/A	N/A	N/A	6
Cedar	N/A	N/A	N/A	N/A	< 1
Mixed Species	N/A	N/A	N/A	N/A	26
Other Species	3	6	9	10	2
Slabs and scrap lumber	15	32	8	4	N/A

Sources of wood fuel

Households continue to do much of the wood harvesting them. As Table 7 shows, 63% of all wood fuel consumed is harvested by the households consuming the wood rather than purchased or received for free. Households who use wood as a heating fuel are most likely to harvest their own wood while households who use wood for pleasure are slightly less likely to harvest their own wood. Comparing these results to previous surveys suggests that more households are harvesting their own wood than in past years, although this comparison is difficult due to the fact that the surveys asked different questions to solicit this information.

[15] The 2011-12 survey only asked about the volume of "wood" burned for each burning activity. Past surveys distinguished between different types of cordwood, including "Roundwood/logs" and "Split wood".

Table 7. Percent of wood consumption by procurement method and reason for burning

Procurement Method	Reason for Burning			All Wood Fuel Consumption
	Primary Heat	Secondary Heat	Pleasure	
Harvested	61	65	60	63
Purchased or Received for Free	39	35	40	37

For all harvested wood fuel, the survey asked respondents to report the locations and sources of the harvests. Harvest locations included private land, state land, county land, municipal land, and national forestland. Harvest sources included live trees from forest land; dead trees from forest land; cut trees and/or tops and branches after a timber harvest; live of dead trees from pasture land and/or cropland; and live or dead trees from yards, inside city limits, or other non-forest land. Tables 8 and 9 present these results separated by reason for burning. Table 8 indicates that the vast majority of all harvested wood fuel, regardless of burning purpose, was harvested from private land. The next most common source of harvested wood fuel was county land, but this was far below the level of harvested wood fuel from private land. Municipal land showed the lowest totals of harvested wood fuel. Table 9 shows that "dead trees from forestland" is the most prevalent type of harvest source, among the choices offered in the survey.[16] The most common harvest source, however, did vary depending on the burning purpose. Wood burned for pleasure (including camping) was most commonly harvested from "live or dead trees from yards, inside city limits, or other non-forest land". For every burning purpose, "cut trees and/or tops and branches after a timber harvest" was the least prevalent harvest source.

Table 8. Percent of wood fuel harvested by type of harvest location and reason for burning

Harvest Location	Reason for Burning			All Wood fuel Harvested
	Primary Heat	Secondary Heat	Pleasure	
Private Land	96	94	96	95
State Land	2.3	1.2	1.4	1.6
County Land	1.3	3.4	2.3	2.5
Municipal Land	<0.1	0.3	0.2	0.2
National Forestland	0	0.9	0.4	0.5

Table 9. Percent of wood fuel harvested by type of harvest source and reason for burning

Harvest Source	Reason for Burning			All Wood fuel Harvested
	Primary Heat	Secondary Heat	Pleasure	
Live trees from forestland	23	15	10	15
Dead trees from forestland	33	39	31	35
Cut trees and/or tops and branches after a timber harvest	10	11	6.5	9.5
Live or dead trees from pasture land and/or cropland	15	20	13	17
Live or dead trees from yards, inside city limits, or other non-forest land	19	14	40	23

[16] The survey questions used to compile the results in both Table 8 and Table 9 included the option "I do not know" for the source of harvested Wood fuel. These responses were not used to compile the results in these tables. Only the respondents who provided percentages of wood fuel harvested in each of the location or source choices were used to compile overall estimates of harvest locations and sources.

Conclusion

Key findings

An estimated 1.29 million cords of wood were burned across the state based on the 2011-12 Survey responses. Our analysis indicates the amount of residential wood burning appears to be on the rise, although identification of trends across time is compromised somewhat by changes to improve survey design and methodology. Much of this apparent increase seems to be due to more households burning wood for pleasure, predominantly in outdoor recreational burning equipment. The amount of wood burned per household does not seem to have drastically changed, but what has changed is the number of households burning wood, largely due to the preponderance of backyard recreational burning. While identifying and quantifying the drivers of residential wood burning is beyond the scope of this report, the results of this survey confirm that it is an issue that needs more attention and further investigation into the drivers behind the apparent increase.

Implications

Residential wood-burning is emerging as an important source of air emissions in Minnesota's communities, in particular as emissions from other sectors such as smokestack industries continue to decline. In communities where wood burning is closely clustered, or where homes are near wood burning appliances that produce large quantities of smoke, exposures may be higher and of greater concern. Exposure to wood smoke can lead to both short term and long term adverse health effects. Chemicals and particles from wood smoke can cause eye, nose and throat irritation, can make asthma worse and are associated with increased respiratory symptoms. Breathing wood smoke may be harmful to the respiratory immune defense system (may increase susceptibility to infectious lung disease) and may permanently damage lung tissue at high doses. Young children as well as people with asthma and other chronic lung diseases are particularly susceptible to adverse effects of wood smoke.

As the emphasis of pollution reduction expands from point sources (which will continue to be regulated) to nonpoint sources, residential wood burning as well as other smaller sources such as vehicles and lawnmowers are garnering attention from policy makers at all levels of government. Recreational wood burning is one of the source categories where the Minnesota Clean Air Dialogue[17] recently recommended actions to reduce emissions both from a health stand point and to avoid the regulatory consequences of not meeting the federal ambient air quality standards. Actions recommended included:

- Wood smoke reduction education and outreach
- Develop a model ordinance for local governments to use to reduce impacts from hydronic heaters (outdoor boilers)
- Wood stove/ fireplace change-outs
- Study options for coordination of seven county metro area brush management systems

The information gleaned from this survey can help inform policy on what are the most significant sources of wood smoke in Minnesota, by type of equipment, by purpose for burning, by source of wood fuel, and by region of the state. This information can inform the outreach and assistance strategies recommended for implementation by the Clean Air Dialogue to address air pollution concerns. As an example, this information can be used to develop communications plans to inform consumers when

[17] Minnesota Clean Air Dialogue (http://www.environmental-initiative.org/projects/minnesotas-clean-air-dialogue)

deciding which new equipment to purchase. The wood harvest information can be used to safeguard Minnesota's forest resources.

