

# **Oregon 2005 Residential Wood Combustion Emissions Inventory: Revised Interpretation of Wood Burning Survey Data Resulting in Emissions Estimates Reductions**

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## **ABSTRACT**

The Washington Department of Ecology and Oregon Department of Environmental Quality worked together to re-interpret results from a 2000 Residential Wood Combustion (RWC) survey conducted for Idaho, Washington, and Oregon. Agency staff reassessed the population of wood burning devices. Changes were made to the emission inventory method to account for only those wood burning devices in which fuel was reported burned, excluding respondents who reported owning devices but did not report burning any fuel. The methodology change was used for the Oregon 2005 RWC inventory, and resulted in significant reductions in RWC emissions estimates as compared to the Oregon 2002 National Emission Inventory submittal. The 2005 Oregon emissions estimates were further reduced by the correction of an error in wood density calculations. Estimated emissions reductions ranged from 62% for benzene to 45% for total VOCs. This paper discusses the re-interpretation of the survey results, outlines the Oregon emissions inventory methodology, and presents the Oregon RWC emissions estimates for 2002 and 2005 for CO, VOC, PM<sub>2.5</sub>, NO<sub>x</sub>, benzene, and 15-PAH.

## **INTRODUCTION**

The Oregon Department of Environmental Quality (DEQ) and the Washington State Department of Ecology (DOE) used a 2000 tri-state Residential Wood Combustion (RWC) telephone survey<sup>1</sup> to estimate RWC emissions for the 2002 National Emissions Inventory (NEI). Examination of the DEQ RWC methodology revealed a likely fault in how survey results were interpreted<sup>2</sup>. For 2002, both the DEQ and the DOE took an extremely conservative approach to estimating RWC emissions, calculating activity levels from the number of respondents that reported owning a wood heating device. The method assigned emissions to devices in which no fuel was being burned, resulting in elevated RWC estimates. NEI data for the Oregon 2002 RWC emissions estimates for six key pollutants, along with national averages, are shown in Table 1.

**Table 1.** 2002 NEI Residential Wood Combustion Emissions Estimates <sup>(1)</sup>

	----- tpy -----					
	15-PAH	Benzene	PM25-PRI	CO	VOC	NOX
Oregon	312 <sup>(3)</sup>	1,772	38,804	267,289	125,936	3,934
National Avg. <sup>(2)</sup>	72	348	7,236	54,996	26,600	698

Notes:

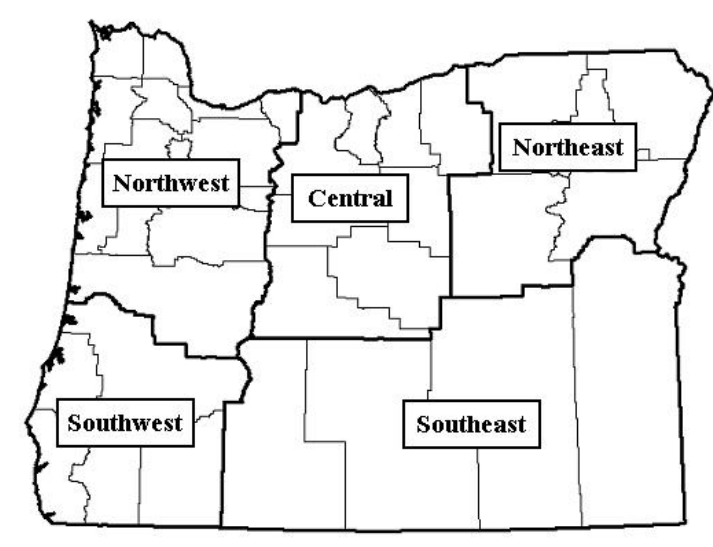
(1) [ftp://ftp.epa.gov/EmisInventory/2002finalnei/2002\\_final\\_v3\\_2007\\_summaries/nonpoint/](ftp://ftp.epa.gov/EmisInventory/2002finalnei/2002_final_v3_2007_summaries/nonpoint/)

(2) National Average is for the NEI excluding OR and WA

(3) Approximate

The DEQ also used the device ownership methodology for the 1999 National Emission Inventory submittal. In the EPA1999 National-Scale Air Toxics Assessment, the high RWC polycyclic aromatic hydrocarbon (PAH) emissions estimates resulted in corresponding higher cancer risk estimates for Oregon. Subsequent news releases described Oregon as having the “third worst air in the nation”<sup>3,4</sup>. These developments prompted the DEQ to re-evaluate its RWC EI method and to work with the DOE to develop an alternative assessment of the survey results. The revised method bases activity on the number of respondents that reported burning wood in a wood heating device, as opposed to the number of respondents that reported owning a wood heating device.

For Oregon, the 2000 RWC survey was divided into five regions, illustrated in Figure 1.



**Figure 1.** RWC 2000 Survey Regions

For all data analysis, raw survey data was imported into an MS Access application. The data was queried and analyzed in a step-by-step fashion, detailed in the ACTIVITY ESTIMATES section. Survey questions that pertain to the data described are denoted in parenthesis.

## ACTIVITY ESTIMATES

Survey respondents indicated whether they owned a fireplace, insert, woodstove, pellet stove, or central furnace (Q1\*). Respondents were also asked if they had burned wood fuel in the device within the previous year (Q9\*). For the 2005 inventory, respondents were designated as “burners” only if they indicated that they had burned wood fuel. Table 2 shows the number of respondents reporting devices owned vs. those who reported burning wood. Figure 2 illustrates the fireplace, woodstove, and insert data shown in Table 2.

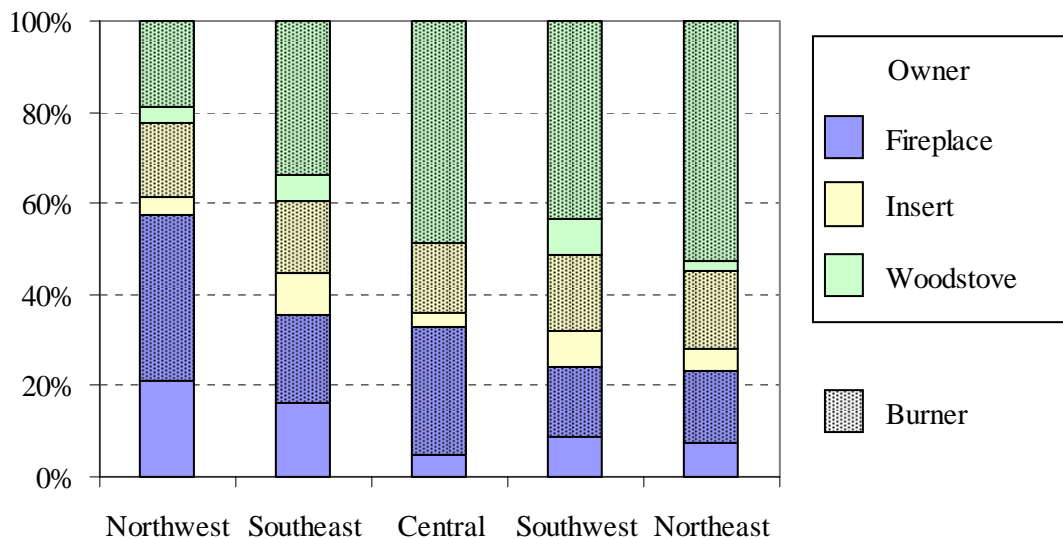
**Table 2.** 2000 RWC Survey Results<sup>1</sup>: Respondents Who Own a Woodburning Device vs. Respondents Who Burn Wood in the Device

