Minnesota Residential Wood Fuel Use

Minnesota Residential Wood Fuel Survey: Results from 2014-2015 Survey

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Summary

Background

In 2015, 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 varying forms every few years since 1960. Historically, the survey was conducted by the Minnesota Department of Natural Resources (MDNR) and the U.S. Forest Service (USFS). These data have been used by state and federal agencies, as well as trade organizations, to manage forests, to inform policymakers 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 residential wood combustion practices. Due to the levels of fine particles ($PM_{2.5}$) 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. Residential wood combustion accounted for 14% of Minnesota's direct fine particle emissions[1] in 2011[2]. Excluding the more difficult to estimate and variable fire sources (wildfires and prescribed fires), residential wood combustion accounted for 22% of the estimated fine particle emissions. This survey provides an improved understanding of residential wood burning in Minnesota, by type of equipment, by purpose for burning, by source of wood fuel, and by region of the state.

In April 2015, the MDNR sent out 7,000 invitations to complete an online survey to randomly selected households throughout the state. All households received three invitations to complete the online survey. Those who did not complete the online version were then sent a paper copy of the survey to further encourage participation. After receiving nearly 1,200 responses (538 online and 649 paper), the survey was closed and the data were analyzed.

For purposes of data collection and analysis, the state was divided into five regions. These regions (Aspen-Birch, Northern Pine, Prairie, Central Hardwoods, and Metro) were also used in analyzing several previous surveys.

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1 Direct fine particle emissions are released from pollution sources as fine particles. Fine particles in the air are a mixture of the directly released fine particles and those that are created in the air by chemical reactions between other pollutants such as the gases released from coal plants and vehicles.

2 Minnesota Pollution Control Agency's 2016 Pollution Report to the Legislature.

Key findings

This survey of households found that Minnesotans burned approximately 2.13 million cords of wood between April 1, 2014 and March 31, 2015. This suggests the amount of residential wood burning is on the rise. However, due to changes made to improve the survey design and methodology, comparisons across surveys to identify trends should be done with caution. The increase can be seen in both the estimated number of households burning wood, as well as the amount of wood burned by households. There were notable increases in the amount of wood burned in all types of equipment, though it appears that compared to the estimates from recent years in which most increases were from residential backyard burning, this time much of the increase was from burning for heat. This may be due, in part, to factors such as variations in weather and cost of propane across years.

Implications

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 decisions regarding overall forestry management and environmental strategies in the state.

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.

The data collected is also used to populate the residential fuel wood consumption reported in the annual Minnesota's Forest Resource Report. The Forest Resource Report describes Minnesota's forest resources such as: current conditions and trends in forest resources, and forest resource industrial use.

Introduction

Project purpose

From April through June 2015, the MPCA, assisted by Wilder Research (Wilder), MDNR, and USFS, surveyed randomly selected households across the state to determine the volume of residential wood burned during a year including the 2014-2015 heating season. Similar surveys were conducted for the 1960, 1969-1970, 1979-1980, 1984-1985, 1988-1989, 1995-1996, 2002-2003, 2007-2008, and 2011-2012. 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. The data collected is used to populate the residential fuel wood consumption reported in the annual Minnesota's Forest Resource Report. The Forest Resource Report describes Minnesota's forest resources such as: current conditions and trends in forest resources, and forest resource industrial use.

In addition to the trend and use information, these surveys offer useful data for Minnesota's air pollutant 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 directly emitted fine particles from combustion processes.

Furthermore, as federal standards are strengthened, Minnesota becomes less likely to meet the revised National Ambient Air Quality 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

The objectives for this survey were similar to those framed by the MPCA, MDNR, and USFS for recent surveys.

Objectives:

1. Estimate the total volume and species of residential wood burned from April 1, 2014 through March 31, 2015 by category of equipment used and geographic location where it was burned.

2. Determine the purpose for the wood burning, whether for: pleasure or heat (primary or supplemental), backyard recreational fires, disposal of wood from residential properties, or camping.

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 and species of fuel wood harvested or obtained by other means, including the amounts harvested from living or dead trees and from land owned by different entities (state, federal, county, forest industry, and private lands).

Methods

Survey methods

Study regions

As in prior surveys, Minnesota households were independently sampled from five geographic regions. Surveys stratify the population into subgroups expected to have similar behaviors as a way to cost-effectively improve the precision of the estimates. These five survey regions, depicted in Figure 1, are based on four U.S. Forest Service survey units for Minnesota forests. The Aspen-Birch and Northern Pine survey regions contain most of the state's boreal forest. The Aspen-Birch region has Minnesota's largest area of reserved forest land including the Boundary Waters Canoe Area Wilderness and Voyageurs National Park. The Central Hardwoods survey region is dominated by hardwoods. The more densely populated seven county Twin Cities Metro region was sampled separately from the less densely populated portion of the Central Hardwoods region. The Prairie survey region is dominated by croplands.

Based on recent census data, the Metro region is geographically the smallest region, but contains just over half of Minnesota's occupied households (54%). The Aspen-Birch (5.4%) and Northern Pine (5.9%) regions are the least densely populated. The Prairie (15%) and Central Hardwoods (20%) regions are also much less densely populated than the Metro region. See Figure 2 for the numbers of households in each region.

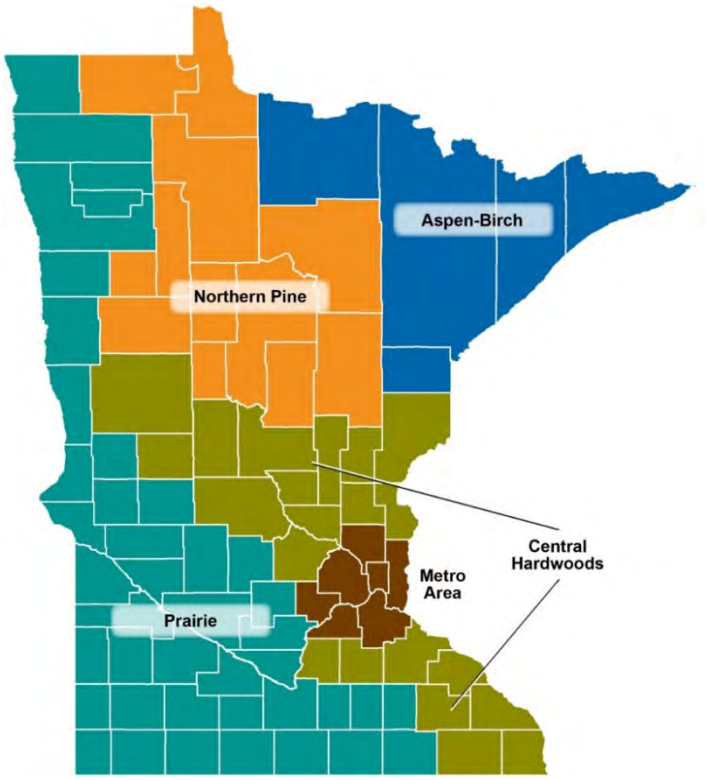
Sample selection

A sample of 7,000 addresses selected at random from valid Minnesota residential addresses, based on a U.S. postal service list of residential addresses, was purchased from Marketing Systems Group (MSG), a company specializing in sampling services. Vacant, seasonal, PO Boxes, and drop points (single addresses that are for multiple residences) were excluded from the sample.

These Minnesota households were included in the sampling frame using a disproportionate stratified sampling design. Households in the Northern Pine region had a five times greater chance of being invited to take the survey than did those living in the Metro region. Chances for households in the Aspen-Birch, Prairie and Central Hardwoods regions to be surveyed were respectively 4.5, 1.9 and1.3 times higher than for the Metro region. Based on the number of households in each region, this resulted in the Metro region being sent about twice as many surveys as each of the other regions. This is consistent with the sampling method used in the 2012 survey design. Figure 2 shows the number of occupied

households in and sampled from each survey region. The pre-2012 surveys invited similar numbers of households to take the survey from each region. Beginning with the 2012 survey, the Metro area was sent twice as many surveys as each of the other regions for several reasons: because more than half of the households in Minnesota are in the Metro area, residential wood smoke from the relatively dense population in the Metro area has been estimated to result in a larger localized air quality impact due to a denser population than the rest of the state and the Metro region has previously experienced slightly lower response rates.

1. Survey regions for stratified sample



Changes from previous survey administration

The 2015 research design was substantially changed to try to increase the accuracy of the results. The first change was to develop a different web version of the survey than previously used. This included complex background skip patterns, screening questions, images of equipment, types of fuels, and definitions of units of fuel quantities throughout the survey. This version of the survey was developed to simplify the survey for the user by only requesting information relevant to the respondent based on a series of screening questions. The web version allowed for more consistent and clear data collection from

respondents because of the embedded logic. The web version was also more cost effective due to decreased postage and printing costs, as well as less need for data cleaning. The push-to-web data collection method involved mailing the households a series of three postcards or letters inviting them to complete the survey online. Households that did not respond to the web invitations were then mailed a paper packet to encourage additional response. Like most previous surveys, this survey asked respondents to report their wood burning and harvesting behaviors for one year spanning from April through March. The 2011-12 survey was an exception in asking about a year starting in July. To encourage survey participation, the 2015 survey offered a chance to receive a $25 VISA gift card, instead of a wood moisture meter, to eliminate the possible bias for response by wood burners.

Wilder pilot tested the web survey by sending it to seven individuals who were known to burn wood at their primary and/or secondary residence. Four individuals completed the test survey and were then asked a series of questions to gather their feedback on the length of the survey, any difficult or confusing questions, and any general suggestions. Based on these results, question language and flow were revised to make the survey easier to complete.

Changes to the questions included on the 2015 (versus 2012) survey questionnaire

In 2012, the survey was substantially revised to make it clearer and easier for respondents to complete. In 2015, most of the 2012 survey language was maintained, with some key exceptions described here. Because the recent surveys identified backyard recreational wood burning as a prevalent wood burning activity, the recreational burning questions were moved to the beginning of the survey. A question addressing recreational backyard wood burning in firepits, chimeneas or firepits was changed to ask the amount of the wood specifically burned to dispose of woody yard materials (e.g., fallen branches, trees and twigs, brush/ trees collected from property). This was accompanied by a new measure of wood burned in firepits, equivalent to a 30 gallon bag of tree branches and woody brush collected from the household's yard. To more accurately reflect the typical size of bundles sold in Minnesota, the defined volume of a bundle of wood was decreased from 2 cubic feet to 0.75 cubic feet[3] (9 inches x 9 inches x 16 inches). The 2015 bundles are 38% of the bundle size used in previous Minnesota surveys.

The web survey allowed respondents unsure about the specific type of wood stove or fireplace insert to answer the questions without specifying whether they had conventional, catalytic or non-catalytic technology.

[3] Using a 0.75 cubic feet per bundle measure there would be 171 bundles per cord. The 2015 questionnaire inadvertently stated there are 210 bundles per cord.

Questions about tree species burned and harvested were revised to minimize nonspecific results. "Mixed species" was eliminated and "Other species" was replaced with "Other hardwood" and "Other softwood." Past surveys found cedar was rarely burned or harvested so "cedar" was excluded. An "Unknown" category was added and the online version required that reported percentages would sum to 100%.

Several questions, including some that were rarely answered on prior surveys, were eliminated for simplification and to improve response rates.

Survey administration

Data collection began in April 2015 in the hopes that the winter burning season would be fresh in the respondents' memories and they would be able to more accurately recall the quantities of wood they burned. On April 1, 2015, all addresses in the sample were mailed a postcard briefly explaining the purpose of the survey and requesting that potential respondents take an online survey. They were given a unique log-in code to enter the survey, ensuring that respondents did not participate more than once and allowing Wilder to track responses. We used returned postcards to eliminate 289 invalid addresses from the pool of potential respondents. A second postcard was mailed two weeks later to the remaining 6,711 potential respondents. Some postcard addresses were smudged during processing at the post office, so some households may not have been able to read the online web address until they received the subsequent mailings. This resulted in the decision to send a third communication.

A third reminder to participate was mailed as a letter on May 17, 2015 with the electronic survey log-in code listed along with the information that if they could not or did not wish to participate online, a paper version of the survey would be mailed to their home along with a postage-paid envelope. There were no within-household respondent selection quotas, so any resident of the household could complete the survey. Presumably, the household member who was willing or who knew the most about the household's wood burning practices completed the survey.

Acuity survey software was used to develop the electronic survey. Those choosing that response method were required to type a short URL printed on the first page of the paper survey.