With the new survey design and improvements in survey analysis methodology, we have created a solid foundation for moving forward with future surveys. We have learned a great deal from this survey, both in the data we have gleaned about residential wood burning in Minnesota as well as improved methods to obtain and analyze this information. While we will make alterations to the survey design and process to improve the quality of information that we obtain, generally adhering to a similar survey design and methodology in future surveys will enable us to more confidently assess wood-burning trends. Other recommendations for future work would be to identify and characterize the drivers of residential wood-burning in Minnesota, in particular for outdoor recreational equipment.

Appendices

Appendix A: Glossary and definitions for this report

Bundle: A unit measure for wood volume that measures about one foot by one foot by two feet. 64 bundles is equivalent to one cord.

Code book: A document that codifies all of the survey responses into the data that was used for analysis. For each question on the survey, the code book lists all assumptions that were made in interpreting survey responses, all the different responses that were given, the frequency of each response, and how each response was recoded into a form that could be used for analysis.

Confidence interval: A range of values centered on the sample estimate that is known to contain the true value with a given degree of confidence (usually 95%).

Conventional fireplace: Conventional fireplaces are generally used for aesthetic purposes rather than for heat. They are often open but may have non-sealed glass doors. The survey did not distinguish whether the fireplaces were located inside or outside the residence.

Cord: A unit of measure for a volume of wood. It measures four feet high by 4 feet wide by eight feet long and has a volume of 128 cubic feet. Cords do not describe how much the wood weighs, so a cord of one species of wood may weigh more than a cord of a less dense wood.

Corn pellet stove: A room heating device, similar to a wood pellet stove, designed to burn corn kernels**.**

Demographics: Characteristics of human populations, which describe their size and distribution as well as their marital status, age, gender, income, etc. The term "demographic" may also be used to describe elements of geography in terms of their human characteristics. For this study, the main demographic information obtained was income level and housing type.

Design effect: An adjustment used in some statistical studies, which inflates the variance of parameter estimates, to allow for the design structure. In this case, it is an adjustment for the population weighting that was done to address the disproportionate stratified sampling. The weighting of the data increases its variance, and the design effect is used to adjust confidence interval estimates to account for the increased variance.

Differential response rates: These refer to the situation where the response rate was (substantially) different in different subgroups of the population (e.g., in households from different survey regions or from different demographic groups).

Disproportionate stratified sampling: Conducting a survey where the sizes of different groups (in this case, number of surveys sent to each survey region) vary and do not represent the percentage of any particular group within the larger population.

Estimate: The value obtained from a sample which is used, with a known margin of error, as an approximation for a population characteristic.

Face cord: A unit of volume that is four feet high by eight feet long by 16 inches wide, equal to one-third of a cord.

Fireplace insert: An enclosed space heating device, similar in function to a wood stove that is designed to fit into the opening of an existing fireplace. These are designed to be more energy efficient than most conventional fireplaces.

Household: The person or persons occupying a housing unit.

Margin of error: The statistic which describes the amount of random sampling error in a survey's results. When the margin of error in great, there is less confidence that the results of the survey correctly represent what would have found by surveying the entire population.

Methodology: A description of the way in which data is collected and analyzed in a research project.

Outdoor recreational burning: In this study, outdoor recreational burning includes burning in outdoor fire pits, chimeneas or fire rings. They may be used for recreational backyard burning or at campgrounds.

Outlier: An extremely small or extremely large value in a set, compared with the mean of all values in the set.

Population weight: A weight, calculated based on survey region of primary residence, given to each survey response to compensate for differential response rates (relative to population size) of households from different survey regions. Survey regions that were over-represented in the survey (i.e., the proportion of households in the survey sample from that region exceeded the proportion of households in the state from that region) were calculated to have weights less than one. Survey regions that were under-represented in the survey (proportion of households in the survey sample fell short of the proportion of households in the population) were calculated to have weights greater than one.

Primary residence: The dwelling where a person or persons usually live, typically a house or an apartment. *The survey questionnaire defined the primary residence as "your main home"*

Response bias: Inaccuracy of data collected caused by participant error. This could be caused by misunderstanding or misinterpreting survey questions or in some cases could be deliberate misrepresentation of one's actions.

Response rate: The number of completed surveys divided by the number of eligible units (i.e., households) in a sample. In other words, this is the number of completed surveys returned divided by the number of surveys sent that successfully reached the households. The surveys sent but returned by the post office are not included.

Sample: A subset of the population from which data is collected to be used in estimating actions or behaviors of the total population. In this case, the "survey sample" is all the households who completed and submitted a survey.

Secondary residence: This includes all dwellings that are not the primary place where a person or persons live. In this study, it includes second homes, cabins, trailer or other vacation properties. Camping locations were not included.

Selection bias: A type of non-sampling error that occurs when participants who chose to participate in some research (i.e., who choose to fill out and submit a survey) are systematically different to the intended sample. This type of bias is caused by certain types of participants replying to a survey invitation more than others or when participants put themselves into groups to which they aspire but do not currently belong. For this study, a potential source of selection bias could be that households who burn wood are more likely to answer a survey about residential wood burning than households who do not burn wood. As a result, the survey analysis could overestimate wood-burning activity in the overall population. Similar to "Non-response error," which is error caused by some sub-groups of the sample responding less often than the rest of the sample.

Statistical significance: Refers to whether some research results genuinely reflect a population of interest in some way or whether the results could occur by chance. Statistical significance is determined by comparing the research results with the values defined by the confidence interval.

Survey regions: The key geographic unit for this analysis. Minnesota is comprised of five regions that roughly correspond to the state's ecoregions. An ecoregion is an area of land with similar ecological characteristics. The five survey regions of Minnesota—Northern Pine, Aspen-Birch, Prairie, Metro Area, and Central Hardwoods—were delineated based on forest cover and predominant tree species types. These same five regions have been used in past Minnesota Residential Wood Burning reports.

Wood boiler: A wood-burning central heating device that heats a liquid (generally water or glycol) as the medium to transfer the heat to where it is needed. Hydronic heater is the more technical term for this equipment as they do not actually boil the water. Wood boilers are generally, though not exclusively, located outside the main building. The heated liquid may provide space heat through radiators, in-floor heating or to the air by the use of a heat exchanger. In residential settings, they may also be used to heat the water supply or swimming pool. Because some wood "boilers" (hydronic heaters) are called "outdoor wood furnaces", this survey distinguished the boilers from the furnaces using descriptive characteristics including brand or model information.

