

# **Oregon DEQ 2002 Residential Wood Combustion Emissions Inventory**

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## **ABSTRACT**

Oregon woodstove National Emissions Inventory (NEI) estimates have been elevated compared to neighboring states and most other areas of the country. This paper outlines the Oregon Department of Environmental Quality's approach for estimating the 2002 annual residential wood combustion emissions by county; the method detailed here is a refinement of the DEQ NEI submittal, and reflects the most recent changes in EPA emission factor and heating device apportionment data. Two separate statewide surveys, completed in 1993 and 2000, were used to determine wood heating activity. A large component of the methodology consisted of estimating the mass of cord wood burned per housing unit for different areas in Oregon. An additional challenge was in calculating the distribution and number of wood burning device types by housing unit. Wood burning devices for the inventory include conventional, catalytic, pellet, and non-catalytic woodstoves, as well as fireplaces. Emission factors used are from a variety of sources, including AP-42, EIPP, OMNI Environmental Services, and the 2002 NEI documentation. Estimated results show that statewide 2002 residential wood combustion emissions were approximately 44,256 tons PM<sub>2.5</sub>; 216,121 tons VOC; 295,224 tons CO; and 4,513 tons of NO<sub>X</sub>. The inventory does not encompass emissions from manufactured firelog combustion, or from wood-fired hydronic heaters, cook stoves, or masonry heaters.

## **INTRODUCTION**

Residential wood combustion (RWC) emissions have been included in DEQ inventories dated 1990 and later, after research conducted in the 1980s showed that RWC played a significant part in PM<sub>10</sub> emissions. In the mid-1980s, PM<sub>10</sub> exceedances were measured in many Oregon urban areas, including Medford-Ashland, Eugene-Springfield, Klamath Falls, LaGrande, and Grants Pass. The number of exceedances eventually led to violations of NAAQS standards in 1987<sup>1</sup>. Emission inventory analysis identified RWC as a principle contributor of particulate matter emissions, and the EI analysis was verified through Chemical Mass Balance Receptor (CMB) model results. CMB results showed that 58% to 82% of PM<sub>10</sub> mass on exceedance days was contributed by residential wood heating<sup>2</sup>.

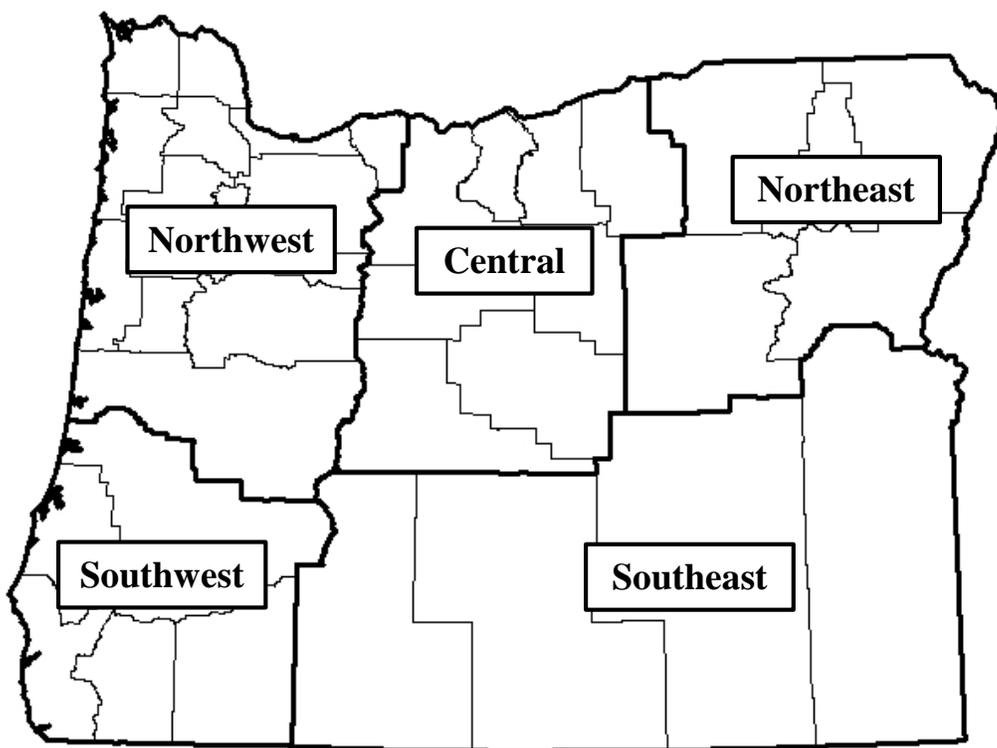
The DEQ RWC emissions inventory methodology was originally developed from guidance outlined in EPA-450/4-91-016<sup>3</sup>. Throughout the 1990s, DEQ EI staff refined the approach in order to achieve a better match to both monitor and CMB modeling results. The methodology is now similar to that shown in the STAPPA-ALAPCO Emission Inventory Improvement Program documents<sup>4</sup>, with changes reflecting the accumulated experience of the DEQ Emissions Inventory Group.