Region	Fireplace		Insert		Woodstove		Pellet Stove		Central Furnace	
	Own	Burn	Own	Burn	Own	Burn	Own	Burn	Own	Burn
Central	17	15	10	8	25	25	9	9	3	3
Northeast	10	7	9	7	23	22	6	6	1	1
Northwest	83	53	30	24	32	28	6	5	2	1
Southeast	20	11	14	9	22	19	4	4	--	--
Southwest	22	14	23	16	47	40	4	3	1	1
Totals	152	99	85	64	148	133	29	27	6	6

Survey results: Owners = 420/856 completed interviews = 49%

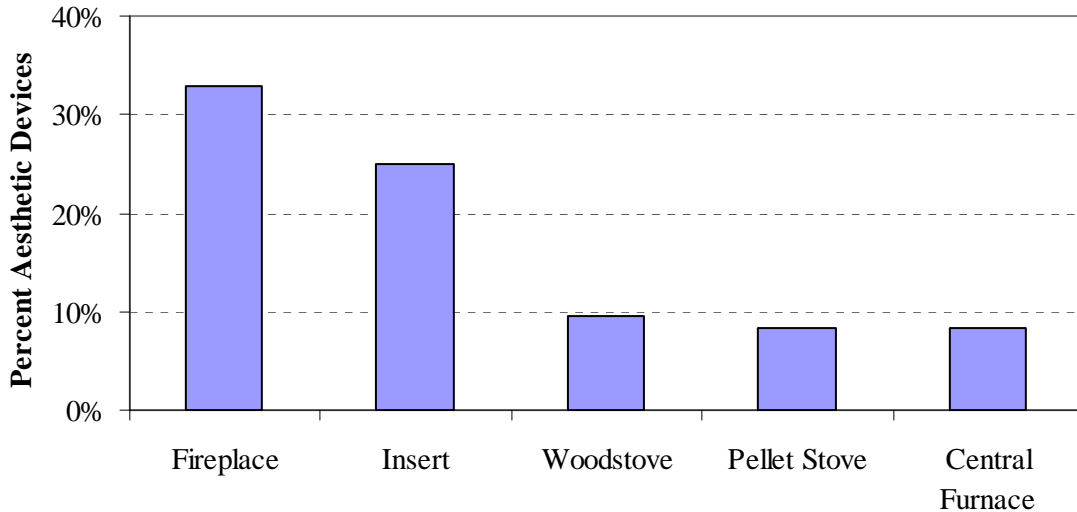
Survey results: Burners = 327/856 completed interviews = 38%

(1) Data is from Reference 1, Q1\* and Q9\*.



**Figure 2.** Respondents Who Own a Woodburning Device vs. Respondents Who Burn Wood in the Device (fireplace, insert, & woodstove only)

Though the sample size is relatively small (856 completed interviews statewide), some patterns can be discerned in Figure 2. Woodstoves are most prevalent in the Central, Northeast, and Southwest regions. The Northwest region, which contains the city of Portland, shows the greatest percentage of fireplace owners and burners. The percentage of devices that are not used is higher for fireplaces than inserts or woodstoves. Figure 3 illustrates the statewide percentage of devices for which respondents did not report the burning of any wood fuel.



**Figure 3.** Statewide percentage of devices for which respondents did not report the burning of any wood fuel

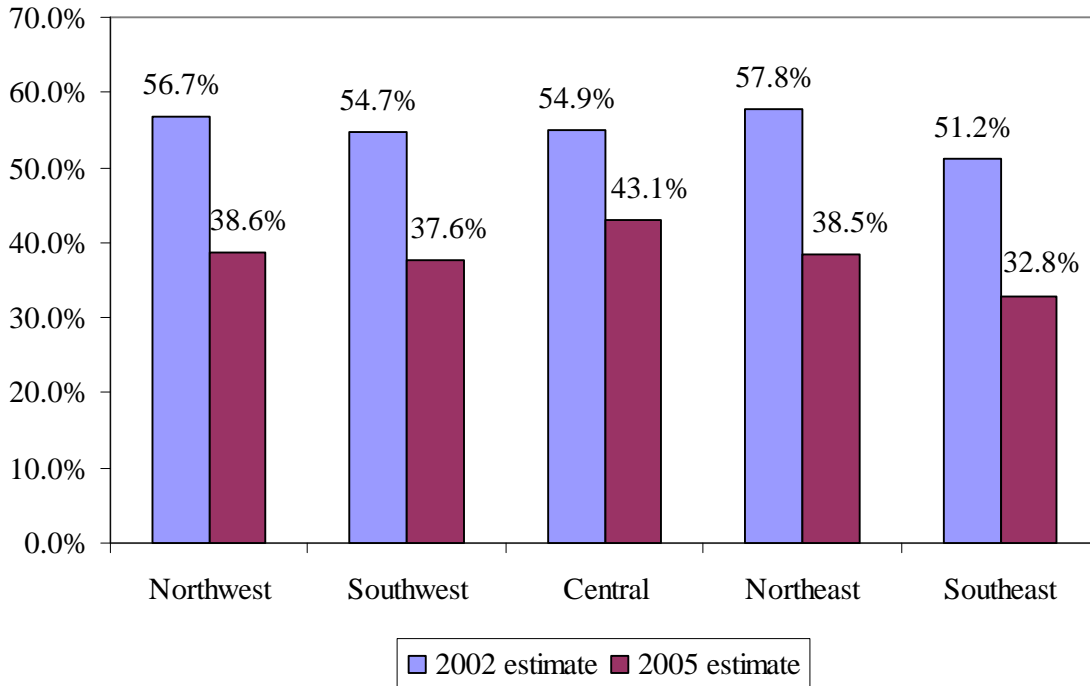
To estimate the number of wood burning housing units (HU) by county, the fraction of HUs that burn wood in a device type was estimated. This was done by dividing the number of burners using a specific device in a region by the total number of completed interviews for that region. As mentioned in the introduction, this differs from previous methodology in that only respondents that reported wood burned were taken into consideration. Survey designated devices included woodstoves, fireplaces, inserts, pellet stoves, and central furnaces. Woodstoves and inserts were flagged as either certified or uncertified depending upon the age of the device (Q2\*). Woodstoves and inserts were also flagged as either catalytic or non-catalytic using a 30/70 ratio of catalytic to non-catalytic, taken from 2002 NEI documentation<sup>5</sup>. The EPA has not assigned a Source Classification Code (SCC) to the Central Furnace device type; as such these devices were assigned the “woodstove, conventional, non-certified” SCC of 21-04-008-010.

Table 3 details woodburning HU estimates by device and region. The ratio of certified to non-certified stoves and inserts in Oregon is approximately 20/30, as estimated from the data in Table 3.