Wood furnace: A wood-burning central heating device in which the heat in the combustion chamber directly heats air that is transferred through ducts to provide space heat to the home or building. In this survey, the term "furnace" was specifically used for heaters that heat air, not those that use water as the heat transfer medium.

Wood pellet stove: A room heating device similar to a wood stove, designed to burn wood pellets.

Wood stove: An enclosed free-standing heating appliance capable of burning wood fuel generally connected by ventilating stove pipes to a suitable chimney or flue. A wood stove can generally be used to burn wood, or wood-derived biomass fuel, such as wood pellets. It is generally designed to heat the air in one or a few nearby rooms.

Appendix B: Sources of secondary calculations of wood fuel volumes

1. **Wood slabs**. A conversion factor of 1.0368 tons per cord was used for sawmill slabs and edgings, based on: *Release No. 232. Cord-Cubic Volume of Relationship of Slabwood and Edgings*, Bell, G. E. and Brooks, E. American Pulpwood Association. New York, NY, 1955.
2. **Wood pellets**. A conversion factor of 2.752 tons per cord was used for wood pellets, based on: Jason Berthiaume, Pellet Fuels Institute (PFI). Current standards require a minimum density for PFI-graded pellets of 40lbs/cu ft. Under newly approved standards, implemented in 2009, density for super-premium and premium pellets are 40-46lbs/cu ft, with standard and utility grades at 38-46lbs/cu ft. As super-premium and premium make up the vast majority of residential heating pellets, it makes sense to use the 40-46 range. Mid-range of 43 X 128 cubic feet per cord = 2.752 tons per cord.
3. **Wax logs**. A conversion factor of 1.0989 tons per cord was used for wax/manufactured fireplace logs, based on: Houck, J. E. OMNI Consulting Services, Inc. Beaverton, Oregon. July 2002. Email: houck@omnitest.com. He determined 444 typical logs make up a cord. The weighted average mass of wax/sawdust fireplace logs is 4.95 lbs (2.5 lbs, 3.2 lbs, 5 lbs, and 6 lbs logs are sold). The average mass of densified logs sold is 5 lbs.
4. **Wood pallets**. A conversion factor of 0.5184 tons per cord was used for wood pallets and crates, based on: WikiAnswers: “How much does a pallet weigh?” And “What is the standard size of a wooden pallet?” It was assumed the Grocery Manufacturers' Association pallet was 48" x 40" and each weighed 45 pounds. Website: http://wiki.answers.com/Q/What_is_the_average_weight_of_a_wooden_pallet and website: http://wiki.answers.com/Q/What_is_the_standard_size_of_a_wooden_pallet. Both accessed June 24, 2013.

Appendix C: Demographic weighting

Additional weighting steps were tried to account for differential response across demographic groups. These steps along with the impact on results are described in this appendix. In each of the five survey regions, statistical tests[18] (Pearson chi-square) were employed to compare the proportion of the survey sample in each demographic group (by income level and by housing type) compared to the proportions of each demographic group in the overall population of the survey region (as determined in the 2011 U.S. Census American Community Survey) to ascertain whether the demographic composition of the survey sample was statistically different than the overall population. In virtually all cases, these tests revealed statistically significant differences between the demographic composition of the survey sample and that of the wider population. For example, in every survey region, residents of single-family detached houses were far over-represented in the survey sample (relative to the general population) while residents of other housing-types (apartments, mobile homes, etc.) were under-represented in the survey sample. Similarly, income strata also showed statistically significant differences between the survey sample and the overall population: high and low income groups were generally under-represented in the survey sample while middle-income groups were over-represented. Because wood burning activities are likely to generally vary across different income groups and different housing types, the different demographic composition of the survey sample relative to the overall population could introduce bias in the estimation of population-wide burning totals.

To address this demographic non-representation issue, demographic weights were calculated for households of each housing type for each of the five survey regions. The method for calculating these weights entailed comparing the proportion of a demographic group (i.e. households of a certain housing type) in the survey sample to the proportion of that demographic group in the general population in the analogous way to how population weights across the survey regions were calculated. Because the disparity between the survey sample and the general population for housing types was far more apparent than the disparity for income ranges, income range weights were not applied. Moreover, applying housing-type weights served to correct for much of the disparity in income levels.

In spite of the demographic non-representativeness of the survey sample, applying demographic weights should be done with caution. Demographic weighting introduces an additional level of complexity to the survey analysis and because it was not considered in the analysis of previous residential fuel wood surveys, it may further distort the analysis of trends through time and across different survey methodologies. An additional issue is that of the 2,360 households in the survey sample, 133 households did not answer the questions in the Demographics section in the survey and thus there was no way to ascertain their housing type (nor their income). As a result, the demographically-weighted survey sample was smaller than the non-weighted sample, creating the tradeoff of potentially correcting for bias created by demographic non-representativeness but basing wood-burning estimates on fewer households. For these reasons, total wood-burning estimates were calculated with and without the application of demographic weights.

All the results presented in the main part of this report apply population weights as explained in the Methods section, but do not include differential demographic weighting to correct for non-representativeness of the survey sample relative to the entire population. Table 10 illustrates some of the demographic discrepancies between the survey sample and the greater population for the two demographic characteristics that were asked on the survey, total household income and housing type. The table presents statewide totals, but totals for each of the five survey regions all exhibited similar

[18] The Pearson chi-square test statistic was used to assess whether there were statistically significant differences between the survey sample and the overall population at 5% significance levels.

patterns. In regards to income, the pool of survey respondents was skewed towards the middle income ranges. Relative to the state population, very low income households (less than $25,000 total household income) and very high income households (greater than $100,000 total household income) were underrepresented in the survey sample while the three mid-range income levels were all overrepresented in the survey sample. The discrepancies for housing type were even more severe. As Table 10 reflects, detached single family homes were significantly overrepresented while apartment building dwellers were vastly underrepresented. Statistical tests (the Pearson chi-square test statistic) determined that these differences between the survey sample and the overall population were statistically significant. The potential problem is if wood-burning behaviors vary with these demographic characteristics then the survey sample may not comprise an accurate representation of the overall population, leading to biased wood-burning estimates for the population.