The statewide RWC emission inventory completed by the DEQ for 2002 was submitted as part of EPA's Consolidated Emissions Reporting Rule (CERR) requirements. The 2002 inventory is based on statewide mail and cold-call surveys conducted in 1993<sup>5</sup> and 2000<sup>6</sup>. Survey questions included amount, type, and species of wood burned annually, and heating device type used per household.

Survey data was distributed by weighted average from regional to county level. The effect of this distribution on emissions estimates has not been determined; however the data was treated in this fashion to accommodate the spatial allocation required by the CERR. DEQ staff have confidence in the validity of the method, since both larger cities and rural communities are represented in the average.

### ACTIVITY ESTIMATES

The 2000 survey was divided into five regions, shown in Figure 1 below.



**Figure 1.** RWC 2000 Survey Regions

The 2000 survey questions asked for information regarding four types of wood heating devices: fireplaces, fireplaces with inserts, free standing woodstoves, and pellet stoves. Using EPA 2002 National Emission Inventory (NEI) documentation<sup>7</sup>, insert and free standing woodstove survey results were apportioned to device types that match NEI SCC convention. Table 1 on the following page shows 2000 survey results allocated to heating device type by housing unit and region.

**Table 1. Residential Wood Combustion: 2000 Survey Data Allocated to Device Type by Housing Unit and Region**

(1)	(2)	(3) Northwest			(4) Southwest			(5) Central			(6) Northeast			(7) Southeast		
		SURVEY: Device Ownership	Apportioned	Normalized												
SCC	EPA Est. % of Total															
<b>Fireplace - no Insert</b>																
21-04-008-001	--	<b>29.3%</b>	29.3%	53.7%	<b>13.9%</b>	13.9%	26.4%	<b>15.3%</b>	15.3%	32.7%	<b>14.7%</b>	14.7%	28.6%	<b>15.3%</b>	15.3%	32.8%
<b>Fireplace with Insert</b>																
Total		<b>12.3%</b>			<b>11.9%</b>			<b>10.3%</b>			<b>12.8%</b>			<b>13.0%</b>		
21-04-008-002	92%		11.3%	20.7%		10.9%	20.8%		9.5%	20.2%		11.8%	22.9%		12.0%	25.7%
21-04-008-003	5.7%		0.7%	1.3%		0.7%	1.3%		0.6%	1.3%		0.7%	1.4%		0.7%	1.6%
21-04-008-004	2.3%		0.3%	0.5%		0.3%	0.5%		0.2%	0.5%		0.3%	0.6%		0.3%	0.6%
<b>Free Standing Woodstove</b>																
Total		<b>13.0%</b>			<b>26.8%</b>			<b>21.2%</b>			<b>23.9%</b>			<b>18.3%</b>		
21-04-008-010	92%		12.0%	21.9%		24.7%	46.9%		19.5%	41.7%		22.0%	42.8%		16.8%	36.1%
21-04-008-030	2.3%		0.3%	0.5%		0.6%	1.2%		0.5%	1.0%		0.5%	1.1%		0.4%	0.9%
21-04-008-050	5.7%		0.7%	1.4%		1.5%	2.9%		1.2%	2.6%		1.4%	2.7%		1.0%	2.2%
<b>Cordwood Burning Device Ownership</b>																
		<b>54.6%</b>	54.6%	100.0%	<b>52.6%</b>	52.6%	100.0%	<b>46.8%</b>	46.8%	100.0%	<b>51.4%</b>	51.4%	100.0%	<b>46.6%</b>	46.6%	100.0%
<b>Pellet Stove</b>																
21-04-008-053	--	<b>2.1%</b>	2.1%	100.0%	<b>2.1%</b>	2.1%	100.0%	<b>8.1%</b>	8.1%	100.0%	<b>6.4%</b>	6.4%	100.0%	<b>4.6%</b>	4.6%	100.0%
<b>Total Device Ownership:</b>		<b>56.7%</b>			<b>54.7%</b>			<b>54.9%</b>			<b>57.8%</b>			<b>51.2%</b>		

Notes:

(1) With the exception of 21-04-008-053, SCCs are those used by EPA in the 2002 National Emission Inventory. Descriptions are as follows

21-04-008-001	Fireplaces: General	21-04-008-010	Woodstoves: General (non-certified)
21-04-008-002	Fireplaces: Insert; non-EPA certified	21-04-008-030	Catalytic Woodstoves: General (certified)
21-04-008-003	Fireplaces: Insert; EPA certified; non-catalytic	21-04-008-050	Non-catalytic Woodstoves: General (certified)
21-04-008-004	Fireplaces: Insert; EPA certified; catalytic	21-04-008-053	Non-catalytic Woodstoves: Pellet Fired

(2) EPA Estimated Percent of Total Fireplace with Insert and Free Standing Woodstove is from Reference 7, p. A-152, note 6.