**Table 3.** % Woodburning HU by Device and Region

SCC	Device	Central	Northeast	Northwest	Southeast	Southwest
2104008001	Fireplace	10.6%	6.0%	18.4%	8.4%	7.2%
2104008010	Central Furnace	1.8%	0.9%	0.4%	--	0.5%
2104008053	Pellet Stove	6.6%	5.5%	1.8%	3.1%	1.5%
2104008002	Insert Not Certified	2.9%	4.1%	3.5%	2.3%	2.6%
2104008003	Insert Non Catalytic Certified	2.0%	1.6%	3.4%	3.2%	3.8%
2104008004	Insert Catalytic Certified	0.9%	0.7%	1.5%	1.4%	1.6%
2104008010	Woodstove Conventional Not Certifi	9.5%	13.3%	4.9%	12.2%	13.4%
2104008030	Woodstove Catalytic Certified	2.6%	1.9%	1.4%	0.7%	2.1%
2104008050	Woodstove Non Catalytic Certified	6.1%	4.5%	3.3%	1.6%	4.9%
Estimated % Woodburning HU		43.1%	38.5%	38.6%	32.8%	37.6%

Figure 4 shows a comparison of woodburning HU estimates for the 2002 and 2005 DEQ RWC inventories. Significant reductions in the number of woodburning HU estimates for the 2005 inventory are shown for all regions.



**Figure 4.** Woodburning HU estimates

2005 county total HU data are not available; as such 2000 HU data<sup>6</sup> was grown linearly to 2005 values using population estimates<sup>7</sup>. The 2005 county HU estimates were then multiplied by the regional percentages shown in Table 3 to obtain the estimated number of woodburning HUs by county.

Respondents also specified the annual volume of wood burned (Q10\*). An average volume of wood burned, estimated from survey results, was assigned to those respondents who indicated wood use but failed to enter the volume burned. Records for which annual fuel usage exceeded either 28 cords of wood or 300 forty-lb bags of pellets per respondent were deemed unreasonable and deleted.

The 2000 survey did not include questions regarding the species of wood burned, but rather the type of wood burned (cord wood, presto logs, pellets). As such, the volume of cordwood burned from the survey results was converted to tons cordwood by using results from a 1993 Oregon statewide RWC survey<sup>8</sup>. The 1993 survey included questions regarding what species of wood was burned, and a typical density for a cord of wood was developed from the data. The volume of a cord of wood was first adjusted from 120 ft<sup>3</sup> to 80 ft<sup>3</sup> (The Woodburners Encyclopedia<sup>9</sup>) to account for air pockets that occur in a cord of wood. Wood density of a “typical” cord of wood was estimated for each region based on both the adjusted volume and the air-dried density for wood species<sup>(10,11)</sup>. Tables 4a and 4b outline the “typical” cord density estimates used in the activity calculations. The volume of presto logs was converted to tons with the assumption that a presto log weighs 8 lbs on average. Pellet conversion to tons was straightforward; one bag of pellets weighs 40 lbs on average.

**Table 4a.** 1993 Oregon Woodheating Survey Results:

Region and City	Type of Wood Burned by City <sup>1</sup>						Madrone /	Mill
	Fir	Pine	Oak	Maple	Cedar	Tamarack	Scraps	
<i>Northwest</i>								
Portland	48%	6%	16%	8%	7%	0%	14%	
<i>Southwest</i>								
Grants Pass	13%	5%	28%	0%	1%	48%	6%	
Medford	31%	7%	12%	0%	2%	39%	9%	
Roseburg	20%	2%	16%	1%	24%	36%	2%	
<i>Central</i>								
Bend	1%	98%	0%	0%	0%	0%	1%	
Prineville	24%	47%	0%	0%	0%	26%	3%	
Sisters	8%	85%	0%	0%	1%	4%	1%	
<i>Northeast</i>								
Lagrande	22%	28%	0%	0%	0%	48%	1%	
Pendleton	24%	34%	0%	0%	0%	41%	1%	
<i>Southeast</i>								
Klamath Falls	9%	85%	1%	0%	3%	1%	2%	
Lakeview	19%	75%	0%	0%	4%	0%	2%	

Notes:

(1) Species wood burned from Reference 8, Item 13 and Item 15 responses.

Distribution corrected based on the number of respondents as follows;

(weighted % of respondents by indicated wood species) / (weighted total % of respondents).

**Table 4b. 1993 Oregon WoodHeating Survey Results: Estimated Average Typical Cord Mass by Region**

Region and City	(1) ----- Tons per Cord -----							(2), (3) ----- Typical Cord Mass -----		(5) 2002 (lbs)	(6) % Reduct.
	Fir	Pine	Oak	Maple	Cedar	Madrone / Tamarack	Mill Scraps	2005 (tons)	2005 (lbs)		
<i>Northwest</i>											
Portland	0.66	0.07	0.30	0.11	0.08	0.01	0.19	1.41			
							Average	1.41	<b>2,830</b>	<b>3,613</b>	22%
<i>Southwest</i>											
Grants Pass	0.18	0.06	0.53	0.00	0.01	0.92	0.08	1.77			
Medford	0.42	0.08	0.24	0.01	0.02	0.75	0.12	1.63			
Roseburg	0.28	0.02	0.30	0.01	0.26	0.69	0.02	1.58			
							Average	1.66	<b>3,315</b>	<b>3,657</b>	9%
<i>Central</i>											
Bend	0.01	1.10	0.004	0.0003	0.001	0.003	0.01	1.12			
Prineville	0.32	0.53	0.001	0.001	0.003	0.50	0.03	1.39			
Sisters	0.11	0.95	0.01	0.002	0.01	0.09	0.01	1.18			
							Average	1.23	<b>2,458</b>	<b>3,630</b>	32%
<i>Northeast</i>											
Lagrande	0.30	0.32	0.002	0.004	0.002	0.92	0.01	1.56			
Pendleton	0.32	0.38	0.001	0.003	0.000	0.79	0.02	1.51			
							Average	1.53	<b>3,065</b>	<b>3,725</b>	18%
<i>Southeast</i>											
Klamath Falls	0.12	0.95	0.02	0.001	0.03	0.01	0.02	1.15			
Lakeview	0.26	0.84	0.005	0.0004	0.04	0.002	0.02	1.17			
							Average	1.16	<b>2,321</b>	<b>3,588</b>	35%

## Notes:

- (1) Tons per cord is calculated from species distribution shown in Table 4a, cord volume given p. 21 of Reference 9. Air-dried species wood density taken from:  
Oak and Madrone/Tamarack: Appendix A, p. A-7 of Reference 10. Madrone/Tamarack set equal to Hickory.  
Fir, Pine, Maple, Cedar = Reference 11, p. 14.  
Mill Scraps set equal to Fir in Western Oregon, Pine in Eastern Oregon.
- (2) Typical cord mass in tons = sum (tons per cord)
- (3) Average typical cord mass in tons = average of the summed tons per cord.
- (4) Typical cord mass in lbs = (avg. typical cord mass, tons) \* (2000 lbs/ton)
- (5) From Reference 2, Table 4b, p. 7.
- (6) % Reduction = 1-[(2005 cord mass, lbs) / (2002 cord mass, lbs)]

An error was found in species wood density values during a review of the 2002 RWC EI method. This error has been corrected for the 2005 EI, and the result, as a reduction to the typical cord mass value, is shown in Table 4b.

Respondents were asked to designate the primary device in which wood fuel was burned in the HU (Q3\*, Q5); this was the device linked to the amount of wood burned for that HU. This method of fuel distribution resulted in linking some devices to unusual fuel types (example: fireplaces linked to pellets in the Northeast region). For records where a primary device was not identified, HU wood use was allocated evenly between the devices indicated by the respondent.