The paper survey packet was mailed in early June 2015. Each survey had a unique number printed in the upper right hand corner that corresponded to an address in the sample. As surveys were completed, the unique survey numbers were checked off a master list. By August 2015, approximately 1,200 surveys had been returned.

2. Survey mailings and response rates

	Northern Pine	Aspen-Birch	Prairie	Metro Area	Central Hardwoods	Statewide
Number of occupied housing units	124,940	112,757	312,331	1,131,621	425,583	2,107,232
Number of addresses in sample	1195	1168	1195	2300	1142	7000
Number returned as undeliverable	73	54	50	75	37	289
Number of refusals	1	1	3	3	1	9
Total completed	220	218	194	347	208	1187
Completed by mail	126	128	109	167	119	649
Completed online	94	90	85	180	89	538
Response rate	20%	20%	17%	16%	19%	18%

Number of occupied housing units is from the 2009-2013 5-year U.S. Census American Community Survey, table DP04.

Paper survey results were entered into an electronic database so all the data could be compared easily using Excel software. 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 specific mailing addresses. The data could still be tracked by city, county, zip code, and survey region.

Survey questionnaire

The paper survey consisted of a 10-page multiple choice and fill in the blank questionnaire. Most questions related to a specific type of wood burning equipment, and survey respondents could skip questions for types of equipment they did not own. The online version of the questionnaire closely mirrored the paper version, with some minor adjustments to make it easier to complete, including the use of color photographs, skip patterns to allow respondents to avoid questions not relevant to them, and options to endorse "unknown" options for types of wood stoves and species harvested. A copy of the paper version of the questionnaire is included in this report as Appendix E, including description of variations in the online survey.

For each type of wood burning equipment, respondents were asked in both paper and online surveys: how many they had, the quantities of types of wood or wax logs (if any) they burned between April 1, 2014 and March 31, 2015, the months during that period in which the equipment was used, and the main purpose for which the equipment was used.

Information was requested about where the burning activity took place, whether it occurred at a primary residence, secondary residence, or campsite. 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. Questions at the end of the survey requested additional information from households that reported burning wood, including tree species breakdowns for all wood that was burned, how the firewood was obtained, the amounts harvested per county, sources of the wood by land ownership and whether from living or dead trees, and the species of all harvested firewood.

Data analysis methods

The basic methodology for using the survey responses to estimate population-wide wood burning for the survey year – for each of the five regions and for the entire state – involved the following steps.

Prepare data for analysis

The first step was to prepare data for analysis by combining both paper survey responses and web responses in the statistical software package (SPSS), review responses for quality, and recode responses into formats appropriate for analysis. To ensure data quality, manually entered data from the paper surveys was rechecked to make any necessary corrections. Additional review of the data set 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 be certain that they were not duplicate surveys). Once the data were checked and quality ensured, the resulting total survey sample was 1,187 responses.

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 questionable responses, including responses which seemed improbable or appeared to be extreme statistical outliers, were checked with the actual paper surveys to ensure that data were captured correctly. If a questionable response was verified as entered correctly, there was no way to determine if the respondent intended to report the questionable response, so 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. This affected a very limited number of cases, for instance two wood stove burning amount responses statewide were determined to be outliers and were replaced with imputed values.

If a secondary residence was not in Minnesota or an open-end response indicated that the residence was not actually a residence (e.g., a camp ground), all responses for secondary residence burning in that survey were dropped.

If information written on a form indicated that wood burning reported for a secondary residence was actually for the primary residence, the responses were moved to primary.

If respondent failed to answer the campfire burning question about whether they burned or said "No" (Q11) but provided an answer for the amount of wood burned (Q12A) or county(s) in which burning took place (Q12B_A1-A4), then the response to Q11 was assumed to be "Yes".

Missing information about the regions where residences and campsites are located

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 at three types of properties: primary residence, secondary residence, or campsite. For respondents who filled out the survey completely and accurately, geographic locations for both types of residences and up to four counties where they camped 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.

In the two cases in which respondents indicated wood burning at a secondary residence, but did not provide location information for a secondary residence, the location was inferred based on probabilities for all respondents who did provide secondary residence information. For example, if for all Northern Pine residents who provided secondary residence information, data showed the following probabilities for the location of its secondary residence:

Primary residence: Northern Pine
Secondary residence: Northern Pine: 68%
Aspen-Birch: 5%
Prairie: 0%
Metro Area: 16%
Central Hardwoods: 11%

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

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

Missing or invalid wood burning quantities

There were many instances when respondents indicated owning particular wood burning equipment, but they did not enter the quantity of wood burned. 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, simple regression models were used to impute missing quantities based on all those that did provide quantities for that particular equipment. For all households that did provide burning quantities for use of equipment, their reported number of pieces of this equipment type and the number of months in which they used equipment were used to estimate the following regression equation:

$$Quantity\ Burned = \propto + \beta_1\ Number\ of\ Equipment + \beta_2\ Number\ of\ Months\ Equipment\ Used$$

Thus, using the responses of all other households that did provide burning quantities, the coefficients in the above equation (α, $\beta 1$, $\beta 2$) 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 and the number of months[4] for which burning activity was reported. Note that a separate version of the equation above was estimated and applied for each of seven different types of wood burning (outdoor recreational equipment, conventional fireplaces, wood stoves, fireplace inserts, wood pellet stoves, wood boilers (hydronic heaters), and forced-air furnaces), and separate equations were estimated for primary and secondary residences. As described below (see "Convert reported fuel quantities to cords of wood and (wax logs)"), the quantities of wood burned by households that did provide burning quantities were converted to cords for this calculation.

In the case of campfires, when respondents reported having campfires, but did not provide the quantity of wood burned, the median campfire burning amount for all respondents was assumed. This affected two responses.

Missing numbers of equipment owned or used

In several cases, respondents indicated having and using wood burning equipment, but did not give complete information. When respondents failed to indicate how many pieces of a particular type of equipment they had, it was assumed they had only one piece of equipment (which was the modal response for all the equipment types for the households that did provide this information). Missing burning amounts for wood stoves and fireplace inserts were imputed collectively, without regard to the specific equipment sub-type (convention, non-catalytic, catalytic).

The survey didn't ask how many campsites were visited per county or how many fire rings or firepits were used per campsite. For campsites, it was assumed the household used one fire ring, chimenea or fire pit per county where they camped.

Missing main reasons for using equipment

When respondents did not provide their main purpose for using a piece of equipment, we followed the guidelines from the 2012 study by assuming the most typical burning purpose of a particular equipment type—"pleasure" for fireplaces and recreational outdoor wood burning equipment; and "secondary heat source" for wood stoves and fireplace inserts. The 2015 survey didn't ask what percent of heat was from wood, so "primary heat source" was assumed for wood burning boilers and furnaces and "secondary heat source" was assumed for pellet stoves. For all but "wood burning boiler or furnace," the purpose question was changed into a multiple response question for the paper surveys because respondents endorsed multiple reasons (without being directed to do so), and

[4] Missing numbers of months were replaced with the median response.

those responses were still considered valid. In order to impute the purpose in the analysis, persons who gave more than one response were placed in a "multiple answers" category.

For each type of equipment, we created variables indicating whether the respondent had the equipment and, if so, whether that equipment was used. Having the equipment was determined from all of the questions in the equipment section of the survey. If the respondent said they had the equipment (for instance, a fire pit), or if any of the follow-up items indicated the equipment existed (for instance, they reported using it for pleasure), then we assumed that the respondent had that type of equipment. Usage of the equipment was defined as having the equipment and reporting any one or more of the following: a purpose for burning, months during which there was burning, or amount of wood burned.

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, but also indicated that the equipment's function was to heat water, which is clearly a characteristic of a wood boiler (not a forced air furnace). In cases of obvious contradictions such as this, corrections were made to most accurately reflect the true behaviors of responding households. The terminology for the wood boilers (hydronic heaters) versus forced-air wood furnaces can be confusing because the wood boilers, defined in the survey, are often also called outdoor wood furnaces. Therefore, the questionnaire included several questions to help verify the respondent correctly distinguished their boilers from furnaces. In reviewing the responses, if a recognized model was listed, this information took precedence. If the brand was listed, and manufacturer only made boilers or furnaces, then this information was used. Lacking that information, if the heater used water to heat anything, then it was assumed to be a boiler.

The species of wood burned and firewood harvesting questions were percentages that would sum to 100 percent. In some cases, however, respondents' answers to these questions did not follow this logic. If a question's percentages summed to more than 100 percent, the residual was placed in the same "unknown" category that respondents could choose if they didn't know the answer. If a question's percentages summed to less than 100 percent they were forced to add to 100 percent by adding the additional percent needed to the "unknown" category. Similarly, respondents who harvested wood were asked to list the counties (up to four) from which the wood came and the percentage of wood that came from each county. In 6 cases, the percentages summed to more than 100 percent. When that occurred, a fifth, "unknown county" was added, and the residual was placed there.

Estimate region-wide and statewide totals

Convert reported fuel quantities to cords of wood (and wax logs)

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.[5] Other wood burning fuel measures of wax logs, pallets, pounds of wood pellets and bags of branches were converted into cord equivalents using the conversion factors listed in Appendix B. Therefore, the results labeled as "wood" may also include wax logs.

Assign to regions and group the equipment and burning activities

Based on the provided or inferred locations of primary and secondary residences and campsite burning, every burning activity reported in the survey was assigned to one of the five regions. The wood burning equipment and burning activities were grouped to report as seven equipment categories (outdoor recreational equipment, conventional fireplaces, wood stoves, fireplace inserts, wood pellet stoves, wood boilers (hydronic heaters), and forced-air furnaces).

Weighting and scaling survey sample responses to statewide and regional totals

As described in this section, reported amounts of equipment owned, wood burned, whether the responding households burned wood were regionally-adjusted and projected (scaled) to estimate amounts for the entire population of households in each region.

The survey sample was drawn from occupied households so the scaling was based on the number of occupied households in each survey region, according to the 2009-2013 5-year U.S. Census American Community Survey, table DP04. The regionally-adjusted scaling weights were calculated as described in this example. There were 356 survey responses from the Metro region, and there are 1,131,621 households in the region. Thus Metro region totals for the survey sample were regionally-adjusted and scaled up by a factor of $\frac{1,131,621}{356} = 3,179$[6] to estimate total burning activities for the Metro region. Regional-adjustment and scaling the survey responses 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) and the differential nonresponse (i.e., the fact that households in some regions were more likely to respond

[5] Three face cords or 171 bundles equal one full cord. Previous survey reports used a 64 bundle per one full cord of wood conversion factor.

[6] This is equivalent to saying that each household responding to the survey from the Metro region represents 3,179 households in the population as a whole.

than those in other regions). It also extrapolates (scales) the household response to estimate the region-wide amount.

The regionally-adjusted scaling weight for each respondent was based on the location of their primary residence, not the location of their reported burning. Regionally-adjusted scaling weights for the Northern Pine, Aspen-Birch, Prairie, Metro and Central Hardwoods regions were 578, 527, 1,610, 3,179 and 2,056, respectively, for respondents living in those regions. Additional weighting by household type, which may reduce possible non-response bias and improve the precision of the estimates, is explored in Appendix C.

The regionally-adjusted scaling weights were applied for all analyses throughout the main body of this report, to estimate the total quantities across the state and within the five regions.

Calculate regional and statewide total amounts

Survey results were tallied and reported as state totals and for the five regions where households live and/or burn wood. The wood burning equipment and burning activities were grouped into seven equipment categories (outdoor recreational equipment, conventional fireplaces, wood stoves, fireplace inserts, wood pellet stoves, wood boilers (hydronic heaters), and forced-air furnaces). Wood burned in each equipment category was grouped according to the main purpose for which the household reported burning the wood.

Calculate the confidence interval for the total wood burned statewide

We calculated 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 percent 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.

Confidence intervals for statewide wood-burning totals were calculated in the following manner. First, a regionally-adjusted non-scaling weight was calculated, as follows. Out of 1,187 total completed surveys, 356 were households living in the Metro region. Thus, the percentage of surveys in the total survey sample from the Metro region was $\frac{356}{1{,}187}$ = 30%. The overall number of households in the Metro region is 1,131,621, while there are 2,107,232 households in the state. Thus, the percentage of the state's households in the

Metro region is $\frac{1,131,621}{2,107,232}$ = 54%. Therefore, Metro region households make up 54 percent of the state population but only 30 percent 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. As was appropriate for the calculations of the regionally-adjusted scaling weights above, 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. Weights for surveys from over-represented survey regions were given regionally-adjusted non-scaling weights less than one (i.e., the contribution of their wood burning activities to state totals was adjusted down), while under-represented regions were given regionally-adjusted non-scaling weights greater than one (their contribution to total estimates was adjusted 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 0.33 in the most over-represented regions (Aspen-Birch) to 1.8 in the most under-represented region (Metro). Specifically, the regionally-adjusted non-scaling weights for the Northern Pine, Aspen-Birch, Prairie, Metro and Central Hardwoods regions were 0.33, 0.30, 0.91, 1.8 and 1.2, respectively, for respondents living in those regions.

