Summary of results: 2014 Portland residential wood combustion survey

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Table of Contents

Initial results: 2014 Portland residential wood combustion survey

Executive summary

DEQ contracted with the Portland State University Survey Research Lab to perform a 2014 telephone survey about residential wood burning in the Portland metro area. This survey provides more current and refined data about wood burning, with the purpose of providing DEQ and community partners a better understanding of wood burning emissions levels, locations, and the most effective pollutant reduction strategies.

The survey results, based on 1,061 residences surveyed, showed that 32 percent of the respondents burned wood in their homes. Five percent of those sampled reported burning wood as their primary source of heat.

Compared to DEQ's last figures on residential wood burning in the 2012 Portland Air Toxics Solutions project commonly refered to as PATS, the current survey shows that residents of the Portland region burn about 80 percent more wood than previously estimated. Much of this increase is due to improved accuracy in data for locations of wood burning. Previous estimates were much lower since regional results from a statewide survey were inaccurately distributed to the PATS study area.

Overall, the five percent of respondents who rely on wood as their primary source of heat burn 51 percent of the wood in the Portland area. Portland wood burners burn 56 percent of wood fuel in higher polluting uncertified devices such as stoves and fireplaces and 44 percent of wood in cleaner certified devices. Similar to other communities in Oregon, uncertified wood stoves, uncertified fireplace inserts and fireplaces emit the bulk of fine particulate from wood burning in the Portland metro area.

Initial survey data indicate that the most effective strategies for emission reduction could be focused on changing out uncertified woodstoves and fireplace inserts for all wood burners, and assisting a heating source switch for the limited number of residents using fireplaces for heat. It could also be effective to reduce the amount of burning for secondary heat, which may be more discretionary than burning as a primary heat source.

DEQ is providing the results of the Portland Residential Wood Combustion survey to partners and stakeholders to further strategies for wood burning emission reduction. DEQ invites feedback and recommendations for additional analysis and use of the survey results.

1. Background/introduction

a. Current wood burning emission information

In 2011, DEQ completed an air toxics model for the Portland Metro area as part of the community air toxics assessment called Portland Air Toxics Solutions. Air toxics are pollutants known or suspected to cause serious health problems including cancer, nerve damage and respiratory irritation. DEQ and its Portland Air Toxics Solutions advisory committee identified five high priority categories for emission reduction, along with recommendations to address risk from each category. The five priority categories are: residential wood combustion, cars and trucks, heavy duty vehicles, construction equipment, and industrial metals facilities. The pollutants causing the most cancer risk

from wood burning are 15 PAH, 1,3 butadiene, formaldehyde, benzene and naphthalene. Woodsmoke also contains fine particulate or $PM_{2.5}$ that is known to damage the heart and lungs, and worsen asthma and other respiratory diseases. Wood burning is a major contributor to unhealthy levels of particulate in the Portland area, especially during periods of winter-time weather inversion and air stagnation. More information on PATS is available at: http://www.deq.state.or.us/aq/toxics/pats.htm .

The map below in Figure 1 shows PATS modeling results estimating cumulative air toxics concentrations from wood combustion in Portland projected for 2017. Darker red areas have higher estimated concentrations of wood burning pollutants. The colors correspond to cumulative concentrations above DEQ's air toxics ambient benchmarks for residential wood burning pollutants modeled in the PATS study. An ambient benchmark concentration is the annual average concentration of a toxic chemical in air that individuals, including more sensitive groups such as children or the elderly, could breathe continuously for a lifetime without experiencing any non-cancer health effects or without increasing their risk above the background cancer rate by greater than one chance in a million. Oregon's benchmarks are available at: http://www.deq.state.or.us/aq/toxics/benchmark.htm .
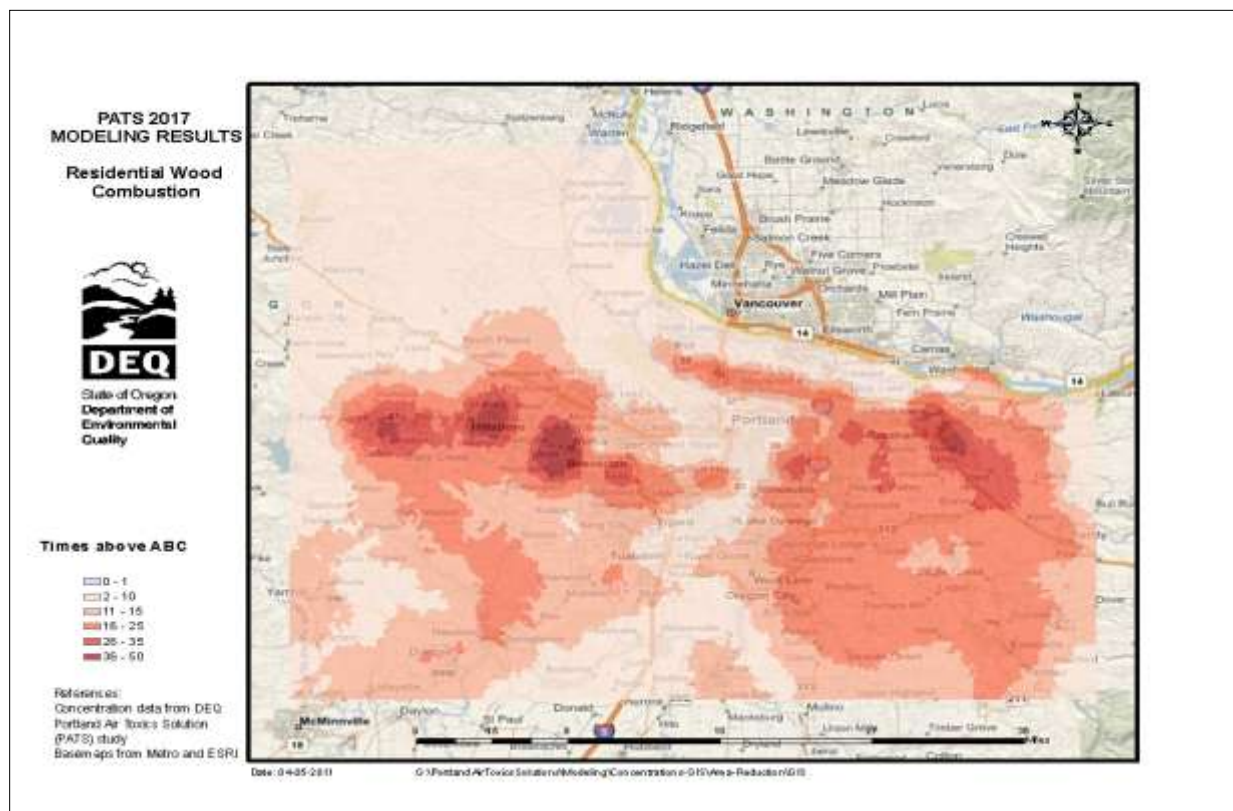

Figure 1 – Estimated air toxics concentrations from residential wood burning in Portland

b. Need for additional wood burning information

The PATS air toxics model used DEQ's 2009 state-wide wood burning survey data to estimate emissions from residential wood heating. DEQ scaled down the larger statewide survey by allocating wood burning activity to Portland residential areas using 2010 census information about primary heat sources. In reality, emissions come from residents burning wood for both primary (main) and secondary (backup or additional) heating. DEQ was concerned that the lack of secondary wood heating data in the PATS study could cause some overestimates and underestimates of wood burning pollutants in parts of the Portland area. In response to PATS advisory committee recommendations, DEQ also sought to refine geographic locations for and risk from wood burning pollutants.