Table 5 shows the estimated average tons fuel combusted by device for each region in Oregon. Each device could be associated with up to three fuel types. As such, the total number of devices listed in Table 5 is greater than the number of burners shown in Table 2 (327 burners vs. 451 devices).

**Table 5. Estimated Average Annual Tons Fuel Combusted per Wood Heating Device**

Region	Device	(1)		(2)	(3)		(4)	(5)
		Fuel Type	Volume Unit		Avg Fuel Volume (per device)	Density (lb/Unit)		
<i>Central</i>								
	Central Furnace	cord	2 Cord	3	0.7	2,458		0.8
	Fireplace	cord	13 Cord	7	1.9	2,458		2.3
	Fireplace	presto	7 Log	8	0.9	8		0.004
	Insert	cord	20 Cord	8	2.5	2,458		3.1
	Pellet Stove	cord	3 Cord	9	0.3	2,458		0.4
	Pellet Stove	pellets	655 Bag	8	81.9	40		1.6
	Woodstove	cord	64 Cord	22	2.9	2,458		3.6
	Woodstove	presto	45 Log	23	2.0	8		0.01
<i>Northeast</i>								
	Central Furnace	cord	1 Cord	1	1.0	3,065		1.5
	Central Furnace	presto	24 Log	1	24.0	8		0.1
	Fireplace	cord	10 Cord	5	2.0	3,065		3.1
	Fireplace	pellets	3 Bag	5	0.6	40		0.01
	Fireplace	presto	4 Log	5	0.8	8		0.003
	Insert	cord	14.5 Cord	6	2.4	3,065		3.7
	Pellet Stove	pellets	385 Bag	5	77.0	40		1.5
	Woodstove	cord	67.5 Cord	18	3.8	3,065		5.7
<i>Northwest</i>								
	Central Furnace	pellets	40 Bag	1	40.0	40		0.8
	Fireplace	cord	35 Cord	32	1.1	2,830		1.5
	Fireplace	presto	175 Log	37	4.7	8		0.02
	Insert	cord	35.5 Cord	19	1.9	2,830		2.6
	Insert	pellets	2 Bag	21	0.1	40		0.002
	Insert	presto	25 Log	20	1.3	8		0.01
	Pellet Stove	pellets	91 Bag	3	30.3	40		0.6
	Woodstove	cord	36.5 Cord	19	1.9	2,830		2.7
	Woodstove	presto	82 Log	24	3.4	8		0.01
<i>Southeast</i>								
	Fireplace	cord	13 Cord	5	2.6	2,321		3.0
	Insert	cord	30 Cord	9	3.3	2,321		3.9
	Pellet Stove	cord	1 Cord	4	0.3	2,321		0.3
	Pellet Stove	pellets	226 Bag	4	56.5	40		1.1
	Woodstove	cord	69 Cord	15	4.6	2,321		5.3
<i>Southwest</i>								
	Central Furnace	cord	3 Cord	1	3.0	3,315		5.0
	Fireplace	cord	12 Cord	9	1.3	3,315		2.2
	Fireplace	presto	43 Log	9	4.8	8		0.02
	Insert	cord	35 Cord	12	2.9	3,315		4.8
	Pellet Stove	pellets	110 Bag	2	55.0	40		1.1
	Woodstove	cord	100 Cord	35	2.9	3,315		4.7
	Woodstove	presto	3 Log	36	0.1	8		0.0003

Notes: (1) From Reference 1

(2) Device count is from Reference 1. Device count not equal to total burners as fuel use was evenly distributed to multiple devices for burners who did not indicate a primary heating device.

(3) (Avg Fuel Volume per Device) = (Fuel Volume) / (Device Count)

(4) Cord density from Table 4b. Pellet bags = 40 lbs per bag, presto log assumed equal to 8 lbs per log

(5) (Avg Fuel Mass Fuel per Device) = (Avg Fuel Volume per Device) \* (Fuel Density, lbs/Fuel volume unit)



Table 6 shows statewide weighted averages for the estimated volume of cordwood burned for fireplaces, woodstoves, inserts, and central furnaces.

<b>Table 6. Statewide Average Volume of Cordwood Burned per Device, Weighted by HU</b>						
Device	Region	(1) Housing Units		(5) Fuel Volume		
		2005 Total	Woodburning Percent	Total Woodburning	Per Device Cords	Total Cords
<i>Fireplace</i>						
	Central	104,858	11%	11,098	1.9	20,610.8
	Northeast	55,191	6%	3,291	2.0	6,582.4
	Northwest	1,131,406	18%	208,417	1.1	227,956.0
	Southeast	48,364	8%	4,061	2.6	10,558.9
	Southwest	201,237	7%	14,522	1.3	19,363.0
	Total			241,390		285,071.0
Weighted Avg. Cords per Fireplace <sup>6</sup>					<b>1.2</b>	
<i>Woodstove</i>						
	Central	104,858	18%	19,135	2.9	55,664.5
	Northeast	55,191	20%	10,886	3.8	40,823.6
	Northwest	1,131,406	10%	109,171	1.9	209,722.8
	Southeast	48,364	15%	7,015	4.6	32,267.3
	Southwest	201,237	20%	40,974	2.9	117,067.2
	Total			187,180		455,545.3
Weighted Avg. Cords per Woodstove <sup>6</sup>					<b>2.4</b>	
<i>Insert</i>						
	Central	104,858	6%	6,123	2.5	15,307.7
	Northeast	55,191	6%	3,544	2.4	8,565.6
	Northwest	1,131,406	8%	95,276	1.9	178,016.2
	Southeast	48,364	7%	3,323	3.3	11,075.7
	Southwest	201,237	8%	16,078	2.9	46,894.8
	Total			124,345		259,860.1
Weighted Avg. Cords per Insert <sup>6</sup>					<b>2.1</b>	
<i>Central Furnace</i>						
	Central	104,858	1.8%	1,913	0.7	1,275.6
	Northeast	55,191	0.9%	506	1.0	506.3
	Northwest	1,131,406	0.4%	3,970	--	--
	Southeast	48,364	--	--	--	--
	Southwest	201,237	0.5%	1,037	3.0	3,111.9
	Total			7,427		4,893.9
Weighted Avg. Cords per Furnace <sup>6</sup>					<b>0.7</b>	

- Notes: (1) 2005 HU estimates from References 5 and 6.  
(2) From Table 3.  
(3) (Total Woodburning HU) = (2005 Total HU) \* (% Woodburning HU)  
(4) From Table 5.  
(5) (Total Cords) = (Total Woodburning HU) \* (Fuel Volume per Device)  
(6) Weighted Average = (Total Fuel Volume) / (Total Woodburning HU)

To adjust wood heating activity from survey year of 2000 to the inventory year of 2005, a heating degree day (HDD) ratio was applied to the fuel burning data. County HDD data and HDD ratios used in activity calculations are shown Table 7. HDD data was taken from *Climatological Data for Oregon*<sup>12</sup>.