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 or when some subsets of the population are sampled more than others.

A regionally-adjusted non-scaling weight was assigned to each of the 1,187 responding households. Next, the mean and standard deviation of the individually reported total wood burned by the households was calculated. For each of the 1,187 household respondents, this calculation used the total number of cords of wood (and wax logs) they burned in all types of equipment anywhere in the state, including zeros for the households who didn't report burning any wood or wax logs. The standard deviation of these 1,187 amounts of wood was divided by the square root of the number of surveys in the sample (1,187) to estimate the standard error (SE) of the sample. For 95 percent confidence intervals, a critical value (*t**) was obtained from tables of the t distribution with a significance level (α) of one minus the 95% 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 regionally-adjusted non-scaling weight parameters and μ is the mean of the regionally-adjusted non-scaling

weight parameters across all 1,187 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 17 percent. This confidence interval was applied to the total estimated cords of wood burned statewide to obtain overall estimates of a 95 percent confidence interval for statewide wood burning quantities.

Limitations

There are some important limitations to this study that should be considered when interpreting the results. First, of the 6,711 households invited to participate in the survey, 1,187 completed the survey for a response rate of 18 percent. The response rate by region varied from 16 to 20 percent, with the Metro region having the lowest response rate (see Figure 2). We anticipated the lower response rate in the Metro based on previous survey administrations, so we mailed more surveys to households in the region.

The low response rate may reflect selection bias, or those who chose to participate are different than those who did not participate in the survey. Respondents may have been more interested in the topic or had more involvement with wood burning, and those who did not burn wood may have been more likely to disregard the survey. This selection bias is likely to lead to a higher estimated rate of burning than may actually be occurring.

While data have been regionally-adjusted (weighted by region), scaled, and imputed to better represent the geographic areas of interest, these responses may not represent the experiences of all households in a particular region or in Minnesota.

The survey also relied on retrospective self-report of burning and wood harvesting behaviors. These retrospective reports are likely to be strong approximations of actual behaviors, but they should be treated as estimates, as opposed to precise measurements.

Another significant limitation is the ability to compare survey years and examine trends. Each survey administration has involved changes to the survey instrument and collection methods, which may change the results. For example, one change to this year's survey was moving the questions about backyard burning to the beginning of the survey. This helped ensure those who only burned in their backyard did not miss the questions or become deterred by all of the questions about other types of equipment. Changes in rates of backyard burning may be on the rise, but they may also be more accurately captured by moving those questions to the front.

In spite of these limitations, the survey results contain an abundance of information that can and will be used by a variety of interested parties.

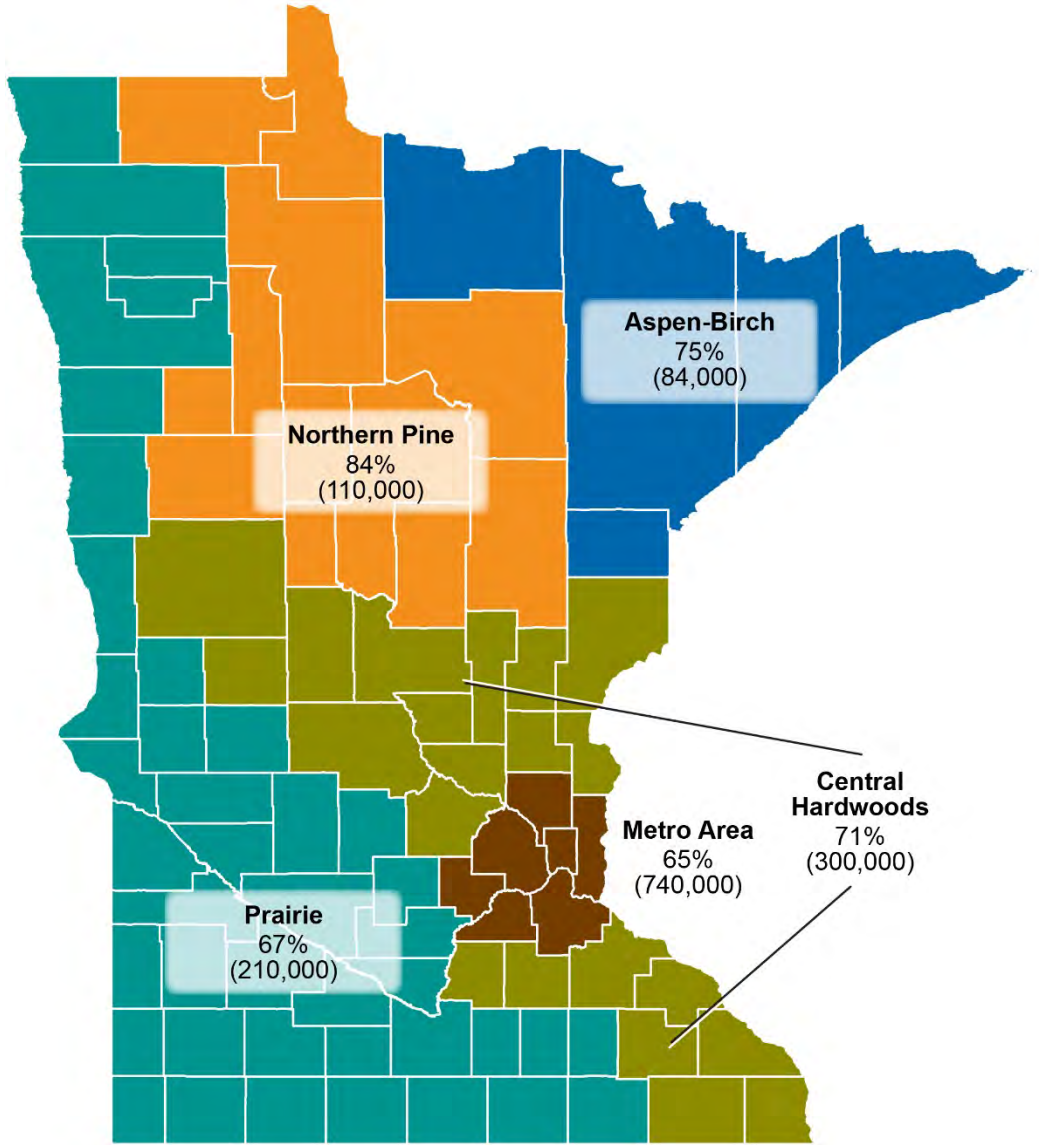
Results

Household burning practices

Between April 1, 2014 and March 31, 2015, an estimated 1.4 million Minnesota households burned wood. This accounts for approximately 68 percent of all Minnesota households. It should be noted that the response rate in 2015 was 18 percent (see Figure 2), which indicates that responses may not represent the overall population. As with previous wood burning surveys, it is highly possible that a greater number of wood burners chose to respond to the survey versus those that do not burn wood, which could lead to an overestimate of actual burning rates when the survey results are scaled to reflect the overall population.

A greater proportion of households with a primary residence in the Northern Pine region reported burning wood (84%) compared to other regions (Figure 3). Burning rates (the proportion of households in the region who burn any wood anywhere) were lower for households in the Prairie (67%) and Metro regions (65%). However, because the Metro region is more densely populated, it has the greatest number of households estimated to burn wood (0.74 million). The geographic distribution of households reporting wood burning is similar to the 2012 report; however, the rates of burning in every region, and across the state, are notably higher than in 2012 (rates ranged from 51% to 63%). These results are based on the self-reported primary residence locations of the households reporting burning anywhere in the state. Some households also burn in other regions, such as at a secondary residence or a campsite, so these results do not necessarily reflect where the wood is being burned. Information about the amount of wood burned per region can be found in the following section.

3. Number and percent of households burning wood, by region



Note: This map represents the extrapolated number and percent of households in each region that burned wood at their main homes or secondary residences or while camping. Households are mapped based on the location of their primary residence.

Volume of wood fuel consumed

Total volume

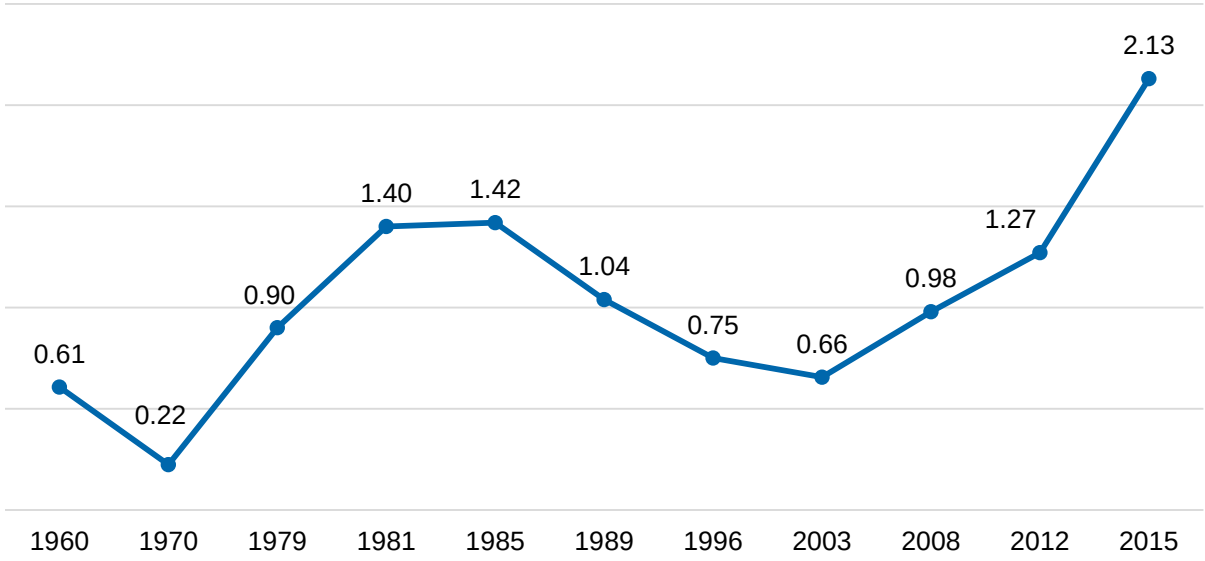
The total volume of wood[7] burned in Minnesota between April 2014 and March 2015 is estimated at 2.13 million cords (Figure 4). This is a 68 percent increase from the 2012 survey, compared to a 30 percent increase between 2008 and 2012, and it reflects an upward trend in volume estimates from 2003 forward. It also represents the highest rate of burning estimated in these reports.

When applying a 95 percent confidence interval around this estimation, the result ranges from 1.62 million cords to 2.65 million cords (see Figure 5). In the 2012 report, the 95 percent confidence interval yielded a range between 1.02 million cords and 1.54 million cords. The 2015 estimate is substantially higher than the 2012 estimate. Although the 2015 estimate has especially wide confidence intervals, the confidence intervals for the two estimates do not overlap, indicating there may be a statistically significant difference between the years using a 95 percent confidence interval.

These estimates and the comparisons over time should be interpreted with a great deal of caution. The estimates are based on the amount of wood burned reported by survey respondents. As described in the limitations section of this report, selection bias and changes to the survey tool and administration may affect burning rates and comparisons over time. Specifically, the survey design, response rates, samples, and methods of administration have changed over time, which may affect who responded to the survey and how they responded in any given year.