(3) Results are from Reference 6, Question #1A-E, page 13-18.

(4) Fireplace with Insert and Free Standing Woodstove apportioned results = (EPA Estimated Percent of Total) \* (Survey: Device Ownership percentage)

(5) Cordwood Burning Device Normalized Results = (Cordwood Burning Device Apportioned Results) / (Cordwood Burning Device Ownership)

Pellet Stove ownership was not apportioned, and as such normalized to 100%.

As shown in the Table 1 “Total Device Ownership,” between 51% and 58% of households surveyed own a wood heating device. The results, from survey Question 1 A-E, are non-weighted and are based upon 856 completed interviews. Question 1 A-E pertained only to if, and what type, of device was present in the HU, and not to whether wood was burned in the device during the previous year. In addition, survey questions did not ascertain whether or not wood was the primary fuel source for the housing unit.

Annual tons pellets and volume cordwood burned were also taken from 2000 survey results. Two hundred and one respondents reported cords wood burned, shown on Table 2 below. Table 3 on the following page shows survey results for the tons pellets burned annually, from reporting by 27 respondents.

**Table 2. 2000 Survey Data: Cords Wood Burned Annually by Respondant (Housing Unit) and by Region<sup>1</sup>**

Cords	Region:	-----Number of Respondants -----				
		Northwest	Southwest	Central	Northeast	Southeast
1		26	15	11	7	5
2		10	16	10	7	4
3		8	10	13	2	7
4		3	4	2	1	4
5		3	2	2	2	3
6		0	2	1	5	3
7		0	1	0	2	3
8		0	1	1	1	0
9		0	0	0	0	1
10		1	2	0	0	0
Weighted Average # of Cords Used <sup>2</sup> :		2.1	2.8	2.6	3.4	3.8

Notes:

(1) 2000 cord use from Reference 6, frequency listing on p. 47.

(2) Weighted average number of cords used = (total cords used) / (total respondents)

**Table 3. 2000 Survey Data: Tons Pellets Burned Annually by Respondant (Housing Unit) and Region<sup>1</sup>**

40-lb Bags Pellets Burned	(2) (3) ----- Northwest -----		(2) (3) ----- Southwest -----		(2) (3) ----- Central -----		(2) (3) ----- Northeast -----		(2) (3) ----- Southeast -----	
	Number of Survey Respondants	Pellets Burned (tpy)								
1	3	0.1					1	0.02		
2							1	0.04		
5									1	0.1
6									1	0.1
10			1	0.2	1	0.2				
15					1	0.3			1	0.3
25							1	0.5		
35							1	0.7		
40	2	1.6								
50	1	1.0			1	1.0				
80					2	3.2	1	1.6		
100			1	2.0	1	2.0				
120					1	2.4	1	2.4		
125							1	2.5		
200					1	4.0			1	4
<b>Total</b>	6	2.7	2	2.2	8	13.1	7	7.8	4	4.5
<b>Weighted Avg. Use (tons)</b>		0.4		1.1		1.6		1.1		1.1

Notes:

(1) 2000 pellet use from Reference 6, frequency listing on p. 53.

(2) Pellets burned, tpy = (number of survey respondents) \* (40-lb bag pellets burned) \* (40 lbs/bag) / (2000 lbs/ton)

(3) Weighted average tons pellets used = (tpy pellets burned) / (total respondents)

The 2000 survey did not include questions regarding the type of wood burned, only the number of cords of wood burned. As such, the volume of cordwood shown in Table 2 was converted to tons cordwood burned by using 1993 survey results. 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>8</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 (AP-42, Appendix A<sup>9</sup>). Table 4a shows the survey results for type of wood burned by city and region. Table 4b on the following page shows estimated results for the typical cord mass, also by city and region.