Table 10. Demographic breakdown of survey sample compared to Minnesota population

		Proportion of Survey Sample	Proportion of State Population
Household Income Range	Less than $25,000	14	20
	$25,001 to $50,000	30	23
	$50,001 to $75,000	24	20
	$75,001 to $100,000	17	14
	Greater than $100,000	16	23
Housing Type of Primary Residence	Detached Single Family	87	75
	Mobile Home or Trailer	3	4
	Duplex (two units)	2	2
	Three-or-Four Family Building	4	2
	Apartment (more than four units)	5	17

The survey analysis team, with consultation input from Rob Daves, opted to apply additional weighting factors to correct for non-representativeness of the survey sample with regards to housing type, but not to income. The survey sample was more skewed with respect to housing type than with respect to income, and it was reasoned that in the process of differentially weighting responses with respect to housing type, some of the income non-representativeness would be corrected. Housing-type weights were calculated separately for each survey region. In a nutshell, this weighting step increased the contribution to overall estimates of survey respondents from apartment buildings and other under-represented housing types and decreased the contribution from detached single family homes.

The application of these housing-type weights did not produce drastic changes. Figure 9 presents an alternate version of Figure 4, showing total Wood fuel consumption in each type of wood-burning equipment in each survey region, but this time with the additional application of housing-type weights. Comparing these results to the results presented in Figure 4, it can be seen that overall wood fuel consumption totals did not change drastically, nor did the general patterns of contribution of which equipment types contributed most to consumption totals in the various regions. In some cases, however, housing-type weighting did produce substantial changes in estimates. For example, close examination of Figures 4 and 9 reveals that wood fuel consumption in pellet stoves increased by 184% in the Prairie region and 58% in the Northern Pine region after weighting the responses. The explanation for this is that in each of these two survey regions there just happens to be a single household that responded to the survey that is a mobile home and that uses a pellet stove. Because mobile home residents were vastly under-represented in the survey samples from both of these regions, each of these two households were weighted quite heavily, and when scaled up to population-wide estimates, these two households skewed the estimates considerably. This is an example of the perils of small samples size in producing population-wide estimates, and applying demographic weights can further

exacerbate these sample-size problems. In spite of these and other similar anomalies, the general results and conclusions that can be derived from these results were not greatly impacted by the application of demographic weights. Thus, they are included here in this appendix but are not included in the body of the report.

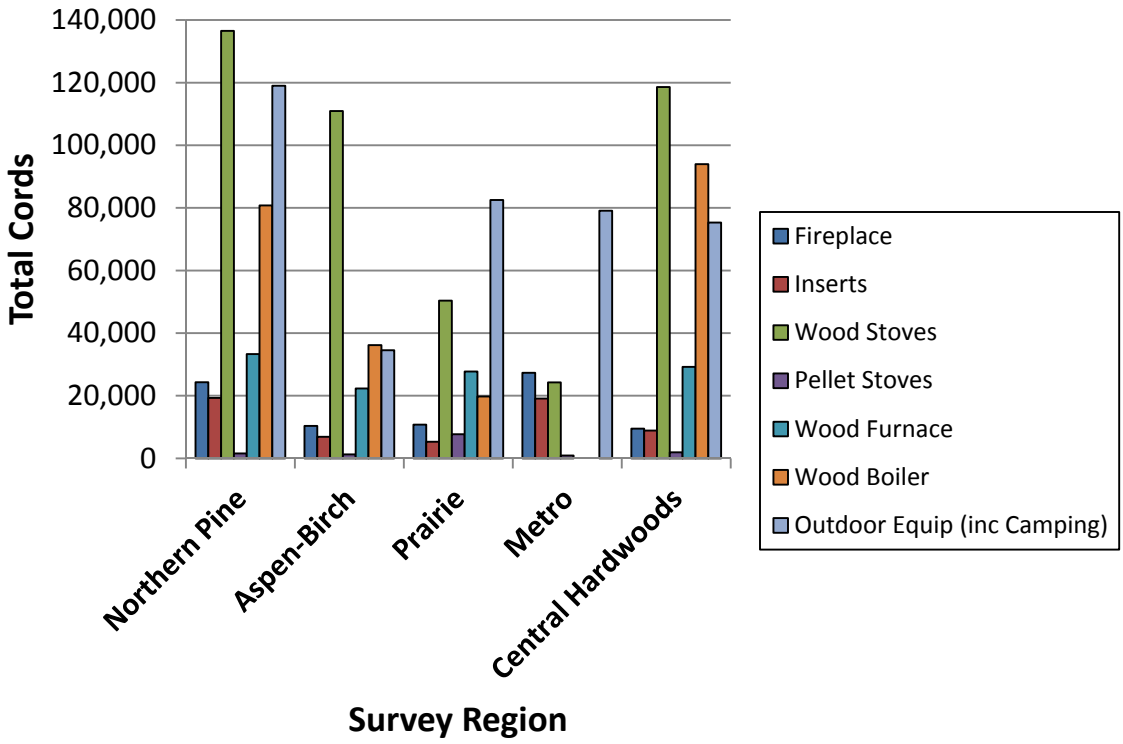


Figure 9. Total wood fuel burned by survey region and type of wood-burning equipment with demographic weights (by housing type)

Note: Campsite burning is included in the totals for outdoor equipment

Appendix D: Minnesota Residential Wood Fuel Survey, 2011-2012

Residential Wood Fuel Survey

for the State of Minnesota during July 2011 – June 2012

Survey # _____

(Used to track who has completed the survey and enter you in the drawing. Information provided in the survey will not be associated with your name.)

You have been randomly selected to participate in a survey being conducted by the U.S. Forest Service, the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency. This survey is used to determine how much firewood is burned in Minnesota, how it is burned, and at what time of year it is burned. Conducted every few years since 1960, the survey results are used, in part, to help manage our forests and determine long-term trends in heating and the types of wood people burn. Even if you do not have wood-burning equipment or did not burn any firewood, fireplace logs or wood pellets, please complete the appropriate portions of the survey; that information is also important.