5

Experience in Portland and research in other Northwest cities indicates that there are high gradients or differences in wood smoke concentrations – some neighborhoods are heavily impacted while others have very low levels of wood burning pollutants. DEQ initiated the Portland Residential Wood Combustion Survey to refine data on wood burning, verify that it is a high priority category for risk reduction, and better understand impacted areas. In addition, DEQ will use survey data to tailor communication and emission reduction efforts and inform particulate and toxics prevention strategies region wide.

2. Survey and methodology

In 2014, DEQ contracted with the Portland State University Survey Research Lab to conduct a telephone survey of residential wood burning activity in the Portland area. DEQ previously contracted with this research lab for the statewide wood burning survey performed in 2009. The Survey Research Lab has been conducting survey research and analysis at Portland State University since 1995, administered through the Office of Graduate Studies and Research. Since 2002, the Survey Research Lab has completed over 60 survey research projects, including more than 30 within the last two years. The Survey Research Lab 's primary concerns are careful, unbiased and ethical gathering of data, along with maintaining respondent anonymity or confidentiality, while working within time and budget constraints. More information about the Survey Research Lab is available at: http://www.srl.pdx.edu/about.html .

The Survey Research Lab worked closely with DEQ air quality staff to review and revise the 2009 statewide survey instrument, maintaining the same item content whenever possible to allow for longitudinal comparisons between the 2009 and 2014 data. The 2014 survey included two new sections that focused on secondary burning and attitudes towards neighborhood wood smoke. This was the biggest difference between the two studies. The secondary burning questions directly mirrored the primary burning questions previously implemented in the 2009 survey.

The survey area was the same as the PATS study area. The PATS study area includes portions of Multnomah, Clackamas and Washington counties, including the Census tracts representing areas of higher air toxics risk, as shown in the 1999 EPA National Air Toxics Assessment report. These areas are generally more densely populated or undergoing population growth and development. As a result, the PATS study area is based on locations where people are most exposed to air pollutants. In addition, the study area includes preexisting boundaries, including the Metro boundary, the Portland ozone control area, and the Portland vehicle inspection boundary.

In the survey, DEQ defined six subareas of interest based on wood burning pollutant concentrations mapped in the PATS study. They are: West, West-Slope/South, Central, North/Outer Eastside, Gresham, and Outer Areas. These subregions correspond to areas of distinct wood burning pollutant concentrations estimated in the PATS model, housing density, demographics, and levels of development such as urban, suburban and rural areas. A map of these subareas is in Figure 2. The survey included questions asking for the nearest intersection to the respondent's home and the respondent's home zip code to locate respondents in the six subareas.
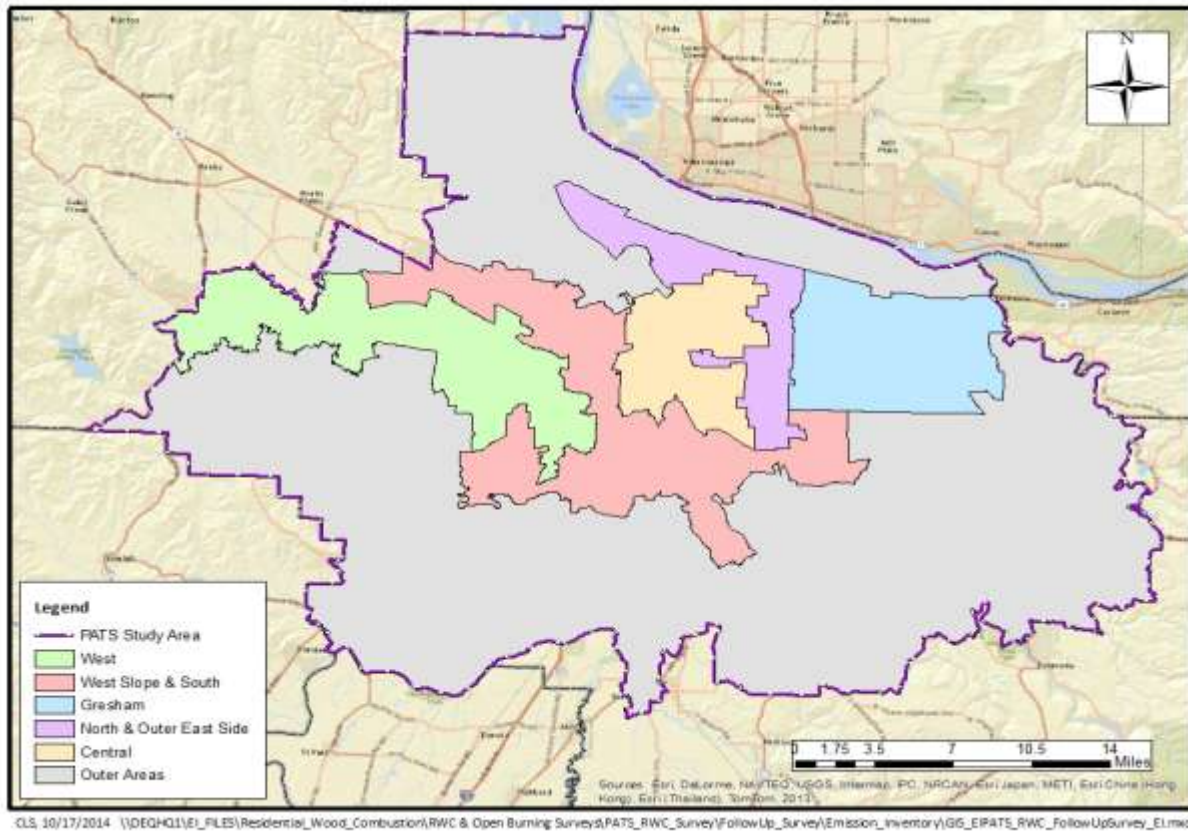
Figure 2 – Survey subareas

Survey calling started on May 21, 2014, concluded on June 12, 2014, and resulted in 1,073 completed surveys. The overall response rate was 20 percent. Survey Research Lab made calls during both weekdays and weekends, in the afternoon and evening hours, until calling was complete. Coordinators provided on-site monitoring, supervision and quality assurance to ensure the highest quality data collection, as well as accurate real-time data entry. Survey Research Lab asked residents questions about their wood burning during the previous 12 months. Each survey took about six and a half minutes to complete. Telephone numbers called included 4,294 listed landline numbers, 644 unlisted randomly generated numbers, and 1,081 cell phone numbers. These came from a purchased sample of 15,600 phone numbers distributed proportionally to the populations of the six subareas.