**Table 4a. 1993 Oregon Woodheating Survey Results: Type of Wood Burned by City<sup>1</sup>**

Region and City	Fir	Pine	Oak	Maple	Cedar	Madrone / Tamarack	Mill 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) Type wood burned from Reference 5, 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 in tons
	Fir	Pine	Oak	Maple	Cedar	Madrone / Tamarack	Mill Scraps	
<i>Northwest</i>								
Portland	0.89	0.11	0.28	0.16	0.10	0.01	0.26	1.81
							Average	1.81
<i>Southwest</i>								
Grants Pass	0.24	0.09	0.50	0.001	0.01	0.92	0.10	1.86
Medford	0.57	0.13	0.22	0.01	0.02	0.75	0.16	1.86
Roseburg	0.37	0.03	0.28	0.01	0.35	0.69	0.03	1.77
							Average	1.83
<i>Central</i>								
Bend	0.02	1.76	0.00	0.0004	0.001	0.003	0.02	1.80
Prineville	0.44	0.85	0.00	0.001	0.004	0.50	0.05	1.84
Sisters	0.14	1.53	0.01	0.003	0.01	0.09	0.02	1.81
							Average	1.82
<i>Northeast</i>								
Lagrande	0.40	0.51	0.002	0.01	0.002	0.92	0.02	1.87
Pendleton	0.43	0.61	0.001	0.005	0.001	0.79	0.03	1.86
							Average	1.86
<i>Southeast</i>								
Klamath Falls	0.16	1.52	0.02	0.002	0.04	0.01	0.03	1.79
Lakeview	0.35	1.35	0.004	0.001	0.06	0.002	0.03	1.79
							Average	1.79

Notes:

- (1) Tons per cord is calculated from species distribution shown in Table 4a, cord volume given p. 21 of Reference 8, and air-dried species wood density given in Appendix A, p. A-5 of Reference 9.
- (2) Typical cord mass in tons = sum (tons per cord)
- (3) Average typical cord mass in tons = average of the summed tons per cord.

To adjust wood heating activity from survey year of 2000 to the CERR base year of 2002, 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 5 on the following page. HDD data was taken from Climatological Data for Oregon<sup>10</sup>.

**Table 5. County Heating Degree Days (HDD) and HDD Ratio**

Region and County	----- Avg. # HDD -----		Ratio 2002/2000
	Inventory Year 2002	Survey Year 2000	
<i>Central</i>			
Deschutes	6,445	6,565	0.98
Crook	6,941	6,023	1.15
Gilliam	5,371	5,701	0.94
Jefferson	5,458	5,705	0.96
Morrow	5,092	5,373	0.95
Sherman	5,961	6,357	0.94
Wasco	3,753	4,087	0.92
Wheeler	5,866	4,519	1.30
<i>NorthEast</i>			
Baker	4,690	5,811	0.81
Grant	5,991	5,688	1.05
Umatilla	4,166	5,412	0.77
Union	5,834	5,853	1.00
Wallowa	7,404	6,983	1.06
<i>NorthWest</i>			
Benton	4,781	5,001	0.96
Clackamas	5,013	5,429	0.92
Clatsop	4,676	4,877	0.96
Columbia	4,797	5,439	0.88
Hood River	5,283	5,657	0.93
Lane	4,484	4,832	0.93
Lincoln	4,928	4,894	1.01
Linn	5,031	5,340	0.94
Marion	4,951	5,032	0.98
Multnomah	4,259	4,297	0.99
Polk	4,400	4,551	0.97
Tillamook	5,055	4,981	1.01
Washington	4,099	3,969	1.03
Yamhill	4,442	3,851	1.15
<i>SouthEast</i>			
Harney	6,662	6,024	1.11
Klamath	7,730	7,082	1.09
Lake	5,700	5,872	0.97
Malheur	5,570	5,576	1.00
<i>SouthWest</i>			
Coos	4,451	4,209	1.06
Curry	3,720	3,890	0.96
Douglas	4,506	4,505	1.00
Jackson	5,091	5,211	0.98
Josephine	4,574	4,889	0.94

*Heating Degree Day data is from Reference 10.*

The previous data was incorporated in the following equations to estimate RWC fuel burned on a county-wide basis:

Equation (1)      Tons Cordwood Burned by County = (a) \* (b) \* (c) \* (d) \* (e)

where

a = County 2002 Housing Units (HU), US Census Bureau data<sup>11</sup>  
b = Regional % Cordwood Burning Device Ownership, from Table 1  
c = Regional Weighted Avg. Cords Wood Burned by HU, from Table 2  
d = Regional Average Typical Cord Mass in tons per cord, from Table 4b  
e = County 2002/2000 HDD ratio, from Table 5

Equation (2)      Tons Pellets Burned by County = (a) \* (f) \* (g) \* (h)

where

a = County 2002 HU; US Census Bureau data<sup>11</sup>  
f = Regional % Survey Device Ownership: Pellet Stoves, from Table 1  
g = Regional Weighted Avg. Pellet Use by HU in tons, from Table 3  
h = County 2002/2000 HDD ratio, from Table 5

Table 6 on page 10 details RWC activity estimates by county. The equations used in Table 6 are (1) and (2) above; the notation on the table matches the parameter notation of the equations.