**Table 7. County Heating Degree Days (HDD) and HDD R**

Region and County	----- Avg. # HDD -----		Ratio 2005/2000
	Inventory Year 2005	Survey Year 2000	
<i>Central</i>			
Deschutes	6,780	6,565	1.03
Crook	7,334	6,023	1.22
Gilliam	5,367	5,701	0.94
Jefferson	6,711	5,705	1.18
Morrow	5,186	5,373	0.97
Sherman	6,078	6,357	0.96
Wasco	5,568	4,087	1.36
Wheeler	5,604	4,519	1.24
<i>Northeast</i>			
Baker	6,737	5,811	1.16
Grant	6,859	5,688	1.21
Umatilla	5,160	5,412	0.95
Union	6,435	5,853	1.10
Wallowa	7,087	6,983	1.01
<i>Northwest</i>			
Benton	4,855	5,001	0.97
Clackamas	5,306	5,429	0.98
Clatsop	4,740	4,877	0.97
Columbia	5,205	5,439	0.96
Hood River	5,636	5,657	1.00
Lane	4,787	4,832	0.99
Lincoln	4,616	4,894	0.94
Linn	5,666	5,340	1.06
Marion	4,821	5,032	0.96
Multnomah	4,424	4,297	1.03
Polk	5,705	4,551	1.25
Tillamook	4,725	4,981	0.95
Washington	4,676	3,969	1.18
Yamhill	4,690	3,851	1.22
<i>Southeast</i>			
Harney	6,978	6,024	1.16
Klamath	8,041	7,082	1.14
Lake	6,983	5,872	1.19
Malheur	6,244	5,576	1.12
<i>Southwest</i>			
Coos	4,096	4,209	0.97
Curry	3,846	3,890	0.99
Douglas	4,639	4,505	1.03
Jackson	5,159	5,211	0.99
Josephine	5,027	4,889	1.03

Heating Degree Day data is from Reference 12.

Equation (1) shows how RWC activity was estimated:

$$\text{Equation (1) Tons Wood Fuel Burned by County} = (a) * (b) * (c) * (d)$$

where

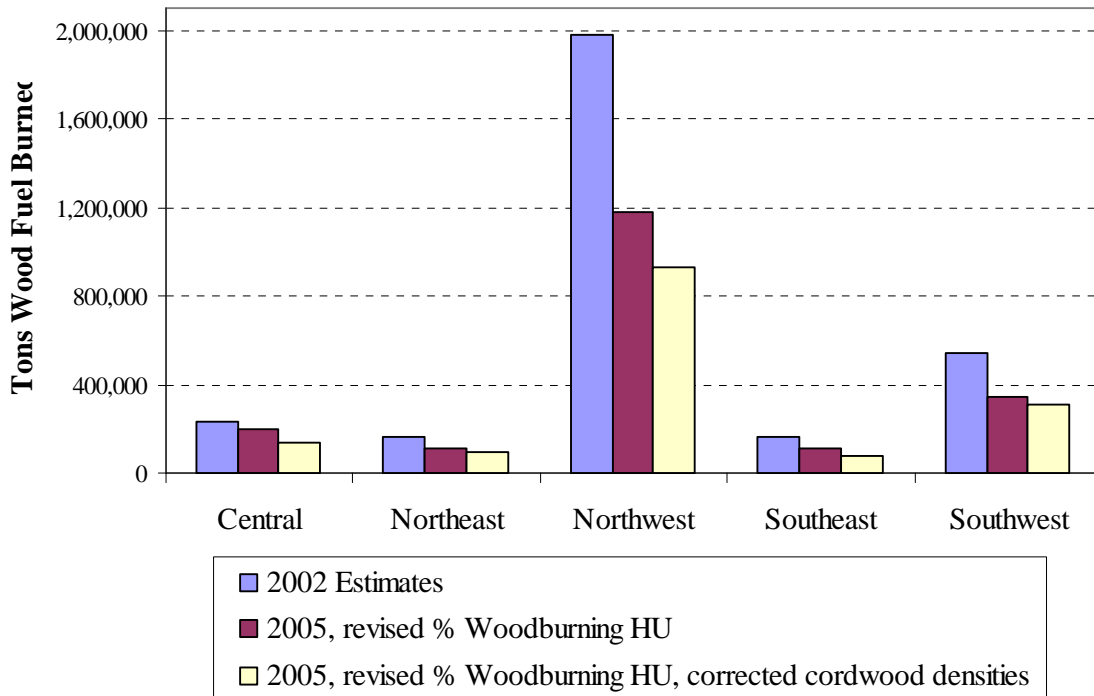
a = County 2005 Housing Units (HU), estimated from US Census Bureau data

b = % Woodburning HU by Region and Device, from Table 3

c = Regional Avg. Annual Tons Fuel Combusted per Device, from Table 5

d = County 2005/2000 HDD ratio, from Table 7

Estimated RWC activity levels by region for the Oregon 2002 and 2005 inventories are shown in Figure 5.



**Figure 5.** Estimated RWC Annual Tons Wood Fuel Combusted, 2002 and 2005 Inventories

The average statewide reduction in 2005 activity estimates from 2002 due to the revised % woodburning HU is 37%. The average statewide reduction in 2005 activity estimates from 2002 due to the correction to species density/cord mass calculations is 13%. The total statewide activity reduction from 2002 estimates is 50% on average. 2002 and 2005 activity data by county is shown in Table 8.