Survey terms

The survey asks about the **wood-burning equipment** you use. **Wood-burning equipment** includes wood-burning fireplaces, fireplace inserts, wood stoves, wood furnaces, wood boilers, masonry heaters, outdoor fire pits, chimeneas etc.

The survey also asks about how much you burn at your **primary residence** (your main home), your **secondary residence** (second home, cabin, trailer or other vacation property) or at a campsite in Minnesota. If you have more than one secondary residence, please consider only the most frequently used secondary residence.

Drawing for Blaze King Moisture Meters

Because your time is valuable and to show appreciation for your participation in this survey, the Hearth, Patio and Barbecue Association has generously provided six **Blaze King Moisture Meters** to be given away in a drawing. (Moisture meters can determine how dry firewood is; drier wood burns more efficiently and more cleanly.) To enter the drawing, complete and return the survey in the envelope provided or complete the on-line version, including your survey number.

On-line version

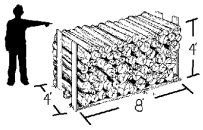
For your convenience, you can complete an on-line version instead of the paper version. This on-line survey is available at:

http://www.pca.state.mn.us/smokesurvey

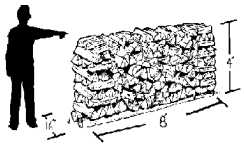
The on-line version automatically skips to the proper section according to the answers you enter. Be sure to provide your survey number so you are entered in the drawing.

Estimating how much firewood you use

A **full cord** is a large amount of wood. It measures 4 feet high by 4 feet wide by eight feet long (4' x 4' x 8') and has a volume of 128 cubic feet.

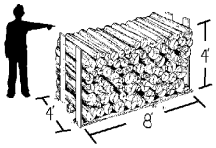


A **face cord** of wood is four feet high by eight feet long and is as wide as the individual firewood pieces, but averages 16 inches wide. A 16-inch wide face cord (sometimes called a **fireplace cord**) is equal to one-third of a full cord.



Face cord (16")

x times 3 three = equals

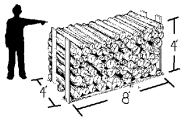


One full cord

Two full-size pick-up truck loads (8 foot box) equals one full cord, whether the wood is stacked carefully so it is about level with the truck box sides, or is thrown into the truck box with the top of the pile about as high as the cab.

Full-size pick-up truck (8')

x times 2 two = equals

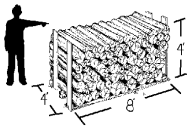


One full cord

Four compact pick-up truckloads (6 foot box) equals **one full cord** of wood, whether the wood is stacked carefully and about level with the truck box sides or thrown into the truck box with the top of the pile about as high as the cab.

Compact pick-up truck (6')

x times 4 four = equals

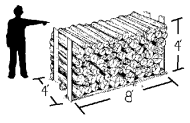


One full cord

64 bags/bundles of firewood that measure about one foot by one foot by two feet (1' x 1' x 2') equals **one full cord**.

Bag or bundle (1' x 1' x 2')

x times 64 sixty four = equals



One full cord

Campsites and campgrounds

Did you burn firewood at a campsite or campground in Minnesota between July 2011 and June 2012?

- ❑ No (Skip the next question and continue)
- ❑ Yes (Go to the next question)

If you burned firewood at a campsite between July 2011 and June 2012, please estimate the total amount of wood burned and list the county(ies) in which it was burned.

_____ Total estimated amount of wood burned at all campsites (in bundles)

_____ County _____ County _____ County _____ County

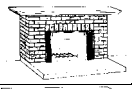
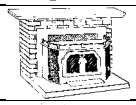
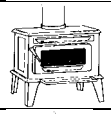
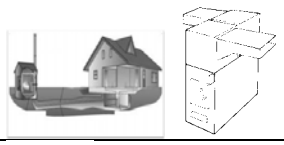
This survey attempts to determine how much wood and other biomass is burned in Minnesota by Minnesota residents. To cover as many possible combinations of fuel-burning equipment as possible, find the equipment you have on the grid below and then complete the corresponding page(s) of the survey.

Primary and secondary residences

Do you have any of the following wood burning equipment in your primary residence or at a secondary residence such as a cabin, trailer, rented cabin, etc that is located in Minnesota? If your secondary residence is not in Minnesota do not include it.

- ❑ Yes. Please continue
- ❑ No. Go to **Q60 Section G** on page **10**

Use the grid below to navigate the survey. For each equipment type for which you have checked a box, fill out the corresponding section on the page indicated. Complete information about the location of your primary and secondary residence below. You may need to complete more than one section; please complete as many sections as necessary.

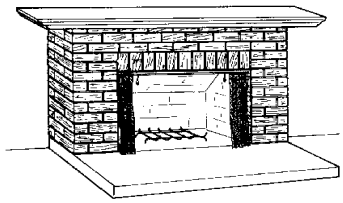
Equipment type	Check if located at your primary residence.	Check if located at a secondary residence.	If checked, complete Section:
 Conventional Fireplace	❑	❑	A Page 3
 Fireplace insert	❑	❑	B Page 4-5
 Wood stove	❑	❑	B Page 4-5
 Wood or corn pellet stove	❑	❑	C Page 5
 Wood-burning boiler or furnace	❑	❑	D Page 6-7
 Outdoor fire ring, chimenea, fire pit, etc.	❑	❑	E Page 8

(After completing section E, also complete sections F & G)

Primary residence location: County _____City/Township _____ ZIP _____

Secondary residence location: County_____City/Township _____ ZIP _____

Section A: Conventional Fireplaces



A conventional fireplace:

- Is mainly for decorative use rather than primarily for heating
- May have hot air grilles
- May either have no doors or doors without gaskets (not airtight)
- Doors can be double or bifold doors
- Includes fireplaces known as “heatilators” and fireplaces with tubular grates or other devices intended to provide heat to a room
- Includes freestanding fireplaces

Primary Residence

Q1. Do you have a conventional fireplace at your primary residence (including outbuildings such as pole barns or garages)?

- ❑ No, go to **Q5**
- ❑ Yes How many? _____

Q2. Did you use this equipment mainly for:

- ❑ Pleasure
- ❑ Primary heat source for my residence
- ❑ Secondary heat source for my primary residence

Q3. If you used your fireplace please indicate how much wood or artificial logs you burned in your fireplace(s) in the past 12 months.