Determining the margin of error (the level of accuracy in the results) requires knowledge of the final sample size, the population from which the sample was drawn, the confidence desired that the data gathered from the sample is representative of the entire population, and how varied the population is expected to be related to a characteristic of interest (Kraemer & Thiemann, 1987; Dillman, 2000; Fowler, 1993). The commonly accepted value for sampling error is plus or minus 5 percent and a typical confidence interval used in survey research is 95 percent. Based on these assumptions, the achieved sample size of 1,073 completed surveys, and an estimated PATS study area population of 1,609,076, the final sampling error was initially plus or minus 2.99 percent.
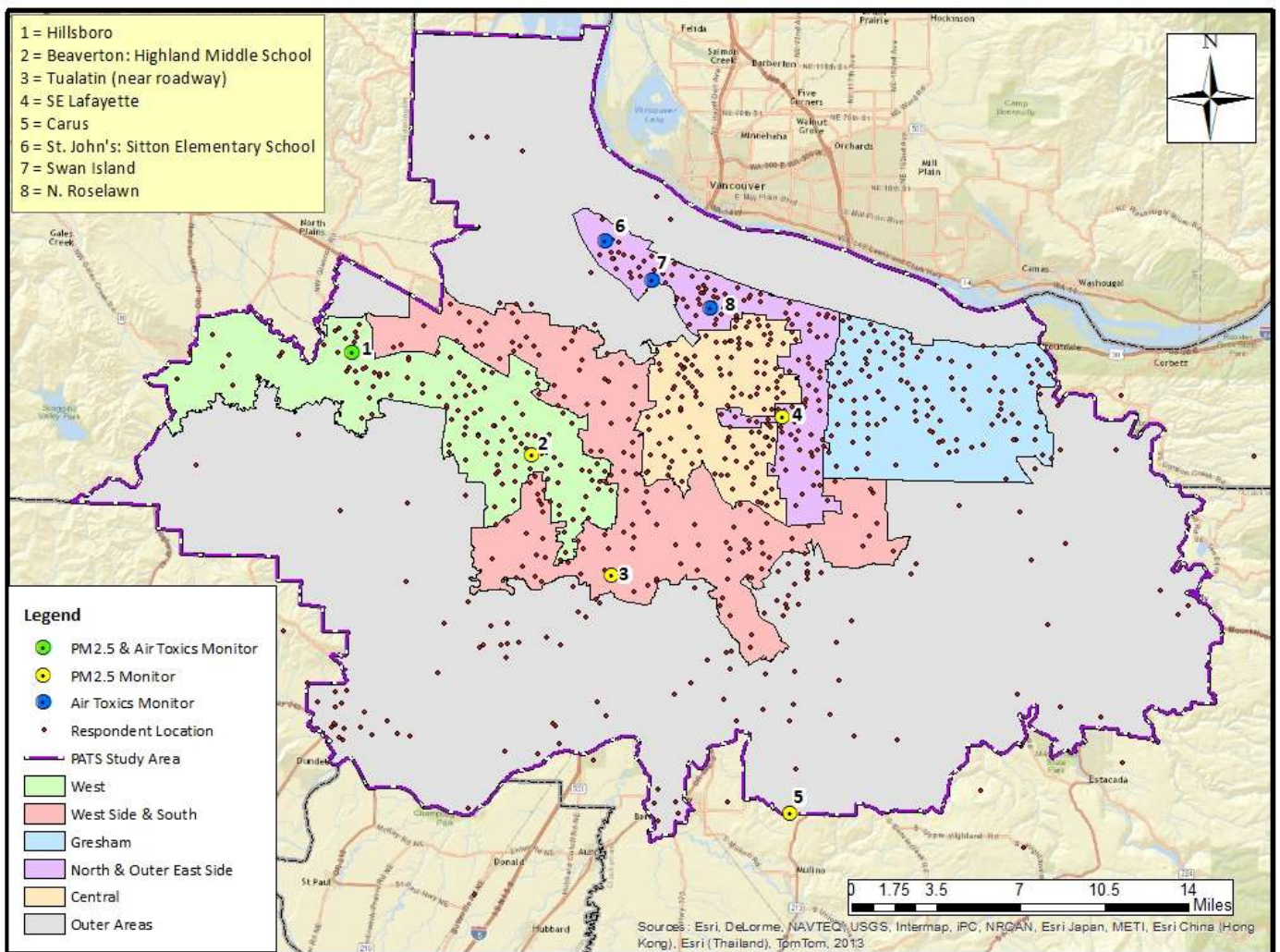
Out of the 1,073 completed surveys, 1,061 surveys were included in analysis. Twelve surveys were excluded after geocoding because the residences were located outside the study area or did not have enough data to accurately identify the location. This increased the sampling error just slightly for the PATS study area to plus or minus 3.01 percent, which is well within the accepted value of plus or minus 5 percent.

Table 1 shows the distribution of survey calls in each area compared to the goals. Survey Research Lab made an effort to distribute calls in each subarea to sample all areas of interest.

Subarea	Original Completed Survey Goal	Final Completed Survey Count
Subarea 1: West	176	175
Subarea 2: West Slope and South	176	175
Subarea 3: Central	176	173
Subarea 4: North and Outer Eastside	176	175
Subarea 5: Gresham	176	176
Subarea 6: Outer Areas	176	187
Completed Surveys Used for Analysis	**1,056**	**1,061**
Outside Study Area		7
Not Enough Data to Locate		5
TOTAL		**1,073**

Table 1- Survey call distribution

Figure 3 below shows the locations of survey respondents in the Portland area. Many red symbols showing respondent locations represent several nearby addresses. Figure 3 also shows current particulate and air toxics monitors in the area as a reference. Monitoring data is available from DEQ at: http://www.deq.state.or.us/aq/forms/annrpt.htm .

Legend:
- 1 = Hillsboro
- 2 = Beaverton: Highland Middle School
- 3 = Tualatin (near roadway)
- 4 = SE Lafayette
- 5 = Carus
- 6 = St. John's: Sitton Elementary School
- 7 = Swan Island
- 8 = N. Roselawn

Legend
- PM2.5 & Air Toxics Monitor
- PM2.5 Monitor
- Air Toxics Monitor
- Respondent Location
- PATS Study Area
- West
- West Side & South
- Gresham
- North & Outer East Side
- Central
- Outer Areas

CLS, 11/21/2014 \\DEQHQ1\EI_FILES\Residential_Wood_Combustion\RWC & Open Burning Surveys\PATS_RWC_Survey\FollowUp_Survey\Emission_Inventory\GIS_EIPATS_RWC_FollowUpSurvey_EI.mxd

Figure 3 -Survey respondent locations

3. Summary of results

a. Respondents and wood heating devices

Based on the 1,061 residences surveyed, 294 or 33 percent of the respondents burned wood in their homes. Fifty two respondents, or 5 percent of those sampled reported burning wood as their primary source of heat. Figure 4 below shows this breakdown.
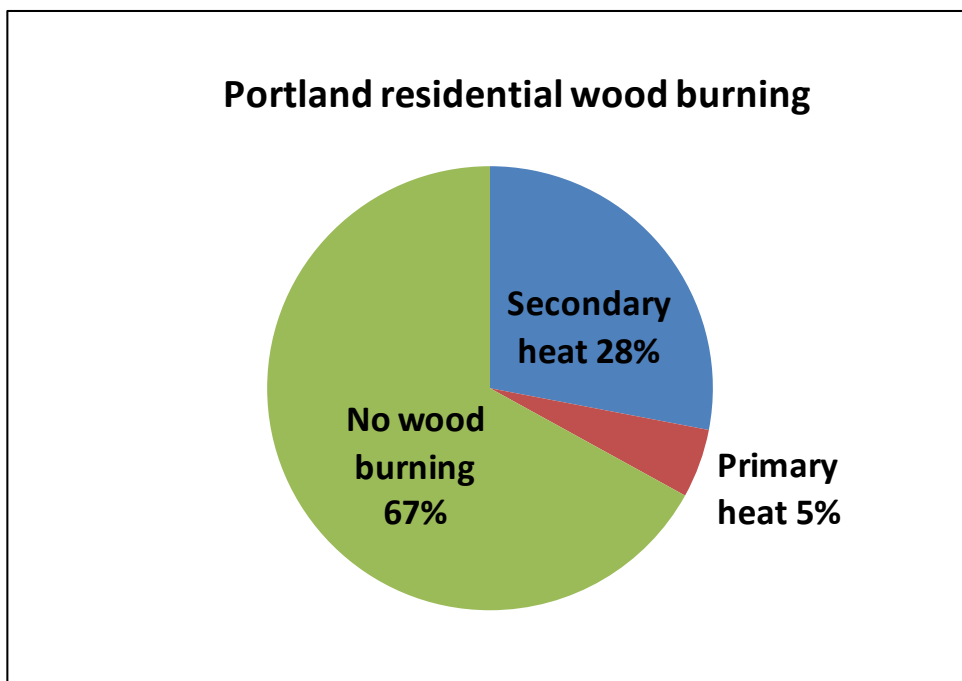

Figure 4 - Wood as primary and secondary heat source

Table 2 summarizes reported wood burning devices and whether those devices were used as primary or secondary sources of heat. Table 2 includes distinctions between free standing woodstoves and appliances built into fireplaces, or inserts; and also catalytic versus non-catalytic appliances. DEQ collects this information for purposes of fuel use and emission tracking, but for simplicity, the data can be grouped to look at certified and uncertified woodstoves, fireplaces and pellet stoves. The numbers of wood burning respondents in each area are not sufficient to make a statistically valid analysis of each sub area, or to accurately compare sub areas. However, the total results for all wood burning respondents can be generalized to represent burning activities in the Portland area. Firelog combustion, though a low contributor to total emissions, is shown as a distinct category since estimates of pollution from firelogs are the same regardless of the types of devices used to burn them.