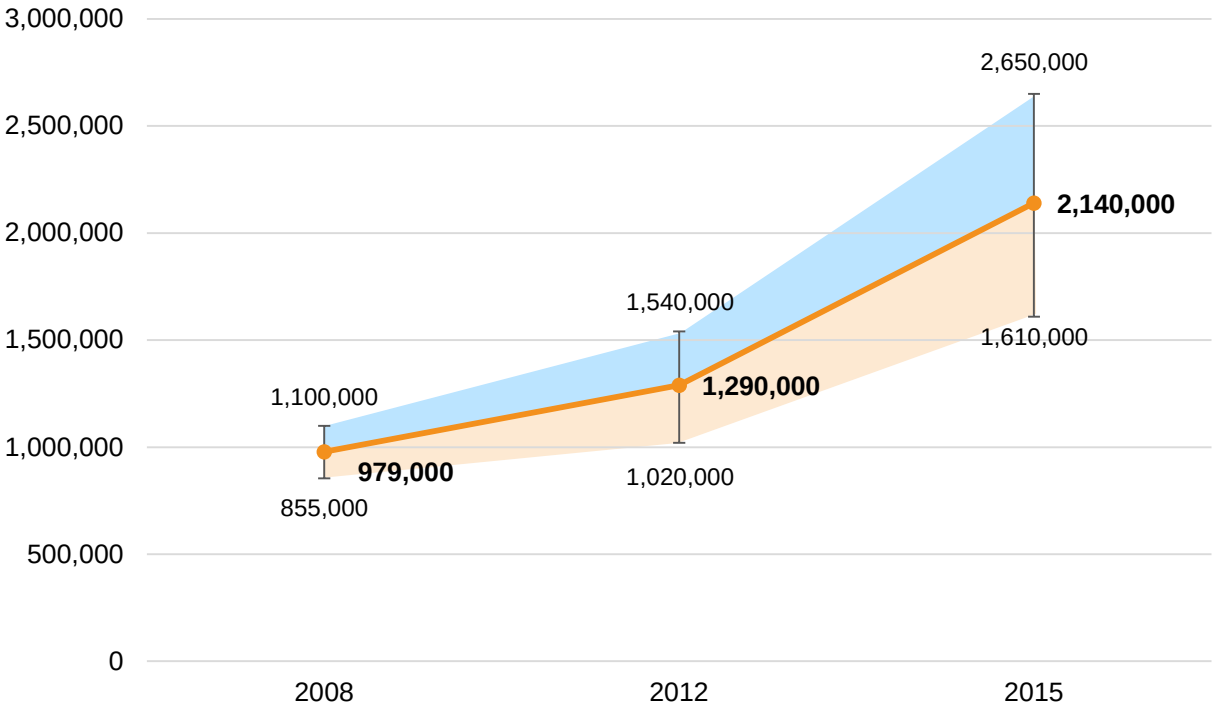
[7] Unless otherwise noted, "wood" may include wax logs, wood reported in cords, face cords or bundles, wood pellets, pallets, slabs, and tree branches and woody brush. Figure 14 describes the breakdown.

4. Wood fuel consumption in Minnesota by survey year (millions of cords)



Note: Changes over time should be interpreted with caution due to changes in the survey design, methodology, response rate, equipment included, wood bundle volume, and conversion rates for different types of wood. Dates shown on the x-axis are the year the survey was administered.

5. Wood fuel consumption in Minnesota by survey year with 95% confidence intervals (cords of wood burned)

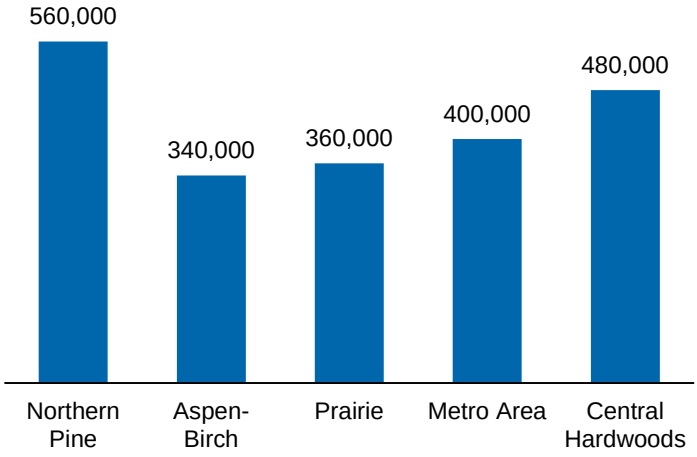


Wood burning by region

Total wood burning by region where it was burned

Similar to the proportion of households reporting wood burning, the total amount of wood burned between April 2014 and March 2015 was highest in the Northern Pine region at approximately 560,000 cords (Figure 6). The Aspen-Birch and Prairie regions had the fewest total cords of wood burned (approximately 340,000 and 360,000 respectively). The Northern Pine and Aspen-Birch regions have the lowest household populations. These results reflect the amount of wood burned in a particular region, including at a primary residence, secondary residence, or campsite, and by Minnesotans from anywhere in the state.

6. Total cords burned in each survey region



Location of wood burning by region

Statewide, the majority of wood was burned at primary residences (78%), followed by secondary residences (21%), and campsites (2%; Figure 7). In the Metro region, nearly all wood burned (97%) was burned at a primary residence. This accounts for the greatest total volume of wood burned at primary residences (390,000 cords). In the Northern Pine region, 40 percent of wood was burned at secondary residences. Secondary residences in the Northern Pine region burned approximately 220,000 total cords, which is over half of the total wood burned at secondary residences statewide (51%). The Aspen-Birch region had the greatest proportion of burning at campsites (3%), and this region alone accounted for nearly one-third of the total cords burned at campsites (31%).

7. Total cords burned by survey region and place of consumption

Region wood burned	Total number of cords burned	Primary residence		Secondary residence		Camping	
		Number of cords burned	Percent of cords burned	Number of cords burned	Percent of cords burned	Number of cords burned	Percent of cords burned
Northern Pine	560,000	330,000	59%	220,000	40%	7,800	1%
Aspen-Birch	340,000	260,000	75%	73,000	21%	11,000	3%
Prairie	360,000	310,000	86%	47,000	13%	2,800	1%
Metro Area	400,000	390,000	97%	5,700	1%	5,400	1%
Central Hardwoods	480,000	380,000	79%	90,000	19%	7,400	2%
Statewide	2,100,000	1,700,000	78%	440,000	21%	34,000	2%

Note: Percentages may not equal 100 percent due to rounding.

Numbers of equipment owned

Based on the extrapolated estimates, the most common type of equipment owned at primary and secondary residences statewide is outdoor recreational equipment, such as fire pits, fire rings, and chimeneas (1.6 million pieces of equipment; Figure 8). It should be noted that fire pits at campsites are excluded from this section because they are not considered "owned" by survey respondents. Even excluding campsite equipment, outdoor recreational equipment accounts for over half of all of the equipment owned (58%), followed by conventional fireplaces (21%), and wood stoves (12%). Some households owned multiple pieces of the same type of equipment. During the survey period, not all of the owned equipment was actively used. Regional estimates of ownership of the wood stoves and outdoor recreational equipment which are common in all regions are more reliable than for the less frequently reported equipment, especially the pellet stoves, and to a lesser degree the wood boilers (hydronic heaters), wood burning forced-air furnaces and fireplace inserts. Outdoor recreational equipment is particularly prevalent in the Metro region (610,000 pieces of equipment). The Metro region also has the majority of conventional fireplaces (370,000) and fireplace inserts (83,000). Woodstoves are slightly more common in the Northern Pine region (73,000), but they are relatively equally dispersed across regions. The Central Hardwoods and Northern Pine regions reported owning the majority of the wood boilers and forced-air furnaces.

8. Count of wood burning equipment owned by region where located

Type of equipment	Number of pieces of equipment owned: Northern Pine	Aspen-Birch	Prairie	Metro Area	Central Hardwoods	Statewide
Outdoor recreational equipment	240,000	140,000	200,000	610,000	390,000	1,570,000
Conventional fireplace	50,000	32,000	56,000	370,000	57,000	560,000
Wood stoves	73,000	65,000	50,000	67,000	57,000	310,000
Fireplace inserts	12,000	5,300	13,000	83,000	21,000	130,000
Pellet stoves	1,200	1,100	3,200	6,400	10,000	22,000
Wood boilers	14,000	7,900	9,700	3,200	16,000	50,000
Wood burning forced-air furnaces	14,000	5,300	6,400	9,500	12,000	48,000

Note: Wood boilers are indoor or outdoor wood-burning hydronic heaters. These may also be called outdoor wood furnaces. Outdoor recreational equipment owned does not include the numbers estimated from use at campsites. Regional estimates of ownership of less frequently reported equipment, especially pellet stoves, are less reliable.

Wood burning by equipment over time

The estimated proportion of the total statewide wood burned in each type of equipment appears to have remained consistent between the 2012 and 2015 surveys, but they vary from previous years (Figure 9). This may be due, in part, to the changing survey design and methodology. Wood stoves and wood boilers have consistently burned more wood than most other types of equipment. In 2012 and 2015, outdoor recreational equipment also burned a relatively high proportion of wood. Pellet stoves have consistently been the type of equipment to burn the least wood, which is understandable given that they are the least common type of wood-burning equipment in the state and generally require less wood than other heaters.

While the relative proportion of wood burned in each type of equipment remained stable between 2012 and 2015, the estimated amount of wood burned in each type of equipment increased during that time. The greatest increases in the estimated amount of wood burned were in wood boilers, outdoor recreational equipment, wood stoves, and forced-air wood furnaces.

9. Wood volume consumed by type of wood burning equipment over time

Type of wood burning equipment	Number of cords burned				Percent of statewide total			
	2002-03	2007-08	2011-12	2014-15	2002-03	2007-08	2011-12	2014-15
Conventional fireplace	170,000	89,000	88,000	160,000	25%	9%	7%	7%
Fireplace inserts	84,000	83,000	70,000	120,000	13%	9%	6%	6%
Wood stoves	130,000	390,000	370,000	510,000	20%	40%	29%	24%
Pellet stoves	0	11,000	8,600	13,000	0%	1%	1%	1%
Wood burning forced-air furnaces	160,000	50,000	100,000	220,000	24%	5%	8%	10%
Wood boilers	100,000	200,000	240,000	500,000	16%	20%	19%	23%
Outdoor recreational equipment	17,000	160,000	400,000	610,000	3%	16%	31%	29%

Note: Changes over time should be interpreted with caution due to changes in the survey design, methodology, response rate, and conversion rates for different types of wood. Wood boilers are indoor or outdoor wood-burning hydronic heaters. These may also be called outdoor wood furnaces.

Wood burning by equipment and region where it was burned

In the Northern Pine and Aspen-Birch regions, the central heaters combined (wood boilers and forced-air furnaces) burned the most wood, followed by zone heating equipment (stoves and fireplace inserts) and outdoor recreational equipment, with fireplaces burning the least (Figure 10). The Prairie region had a similar ranking, except zone heaters were estimated to burn more than central heating equipment. In the Central Hardwoods region, central heaters burned the most wood, followed by outdoor recreational equipment, zone heating equipment, and with fireplaces burning the least. The Metro region burned the most wood in outdoor recreational equipment, followed by the zone heating equipment, central heating equipment (forced-air furnaces) and with fireplaces burning the least. Across the four less densely populated regions in Greater Minnesota, zone and central heating equipment accounted for about 70 percent of the cords of wood burned. Outdoor recreational equipment was less than about 30 percent. In contrast, in the Metro region, the greatest volume of wood was burned in residential outdoor recreational equipment (41 percent). Less than half of the wood burned in the Metro region was burned in zone and central heating equipment combined. In the Metro and the Central Hardwoods regions, more wood was burned in fireplace inserts than in conventional fireplaces, while the opposite was true in the other three regions. The Metro region burned much more wood in fireplace inserts than any other region.

10. Total cords burned by equipment type in each region

	Northern Pine	Aspen-Birch	Prairie	Metro	Central Hardwoods
Outdoor recreational equipment	140,000	79,000	80,000	170,000	150,000
Wood stoves	130,000	100,000	150,000	43,000	87,000
Conventional fireplace	45,000	27,000	24,000	48,000	14,000
Fireplace inserts	15,000	4,600	9,900	70,000	18,000
Pellet stoves	1,100	1,100	760	1,900	8,000
Wood burning furnaces	87,000	37,000	5,200	74,000	17,000
Wood boilers	140,000	90,000	87,000	0	190,000

Note: Wood boilers are indoor or outdoor wood-burning hydronic heaters. These may also be called outdoor wood furnaces. Regional estimates of wood burned in the less frequently reported equipment, especially pellet stoves, are the least reliable.