_____None. Please check if you did not burn wood in your fireplace and skip to **Q5**
_____Full cords of wood (If necessary, you can answer in fractions of full cords, such as 1/2, 1.5)
_____Face cords of wood
_____Bundles of wood
_____Number of wax logs (such as Duraflame)
_____Full cords of slabs (the round parts of a log cut off to make milled wood such as boards)
_____Other (please specify)_____

Q4. Please check which months you used this wood-burning equipment in your home.

July 2011	August 2011	Sept. 2011	Oct. 2011	Nov. 2011	Dec. 2011	January 2012	Feb. 2012	March 2012	April 2012	May 2012	June 2012
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Secondary Residence

Q5. Do you have a conventional fireplace in your secondary residence, cabin, trailer or rented cabin?

- ❑ No, go to **Q9 Section B**
- ❑ Yes How many____

Q6. Did you use this equipment mainly for:

- ❑ Pleasure
- ❑ Primary heating source for my secondary residence, cabin, trailer or rented cabin
- ❑ Secondary heating source for my secondary residence, cabin, trailer or rented cabin

Q7. If you used your fireplace please indicate how much wood or artificial logs you burned in your fireplace(s) in the last 12 months

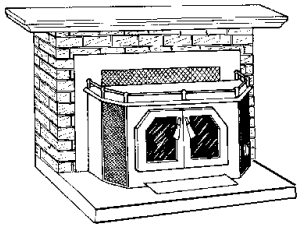
_____None. Please check if you did not burn wood in your fireplace and skip to **Q9 Section B**
_____Full cords of wood (If necessary, you can answer in fractions of full cords, such as 1/2, 1.5)
_____Face cords of wood
_____Bundles of wood
_____Number of wax logs such as Duraflame
_____Full cords of slabs (the round parts of a log cut off to make milled wood such as boards)
_____Other (please specify)_____

Q8. Please check which months you used this wood-burning equipment in your secondary residence, cabin, trailer or rented cabin.

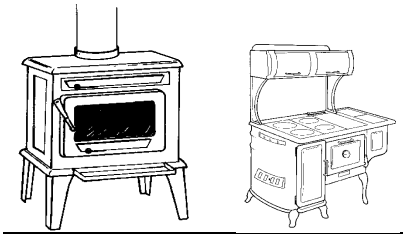
July 2011	August 2011	Sept. 2011	Oct. 2011	Nov. 2011	Dec. 2011	January 2012	Feb. 2012	March 2011	April 2012	May 2012	June 2012
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Section B: Fireplace inserts and wood stoves

Fireplace inserts



Wood stoves



Fireplace inserts are space heaters designed to fit into an existing fireplace opening.

Wood stoves are freestanding space heaters often used to heat a specific room or zone of the house.

Wood stoves and fireplace inserts have conventional or EPA-certified advanced technology

Most conventional stoves and inserts were sold or installed before 1989. They also include the box or parlor stoves, 'airtights' or cook stoves

Advanced EPA-certified technology stoves and inserts use catalytic or non-catalytic technology:

- Catalytic designs have ceramic or metal honeycomb combustors to burn the smoke
- Catalytic designs have bypass levers
- Non-catalytic designs are engineered for improved combustion
- Non-catalytic designs use air tubes, baffles and fire brick to reduce the smoke (improve the combustion)

Primary residence

Q9. Do you have this equipment in your primary residence (including outbuildings such as pole barns or garages)?

- ❑ No, go to **Q13**
- ❑ Yes. How many? _____

Q10. Did you use this equipment mainly for:

- ❑ Pleasure
- ❑ Primary heat source for my residence
- ❑ Secondary heat source for my residence

Q11. Mark the grid below for each piece of equipment you have at your primary residence

		EPA Certified		**Estimate the amount of fuel burned for each** (If necessary, you can answer in fractions of full cords, such as 1/2 , 1.5)				
Type of equipment	Conven-tional	Catalytic	Non-catalytic	None (did not use equipment)	Full cords	Face cord	# Wood bundles	# of wax logs
Wood stove # 1	❑	❑	❑	❑				
Wood stove # 2	❑	❑	❑	❑				
Insert # 1	❑	❑	❑	❑				
Insert #2	❑	❑	❑	❑				

Q12. Check the months in which you used this wood-burning equipment in your home over the last year.

July 2011	August 2011	Sept. 2011	Oct. 2011	Nov. 2011	Dec. 2011	January 2012	Feb. 2012	March 2012	April 2012	May 2012	June 2012
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Secondary residence

Q13. Do you have an insert or wood stove in your secondary residence, cabin, trailer, or rented cabin?

- ❑ No. **Go to Q17 Section C**
- ❑ Yes. How many____

Q14. Did you use this equipment mainly for:

- ❑ Pleasure
- ❑ Primary heat source for my secondary residence, cabin, trailer or rented cabin
- ❑ Secondary heat source for my secondary residence, cabin trailer or rented cabin

Secondary residence *continued*

Q15. Please mark the grid below for each piece of equipment you have at your secondary residence

Type of equipment	Conventional	EPA Certified: Catalytic	EPA Certified: Non-catalytic	None (did not use equipment)	**Estimate the amount of fuel burned for each** (If necessary, you can answer in fractions of full cords, such as 1/2 , 1.5) Full cords	Face cord	# Wood bundles	# of wax logs
Wood stove # 1	❑	❑	❑	❑				
Wood stove # 2	❑	❑	❑	❑				
Insert # 1	❑	❑	❑	❑				
Insert #2	❑	❑	❑	❑				

Q16. Check the months in which you used this wood-burning equipment in your home over the last year.

July 2011	August 2011	Sept. 2011	Oct. 2011	Nov. 2011	Dec. 2011	January 2012	Feb. 2012	March 2012	April 2012	May 2012	June 2012
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Section C: Wood Pellet Stove or Corn Pellet Stove

Wood pellet stoves burn small compressed wood pellets.

Corn pellet stoves burn corn kernels.

A pellet-burning appliance has a hopper to hold the fuel and can burn for a long time without reloading

Primary Residence

Q17. Do you have this equipment in your primary residence (including outbuildings such as pole barns or garages)?