County activity estimates are summed by region and allotted to heating device type in Table 7, found on page 11. The equation used is:

Equation (3)      Tons Fuel Burned by Region and Device = (a) \* (b)

where

a = Survey Device Ownership, Apportioned to Device Type and Normalized, from Table 1  
b = County Fuel Use, Summed by Region, from Table 6

**Table 6. Residential Wood Combustion Activity Estimates by County**

Region and County	(a)	----- CordWood Activity -----				----- Pellet Activity -----		
	2002 HU	Wood Burning HU	2000 Wood Burned (cords)	2000 Wood Burned (tons)	2002 HDD	2000 Pellet Burning HU	2000 Pellets Burned (tons)	2002 HDD
					Adjust. Wood Burned (tons)			Adjust. Pellets Burned (tons)
<i>Central</i>								
Deschutes	59,339	27,771	70,815	128,542	126,198	4,806	7,871	7,727
Crook	8,741	4,091	10,432	18,935	21,821	708	1,159	1,336
Gilliam	1,039	486	1,240	2,251	2,121	84	138	130
Jefferson	8,771	4,105	10,467	19,000	18,179	710	1,163	1,113
Morrow	4,356	2,039	5,198	9,436	8,943	353	578	548
Sherman	939	439	1,121	2,034	1,907	76	125	117
Wasco	10,706	5,010	12,777	23,192	21,296	867	1,420	1,304
Wheeler	843	395	1,006	1,826	2,370	68	112	145
<i>Northeast</i>								
Baker	8,506	4,372	15,059	28,047	22,635	544	603	487
Grant	4,104	2,109	7,266	13,532	14,253	263	291	307
Umatilla	28,188	14,489	49,905	92,946	71,558	1,804	2,000	1,540
Union	10,648	5,473	18,852	35,110	34,997	681	755	753
Wallowa	3,950	2,030	6,993	13,025	13,810	253	280	297
<i>Northwest</i>								
Benton	33,179	18,116	38,008	68,663	65,649	697	309	295
Clackamas	141,726	77,382	162,351	293,297	270,816	2,976	1,319	1,218
Clatsop	19,850	10,838	22,739	41,079	39,380	417	185	177
Columbia	18,194	9,934	20,842	37,652	33,210	382	169	149
Hood River	8,045	4,393	9,216	16,649	15,550	169	75	70
Lane	141,963	77,512	162,623	293,788	272,617	2,981	1,322	1,226
Lincoln	27,364	14,941	31,346	56,629	57,017	575	255	257
Linn	43,601	23,806	49,946	90,231	84,996	916	406	382
Marion	111,220	60,726	127,406	230,166	226,497	2,336	1,035	1,019
Multnomah	292,696	159,812	335,292	605,725	600,368	6,147	2,725	2,701
Polk	25,193	13,755	28,859	52,136	50,406	529	235	227
Tillamook	16,294	8,897	18,665	33,720	34,224	342	152	154
Washington	187,513	102,382	214,802	388,052	400,761	3,938	1,746	1,803
Yamhill	31,773	17,348	36,397	65,753	75,844	667	296	341
<i>Southeast</i>								
Harney	3,554	1,656	6,238	11,191	12,375	163	185	204
Klamath	29,264	13,637	51,366	92,145	100,572	1,346	1,521	1,660
Lake	4,048	1,886	7,105	12,746	12,373	186	210	204
Malheur	11,351	5,290	19,924	35,741	35,702	522	590	589
<i>Southwest</i>								
Coos	29,429	15,480	43,810	80,114	84,715	618	680	719
Curry	11,721	6,165	17,449	31,908	30,515	246	271	259
Douglas	44,229	23,264	65,843	120,404	120,431	929	1,022	1,022
Jackson	79,009	41,559	117,619	215,085	210,146	1,659	1,825	1,783
Josephine	34,236	18,008	50,966	93,200	87,195	719	791	740
<b>Totals</b>	<b>1,495,582</b>	<b>799,596</b>	<b>1,849,943</b>	<b>3,353,950</b>	<b>3,281,448</b>	<b>40,679</b>	<b>33,818</b>	<b>33,004</b>

Notation used is from equations (1) and (2).