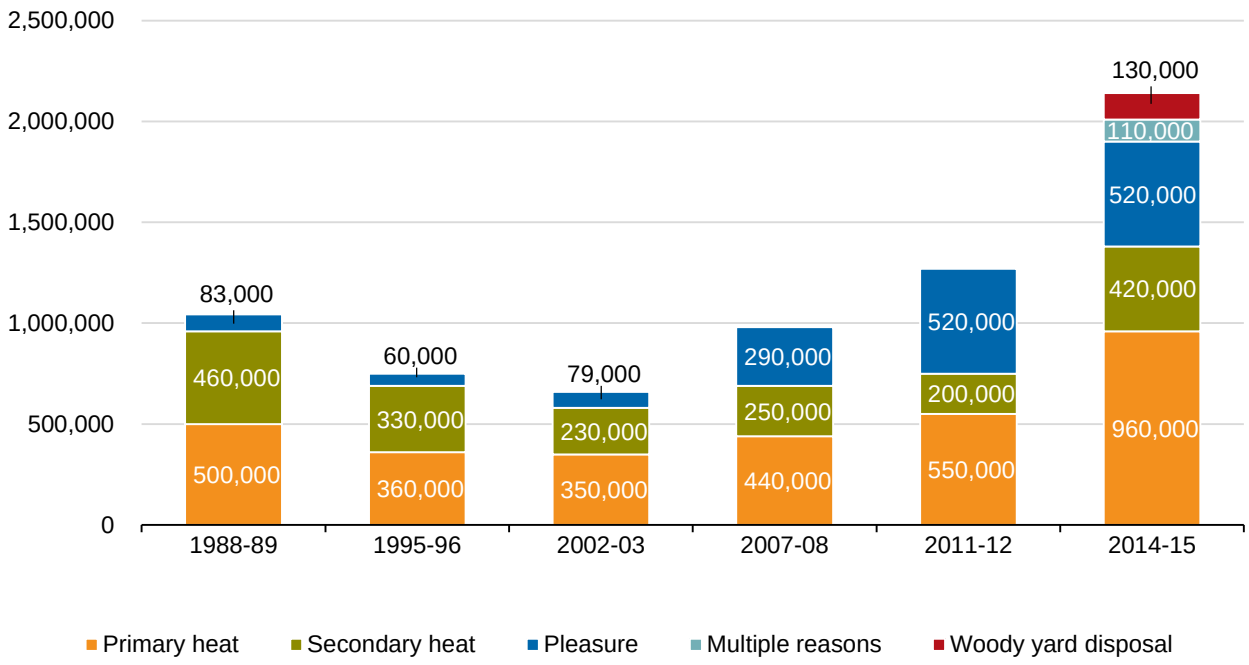
Characteristics of wood fuel users

Wood consumption by reason for burning

Respondents were asked to report the primary reason for burning wood in each category of equipment they reported using at each residential location. The main reason for burning could be for pleasure, as a primary heat source, as a secondary heat source, or for disposal of woody yard materials. Disposal of woody yard materials was a new response option specific to burning in residential outdoor recreational equipment in the 2015 survey. The greatest volume of wood is burned for primary heat (45%), followed by pleasure (24%) and secondary heat (20%). Disposal of woody yard materials as a primary reason for burning was reported for 6% of the cords burned (Figure 11).

Some of the 2015 survey respondents who filled out the paper questionnaire gave multiple reasons for burning in firepits, fireplaces and wood stoves. A multiple response category was included in the analysis, and this category makes up 5.3% of the wood burned. Since 2012 there appears to be an increase in burning for primary and secondary heat, but trends should be interpreted with caution.

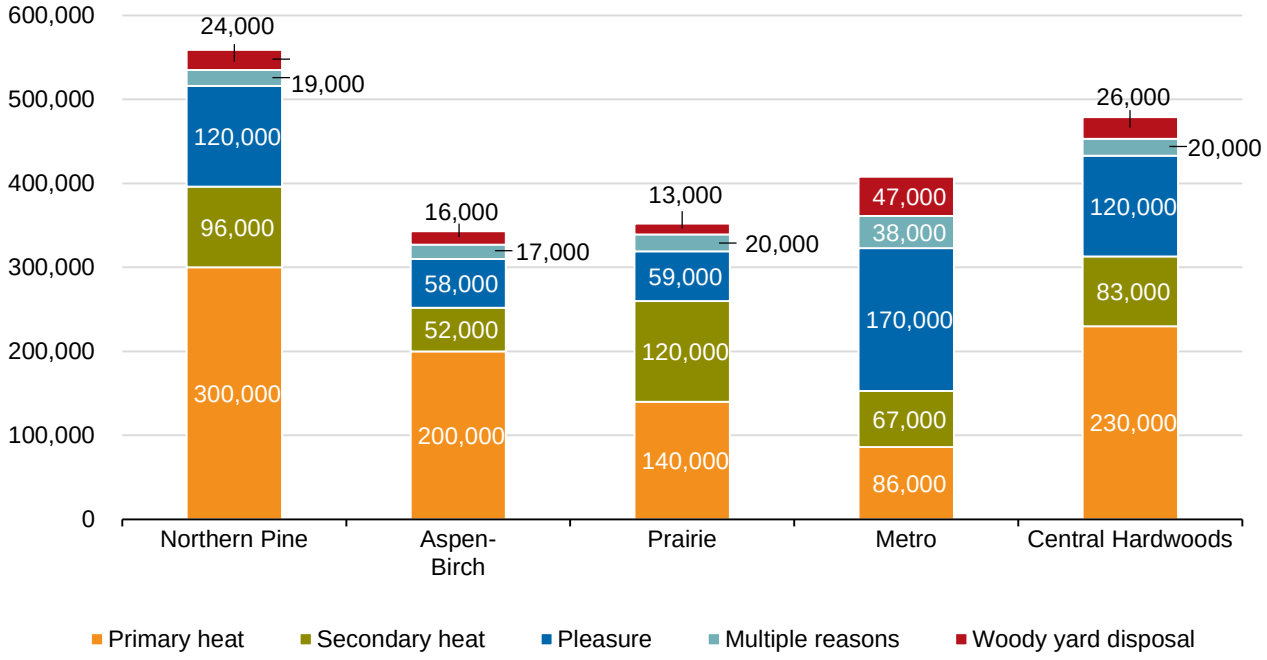
11. Total cords burned by primary reason for burning over time



Note: Burning for pleasure includes burning at campsites. Through the 2012 survey, respondents were asked to share the main reason for their burning in a particular piece of equipment, so these volumes are considered estimates. For residential outdoor wood burning firepits, chimeneas and fire rings, a new reason was added to the survey and respondents could select 'disposal of woody yard materials '(e.g., fallen branches, trees and twigs, brush/trees collected from property). In the 2015 survey, many respondents selected multiple reasons for burning in a particular piece of equipment, so these responses were recoded into "multiple reasons." Changes over time should be interpreted with caution due to changes in the survey design, methodology, response rate, and conversion rates for different types of wood.

The primary reason for burning varied greatly across the regions, with the greatest volume of wood being burned for primary heat in the Northern Pine region (54%, or 300,000 cords of the wood burned in the Northern Pine region was for primary heat). Both the Central Hardwoods and Aspen-Birch regions have the largest proportion of wood burned used for primary heat (58% in Aspen-Birch and 49% in Central Hardwoods). A slightly smaller proportion of wood burned in the Prairie region was burned for primary heat (40%). The Metro region had the greatest volume of wood burned for pleasure, accounting for approximately 41 percent of wood burned in the region. The Metro region also had the greatest volume of wood being burned for woody yard disposal (12%; Figure 12).

12. Total cords burned by primary reason for burning in each region



Note: Burning for pleasure includes burning at campsites. Through the 2012 survey, respondents were asked to share the main reason for their burning in a particular category of equipment, so these volumes are considered estimates. For residential outdoor wood burning firepits, chimeneas and fire rings, a new reason was added to the survey and respondents could select 'disposal of woody yard materials '(e.g., fallen branches, trees and twigs, brush/trees collected from property). In the 2015 survey, many respondents selected multiple reasons for burning in a particular piece of equipment, so these responses were recoded into "multiple reasons." Changes over time should be interpreted with caution due to changes in the survey design, methodology, response rate, and conversion rates for different types of wood.

While statewide the greatest volume of wood is burned for primary heat (960,000 cords), burning for pleasure is the most common reason a household burns wood statewide (57% of households that are burning, Figure 13). As shown in Figure 13, this holds true across all regions, with the greatest proportion of households burning wood doing so for pleasure across all regions (58%-68%). This reflects that while the greatest volume of wood burned statewide may be for primary heat, the most common reason households are burning wood is for pleasure.

13. Number of households burning wood for one or more reasons in each region*

Region wood burned	Estimated total households burning	For primary heat	For secondary heat	For pleasure	Multiple reasons	For woody yard disposal
Northern Pine	370,000	13%	12%	58%	6%	11%
Aspen-Birch	330,000	12%	7%	68%	5%	8%
Prairie	310,000	9%	12%	61%	5%	13%
Metro Area	730,000	2%	9%	61%	8%	20%
Central Hardwoods	510,000	7%	8%	65%	9%	11%
Statewide*	1,900,000	8%	11%	57%	8%	16%

Note: Burning for pleasure includes burning at campsites. The total number of unique households burning wood statewide is 1.3 million. These numbers are considered estimates because respondents who burned wood in more than one region, for more than one purpose, or who gave multiple reasons for their burning in a particular category of equipment, were tallied in each of the applicable region and purpose categories. For residential outdoor wood burning firepits, chimeneas and fire rings, a new reason was added to the survey and respondents could select disposal of woody yard materials '(e.g., fallen branches, trees and twigs, brush/trees collected from property). Changes over time should be interpreted with caution due to changes in the survey design, methodology, response rate, and conversion rates for different types of wood.

* Some households are included multiple times so the numbers of households shown exceed the unique numbers of households who burned wood.

Types of wood and tree species burned as wood fuel

In surveys before 2012 a distinction was made between the type of cord wood burned (roundwood/logs and split wood). In the 2015 survey respondents were only asked to report the volume of wood in full cords, face cords, bundles, and bags of branches. Depending on the equipment type, they could also report the volume of wood in the form of pallets, slabs, wood pellets, and wax logs. These volumes were converted to full cords for analysis. Nearly all wood consumed in the state was in the form of "wood" which is likely to predominantly be roundwood/logs and split wood (93%), with small proportions being accounted for by bags of branches (4%), pallets (2%), slabs (0.7%), wood pellets (0.5%), and very little by wax logs (<0.05%; Figure 14).

14. Number of cords burned by fuel type

Fuel type	Cords	Percent of total
Wood[8] (cords, face cords, and bundles)	2,000,000	93%
Bags of branches	80,000	4%
Pallets	40,000	2%
Slabs	15,000	0.7%
Wood pellets	12,000	0.5%
Wax logs	1,000	0.05%

[8] While not explicitly asked on the questionnaire, "wood" was assumed to be logs and split wood

Using this survey's conversion of 171 bundles per cord, bundles accounted for 73,000 of the estimated cords of wood burned. If the 64 cord to bundle conversion metric used in prior surveys had been used in the analysis, this survey would have estimated 195,000 cords of wood bundles.

The species of wood consumed in 2015 were similar to previous years, but changes to the survey may impact the ability to compare trends over time. In the 2015 survey, three new response options were added: "Other Hardwoods," "Other Softwoods," and "Unknown Species." Several categories were excluded from the 2015 survey including cedar, mixed species, other species, and slabs and scrap lumber. Even given these changes, the greatest percent of wood consumption continued to be oak (27%), with the next highest being birch and ash (11% each). Less wood was burned statewide from aspen (9%), pine (7%), maple (6%), elm (5%), and basswood (2%) trees (Figure 15).

15. Percent of wood consumption by species

	Percent of statewide total					
Species	**1988-89**	**1995-96**	**2002-03**	**2007-08**	**2011-12**	**2014-15**
Oak	32%	27%	38%	29%	29%	27%
Birch	13%	14%	13%	9%	11%	11%
Ash	8%	4%	10%	17%	11%	11%
Elm	14%	3%	5%	9%	6%	5%
Maple	8%	4%	8%	10%	9%	6%
Aspen	7%	10%	8%	12%	7%	9%
Basswood	N/A	N/A	N/A	N/A	1%	2%
Pine	N/A	N/A	N/A	N/A	6%	7%
Cedar	N/A	N/A	N/A	N/A	<1%	N/A
Other Hardwoods	N/A	N/A	N/A	N/A	N/A	5%
Other Softwoods	N/A	N/A	N/A	N/A	N/A	3%
Unknown species	N/A	N/A	N/A	N/A	N/A	14%
Mixed species	N/A	N/A	N/A	N/A	16%	N/A
Other species	3%	6%	9%	10%	4%	N/A
Slabs and scrap lumber	15%	32%	8%	4%	N/A	N/A

Note: Changes over time should be interpreted with caution due to changes in the survey design, methodology, response rate, and conversion rates for different types of wood.
NA – Minimal or not asked on the survey

Sources of wood fuel

The survey asked where the wood that is consumed in the state originates. This includes whether it was harvested and, if it was harvested, where it was harvested from and in what form. The survey asked how much firewood was harvested for the purpose of burning, not including wood that was gathered during yard clean-up or maintenance. Minnesota residents reported harvesting 1.7 million cords of wood.