- ❑ No, go to **Q20**
- ❑ Yes, a wood pellet stove. How many? _____
- ❑ Yes, a corn kernels stove. How many? _____

Q18. If you used your pellet stove please indicate how much fuel you burned in your pellet burning equipment in the past 12 months.

_____None. Please check if you did not use or burn anything in your pellet stove, then skip to **Q20**
_____Number of pounds of wood pellets
_____Number of pounds of corn kernels or
_____Number bushels of corn

Q19. Check which months you used this pellet burning or corn burning equipment in your home over the last year.

July 2011	August 2011	Sept. 2011	Oct. 2011	Nov. 2011	Dec. 2011	January 2012	Feb. 2012	March 2012	April 2012	May 2012	June 2012
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Secondary Residence

Q20. Do you have this equipment in your secondary residence, cabin trailer or rented cabin?

- ❑ No, go to **Q23 Section D**
- ❑ Yes, a wood pellet stove. How many? _____
- ❑ Yes, a corn pellet stove. How many? _____

Q21. If you used your pellet stove, please indicate how much fuel you burned in your pellet burning equipment in the past 12 months.

_____None. Please check if you did not use or burn anything in your pellet stove, then skip to **Q23 Section D**
_____Number of pounds of wood pellets
_____Number of pounds of corn kernels **or**
_____Number of bushels of corn

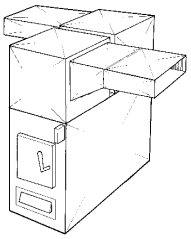
Q22. Please check which months you used this wood burning or corn burning equipment in your home over the last year.

July 2011	August 2011	Sept. 2011	Oct. 2011	Nov. 2011	Dec. 2011	January 2012	Feb. 2012	March 2012	April 2012	May 2012	June 2012
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Section D: Wood burning furnace or boiler

Outdoor Wood Boiler

Indoor Wood Furnace



Wood furnaces and boilers

- Wood furnaces are usually installed in basement or utility rooms
- Wood furnaces heat air directly and are connected to ducts that move the hot air around the building
- Wood boilers are usually installed outside and may look like a small shed
- Wood boilers heat water that moves in pipes to where the heat is used
- EPA-qualified boilers are labeled "Qualified at EPA Phase 1 Emission Level" or "Qualified at EPA Phase 2 Emission Level"

Primary Residence

Q23. Do you have this equipment at your primary residence (including outbuildings such as pole barns or garages)?

- ❑ No, go to **Q31**
- ❑ Yes a forced air furnace
- ❑ Yes a wood boiler

Q24. Is the equipment inside or outside the house?

- ❑ Inside
- ❑ Outside

Q25. The boiler (may also be called an outdoor wood furnace or hydronic heater)

- ❑ Heats water to heat my home
- ❑ Heats water to heat my other building(s) (workshops, garages, greenhouse)
- ❑ Heats water to heat my domestic water supply (for washing, showering, cooking, etc.)
- ❑ Heats water to heat my swimming pool

Q26. If you have a boiler is it:

- ❑ EPA qualified
- ❑ Not EPA qualified
- ❑ I don't know

Q27. Brand or model (if known) _____

Q28. What is the manufacturer's rated heat output of the boiler or furnace in BTUs per hour (if known) _____

Q29. If you used your boiler or furnace, please indicate how much wood you burned in your furnace or boiler in the past 12 months (If necessary, you can answer in fractions of full cords, such as 1/2, 1.5).

_____None, Please check if you did not use or burn anything in your heater or boiler, then skip to **Q31**
_____Full cords of wood
_____Face cords of wood
_____Number of wooden pallets
_____Full cords of slabs (the round parts of a log cut off to make milled wood such as boards)
_____Other: please specify_____

Q30. Please check which months you used this wood-burning equipment in your home over the last year.

July 2011	August 2011	Sept. 2011	Oct. 2011	Nov. 2011	Dec. 2011	January 2012	Feb. 2012	March 2012	April 2012	May 2012	June 2012
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Continue Section D on next page

Section D: Wood burning furnace or boiler *continued*

Secondary Residence

Q31. Do you have this equipment at your secondary residence, cabin, trailer or rented cabin?

- ❑ No. Go to **Q39 Section E**
- ❑ Yes a forced air furnace
- ❑ Yes a wood boiler

Q32. Is the equipment inside or outside the house?

- ❑ Inside
- ❑ Outside

Q33. The boiler (may also be called an outdoor wood furnace or hydronic heater)

- ❑ Heats water to heat my second home
- ❑ Heats water to heat my other building(s) (workshops, garages, greenhouse)
- ❑ Heats water to heat my domestic water supply (for washing, showering, cooking, etc.)
- ❑ Heats water to heat my swimming pool

Q34. If you have a boiler is it:

- ❑ EPA qualified
- ❑ Not EPA qualified
- ❑ I don't know

Q35. Brand or model (if known) _____

Q36. What is the manufacturer's rated heat output of the boiler or furnace in BTUs per hour (if known) _____

Q37. If you used your boiler or furnace please indicate how much wood you burned in your furnace or boiler in the past 12 months. (If necessary, you can answer in fractions of full cords, such as 1/2, 1.5)

_____None, Please check if you did not use the boiler or furnace(s) this year and skip to **Q39, Section E**
_____Full cords of wood
_____Face cords of wood
_____Number of wooden pallets
_____Full cords of slabs (the round parts of a log cut off to make milled wood such as boards)
_____Other: please specify_____

Q38. Please check which months you used this wood-burning equipment in your home over the last year.

July 2011	August 2011	Sept. 2011	Oct. 2011	Nov. 2011	Dec. 2011	January 2012	Feb. 2012	March 2012	April 2012	May 2012	June 2012
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Section E: Outdoor wood burning fire pits, Chimeneas or fire rings

Chiminea **Fire ring**

Chimineas, fire pits, fire rings, etc.

- Can be above the ground or dug into the ground
- Are located outside the house

Please answer only for those that burn wood rather than propane

---

Primary Residence

Q39. Do you have this equipment at your primary residence?

- ❑ No, go to **Q43**
- ❑ Yes How many? _____

Q40. Do you use your fire ring, chimenea or fire pit to dispose of sticks or wood from your yard?