Sub Area ID Key

1. West   4. North and Outer East Side
2. West Side and South   5. Gresham
3. Central   6. Outer Areas

Device	Activity	Survey Count	Sub-Area ID					
			1	2	3	4	5	6
Fireplace	Primary	2	1	1				
	Secondary	90	14	20	27	10	7	12
Certified Catalytic Woodstove Insert	Primary	7	1	2				4
	Secondary	8	2	1	1	2	2	
Certified Non Catalytic Woodstove Insert	Primary	3				1		2
	Secondary	7		2	1		2	2
Uncertified Woodstove Insert	Primary	2		1			1	
	Secondary	37	8	9	6	7	4	3
Pellet Stove	Primary	3					1	2
	Secondary	5	1		1			3
Certified Catalytic Woodstove	Primary	11		1		3		7
	Secondary	4					1	3
Certified Non Catalytic Woodstove	Primary	6	1	1	0	1	2	1
	Secondary	7		2	2			3
Uncertified Woodstove	Primary	12			2		2	8
	Secondary	31	2	5	8	5	3	8
Firelog Combustion: All Device Types	Primary	6	1		1	2		2
	Secondary	53	7	10	11	12	6	7
Total		294	38	55	60	43	31	67

Table 2 - Wood burning by appliance type and primary or secondary heat source

Figure 5 shows the number of fuel burning devices reported by survey respondents, with a breakdown for primary and secondary heating sources. The count of uncertified devices, including fireplaces, is much greater than the number of certified or cleaner burning devices.
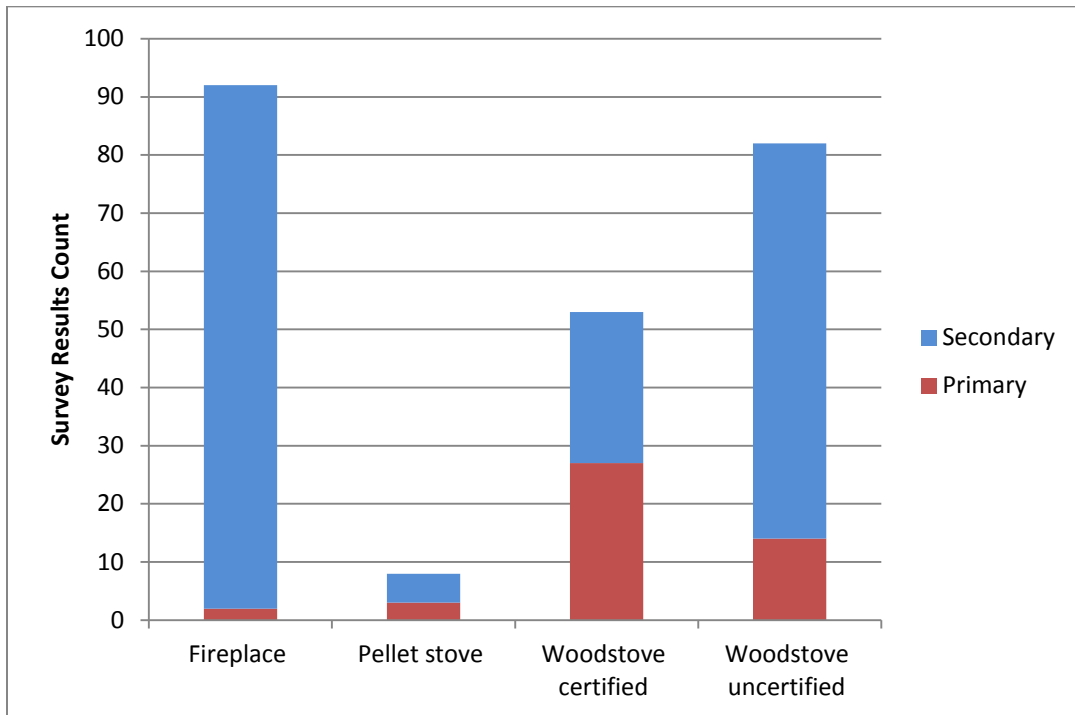
Figure 5 – fuel burning devices used for primary and secondary heat

Wood burning devices all emit fine particulate pollution, but there is a vast difference in the amount of pollution from fireplaces, uncertified woodstoves and clean burning EPA certified woodstoves and pellet stoves. Figure 6 below illustrates relative particulate emissions per heat output or BTU for different wood burning devices and oil and gas heating furnaces.
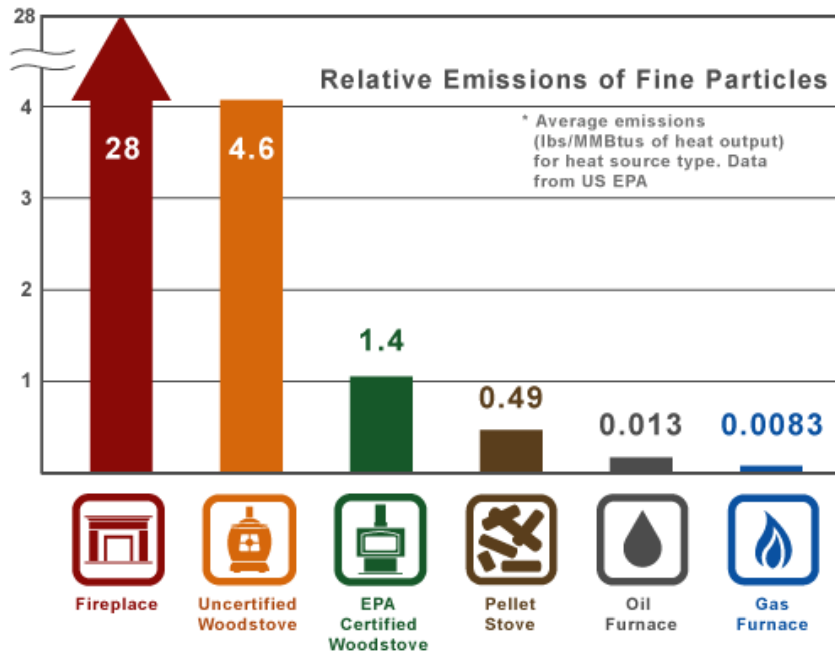

Figure 6 – Relative emissions per BTU of wood burning devices
(http://www.epa.gov/burnwise/energyefficiency.html**)**

b. Amount of wood fuel burned

DEQ estimates pollution from residential wood burning by first estimating activity as tons wood fuel burned (cords, pellets, and firelogs) within the survey area. Tons of fuel is then multiplied by an emission factor that is specific to each device (for each pollutant) and represents the amount of emissions produced per ton of fuel burned. Emissions can then be entered spatially into a dispersion model that factors in weather and terrain so that DEQ can predict pollutant concentrations throughout the modeled area. The Portland Air Toxics Solutions model estimated wood burning emissions in this way and expressed concentrations of air toxics as annual averages compared to a benchmark, as shown in Figure 1.