**Table 8. Oregon RWC 2002 and 2005 Estimated Tons Wood Fuel Burned by County**

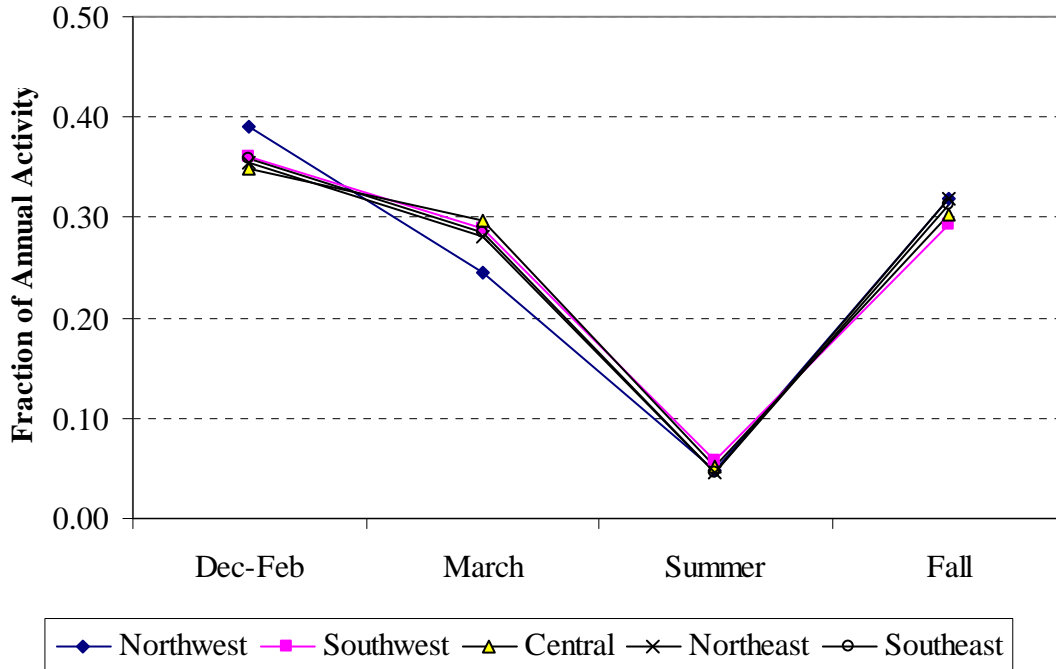
Region	County	(1)	(2)	(2)	(2)	(3)
		2002 Total (tpy)	----- 2005 tpy -----			
			Cordwood	Pellets	Presto	Total
<i>Central</i>						
	CROOK	24,689	13,326	1,285	21	14,632
	DESCHUTES	142,786	78,198	7,542	126	85,866
	GILLIAM	2,397	1,081	104	2	1,187
	JEFFERSON	20,567	11,828	1,141	19	12,987
	MORROW	10,118	5,000	482	8	5,490
	SHERMAN	2,156	969	93	2	1,064
	WASCO	24,094	16,279	1,570	26	17,875
	WHEELER	2,680	1,166	112	2	1,280
	<b>Total</b>	<b>229,487</b>				<b>140,384</b>
<i>Northeast</i>						
	BAKER	23,579	15,057	821	10	15,888
	GRANT	14,848	7,332	400	5	7,737
	UMATILLA	74,548	42,469	2,315	29	44,813
	UNION	36,458	18,597	1,014	13	19,623
	WALLOWA	14,385	6,124	334	4	6,462
	<b>Total</b>	<b>163,818</b>				<b>94,523</b>
<i>Northwest</i>						
	BENTON	58,231	25,338	448	172	25,958
	CLACKAMAS	240,222	110,053	1,945	747	112,745
	CLATSOP	34,930	15,147	268	103	15,518
	COLUMBIA	29,458	13,739	243	93	14,075
	HOOD RIVER	19,019	6,225	110	42	6,377
	LANE	241,820	110,307	1,950	748	113,006
	LINCOLN	50,574	19,495	345	132	19,972
	LINN	75,393	36,114	638	245	36,997
	MARION	200,910	84,663	1,496	574	86,734
	MULTNOMAH	532,549	239,991	4,242	1,628	245,861
	POLK	44,709	24,860	439	169	25,468
	TILLAMOOK	30,357	12,072	213	82	12,367
	WASHINGTON	355,490	178,470	3,155	1,211	182,836
	YAMHILL	67,275	30,163	533	205	30,901
	<b>Total</b>	<b>1,980,937</b>				<b>928,814</b>
<i>Southeast</i>						
	HARNEY	12,603	5,367	142	-	5,509
	KLAMATH	102,442	43,560	1,154	-	44,714
	LAKE	12,601	6,264	166	-	6,430
	MALHEUR	36,365	16,475	437	-	16,911
	<b>Total</b>	<b>164,011</b>				<b>73,565</b>
<i>Southwest</i>						
	COOS	86,446	43,643	483	41	44,168
	CURRY	31,138	17,363	192	16	17,572
	DOUGLAS	122,892	70,152	777	66	70,996
	JACKSON	214,442	123,565	1,369	116	125,050
	JOSEPHINE	88,976	55,206	612	52	55,869
	<b>Total</b>	<b>543,894</b>				<b>313,655</b>
<b>Statewide Total</b>		<b>3,082,147</b>	<b>1,505,658</b>	<b>38,572</b>	<b>6,711</b>	<b>1,550,941</b>

Notes: (1) Oregon 2002 National Emissions Inventory submittal. June 1, 2005.

(2) Estimated using Equation (1), page 11 of this paper.

(3) Total = (Cordwood) + (Pellets) + (Presto Logs)

Temporal resolution was also calculated using survey results. Respondents were asked during which season they used their wood burning equipment (Q6\*). The data follows an expected trend, regardless of region, as shown in Figure 6.



**Figure 6.** Oregon RWC Seasonal Temporal Profile by Region

## EMISSION FACTORS

Emission factors (EFs) are in pounds (lbs) pollutant per ton fuel burned, and are specific to heating device type. The EFs for cordwood burning device emissions estimates were obtained from the EPA 2002 NEI documentation, specifically Appendix A, pp. A154 – A161<sup>5</sup>. Research into EFs for pellet stoves resulted in data from three sources; AP-42<sup>10</sup>, EIIP<sup>13</sup>, and research presented by OMNI Environmental Services<sup>14</sup>.

The following groups of RWC categories have identical emission factors:

- non-certified inserts and non-certified woodstoves
- certified non-catalytic inserts and certified non-catalytic woodstoves
- certified catalytic inserts and certified catalytic woodstoves

EPA SCC convention could be revised to group the woodstove/insert categories together based on EF values.

EFs used in the RWC emissions calculations are shown in Tables 9a and 9b. All EF data researched was specific to device, and not fuel type. Dioxin/furan EFs for pellet stoves were not found.

**Table 9a.** Residential Wood Combustion Emission Factors: Criteria and Air Toxic Pollutants

CAS	Pollutant	(1)				(2)
		----- <i>EF, lbs pollutant per ton fuel combusted</i> -----				
		2104008001	2104008010	2104008050	2104008030	2104008053
<b>Criteria</b>						
630-08-0	Carbon Monoxide	128	231	141	104	39.4
NOX	Nitrogen Oxides	2.6	2.8		2	13.8
PM10	Primary PM10, total	23.6	30.6	19.6	20.4	4.2
PM25	Primary PM2.5, total	23.6	30.6	19.6	20.4	4.1
7446-09-5	Sulfur Dioxide	0.4	0.4	0.4	0.4	0.4
VOC	Volatile Organic Compounds	229	53	12	15	
<b>16-PAH</b>						
83-32-9	Acenaphthene		0.00621	0.00404	0.00308	
208-96-8	Acenaphthylene		0.132	0.0129	0.0349	
120-12-7	Anthracene		0.00869	0.00364	0.0041	
56-55-3	Benz(a)anthracene		0.0124		0.0123	
50-32-8	Benzo(a)pyrene		0.00248	0.00242	0.00205	
205-99-2	Benzo(b)fluoranthene		0.00373	0.00162	0.00205	0.000026
191-24-2	Benzo(g,h,i)perylene		0.00248	0.00808	0.00103	
207-08-9	Benzo(k)fluoranthene		0.00124		0.00103	
218-01-9	Chrysene		0.00745	0.00404	0.00513	0.0000752
53-70-3	Dibenzo(a,h)anthracene			0.00162	0.00103	
206-44-0	Fluoranthene		0.0124	0.00323	0.00616	0.0000548
86-73-7	Fluorene		0.0149	0.00566	0.00718	
193-39-5	Indeno(1,2,3-cd)pyrene			0.00808	0.00205	
91-20-3	Naphthalene		0.179	0.0582	0.0954	
85-01-8	Phenanthrene		0.0484	0.0477	0.0246	0.0000332
129-00-0	Pyrene		0.0149	0.00323	0.00513	0.0000484
<b>Benzene and other HAPs</b>						
71-43-2	Benzene	0.6	1.94		1.46	
192-97-2	Benzo(e)pyrene		0.00745	0.000808	0.00205	
203-12-3	Benzo(g,h,i)Fluoranthene			0.0113	0.00308	
92-52-4	Biphenyl			0.00889		
7440-43-9	Cadmium		0.000022	0.00002		
7439-96-5	Manganese		0.00017	0.00014		
78-93-3	Methyl Ethyl Ketone		0.29		0.062	
7440-02-0	Nickel		0.000014	0.00002		
95-47-6	O-Xylene		0.202		0.186	
198-55-0	Perylene			0.000808		
108-88-3	Toluene		0.73		0.52	
57-97-6	7,12-Dimethyl/benz(a)anthracene			0.00162		

(1) Emission Factors are from Reference 5, Appendix A, pp. A-154 through A-161.