Forty-four percent of the wood Minnesota residents burned was self-harvested by the household or an immediate family member, while 35 percent was purchased or received for free. A large portion of wood consumed also came from an unknown source (21%; Figure 16). Note that the total cords of wood harvested shouldn't have included the wood gathered during yard clean-up or maintenance.

16. Amount and percent of wood consumption by procurement method

Procurement method	Cords	Percent of total
Self-harvested	770,000	44%
Purchased or received for free	600,000	35%
Unknown	360,000	21%

Results shown are the directly reported responses and were not imputed so they vary slightly from the total wood reported as harvested.

For the wood that was harvested, respondents were asked the harvest location. The majority was harvested from private land (83%) and small proportions were harvested from county land (4%), state land (3%), national forestland (2%), and municipal land (1%; Figure 17).

17. Amount and percent of wood harvested by type of location

Harvest location	Cords	Percent of total
Private land	480,000	83%
County land	22,000	4%
State land	19,000	3%
National Forestland	9,600	2%
Municipal land	6,900	1%
Unknown	39,000	7%

Results shown are the directly reported responses and were not imputed so they vary slightly from the total wood reported as harvested.

About a third of wood harvested came from dead trees from forestland (34%) and another third from live or dead trees from yards inside city limits, or other non-forest land (31%). Smaller quantities were harvested from live or dead trees from pasture land and/or cropland (12%), live trees from forestland (11%), and cut trees and/or tops and branches after a timber harvest (6%; Figure 18).

18. Amount and percent of wood fuel harvested by type of harvest source

Harvest source	Cords	Percent of total
Dead trees from forestland	250,000	34%
Live or dead trees from yards, inside city limits, or other non-forestland	230,000	31%
Live or dead trees from pasture land and/or cropland	91,000	12%
Live trees from forestland	83,000	11%
Cut trees and/or tops and branches after a timber harvest	46,000	6%
Unknown	40,000	5%

Results shown are the directly reported responses and were not imputed so they vary slightly from the total wood reported as harvested

Conclusion

Key findings

Residential wood burning appears to have increased. An estimated 2.13 million cords were burned between April 1, 2014 and March 31, 2015. This is a 68 percent increase from the 2012 residential wood survey report estimate, and it reflects an upward trend in volume estimates from 2003 forward. However, due to changes made to improve the survey design and methodology, comparisons across surveys to identify trends should be done with caution. The increase can be seen in both the estimated number of households burning wood, as well as the amount of wood burned by households. There were notable increases in the amount of wood burned in all types of equipment, though it appears that compared to the estimates from recent years in which most increases were from residential backyard burning, this time much of the increase was from burning for heat. This may be due, in part, to factors such as variations in weather and cost of propane across years.

Statewide, the greatest volume of wood burned is for primary heat, but behavior varies greatly across regions. Statewide, 45 percent of wood burned was burned for primary heat or 960,000 cords. This varied greatly by region with 58 percent of wood in the Aspen-Birch region being burned for primary heat, 54 percent in Northern Pine, 49 percent in Central Hardwoods, 40 percent in Prairie, and just 21 percent the Metropolitan region. Although 65 percent of the wood in the state was burned for heat, pleasure was the most common reason households reported for burning wood.

Households use their backyard recreational wood burning equipment to dispose of woody materials from their yards. This survey introduced a question about outdoor recreational equipment to estimate the amount of the wood burned mainly to dispose of woody yard materials from their properties. More than 5 percent of the wood was burned mainly for this purpose, with half of that (47,000 cords) burned in the Metro region.

More than half of the wood in the Metro region is burned for pleasure and/or disposal, unlike the regions in Greater Minnesota that burn at least twice as many cords for heat than pleasure and disposal combined. Of the 400,000 cords of wood burned in the Metro region, 41 percent was mainly burned for pleasure, 38 percent for primary or secondary heat, 12 percent was woody yard materials mainly burned for disposal and 9.4 percent was burned for multiple purposes.

Minnesota residents were estimated to harvest 1.4 million cords of the wood. This accounted for 44 percent of the wood they burned. The majority (83%) of the harvested wood was from private land.

Implications

The Metro region covers a much smaller geographic area than any other region, but it burns a fairly comparable amount of wood. Therefore, on average, the Metro region burns more cords of wood per acre than any other region.

More wood burning translates to more air pollution. The amount of air pollution released from the different types of equipment varies depending on the air pollution controls. Outdoor recreational residential fires, which are an uncontrolled source of air pollution, account for 41 percent of the wood burned in the Metro region and 7 percent of the wood burned statewide.

Estimates from this study indicate residents use their backyard recreational equipment to dispose of woody materials from their yards. If other methods for disposing of branches and brush from residential properties were convenient and widely available, this air pollution source could be reduced.

This information can help inform our partners in Clean Air Minnesota[9] who are working on voluntary measures to reduce air pollution from sources of air pollution such as residential wood burning. It can also be used to provide information to the public, local officials, communities and businesses through the Be Air Aware website[10].

Future research

This report provides initial data analyses. MPCA will be conducting additional analyses of the dataset. For example, the results in the main body of the report were produced using regionally-adjusted scaling weights. As described in Appendix C, a comparison of the respondents' housing categories versus the census estimates showed that residents of single-family houses were over-represented in the weighted survey sample (relative to the general population). Therefore, additional weighting in additional analyses to adjust for the type of household (single-family vs. all other types) could be further explored to reduce non-response bias and improve the estimates.

The number of respondents reporting specific activities described in this report could be further evaluated to characterize which were frequently or rarely reported from individual respondents. This would better inform the level of confidence in the various estimates. The dataset will also available from MPCA on request.

Compared to the 2012 survey results, this survey reported a substantial (68%) increase in wood burning which was most notably for heating purposes. While not evaluated by this

[9] Clean Air Minnesota http://www.environmental-initiative.org/our-work/clean-air/clean-air-minnesota
[10] Be Air Aware website https://www.beairawaremn.org/

survey, a number of factors may have influenced burning behaviors over time, including changes in the weather, the price of alternative space heating fuels or equipment pricing. Minnesota experienced a spike in the cost of propane during the heating season just prior to this survey. The U.S. Environmental Protection Agency (EPA) was developing air pollutant emission performance standards for sales of new residential wood burning equipment. In February 2015, EPA revised the standard for new wood stoves and fireplace inserts and added standards for previously unregulated boilers (hydronic heaters) and forced-air furnaces. Older models of residential wood burning equipment that wouldn't meet the new standards were offered at discount prices. While these additional factors are outside of the scope of the current study, they may have affected the year-to-year results.

Appendices

Appendix A: Glossary and definitions for this report

Bundle: A unit measure for wood volume that measures about 16 inches by 9 inches by 9 inches (0.75 cubic feet) or 171 bundles is equivalent to one cord. Note that in prior surveys a bundle was defined as 2 cubic feet or 64 bundles per cord.

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 four 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.

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 and response rates. 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 is great, there is less confidence that the results of the survey correctly represent what would have been found by surveying the entire population.

Methodology: A description of the way in which data are 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.

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 are 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, trailers, 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 than 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. The five survey sampling regions have been used in past Minnesota residential fuelwood use surveys. 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.

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 multiple buildings, the domestic water supply swimming pools, etc. Because some wood "boilers" (hydronic heaters) are called "outdoor wood furnaces", this survey distinguished the boilers from the forced-air furnaces using descriptive characteristics including brand or model information and whether it used water to transfer the heat.

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 the forced-air furnaces 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 a few rooms or a smaller home.

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: Bell, G. E., & Brooks, E. (1955). *Cord-cubic volume of relationship of slabwood and edgings* [Release No. 232]. American Pulpwood Association. New York, NY.

2. Wood pellets. A conversion factor of 2.752 tons per cord was used for wood pellets, based on information from 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. (July 2002). OMNI Consulting Services, Inc. Beaverton, Oregon. 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.

5. 30 gallon bag of branches. A conversion factor of 63 "30 gallon bags of tree branches and wood brush collected from your yard" per cord of wood was used. This is based on a commonly used estimate of 300 pounds per cubic yard of loose yard waste branches from the National Recycling Measurement Standards and Reporting Guidelines, based on information from John Springman, Ramsey County Minnesota Yard Waste Program (2016). This estimate falls within the 250 to 350 pound per cubic yard of loose brush range referenced in Resource Recycling, November 1991.

Appendix C: Weighting survey responses for housing category

The survey analysis team opted to apply additional weighting factors to correct for non-representativeness of the survey sample with regards to housing type. 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 underrepresented housing types and decreased the contribution from detached single-family homes.

Additional weighting steps were explored to account for differential response across housing types. These steps along with the impact on results are described in this appendix. In each of the five survey regions, statistical tests (Z-test of proportions) were employed to compare the proportion of the survey sample, weighted by region only, for single-family homes compared to the proportions of single-family homes in the overall population of the survey region (as determined in the 2009-2013 5-year U.S. Census American Community Survey) to ascertain whether the household composition of the survey sample was statistically different than the overall households population. These tests revealed statistically significant differences between the demographic composition of the weighted survey sample and that of the wider population. For example, in every survey region, residents of single-family houses were far over-represented in the weighted survey sample (relative to the general population). Other housing types listed on the survey were townhouse or twinhome, multi-family building (such as condominiums, apartments, or cooperatives), mobile home or trailer, and cabin (Figure A1). Because wood burning activities are likely to generally vary across 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.

A1. Housing-type by region

Primary Residence Region	Single-family housing	All other housing types	Total number of survey respondents	Percent living in single family home	
				Sample	American Community Survey
Statewide	996	191	1187	84%	67%
Northern Pine	192	24	216	89%	79%
Aspen-Birch	190	24	214	89%	75%
Prairie	175	19	194	90%	76%
Metro	271	85	356	76%	59%
Central Hardwoods	168	39	207	81%	75%

Proportion of state household population is derived from the 2009-2013 5-year U.S. Census American Community Survey, table DP04.

To address this non-representation issue, household weights were calculated for single-family households and all the others combined (townhouse or twin home, multi-family building, mobile home or trailer or other) for each of the five survey regions.[11] The method for calculating these weights entailed comparing the proportion of households of a certain housing type in the survey sample to the proportion of that particular housing type in the general population, which is analogous to how population weights across the survey regions were calculated to estimate a confidence interval around the statewide burning total. The household weights were also adjusted by region, so the final weighted survey sample matched both the region and the household type proportions found in the occupied household population targets (American Community Survey).

Figure A2 shows the resulting house-type and regionally-adjusted scaling weights used to scale respondents' answers to region-wide quantities and to calculate the confidence interval.

A2. Housing-type and regionally adjusted scaling weights

Primary residence region	House-type and regionally-adjusted scaling weight	House type
Northern Pine	511	Single family
	1,116	All others
Aspen-Birch	448	Single family
	1,154	All others
Prairie	1,362	Single family
	3,892	All others
Central Hardwoods	1,905	Single family
	2,706	All others
Metro	2,448	Single family
	5,508	All others

Using the household and regionally-adjusted scaled weights, resulted in a total statewide wood use estimate of 2.0 million cords, which is 7.1 percent lower than the estimate presented in the main body of the report (which doesn't adjust for house-type). When applying a 95 percent confidence interval around the region-only weights the result

[11] The low number of sample households in each of the non-single-family types prohibited the creation of separate weights for each household type.

ranges from 1.62 million cords to 2.65 million cords. When region and household were included in the weighting the 95 percent confidence interval ranges from 1.47 million cords to 2.51 million cords. While the confidence intervals for the household weighting are lower than the region-only weighting they overlap in range with the region-only weights. The overall volume of wood consumed was less when applying the household and region weights, but the distribution about types of equipment was similar to region-only weights (Figure A3). Intuitively this makes sense because one would expect that in general single-family detached households would burn more wood than apartments and other multi-family households. Therefore, because single-family detached homes were over-represented in the survey sample, one would expect that the wood-burning estimates would be biased upwards. Thus, using housing-type weights to correct for this unequal representation of housing types would be expected to reduce the overall wood-burning estimates.