**Table 7. 2002 Estimated Fuel Burned by Region and Woodheating Device<sup>1</sup>**

SCC	Description	----- Fuel Burned, tons -----					Totals
		Central	Northeast	Northwest	Southeast	Southwest	
21-04-008-001	Fireplaces: General	66,312	44,973	1,195,255	52,868	140,850	<b>1,500,258</b>
21-04-008-002	Fireplaces: Insert; non-EPA certified	41,070	36,027	461,621	41,327	110,937	<b>690,983</b>
21-04-008-003	Fireplaces: Insert; EPA certified; non-catalytic	2,545	2,232	28,600	2,560	6,873	<b>42,811</b>
21-04-008-004	Fireplaces: Insert; EPA certified; catalytic	1,027	901	11,541	1,033	2,773	<b>17,275</b>
21-04-008-010	Woodstoves: General (non-certified)	84,532	67,270	487,893	58,175	249,842	<b>947,712</b>
21-04-008-030	Catalytic Woodstoves: General (certified)	2,113	1,682	12,197	1,454	6,246	<b>23,693</b>
21-04-008-050	Non-catalytic Woodstoves: General (certified)	5,237	4,168	30,228	3,604	15,479	<b>58,717</b>
	<b>Cordwood Total</b>	<b>202,836</b>	<b>157,253</b>	<b>2,227,336</b>	<b>161,022</b>	<b>533,002</b>	<b>3,281,448</b>
21-04-008-053	Non-catalytic Woodstoves: Pellet Fired	12,420	3,384	10,020	2,658	4,523	<b>33,004</b>
	<b>Pellet Total</b>	<b>12,420</b>	<b>3,384</b>	<b>10,020</b>	<b>2,658</b>	<b>4,523</b>	<b>33,004</b>

Notes:

(1) Fuel burned, tpy =

(Survey Device Ownership, Apportioned to Device Type and Normalized, from Table 1) \* (HDD Adjusted Wood or Pellets burned from Table 6)

## **EMISSION FACTORS**

Emission factors (EFs) are in 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>7</sup>. Research into EFs for pellet stoves resulted in data from three sources; AP-42<sup>9</sup>, EIIP<sup>4</sup>, and papers presented by OMNI Environmental Services<sup>12</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 on Tables 8a and 8b on pages 13 and 14. All EF data researched was specific to device, and not fuel type. Dioxin/furan EFs for pellet stoves was not found.

**Table 8a. Residential Wood Combustion Emission Factors: Criteria and Air Toxic Pollutants**

CAS	Pollutant	(1)				(2)
		----- EF, lbs pollutant per ton fuel combusted -----				
		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		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 7, Appendix A, pp. A-154 through A-161.

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

Carbon Monoxide & Primary PM10 total: Reference 4, p. 2.4-5, Table 2.4-1, Certified Pellet Stoves  
 Nitrogen Oxides & Sulfur Dioxide: Reference 9, Table 1.10-1  
 Primary PM2.5 total: Reference 12, pp. 16 (Emission Units) and  
 17 (Comments on AP-42 Efs).  
 All Others: Reference 4, p. 2.4-7, Table 2.4-3, Exempt Pellet Stoves

**Table 8b. 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 7, 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 AND DISCUSSION

Emissions estimates are calculated using the following equation:

$$\text{Equation (4) RWC Emissions} = (\text{Tons Fuel Burned}) * (\text{EF})$$

where

Tons Fuel Burned	= tons fuel burned by device and region, from Table 7
EF	= pollutant and device specific emission factor, lbs pollutant per ton fuel burned, from Tables 8a and 8b

Emissions estimates on a statewide basis are shown in Table 9 on page 15. Emissions were calculated using Equation (4) above, results were then divided by 2,000 lbs/ton to obtain estimates in tons for all results except dioxin/furan. Units for dioxin/furan emissions estimates are lbs.