The 2014 survey results allow for activity estimates that are specific to both burn type (primary vs. secondary) and device type. A significant step is to apply percentages from survey results to occupied housing unit data for the Portland area. Equation 1 details how DEQ estimates tons of wood burned in the Portland study area from survey results for both the amount and species or type of wood burned. The current survey does not evaluate wood moisture content or how residents operate their wood burning devices.

A = (a) x (b) x (c) x (d)
where
    A = activity, tons wood burned
    a = 2014 occupied housing unit data, from the PSU Population Research Center
    b = percent wood burning housing units, by device: from survey results
   c = average volume of wood burned in cords, by device: from survey results
    d = typical cord density (weight) in tons per cord: from survey results for species burned

Equation 1- Estimating Tons of Wood Burned from Survey Results

The 2014 survey distinguished between primary and secondary burning, so DEQ applied Equation 1 separately to primary and secondary burning survey results. A similar method is used to estimate the amount of pellet and firelog burning, except that survey results are in the form of the number of 40 pound bags of pellets or eight pound firelogs burned, eliminating the need to convert a volume of wood cords to tons burned.

Figure 7 illustrates the estimated tons of wood fuel burned annually for the Portland study area based on 2014 survey results. Although the device count for primary heat woodstoves in Figure 5 is lower than the count for secondary heat woodstoves, the tons of fuel burned in these devices for primary heating is higher. This is due to the larger amount of fuel burned on average per device for primary heating compared to secondary heating. Over half of the wood burned in the Portland area, or 55 percent is burned in inefficient higher polluting fireplaces and uncertified devices.
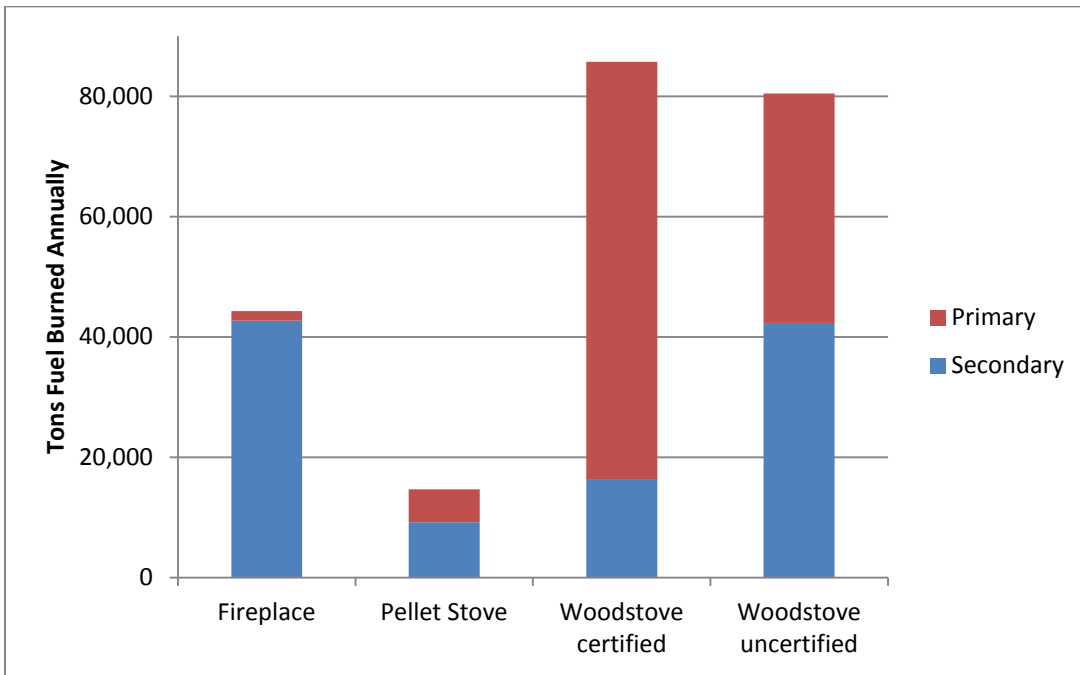
Figure 7 – Tons of fuel burned by device

Based on the current survey, the 5 percent of residents who rely on wood as their primary source of heat burn 114,723 tons per year or 51 percent of the wood burned in the area. The remaining 95 percent of wood heating respondents combusted a total of 111,773 tons per year, or 49 percent of the wood burned in the study area. Figure 8 displays this breakdown.
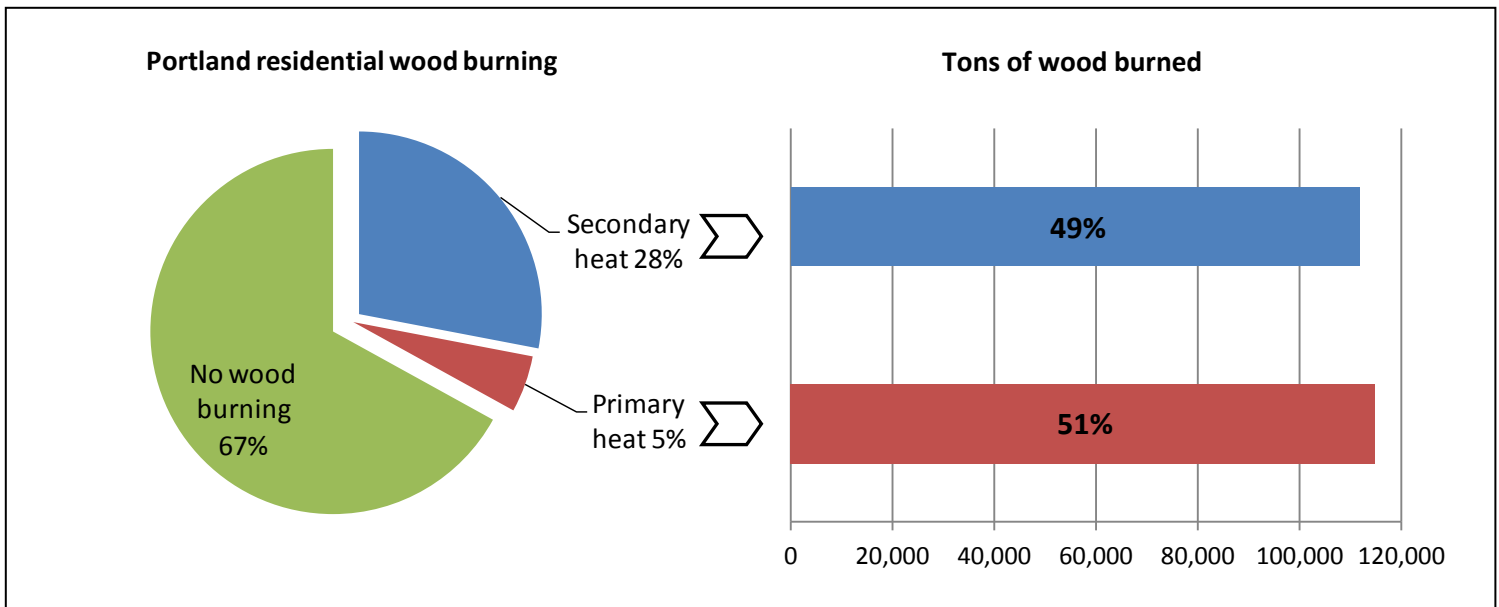
Figure 8 – Tons of wood burned by primary and secondary burners

The original PATS wood combustion information was based on a 2009 statewide survey that was not specific to the the Portland area. Compared to the earlier PATS information, the 2014 wood combustion survey shows that residents of the Portland region burn about 80 percent more wood than previously estimated. Most of this increase is due to improved information on locations of wood burning activity,