A3. Wood volume consumed by type of wood burning equipment with household weights

	Number of cords burned		Percent of statewide total	
Type of wood burning equipment	Regionally-adjusted scaling weight	Household and regionally-adjusted scaling weight	Regionally-adjusted scaling weight	Household and regionally-adjusted scaling weight
Conventional fireplace	160,000	140,000	7%	7%
Fireplace inserts	120,000	100,000	6%	5%
Wood stoves	510,000	470,000	24%	24%
Pellet stoves	13,000	12,000	1%	1%
Wood burning forced-air furnaces	220,000	220,000	10%	11%
Wood boilers	500,000	490,000	23%	25%
Outdoor recreational equipment	610,000	550,000	29%	28%
Statewide total	2,100,000	2,000,000	100%	100%

In spite of the housing-type non-representativeness of the survey sample, applying household and regionally-adjusted weights should be done with caution. Household weighting introduces an additional level of complexity to the survey analysis and because it was not considered in the analysis of residential fuel wood surveys prior to 2012, it may further distort the analysis of trends through time and across different survey methodologies.

All the results presented in the main part of this report apply regionally-adjusted scaling weights as explained in the Methods section, but do not include differential household

weighting to correct for demographic non-representativeness (i.e., by housing type) of the survey sample relative to the entire population.

If there is an association between household and burning behaviors, then the household weights combined with regionally-adjusted weights may result in better estimates of wood consumption.

Appendix D: Full data tables

Total volume of wood burned by Minnesota residents

A4. Wood fuel consumption in Minnesota by survey year (millions of cords)

	Total number of cords burned (in millions)
1960	0.61
1970	0.22
1978-79	0.90
1980-81	1.40
1984-85	1.42
1988-89	1.04
1995-96	0.75
2002-03	0.66
2007-08	0.98
2011-12	1.27
2014-15	2.13

Note: Changes over time should be interpreted with caution due to changes in the survey design, methodology, response rate, and conversion rates for different types of wood.

Wood consumption by reason for burning

A5. Total cords burned by primary reason for burning over time

	1988-89	1995-96	2002-03	2007-08	2011-12	2014-15
Pleasure	83,120	60,080	78,720	294,000	522,510	517,926
Primary heat	498,720	360,480	347,680	441,000	552,599	956,766
Secondary heat	457,160	330,440	229,600	254,800	196,002	419,919
Woody yard material disposal	-	-	-	-	-	126,432
Multiple reasons	-	-	-	-	-	113,115

Note: Burning for pleasure includes burning at campsites. Respondents were able to share multiple reasons for their burning in a particular piece of equipment, so these numbers are considered estimates. Through the 2011-12 survey, respondents were asked to share the main reason for their burning in a particular piece of equipment, so these volumes are considered estimates. In the 2015 survey, many respondents selected multiple reasons for burning in a particular piece of equipment, so these responses were recoded into "multiple reasons." For residential outdoor wood burning firepits, chimeneas and fire rings, a new reason was added to the survey and respondents could selected 'disposal of woody yard materials '(e.g., fallen branches, trees and twigs, brush/trees collected from property). Changes over time should be interpreted with caution due to changes in the survey design, methodology, response rate, and conversion rates for different types of wood.

A6. Total cords burned by primary reason for burning in each region

	Northern Pine	Aspen-Birch	Prairie	Metro	Central Hardwoods
Pleasure	119,781	58,081	58,767	165,728	115,569
Primary heat	299,954	198,325	141,625	86,400	230,463
Secondary heat	95,684	51,985	122,670	66,901	82,678
Woody yard material disposal	23,573	16,380	13,028	47,032	26,419
Multiple reasons	19,106	16,697	19,497	37,862	19,954

Appendix E: Residential Wood Fuel Survey 2014-2015

Online version variations from paper survey

There were a few differences between the paper version of the survey and the online version. For the online version, all images were in color and respondents had access to definitions of fuel amounts throughout the survey. If you are interested in obtaining copies of the images used in the online version please contact MPCA.

For question 29 on the paper version, in the online version an additional option of "unknown woodstove" was added so respondents were not forced to answer whether it was a conventional wood stove, non-catalytic EPA-certified wood stove, or catalytic EPA-certified wood stove.

Only one response was allowed for the following questions (respondents could not select more than one response): 2, 2a, 3, 4,7,8,11,13, 14, 15, 18, 19, 22, 23, 26, and 27. In the paper version respondents could mark any response options they wanted to and multiple answers were allowed for questions 4, 8, 15, 19, 23, and 27. This is referenced in the report where "multiple reasons" for burning were included.

Another difference in the online survey is that skip patterns were used in the online survey so if a respondent did not have a piece of equipment they were not shown questions about that piece of equipment.

Help us understand how

MINNESOTANS USE FIREWOOD

Residential Wood Fuel Survey

Minnesota, April 2014 – March 2015

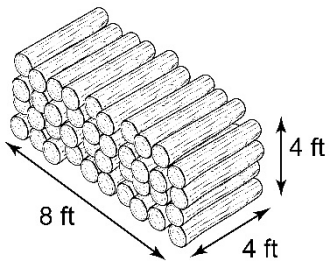
Minnesota Pollution Control Agency

Conducted by the Minnesota Pollution Control Agency in partnership with the Department of Natural Resources and the US Forest Service

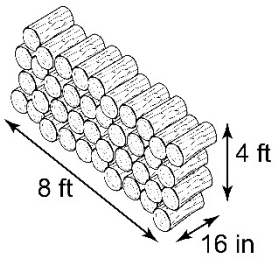
Key

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 8 feet long (4’ x 4’ x 8’) and has a volume of 128 cubic feet.



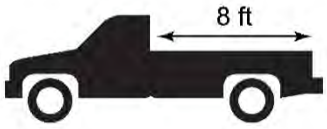
A full cord



A face cord

x3

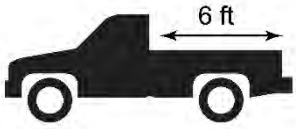
A face cord of wood is 4 feet high by 8 feet long and is as wide as the individual firewood pieces, but averages 16 inches wide. A 16-inch wide face cord (sometimes called **a fireplace cord**) is equal to one-third of a full cord.



Full-size pick-up

x2

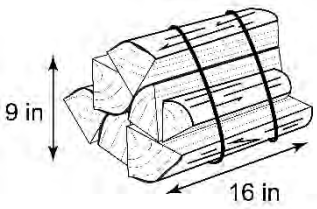
Two full-size pick-up truck loads (8 foot box) equals **one full cord**, whether the wood is stacked carefully so it is about level with the truck box sides, or is thrown into the truck box with the top of the pile about as high as the cab.



Compact pick-up

x4

Four compact pick-up truckloads (6 foot box) equals **one full cord of wood**, 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.



x210

Bundles of wood sold at gas stations, hardware stores and state parks are often 0.75 cubic feet. They often measure about 16 inches x 9 inches x 9 inches. 210 bundles equals **one full cord**.

Definitions

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, outdoor fire pits, chimeneas, etc.

The survey also asks about how much you burn at your **primary residence** (your main home, including garages and outbuildings), your **secondary residence** (second home, cabin, trailer, rented cabin, 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.

1. Where is your **primary** residence located? (Your main home, including garages and other outbuildings.)

   Primary residence location:

   County _____

   City/Township _____

   ZIP _____

2. Which of the following best describes your ***primary*** residence?
   - £ 1 Single-family house
   - £ 2 Townhouse or twinhome
   - £ 3 Multi-family building (such as condominiums, apartments, or cooperatives)
   - £ 4 Mobile home or trailer
   - £ 5 Other (please specify)

     _____

1a. If you have a **secondary** residence, where is it located? (A second home, cabin, trailer, rented cabin, or other vacation property that is located in Minnesota. If your secondary residence is not in Minnesota do not include it.)

Secondary residence location:

County _____

City/Township _____

ZIP _____

£ I do not have a secondary residence in Minnesota.

2a. Which of the following best describes your ***secondary*** residence, cabin, trailer, rented cabin, or vacation property?
   - £ 1 I do not have/use a second residence, cabin, or other vacation property.
   - £ 2 Single-family house
   - £ 3 Cabin
   - £ 4 Townhouse or twinhome
   - £ 5 Multi-family building (such as condominiums, apartments, or cooperatives)
   - £ 6 Mobile home or trailer
   - £ 7 Other (please specify)

     _____

Outdoor wood burning fire pits, chimeneas or fire rings

Chimenea

Fire pit

Chimeneas, 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

3. Do you have a fire ring, fire pit, chimenea or similar type of equipment at your primary residence?
   - £ 1 No. Go to Q7.
   - £ 2 Yes. How many? _____

4. In the past 12 months, did you use this equipment ***mainly*** for:
   - £ 1 Pleasure
   - £ 2 Disposal by burning of woody yard materials (e.g. fallen branches, trees and twigs, brush/trees collected from property)
   - £ 3 None. Please check if you did not burn wood in this equipment during the last year and **Skip to Q7.**

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

2014									2015		
APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
£ 1	£ 2	£ 3	£ 4	£ 5	£ 6	£ 7	£ 8	£ 9	£ 10	£ 11	£ 12

6. Please indicate how much wood or wax logs you burned in the past 12 months in your fire ring, fire pit, chimenea or any similar type of equipment. (Respond to as many as you need to collectively best describe how much wood was burned.)
   - 1 _____ Bundles of wood
   - 2 _____ Bags of tree branches and woody brush collected from your yard (Estimate how many 30 gallon bags – typical size of yard waste bags sold)
   - 3 _____ Full cords (answer to the nearest tenth of a cord)
   - 4 _____ Face cords (answer to the nearest tenth of a face cord)
   - 5 _____ Number of wax logs
   - 6 _____ Number of wood pallets

SECONDARY RESIDENCE

7. Do you have a fire ring, fire pit, chimenea or similar type of equipment at your secondary residence?
   - £ 1 No. Go to Q11.
   - £ 2 Yes. How many? _____

8. In the past 12 months, did you use this equipment ***mainly*** for:
   - £ 1 Pleasure
   - £ 2 Disposal by burning of woody yard materials (e.g. fallen branches, trees and twigs, brush/trees collected from property)
   - £ 3 None. Please check if you did not burn wood in this equipment during the last year and **Skip to Q11.**

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

2014									2015		
APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
£ 1	£ 2	£ 3	£ 4	£ 5	£ 6	£ 7	£ 8	£ 9	£ 10	£ 11	£ 12

10. Please indicate how much wood or wax logs you burned in the past 12 months in your fire ring, fire pit, chimenea or any similar type of equipment. (Respond to as many as you need to collectively best describe how much wood was burned.)
    - 1 _____ Bundles of wood
    - 2 _____ Bags of tree branches and woody brush collected from your yard (Estimate how many 30 gallon bags – typical size of yard waste bags sold)
    - 3 _____ Full cords (answer to the nearest tenth of a cord)
    - 4 _____ Face cords (answer to the nearest tenth of a face cord)
    - 5 _____ Number of wax logs
    - 6 _____ Number of wood pallets

Campsites and campgrounds

11. Did you burn firewood at a campsite or campground in Minnesota between April 2014 and March 2015?
    £ 1 No. Skip to Q13.
    £ 2 Yes

12. If you burned firewood at a campsite between April 2014 and March 2015, please estimate the total amount of wood burned and list the county(ies) in which it was burned, if known.

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

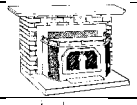
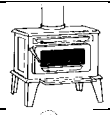
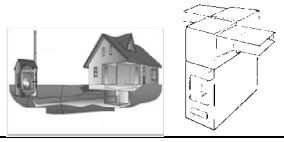
    _____ County _____ County _____ County _____ County

Wood Burning Equipment

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

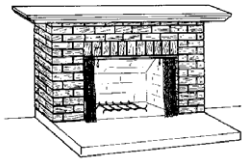
13. Do you have any of the following wood burning equipment at your primary residence or at a secondary residence such as a cabin, trailer, rented cabin, or other vacation property that is located in Minnesota? If your secondary residence is not in Minnesota do not include it.
    £ 1 Yes. Please continue.
    £ 2 No. Go to Q44 Section D on page 9.