**Table 9. 2002 Oregon Statewide Residential Wood Combustion Emissions Estimates**

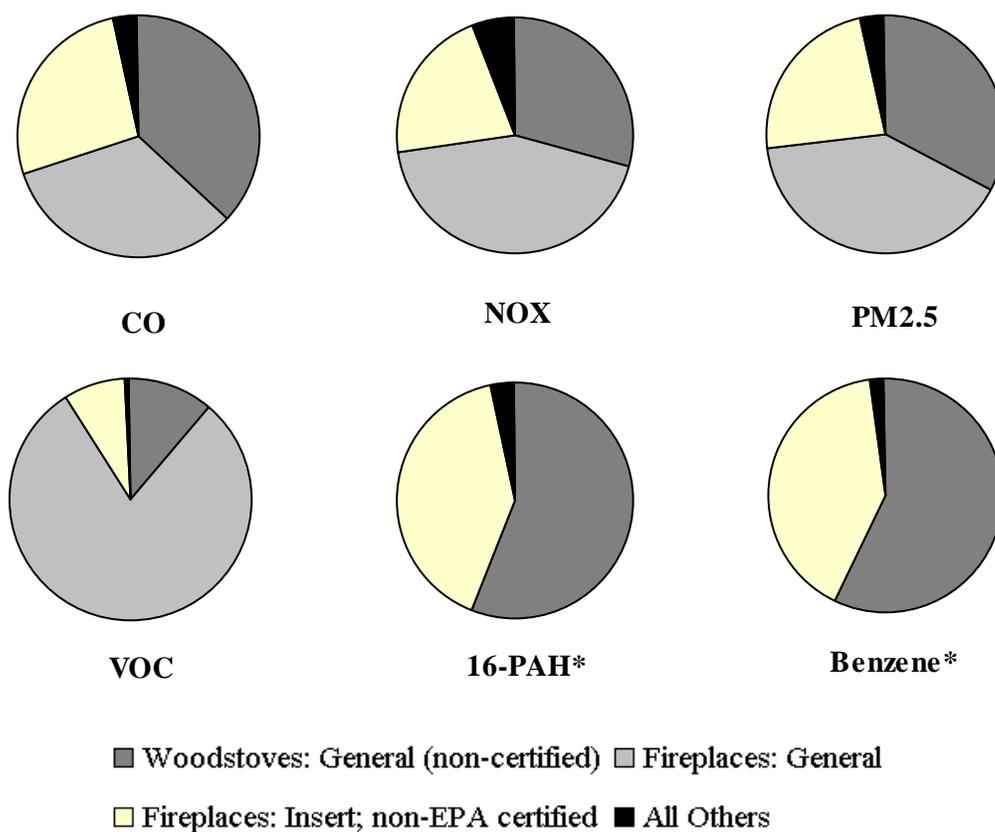
		----- Emissions Estimates -----			
SCC	Description	CO (tons)	NOX (tons)	PM2.5 (tons)	VOC (tons)
21-04-008-001	Fireplaces: General	96,017	1,950	17,703	171,780
21-04-008-002	Fireplaces: Insert; non-EPA certified	79,809	967	10,572	18,311
21-04-008-003	Fireplaces: Insert; EPA certified; non-catalytic	3,018	*	420	257
21-04-008-004	Fireplaces: Insert; EPA certified; catalytic	898	17	176	130
21-04-008-010	Woodstoves: General (non-certified)	109,461	1,327	14,500	25,114
21-04-008-030	Catalytic Woodstoves: General (certified)	1,232	24	242	178
21-04-008-050	Non-catalytic Woodstoves: General (certified)	4,140	*	575	352
21-04-008-053	Non-catalytic Woodstoves: Pellet Fired	650	228	68	*
<b>Totals</b>		<b>295,224</b>	<b>4,513</b>	<b>44,256</b>	<b>216,121</b>

		----- Emissions Estimates -----			
SCC	Description	16-PAH (tons)	Benzene (tons)	Dioxin/ Furan (lbs)	Other HAPs (tons)
21-04-008-001	Fireplaces: General	*	*	5.E-07	*
21-04-008-002	Fireplaces: Insert; non-EPA certified	154	670	4.E-04	425
21-04-008-003	Fireplaces: Insert; EPA certified; non-catalytic	4	*	3.E-05	0.5
21-04-008-004	Fireplaces: Insert; EPA certified; catalytic	2	13	1.E-05	7
21-04-008-010	Woodstoves: General (non-certified)	211	919	6.E-04	583
21-04-008-030	Catalytic Woodstoves: General (certified)	2	17	1.E-05	9
21-04-008-050	Non-catalytic Woodstoves: General (certified)	5	*	4.E-05	0.7
21-04-008-053	Non-catalytic Woodstoves: Pellet Fired	0.004	*	*	*
<b>Totals</b>		<b>378</b>	<b>1,619</b>	<b>0.001</b>	<b>1,025</b>

\* Emission Factor data not available

The majority of estimated Oregon RWC emissions come from three categories; non-certified woodstoves, non-certified fireplace inserts, and fireplaces. These three source categories contribute 98% of the estimated emissions for all pollutants. Figure 2 on page 16 shows statewide emissions estimates by device type.



**Figure 2.** 2002 OR Statewide Residential Wood Combustion Emissions Estimates By Device Type.  
 \* Emission factor data not available for "Fireplaces: General"

Wood burning EFs, activity, and device apportionment were examined in an effort to better ascertain the cause of the large contribution to total RWC emissions made by fireplaces, non-certified inserts, and non-certified woodstoves (as shown in Figure 2 above). Table 10 on page 17 shows calculations for the approximate contributions toward device type, activity, and emission factors made by the three categories.