13

both primary and secondary burning. Figure 9 shows a comparison of the original Portland Air Toxics Solutions wood burning estimates in tons burned annually to the current survey results. While the amount of wood burned in Clackamas County dropped slightly, the amounts burned in Washington and Multnomah Counties more than doubled. The 2014 survey supports original findings that wood burning emissions are a major source of air toxics and particulate risk, and also indicates that risk from wood burning pollutants in Portland is likely higher than originally estimated. In further analysis DEQ may adjust or scale modeled concentration levels to revise wood burning pollutant risk estimates.
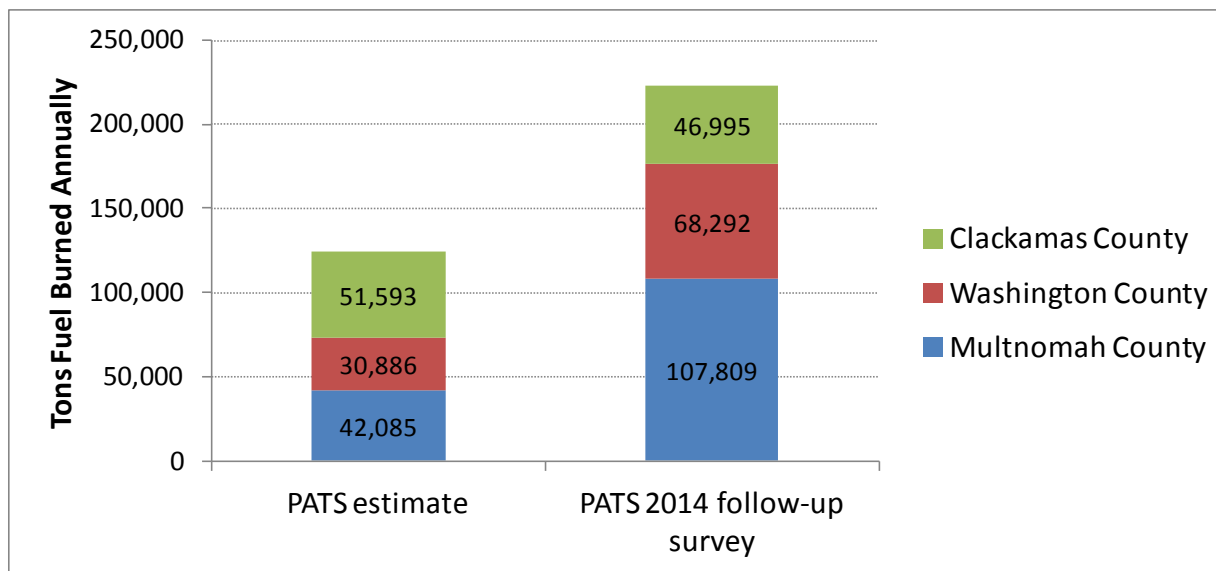

Figure 9 – Tons of wood burned annually in original PATS study and 2014 follow-up survey

c. Types of wood fuel burned

As shown in part d of Equation 1, wood species is an important component of estimating tons of wood burned from survey data. Different species of wood have different densities or weight per volume. Survey respondents provide cords of wood burned and species of the wood they burn. Survey respondents included 43 different types of wood and wood mixes. The most prevalent species of wood burned for both primary and secondary burning in order of use are Douglas fir, oak, maple, alder, cedar and cherry wood. Other wood species and types burned include pine, juniper, scrap wood and pallets, construction debris and various fruit, nut and ornamental trees. Denser woods like oak and maple produce more energy per volume when burned, but any well-seasoned wood can be burned effectively. Figure 10 shows the breakdown of type of wood burned for primary and secondary heating.
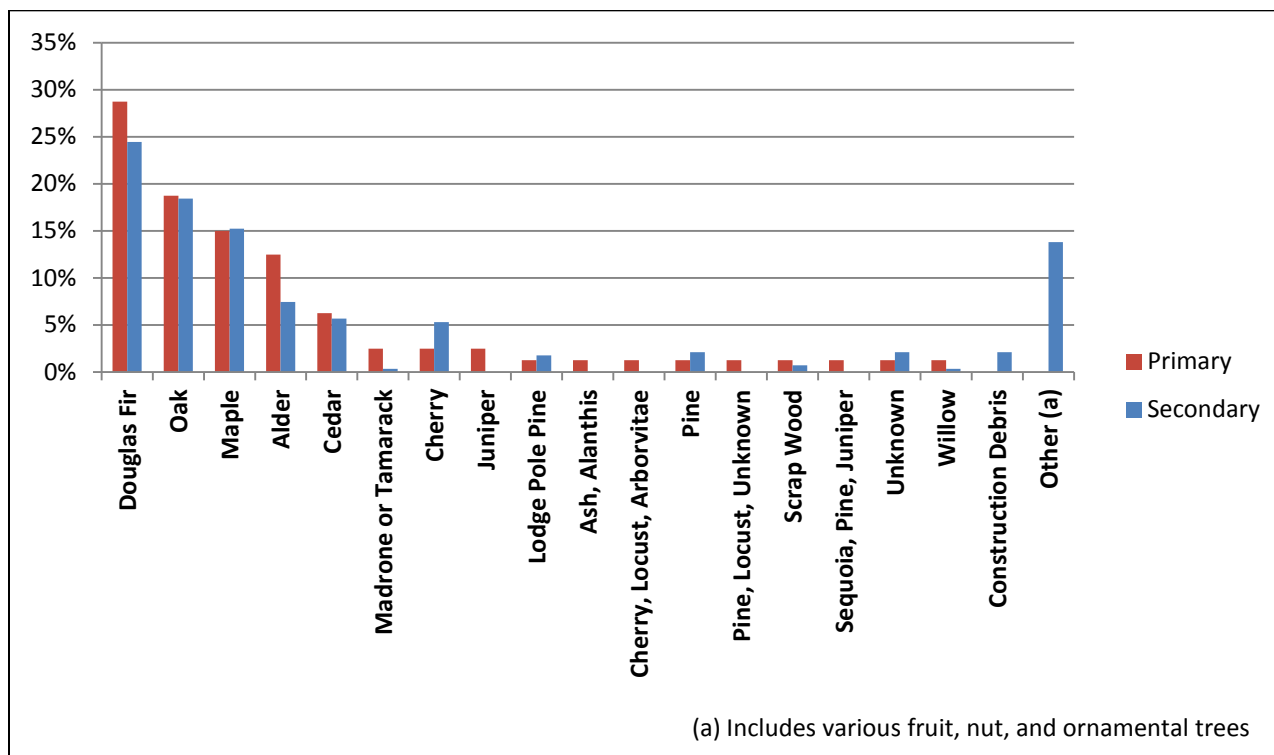
(a) Includes various fruit, nut, and ornamental trees

Figure 10 – Wood species burned for primary and secondary heat

d. Particulate emissions from wood burned

After using Equation 1 above to estimate tons of wood burned, DEQ converts the fuel tonnage to pollutant emissions by applying Equation 2. Equation 2 includes an emission factor specific to each type of wood burning device to estimate tons of different pollutants. In the survey analysis, DEQ has applied Equation 2 for the count of each type of wood burning device and added the results to estimate total tons of $PM_{2.5}$ emissions for the area.