Fireplace Benzene emissions factor is from Reference 15

(2) Pellet Stove EFs are from the following sources;

Carbon Monoxide & Primary PM10 total:	Reference 13, p. 2.4-5, Table 2.4-1, Certified Pellet Stoves
Nitrogen Oxides & Sulfur Dioxide:	Reference 10, Table 1.10-1
Primary PM2.5 total:	Reference 14, pp. 16 (Emission Units) and 17 (Comments on AP-42 EFs).
All Others:	Reference 10, p. 2.4-7, Table 2.4-3, Exempt Pellet Stoves

**Table 9b.** Dioxin/Furan Emission Factors, All Device Types Except Pellet Stoves (21-04-008-053)

<b>CAS</b>	<b>Pollutant</b>	(1) EF, lbs pollutant per ton fuel combusted
39001-02-0	Octachlorodibenzofuran	1.67E-11
3268-87-9	Octachlorodibenzo-p-dioxin	6.66E-11
67562-39-4	1,2,3,4,6,7,8-Heptachlorodibenzofuran	3.00E-11
35822-46-9	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	3.16E-11
55673-89-7	1,2,3,4,7,8,9-Heptachlorodibenzofuran	2.34E-11
70648-26-9	1,2,3,4,7,8-Hexachlorodibenzofuran	3.56E-11
39227-28-6	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	2.50E-11
57117-44-9	1,2,3,6,7,8-Hexachlorodibenzofuran	2.20E-11
57653-85-7	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	2.50E-11
72918-21-9	1,2,3,7,8,9-Hexachlorodibenzofuran	1.98E-11
19408-74-3	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	2.50E-11
57117-41-6	1,2,3,7,8-Pentachlorodibenzofuran	4.56E-11
40321-76-4	1,2,3,7,8-Pentachlorodibenzo-p-dioxin	2.58E-11
60851-34-5	2,3,4,6,7,8-Hexachlorodibenzofuran (2)	1.65E-11
57117-31-4	2,3,4,7,8-Pentachlorodibenzofuran	6.44E-11
51207-31-9	2,3,7,8-Tetrachlorodibenzofuran	1.25E-10
1746-01-6	2,3,7,8-Tetrachlorodibenzo-p-dioxin	2.28E-11

(1) Emission Factors are from Reference 5, Appendix A, pp. A-154 through A-161.

(2) Given as 1.85E-11 for 21-04-008-001 in the documentation, this is assumed to be a typo.

## RESULTS

Emissions estimates are calculated using the following equation:

$$\text{Equation (2) RWC Emissions} = (\text{Tons Fuel Burned}) * (\text{EF})$$

where

Tons Fuel Burned = tons fuel burned by device and region, estimated from survey data

EF = pollutant and device specific emission factor, lbs pollutant per ton fuel burned, from Tables 9a and 9b

Table 10 shows the RWC emissions estimates for the Oregon 2002 and 2005 inventories. Emissions for criteria pollutants, benzene, and 15-PAH are shown in the table.

**Table 10. 2002 and 2005 Oregon Statewide Residential Wood Combustion Emissions Estimates**

SCC	Description	Emissions Estimates, tpy-----			
		CO -----		PM2.5 -----	
		(1)	(2)	(1)	(2)
		2002	2005	2002	2005
21-04-008-001	Fireplaces: General	44,797	27,163	8,259	5,008
21-04-008-002	Insert; non-EPA certified	#	18,312	#	2,426
21-04-008-003	Insert; EPA certified; non-catalytic	#	11,400	#	1,585
21-04-008-004	Insert; EPA certified; catalytic	#	3,604	#	707
21-04-008-010	Woodstoves: General (non-certified)	#	48,012	#	6,360
21-04-008-030	Woodstoves: Catalytic, General (certified)	12,599	4,410	2,462	865
21-04-008-050	Woodstoves: Non-catalytic, General (certified)	53,521	13,950	7,222	1,939
21-04-008-051	Woodstoves: Non-catalytic, Conventional	155,766	#	20,652	#
21-04-008-053	Woodstoves: Non-catalytic, Pellet Fired	607	761	63	79
	<b>Totals</b>	<b>267,289</b>	<b>127,611</b>	<b>38,658</b>	<b>18,969</b>
		(1)	(2)	(1)	(2)
		Emissions Estimates, tpy-----			
		VOC -----		Benzene ---	
		2002	2005	2002	2005
21-04-008-001	Fireplaces: General	80,145	48,596	210	127
21-04-008-002	Insert; non-EPA certified	#	4,202	#	154
21-04-008-003	Insert; EPA certified; non-catalytic	#	970	*	*
21-04-008-004	Insert; EPA certified; catalytic	#	520	#	51
21-04-008-010	Woodstoves: General (non-certified)	#	11,016	#	403
21-04-008-030	Woodstoves: Catalytic, General (certified)	1,810	636	176	62
21-04-008-050	Woodstoves: Non-catalytic, General (certified)	4,561	1,187	380	*
21-04-008-051	Woodstoves: Non-catalytic, Conventional	35,769	#	1,309	#
21-04-008-053	Woodstoves: Non-catalytic, Pellet Fired	*	*	*	*
	<b>Totals</b>	<b>122,286</b>	<b>67,126</b>	<b>2,076</b>	<b>797</b>
		(1)	(2)	(1)	(2)
		Emissions Estimates, tpy-----			
		NOX -----		15-PAH ----	
		2002	2005	2002	2005
21-04-008-001	Fireplaces: General	910	552	*	*
21-04-008-002	Insert; non-EPA certified	#	222	#	21
21-04-008-003	Insert; EPA certified; non-catalytic	*	*	#	9
21-04-008-004	Insert; EPA certified; catalytic	#	69	#	4
21-04-008-010	Woodstoves: General (non-certified)	#	582	#	56
21-04-008-030	Woodstoves: Catalytic, General (certified)	241	85	13	5
21-04-008-050	Woodstoves: Non-catalytic, General (certified)	1,064	*	41	11
21-04-008-051	Woodstoves: Non-catalytic, Conventional	1,890	#	180	#
21-04-008-053	Woodstoves: Non-catalytic, Pellet Fired	213	266	0.004	0.005
	<b>Totals</b>	<b>4,318</b>	<b>1,776</b>	<b>235</b>	<b>104</b>