**Table 10. Approximate Contributions Made by Fireplaces (general), Non-Certified Inserts, and Non-Certified Woodstoves in the Oregon RWC Emission Inventory.**

<u>Statewide Average Device Apportionment<sup>1</sup></u>	
(Fireplaces, general) + (Inserts, non-cert.) + (Woodstoves, non-cert.) =	48%
device apportionment percentages summed for all other categories =	7%
	-----
(Fireplaces, general) + (Inserts, non-cert.) + (Woodstoves, non-cert.) =	87% of all RWC devices
<hr/>	
<u>Activity in Total Annual Tons Fuel Burned<sup>2</sup></u>	
(Fireplaces, general) + (Inserts, non-cert.) + (Woodstoves, non-cert.) =	3,138,953 tons fuel
fuel tpy summed for all other categories =	175,500 tons fuel
	-----
(Fireplaces, general) + (Inserts, non-cert.) + (Woodstoves, non-cert.) =	95% annual RWC activity
<hr/>	
<u>Criteria Pollutant Emission Factors Summed<sup>3</sup></u>	
(Fireplaces, general) + (Inserts, non-cert.) + (Woodstoves, non-cert.) =	1,104 lbs/ton fuel combusted
criteria pollutant EFs summed for all other categories =	772 lbs/ton fuel combusted
	-----
(Fireplaces, general) + (Inserts, non-cert.) + (Woodstoves, non-cert.) =	59% of total lbs/ton fuel combusted

Notes:

- (1) Averaged from regional data in Table 1
- (2) From Table 7
- (3) From Table 8a

From Table 10, it appears that a combination of the total fuel burned and the apportioned device type is the primary cause of the large percentage contributed by fireplaces, non-certified woodstoves, and non-certified inserts to Oregon's total RWC emissions. The following section contains recommendations for addressing the separate issue of Oregon's elevated RWC emissions.

## CONCLUSIONS AND RECOMMENDATIONS

Residential wood combustion emissions in Oregon are elevated compared to neighboring states and most other areas of the country. For this paper and for the NEI submittal, DEQ staff have estimated that the percent of households burning wood is equal to the percent of homes that own a wood heating device. As a result, emissions estimates may be too high. Table 11 on the following page details three options for determining the percent of occupied housing units in Oregon that burn wood. One of the options shown on Table 11 is a revised estimate using only those 2000 survey respondents who reported the amount of wood burned, either in cords wood or bags pellets. The authors of this paper feel that this option may provide the best assessment of the percent of households in Oregon that burn wood, either as a primary heating fuel or for recreational purposes.

**Table 11. Options for Estimating the Percent WoodBurning Housing Units in Oregon**

	Central	Northeast	Northwest	Southeast	Southwest
DEQ Current Estimates <sup>1</sup>	54.9%	57.8%	56.7%	51.2%	54.7%
Revised Estimates <sup>2</sup>	35.0%	31.2%	20.0%	26.0%	28.4%
US Census 2000 Oregon Data <sup>3</sup>	17.8%	21.5%	8.5%	17.7%	15.5%

Notes:

- (1) From Table 1: Total Device Ownership
- (2) Percentage equals only those respondents reporting volume cordwood or tons pellets burned in the 2000 survey (Reference 6, frequency listings on pages 11, 47, and 53)
- (3) US Census Bureau, 2000 data, H40 House Heating Fuel (Reference 13)

A combination of the apportioned device type and total fuel burned appears to be the primary cause of the large percentage contributed by fireplaces, non-certified woodstoves, and non-certified inserts to the total RWC emissions in Oregon.

Gaps in EF data indicate that further research is needed to develop benzene and 16-PAH EFs for fireplaces, and NOX EFs for certified non-catalytic woodstoves/inserts. For the pellet stove category, EFs for both exempt and certified pellet stoves were used due to lack of data. As such, further research is also needed to develop pellet stove EFs, including VOC.

Future inventories should include activity in the form of manufactured firelogs, and emissions estimates from hydronic wood heating systems (wood furnaces).

New surveys should be conducted for any future RWC emission inventory work. The allocation of certified and non-certified stoves shown in Table 1 is based on EPA data, which may not be representative of Oregon. Oregon led the nation in device certification; all new stoves sold have been certified since 1986, and the sale of non-certified used stoves/inserts has been banned since 1991. However, the last statewide Oregon survey containing questions regarding heating device certification was conducted in 1993. In addition to volume cordwood burned, subsequent surveys should contain questions regarding species of wood burned. If National Emissions Inventory SCC convention is used, it may not be necessary to ask questions discerning between inserts and free-standing woodstoves. Survey questions concerning if and what type of device is present in the home should be linked to questions concerning volume and type of wood burned, and whether or not wood is the primary heating fuel.

Due to growing energy prices, wood heating activity is increasing throughout Oregon,<sup>14,15</sup>. The demand for wood fuel and wood heating devices is escalating as heating costs make wood a more attractive option for homeowners<sup>15</sup>. In light of mounting energy costs, it is anticipated that the need for accurate RWC emission inventories will only increase in the future.

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