- ❑ Yes
- ❑ No

Q41. If you used a fire pit, chimenea or burned wood outdoors please indicate how much wood or artificial logs you burned in your fire pit or chimenea in the past 12 months. (If necessary, you can answer in fractions of full cords, such as 1/2, 1.5)

_____None. Please check if you did not use the fire pit/chimenea(s) at your residence this year and skip to **Q43**
_____Full cords
_____Face cords
_____Bundles of wood
_____Number of wax logs such as Duraflame
_____Number of wood pallets
_____Full cords of slabs (the round parts of a log cut off to make milled wood such as boards)
_____Other (please specify) _____

Q42. Please check which months you used this wood-burning equipment in your home over the last year.

July 2011	August 2011	Sept. 2011	Oct. 2011	Nov. 2011	Dec. 2011	January 2012	Feb. 2012	March 2012	April 2012	May 2012	June 2012
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Secondary Residence

Q43. Do you have this equipment at your secondary residence, cabin, trailer or rented cabin?

- ❑ No, go to **Q47, Section F**
- ❑ Yes How many? _____

Q44. Do you use your fire ring, chimenea or fire pit to dispose of sticks or wood from your yard?

- ❑ Yes
- ❑ No

Q45. Indicate how much wood or artificial logs you burned in your fire pits, chimeneas etc. in the past 12 months. (If necessary, you can answer in fractions of full cords, such as 1/2, 1.5)

_____None. Please check if you did not use the pit/chimenea(s) at your secondary residence, and skip to **Q47 Section F**
_____Full cords
_____Face cords
_____Bundles of wood
_____Number of wax logs such as Duraflame
_____Number of wood pallets
_____Full cords of slabs (the round parts of a log cut off to make milled wood such as boards)
_____Other (please specify) _____

Q46. Please check which months you used this wood-burning equipment in your home over the last year.

July 2011	August 2011	Sept. 2011	Oct. 2011	Nov. 2011	Dec. 2011	January 2012	Feb. 2012	March 2012	April 2012	May 2012	June 2012
❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Section F: Other

Q47. Are there any other appliances not pictured in the questions above that burn wood in your primary residence, or secondary residence, cabin, or trailer? If so, please describe them and tell us how much wood (in cords) you burned in them between July 2011 and June 2012 _____

Q48. For your **primary residence**, indicate the percent of heat provided by each heat source. Percents should add up to 100%.

_____% Electricity
_____% Natural gas
_____% Oil
_____% Wood
_____% Propane
_____% Other: please specify_____

Q49. What is the approximate square footage of your **primary residence**? _____

Q50. For your **secondary residence**, indicate the percent of heat provided by each heat source. Percents should add up to 100%.

_____% Electricity
_____% Natural gas
_____% Oil
_____% Wood
_____% Propane
_____% Other : please specify _____

Q51. What is the approximate square footage of your **secondary residence**, cabin, trailer etc. if you have one?_____

Q52. Of all the firewood you burned at your primary residence this past year, what percent was burned of each species (if known)? Percents should add up to 100%

Oak	Birch	Ash	Elm	Maple	Aspen	Basswood	Pine	Cedar	Mixed	Other
%	%	%	%	%	%	%	%	%	%	%

Q53. If you burned fuel wood at a cabin, rented vacation home, or trailer, what percent was burned of each species (if known)? Percents should add up to 100%

Oak	Birch	Ash	Elm	Maple	Aspen	Basswood	Pine	Cedar	Mixed	Other
%	%	%	%	%	%	%	%	%	%	%

Q54. Of all the wood burned in the past 12 months, indicate the percent you harvested and the percent purchased or received free:

_____**%** Harvested
_____% Purchased or received for free

Q55. If you or a member of your immediate household harvested firewood in the past 12 months, indicate the percent that came from the following locations: (Percents should add up to 100%)

❑ I do not know

_____Private land
_____State land
_____County land
_____Municipal land
_____National forestland

Q56. If you or members of your immediate household harvested firewood in the last 12 months please indicate what percent came from the following sources:

❑ I do not know

_____Live trees from forest land
_____Dead trees from forest land
_____ Cut trees and/or tops and branches after a timber harvest
_____Live or dead trees from pasture land and/or cropland
_____Live or dead trees from yards, inside city limits, or other non-forest land

Q57. If you or members of your immediate household harvested firewood in the past 12 months please indicate what percent came from the following species:

Oak	Birch	Ash	Elm	Maple	Aspen	Basswood	Pine	Cedar	Mixed	Other
%	%	%	%	%	%	%	%	%	%	%

Q58. If you or a member of your immediate household harvested firewood in the past 12 months, indicate the counties from which the firewood came and the percent from each county:

- ❑ I do not know

County name: 1. _____ Percent _____

2. _____ _____

3. _____ _____

4. _____ _____

Q59. Indicate the total amount of firewood that was harvested by you or a member of your immediate family in the past 12 months [If necessary, you can answer in fractions of full cords, such as 1/2, 1.5]

_____full cords

Section G: Demographics

Q60. Total household income

- ❑ Less than $25, 000
- ❑ $25,001 to $50,000
- ❑ $50,001 to $75,000
- ❑ $75,001 to $100,000
- ❑ Greater than $100,000

Q61. Which of the following best describes your primary residence?

- ❑ Detached single-family house
- ❑ Mobile home or trailer
- ❑ Duplex (two units)
- ❑ Three-or-four family building
- ❑ Apartment (more than four units)
- ❑ Other (please specify) _____

Q62. Which of the following best describes your secondary residence, cabin, trailer rented cabin, etc.?

- ❑ I do not have/use a second residence, cabin etc.
- ❑ Detached single-family house
- ❑ Mobile home or trailer
- ❑ Duplex (two units)
- ❑ Three-or-four family building
- ❑ Apartment (more than four units
- ❑ Other (please specify) _____

Thank you for completing this survey. Please place the survey in the envelope provided and mail it promptly.

Your survey number will be entered in the drawing. You will be notified if you win a **Blaze King Moisture Meter.**

Survey sponsored by

Minnesota Department of Natural Resources

Minnesota Pollution Control Agency

U.S. Forest Service

Hearth Patio and Barbecue Association

Thanks to John Gulland of Gulland and Associates, Killaloe, Ontario, Canada for allowing the use of parts of his survey.