Notes: # Not inventoried

\* Emission Factor data not available

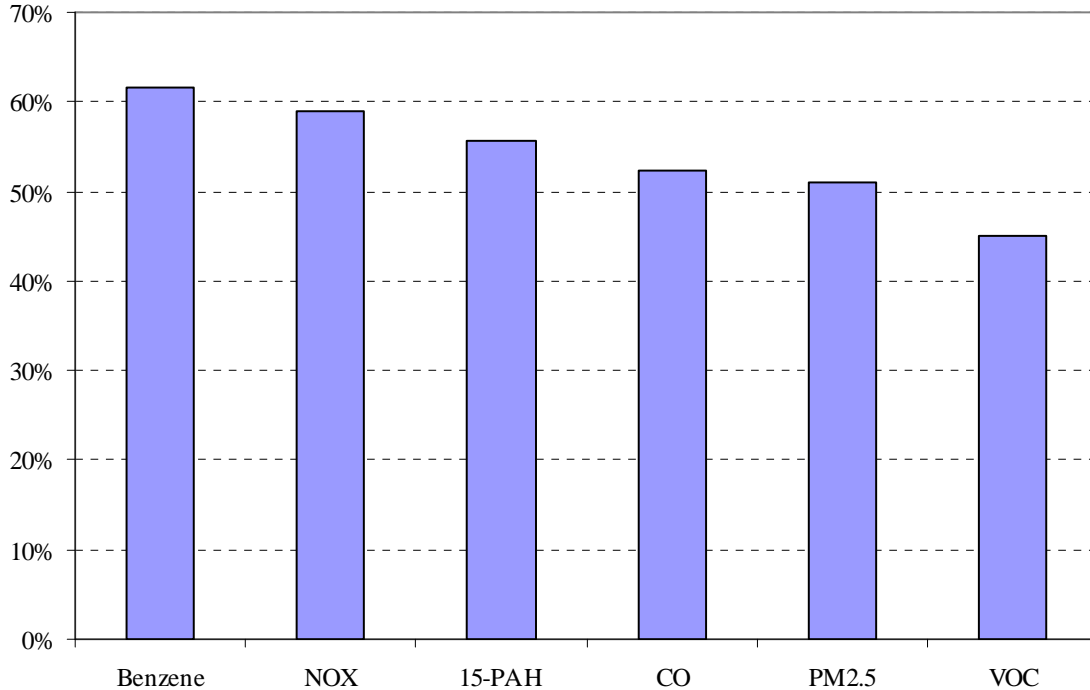
(1) Oregon 2002 NEI submittal. Data is from the DEQ Area Mobile Emissions Estimates (AMEE) database

(2) Emissions estimated as in Equation 2, page 15.



## DISCUSSION and CONCLUSIONS

Figure 7 shows the percent reduction in emissions estimates between the Oregon DEQ 2002 and the 2005 inventories.



**Figure 7.** Percent reduction between the Oregon DEQ 2002 and 2005 RWC emissions estimates.

The reduction in estimated emissions is caused primarily by the decrease in estimated activity from the elimination of wood burning devices in which no fuel was burned. Compared to DEQ 2002 RWC emissions data, the reduction in 2005 emissions estimates resulting from the non-allocation of wood fuel burned to purely aesthetic devices is 37% on average. Although volume wood burned was allocated to survey respondents who indicated wood use but failed to enter the amount burned, the estimated average volume of cordwood burned per device (Table 6) compares favorably to cross-tabbed results from the 1993 survey<sup>8</sup>.

The reduction in estimated emissions is also caused by the correction made to wood species densities. Compared to 2002 DEQ RWC emissions data, the reduction in 2005 emissions estimates resulting from the correction to wood species densities is 13% on average.

The reduction in DEQ estimated RWC statewide emissions between 2002 and 2005 is 50% on average; however, the DEQ estimates are still larger than national averages. The 2005 Oregon estimates are shown compared to the 2002 NEI averages in Table 11.

**Table 11.** 2005 Oregon RWC Emissions Estimates Compared to 2002 National Averages

	----- tpy -----					
	15-PAH	Benzene	PM25-PRI	CO	VOC	NOX
Oregon <sup>(1)</sup>	104	797	18,969	127,611	67,126	1,776
National Avg. <sup>(2)</sup>	72	348	7,236	54,996	26,600	698

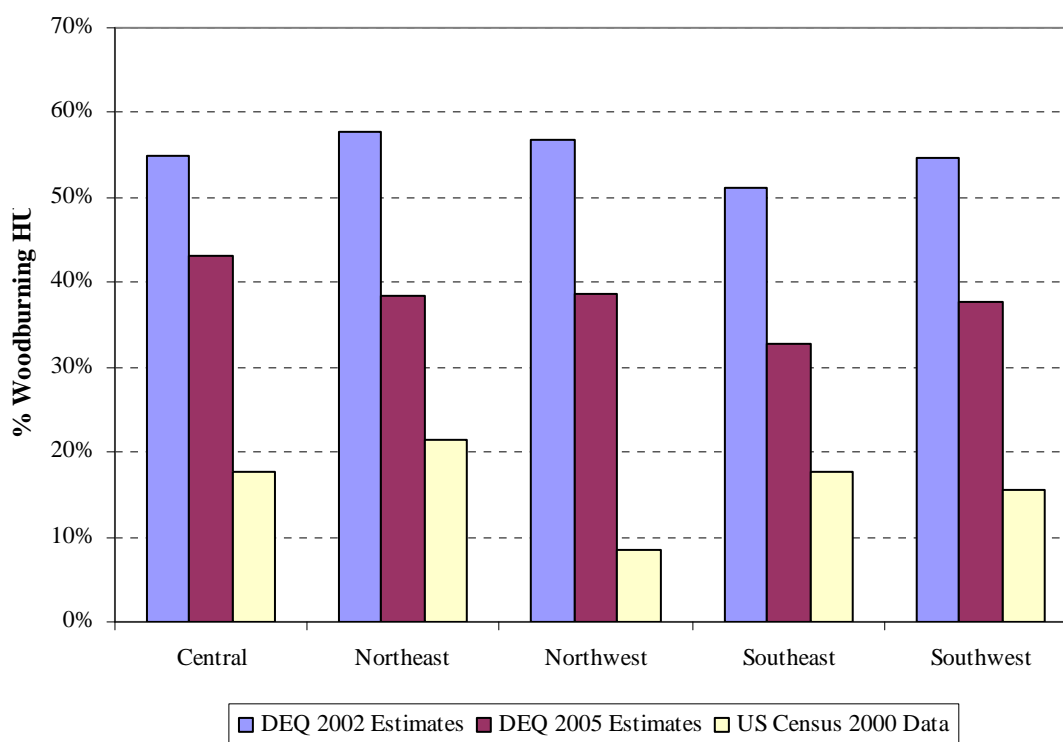
Notes:

(1) From Table 10

(2) [ftp://ftp.epa.gov/EmisInventory/2002finalnei/2002\\_final\\_v3\\_2007\\_summaries/nonpoint/](ftp://ftp.epa.gov/EmisInventory/2002finalnei/2002_final_v3_2007_summaries/nonpoint/)

National Average is for the NEI excluding OR and WA

Figure 8 shows the estimated percent of woodburning HUs in Oregon, given in the 2000 US Census<sup>16</sup> (the latest year available), as compared to recent DEQ estimates. The Census data indicates HUs for which wood is the primary heating fuel, a question not asked in the Tri-State survey.



**Figure 8.** Percent Woodburning HU

DEQ staff have confidence that this re-interpretation of the 2000 Tri-State survey data results in a “clearer snapshot” of RWC emissions. However, new surveys should be conducted for any future RWC emission inventory work. Survey questions concerning if and what type of device is present in the home should be closely linked to questions concerning volume and type of wood burned, and whether or not wood is the primary heating fuel. In addition to volume cordwood burned, subsequent surveys should contain questions regarding species of wood burned.

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## **KEY WORDS**

Emission Inventories  
Nonpoint Sources  
Residential Wood Combustion  
Survey Data  
Emission Factors