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 wood burning fireplace	£ 1	£ 2	A Page 5
	Fireplace insert	£ 1	£ 2	B Page 6
	Wood stove	£ 1	£ 2	B Page 6
	Wood pellet stove	£ 1	£ 2	B Page 6
	Wood-burning boiler or furnace	£ 1	£ 2	C Page 7

(After completing sections A-C, also complete sections D and E)

Section A: Conventional wood burning fireplaces



DEFINITION: A CONVENTIONAL FIREPLACE

- Is mainly for decorative use rather than primarily for heating
- May have hot air grilles
- May either have no doors or glass 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

14. Do you have a conventional wood burning fireplace at your primary residence (including outbuildings such as pole barns or garages)?
    - £ 1 No. Go to Q18.
    - £ 2 Yes à How many? _____

15. During the past 12 months, did you use this equipment ***mainly*** for:
    - £ 1 Pleasure
    - £ 2 Primary heat source for my primary residence
    - £ 3 Secondary heat source for my primary residence
    - £ 4 None. Please check if you did not burn wood in your fireplace and **Skip to Q18.**

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

2014									2015		
APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
£ 1	£ 2	£ 3	£ 4	£ 5	£ 6	£ 7	£ 8	£ 9	£ 10	£ 11	£ 12

17. If you used your fireplace please indicate how much wood or wax logs you burned in your fireplace(s) in the past 12 months.
    - 1 _____ Full cords of wood (If necessary, you can answer in fractions of full cords, such as 1/2, 1.5)
    - 2 _____ Face cords of wood
    - 3 _____ Bundles of wood
    - 4 _____ Number of wax logs (such as Duraflame)

SECONDARY RESIDENCE

18. Do you have a conventional wood burning fireplace at your secondary residence (including outbuildings such as pole barns or garages)?
    - £ 1 No. Go to Q22 Section B on page 6.
    - £ 2 Yes à How many? _____

19. During the past 12 months, did you use this equipment ***mainly*** for:
    - £ 1 Pleasure
    - £ 2 Primary heat source for my secondary residence
    - £ 3 Secondary heat source for my secondary residence
    - £ 4 None. Please check if you did not burn wood in your fireplace and **Skip to Q22.**

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

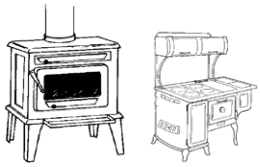
2014									2015		
APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
£ 1	£ 2	£ 3	£ 4	£ 5	£ 6	£ 7	£ 8	£ 9	£ 10	£ 11	£ 12

21. If you used your fireplace please indicate how much wood or wax logs you burned in your fireplace(s) in the past 12 months.
    - 1 _____ Full cords of wood (If necessary, you can answer in fractions of full cords, such as 1/2, 1.5)
    - 2 _____ Face cords of wood
    - 3 _____ Bundles of wood
    - 4 _____ Number of wax logs (such as Duraflame)

Section B: Wood stoves, fireplace inserts, and pellet stoves

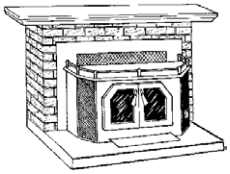
DEFINITION: WOOD STOVES, FIREPLACE INSERTS, AND WOOD PELLET STOVES

Wood stoves



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

Fireplace inserts



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

Wood pellet stoves

Wood pellet stoves burn small compressed wood pellets. A pellet-burning appliance has a hopper to hold the fuel and can burn for a long time without reloading

Wood stoves and fireplace inserts have conventional or EPA-certified advanced technology
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 and are less common
- 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)

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

PRIMARY RESIDENCE

22. Do you have this equipment in your primary residence (including outbuildings such as pole barns or garages)?
    - £ 1 No. Go to Q26.
    - £ 2 Yes.

23. In the past 12 months, did you use this equipment ***mainly*** for:
    - £ 1 Pleasure
    - £ 2 Primary heat source for my residence
    - £ 3 Secondary heat source for my residence
    - £ 4 None. Please check if you did not burn wood in your wood stove, fireplace insert, or wood pellet stove, and Skip to Q26.

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

2014									2015		
APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
£ 1	£ 2	£ 3	£ 4	£ 5	£ 6	£ 7	£ 8	£ 9	£ 10	£ 11	£ 12

SECONDARY RESIDENCE

26. Do you have this equipment in your secondary residence (including outbuildings such as pole barns or garages)?
    - £ 1 No. Go to Q30.
    - £ 2 Yes

27. In the past 12 months, did you use this equipment ***mainly*** for:
    - £ 1 Pleasure
    - £ 2 Primary heat source for my residence
    - £ 3 Secondary heat source for my residence
    - £ 4 None. Please check if you did not burn wood in your wood stove, fireplace insert, or wood pellet stove, and Skip to Q30.

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

2014									2015		
APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
£ 1	£ 2	£ 3	£ 4	£ 5	£ 6	£ 7	£ 8	£ 9	£ 10	£ 11	£ 12

29. Fill in the grid below for each piece of equipment you have at your primary/secondary residence. If you are unsure which type of equipment you have, please make your best guess.

	Type of equipment		NUMBERS OF UNITS: How many do you own?	NUMBERS OF UNITS: How many did you use in the past 12 months?	AMOUNT OF FUEL WOOD BURNED between April 2014 and March 2015: # Full cords	# Face cords	# Wood bundles	# Wax logs	Pounds of wood pellets
WOOD STOVES	Conventional wood stove (sold before 1989)	Primary residence	_____	_____	_____	_____	_____	_____	_____
		Secondary residence	_____	_____	_____	_____	_____	_____	_____
	Non-catalytic EPA-certified wood stove (sold after 1988)	Primary residence	_____	_____	_____	_____	_____	_____	_____
		Secondary residence	_____	_____	_____	_____	_____	_____	_____
	Catalytic EPA-certified wood stove(sold after 1988)	Primary residence	_____	_____	_____	_____	_____	_____	_____
		Secondary residence	_____	_____	_____	_____	_____	_____	_____
FIREPLACE INSERTS	Conventional fireplace insert (sold before 1989)	Primary residence	_____	_____	_____	_____	_____	_____	_____
		Secondary residence	_____	_____	_____	_____	_____	_____	_____
	Non-catalytic EPA-certified fireplace insert (sold after 1988)	Primary residence	_____	_____	_____	_____	_____	_____	_____
		Secondary residence	_____	_____	_____	_____	_____	_____	_____
	Catalytic EPA-certified fireplace insert (sold after 1988)	Primary residence	_____	_____	_____	_____	_____	_____	_____
		Secondary residence	_____	_____	_____	_____	_____	_____	_____
PELLET	Pellet stove	Primary residence	_____	_____	_____	_____	_____	_____	_____
		Secondary residence	_____	_____	_____	_____	_____	_____	_____

Section C: Wood burning boiler or furnace

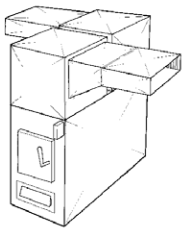
DEFINITION: WOOD BURNING BOILER OR FURNACE

Outdoor wood boiler

Wood boilers

- 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

Indoor wood furnace



Wood furnaces

- 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

PRIMARY RESIDENCE

30. Do you have this equipment at your primary residence (including outbuildings such as pole barns or garages)?
    - £ 1 No. Go to Q37.
    - £ 2 Yes a forced air furnace
    - £ 3 Yes a wood boiler

31. Brand or model (if known)

    _____

32. Is the equipment inside or outside the house?
    - £ 1 Inside
    - £ 2 Outside

33. The boiler (may also be called an outdoor wood furnace or hydronic heater)
    - £ 1 Heats water to heat my home
    - £ 2 Heats water to heat my other building(s) (workshops, garages, greenhouse)
    - £ 3 Heats water to heat my domestic water supply (for washing, showering, cooking, etc.)
    - £ 4 Heats water to heat my swimming pool

34. In the past 12 months did you use this equipment ***mainly*** for:
    - £ 1 Primary heat source at my residence
    - £ 2 Secondary heat source at my residence
    - £ 3 None. Please check if you did not burn any wood in your heater or boiler, then Skip to Q37.

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

2014									2015		
APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
£ 1	£ 2	£ 3	£ 4	£ 5	£ 6	£ 7	£ 8	£ 9	£ 10	£ 11	£ 12

36. 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).
    - 1 _____ Full cords of wood
    - 2 _____ Face cords of wood
    - 3 _____ Number of wooden pallets
    - 4 _____ Full cords of slabs (the round parts of a log cut off to make milled wood such as boards)

SECONDARY RESIDENCE

37. Do you have this equipment at your secondary residence (including outbuildings such as pole barns or garages)?
    - £ 1 No. Go to Q44.
    - £ 2 Yes a forced air furnace
    - £ 3 Yes a wood boiler

38. Brand or model (if known)

    _____

39. Is the equipment inside or outside the house?
    - £ 1 Inside
    - £ 2 Outside

40. The boiler (may also be called an outdoor wood furnace or hydronic heater)
    - £ 1 Heats water to heat my home
    - £ 2 Heats water to heat my other building(s) (workshops, garages, greenhouse)
    - £ 3 Heats water to heat my domestic water supply (for washing, showering, cooking, etc.)
    - £ 4 Heats water to heat my swimming pool

41. In the past 12 months did you use this equipment ***mainly*** for:
    - £ 1 Primary heat source at my residence
    - £ 2 Secondary heat source at my residence
    - £ 3 None. Please check if you did not burn any wood in your heater or boiler, then Skip to 44.

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

2014									2015		
APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
£ 1	£ 2	£ 3	£ 4	£ 5	£ 6	£ 7	£ 8	£ 9	£ 10	£ 11	£ 12

43. 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).
    - 1 _____ Full cords of wood
    - 2 _____ Face cords of wood
    - 3 _____ Number of wooden pallets
    - 4 _____ Full cords of slabs (the round parts of a log cut off to make milled wood such as boards)

Section D: Complete this section if you burned or harvested wood in the past 12 months

44. Of all the firewood you **burned** at your ***primary*** residence this past 12 months, what percent was burned of each species (if known)? (Percentages should add up to 100%.)

Hardwoods								Softwoods		Unknown species
Oak	Birch	Ash	Elm	Maple	Aspen	Basswood	Other Hardwoods	Pine	Other Softwoods	
____%	____%	____%	____%	____%	____%	____%	____%	____%	____%	____%

45. Of all the firewood you **burned** at your ***secondary*** residence, what percent was burned of each species (if known)? (Percentages should add up to 100%)

Hardwoods								Softwoods		Unknown species
Oak	Birch	Ash	Elm	Maple	Aspen	Basswood	Other Hardwoods	Pine	Other Softwoods	
____%	____%	____%	____%	____%	____%	____%	____%	____%	____%	____%

HARVESTED WOOD

46. Indicate the total amount of firewood that was ***harvested*** by you or a member of your immediate family between April 2014 and March 2015. (This includes wood that was harvested for the purpose of burning, and not wood that was gathered during yard clean-up or maintenance. If necessary, you can answer in fractions of full cords, such as 1/2, 1.5. If none enter "0.")

    _____ Full cords

47. Of all the wood your household burned between April 2014 and March 2015, indicate the percent(s) you harvested or obtained from the following sources:

    £ [1] _____ **%** Harvested by you or a member of your immediate family
    £ [2] _____ % Purchased or free slabs from sawmills
    £ [3] _____ % Purchased from a firewood dealer or logger
    £ [4] _____ % Purchased from a store or campground
    £ [5] _____ % Free or purchased from other sources

48. If you or a member of your immediate household ***harvested*** firewood between April 2014 and March 2015, indicate the percent that came from the following locations: (Harvested does not include yard clean-up. Percentages should add up to 100%.)

    [1] _____ % Private land
    [2] _____ % State land
    [3] _____ % County land
    [4] _____ % Municipal land
    [5] _____ % National forestland
    [6] _____ % Unknown location

49. If you or a member of your immediate household ***harvested*** firewood between April 2014 and March 2015 please indicate what percent came from the following sources (Harvested does not include yard clean-up. Percentages should add up to 100%.):

    [1] _____ % Live trees from forest land
    [2] _____ % Dead trees from forest land
    [3] _____ % Cut trees and/or tops and branches after a timber harvest
    [4] _____ % Live or dead trees from pasture land and/or cropland
    [5] _____ % Live or dead trees from yards, inside city limits, or other non-forest land
    [6] _____ % Unknown location

50. If you or members of your immediate household ***harvested*** firewood in the past 12 months please indicate what percent came from the following species: (Harvested does not include yard clean-up. Percentages should add up to 100%.)

Hardwoods								Softwoods		
Oak	Birch	Ash	Elm	Maple	Aspen	Basswood	Other Hardwoods	Pine	Other Softwoods	Unknown species
____%	____%	____%	____%	____%	____%	____%	____%	____%	____%	____%

51. 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:

£ [1] I do not know

County name: 1. _____ Percent _____

2. _____ _____

3. _____ _____

4. _____ _____

Thank you for completing this survey.
Please place the survey in the postage paid envelope provided along with the enclosed drawing entry form and mail it promptly.

Survey sponsored by
Minnesota Department of Natural Resources
Minnesota Pollution Control Agency
U.S. Forest Service

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