Emissions, tons per year = A x EF / (2000 lb/ton)
Where
A= Activity in tons fuel burned per year
EF = Device Specific Emission Factor in lbs/ton fuel burned

Equation 2 – Estimating Emissions from Wood Fuel Tonnage

Figure 11 shows the breakdown of total $PM_{2.5}$ emissions by device type and primary or secondary heating. These data indicate that the most effective strategies for emission reduction could be focused on changing out uncertified woodstoves and fireplace inserts for all wood burners, and assisting the limited number of residents using fireplaces for heat. It could also be effective to reduce the amount of secondary burning, which may be more discretionary than primary burning.
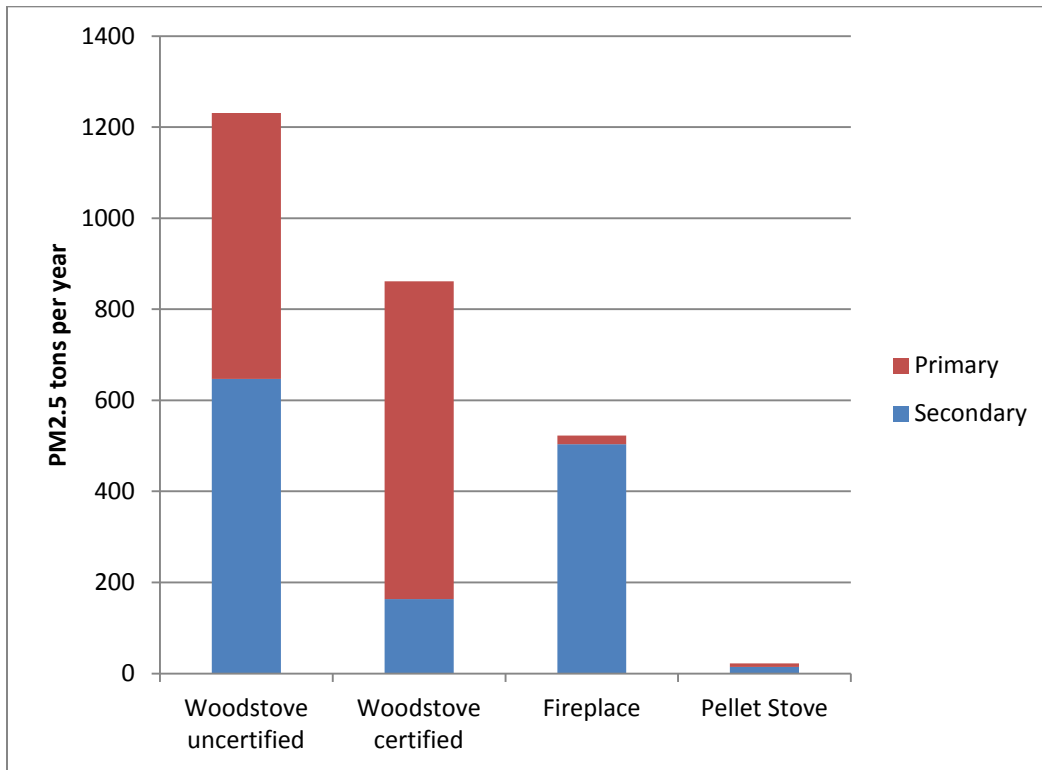
15

Figure 11 – PM$_{2.5}$ Emissions from wood burning device types for primary and secondary burning

Figure 12 shows the same data as Figure 11, but with primary and secondary heating combined as total PM$_{2.5}$ emissions, and displaying the contribution from each type of device as a percentage.
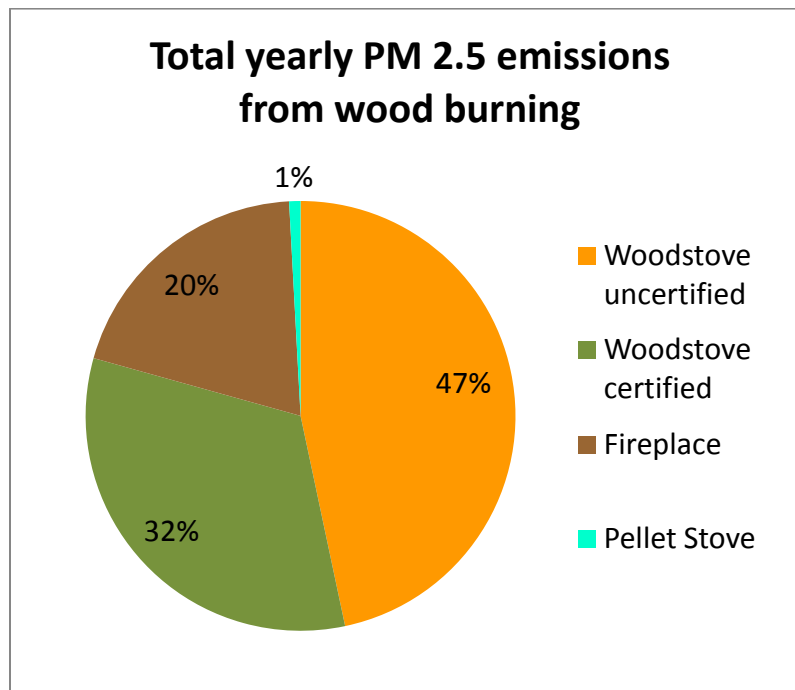

Figure 12 - PM2.5 Emissions from device types

e. Attitude information

1. Why people burn wood

Of the 267 respondents (out of 1,061) who provided the main reason why they burn wood, 51 percent reported either that they enjoy burning wood or that they enjoy wood heating. Twenty five percent cited other reasons not listed in the survey. Twenty one percent of respondents gave cost as a reason for heating with wood, either the cost of other fuels or the cost of switching to other heating sources. Figure 13 shows the breakdown of reasons for burning in a pie chart.
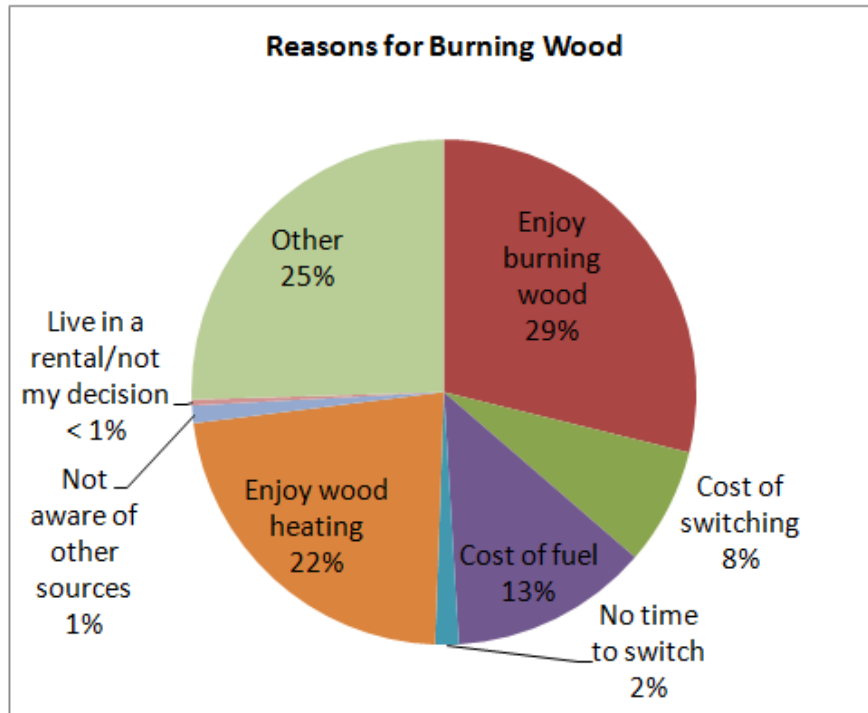
Reasons for Burning Wood

- Other 25%
- Enjoy burning wood 29%
- Live in a rental/not my decision < 1%
- Not aware of other sources 1%
- Enjoy wood heating 22%
- Cost of fuel 13%
- Cost of switching 8%
- No time to switch 2%

Figure 13 – Reasons for Burning Wood

2. Perception of problem from smoke

Survey respondents did not indicate a strong perception that smoke was a problem in their neighborhoods. On a scale where 1 indicated wood smoke was "not a problem" and 5 indicated it was "a major problem" the mean value was 1.4.

3. Interest in using advisory

Survey respondents who reported that they burned wood in their household were asked how likely they would be to consult local weather or wood burning advisory information before burning wood. On a scale from one to five where one means "not at all likely" and five means "very likely", the mean value was 2.3.

4. Interest in cash incentives for unused wood burning devices

Out of the 1,061 respondents, 87 indicated interest in receiving a cash incentive for turning in an unused wood burning device at their residence.

e. Housing information

1. Housing type

The majority of survey respondents who burned wood as their primary or secondary source of heat live in single family houses. Table 3 below shows the breakdown of housing types for wood burning survey respondents.

Household Building Type	Primary Burning (n=43)		Secondary Burning (n=200)	
	Count	Percent	Count	Percent
Single Family House	41	95.3%	189	94.5%
Duplex or Multiplex	0	---	3	1.5%
Apartment, Condominium, or Townhouse	1	2.3%	5	2.5%
Mobile Home (or Manufactured Home)	1	2.3%	2	1.0%
Other	0	---	1	0.5%

Table 3 –Building types for households with primary and secondary wood burning

2. Age of homes, comparison of subareas

For primary wood burners, four respondents did not provide the year their home was built, so only 39 of the 43 respondents could be included in the analysis to compare subareas. The differences in ages of homes across the subareas were not statistically significant for primary wood burners. However, this result should be interpreted cautiously due to the very small sample sizes in each of the subareas.

Subareas	Minimum age of home (years)	Maximum age of home (years)	Mean age of home (years)	Standard deviation
West (n=2)	21	58	39.50	26.163
West Slope and South (n=4)	42	89	67.25	19.721
Central (n=2)	79	86	82.50	4.950
North and Outer East (n=4)	19	109	69.50	43.317
Gresham (n=6)	25	65	48.00	16.149
Outer Areas (n=21)	14	103	42.29	26.008

Table 4 - Primary burning by home age

For secondary wood burners, 20 respondents did not provide the year their home was built, so only 180 of the 200 respondents could be included in the analysis to compare subareas. The differences in ages of homes across the subareas were statistically significant for secondary wood burners. Looking at the means for each of the subareas, the significant difference is influenced by the older homes in Central and North/Outer East and the newer homes in West and Outer Areas.

Subareas	Minimum age of home (years)	Maximum age of home (years)	Mean age of home (years)	Standard deviation
West (n=25)	8	105	39.88	19.103
West Slope and South (n=38)	11	107	44.84	21.107
Central (n=41)	24	112	75.49	26.570
North and Outer East (n=20)	19	154	77.05	29.550
Gresham (n=24)	12	69	45.33	14.966
Outer Areas (n=32)	<1	110	41.75	25.959

Table 5 - Secondary burning by home age

f. Income information

As part of the demographic information collected, survey respondents were asked to identify a range for their 2013 household income. Figure 14 shows this information broken down for respondents using wood as primary and secondary heat sources. Upon initial analysis, it appears that income is not a significant factor for primary burning in the Portland area while secondary burning generally increases with higher incomes.
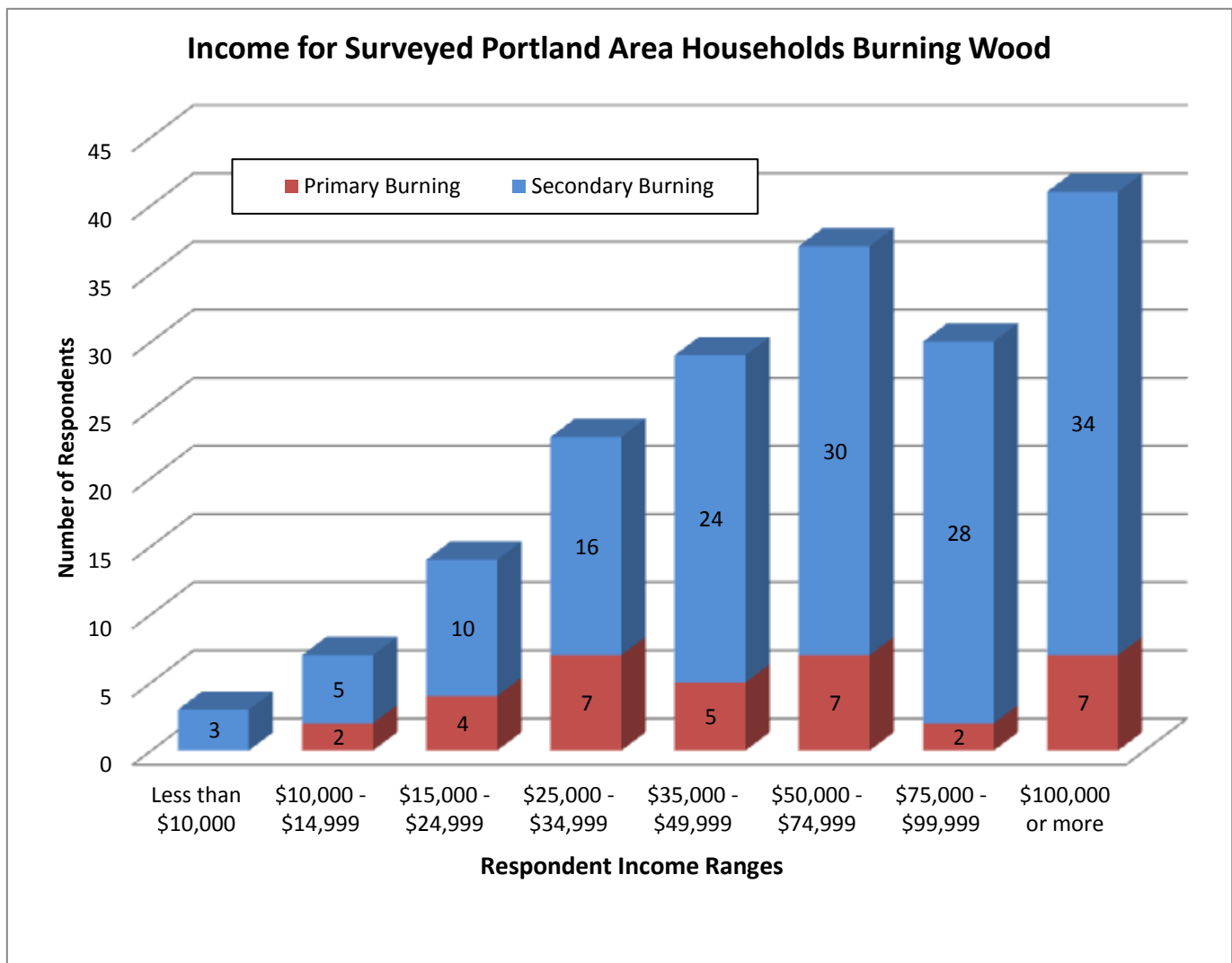

Figure 14 - Income ranges of survey respondents who burn wood

4. Next steps

DEQ plans to perform additional analysis on data from the Portland Residential Wood Combustion Survey to understand on the spatial distribution of emissions. DEQ may scale or adjust existing air toxics modeling or create additional maps. DEQ is providing the results of the Portland Residential Wood Combustion survey to partners and stakeholders to further strategies for wood burning emission reduction. DEQ invites feedback and recommendations for additional analysis and use of the survey results.