Residential Wood Combustion Emission Inventory
South Coast Air Basin and Coachella Valley Portion of Salton Sea Air Basin
2002 Base Year

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ABSTRACT

Residential wood combustion (RWC) particulate emission inventories were prepared for the South Coast Air Basin (SCAB) and the Coachella Valley portion of the Salton Sea Air Basin (SSAB) of California. Both the number of wood-burning appliances that were used and the number that were owned were estimated by category for the 2002 base year.

American Housing Survey current housing reports for the Anaheim – Santa Ana, Riverside – San Bernardino – Ontario, and Los Angeles – Long Beach metropolitan areas were a key source of data. Other surveys conducted in the state of California, nationwide surveys, data from firewood vendors, and hearth industry records supplied supplemental data.

The wood-burning categories were: (1) conventional pre-EPA certification cordwood heaters, (2) EPA certified catalytic cordwood heaters, (3) EPA certified non-catalytic cordwood heaters, (4) pellet heaters, and (5) cordwood fireplaces without inserts. The term "heater" includes both freestanding units and fireplace inserts. The relative contribution of manufactured wax/fiber firelogs and cordwood used in fireplaces was also assessed. The average amount of fuel (cordwood, pellets, or wax/fiber firelogs) burned in each category of appliance was estimated from previous surveys conducted in California. Updated particulate emission factors (mass particulate emissions/mass dry fuel burned) were obtained from recent literature reviews and testing reports and were in turn applied to each category of appliance to produce the overall particulate emission inventories.

INTRODUCTION

OMNI Environmental Services, Inc. (OMNI) under contract with the Hearth, Patio and Barbecue Association (HPBA) prepared residential wood combustion (RWC) emission inventories, separately, for the South Coast Air Basin (SCAB) and the Coachella Valley portion of the Salton Sea Air Basin (SSAB) of California. The work was conducted on behalf of the South Coast Air Quality Management District (SCAQMD). Under instructions from the SCAQMD, the emission inventories were compiled for the 2002 base year.

BASIN APPORTIONMENT BY COUNTY

RWC appliance ownership data have historically been compiled on a county-by-county basis or for specific metropolitan areas. The SCAQMD jurisdiction includes all of Orange (OR) County but only portions of Los Angeles (LA), Riverside (RV) and San Bernardino (SB) counties. Further, SCAQMD has requested separate RWC emission inventories for the SCAB and the Coachella Valley portion of the SSAB that are under its jurisdiction. Table 1 shows the total population of counties in the SCAB and SSAB and the fraction of the population of the counties in the respective air basins. Table 2 shows the number of households in the air basins.

Table 1. 2002 population in the South Coast Air Basin (SCAB) and Salton Sea Air Basin (SSAB).

Population	County			
	LA	OR	RV	SB
Total Population	9,871,506	2,956,992	1,683,880	1,858,678
SCAB Population	9,572,437	2,956,992	1,294,381	1,413,868
SSAB Population	0	0	345,934	0
Fraction of Population in SCAB	0.9697	1.00000	0.7687	0.7607
Fraction of Population in SSAB (Coachella Valley)	0	0	0.2054	0
Fraction of Population outside SCAQMD	0.0303	0	0.0261	0.2393

Table 2. 2002 households in the South Coast Air Basin (SCAB) and Salton Sea Air Basin (SSAB).

Households	County			
	LA	OR	RV	SB
Households in SCAB	3,064,417	956,485	410,113	415,713
Households in SSAB (Coachella Valley)	0	0	125,042	0

NUMBERS OF WOODSTOVES, WOOD-BURNING FIREPLACE INSERTS AND WOOD-BURNING FIREPLACES WITHOUT INSERTS

The American Housing Survey (AHS) has conducted surveys specifically in the time frame applicable to the 2002 base year in the SCAB and SSAB and provides useful data for the development of a RWC emission inventory. Surveys have been conducted for: (1) the Anaheim-Santa Ana metropolitan area (all of Orange County), (2) the Riverside-San Bernardino-Ontario metropolitan area (all of Riverside County plus all of San Bernardino County), and (3) the Los Angeles-Long Beach metropolitan area (all of Los Angeles County)[1-4]. Tables 3 and 4 summarize key data taken from these surveys. There are no 2002 AHS data for the Los Angeles-Long Beach Metropolitan area. The 2002 estimate was calculated by linearly interpolating between the 1999 and 2003 data.

Table 3. Number of occupied units with stoves, fireplaces with inserts, and fireplaces without inserts used as main heating equipment and as other heating equipment in the Los Angeles area.

Metropolitan Area, Year	Main Heating Equipment			Other Heating Equipment		
	Stove	Fireplace with Insert	Fireplace w/o Insert	Stove	Fireplace with Insert	Fireplace w/o Insert
Anaheim-Santa Ana, 2002	<50	<50	800	2400	32,100	54,100
Riverside-San Bernardino-Ontario, 2002	6500	1800	3700	18,200	65,300	84,400
Los Angeles-Long Beach, 1999	1000	4200	2200	28,400	81,500	184,200
Los Angeles- Long Beach, 2003	900	6400	2300	13,900	68,500	170,900
Los Angeles-Long Beach, 2002	925	5850	2275	17,525	71,750	174,225

Table 3 notes:
AHS definitions of terms: *Other Heating Equipment* is the sum of *Parallel Heating Equipment* which is defined as, "This is additional heating equipment for an area not heated by the main heating equipment." and *Supplemental Heating Equipment* which is defined as "Additional heating equipment for a heated area of the housing unit." *Fireplaces with inserts* have a fan-forced air circulation system to force the heat into the room. *Fireplaces without inserts* refers to glass door fire screens or fire backs inserted in the back of the fireplace to passively reflect heat. *Stove* refers to any range or stove that burns solid fuel including wood burning, pot belly, and Franklin stoves.

Table 4. Total occupied units using stoves, using fireplaces with inserts, and using fireplaces without inserts as heating equipment; total occupied units with wood as a fuel; and total occupied units having a usable fireplace in the Los Angeles area.

Metropolitan Area, Year	Heating Equipment (Sum of "Main" and "Other" Heating Equipment in Table 3			Sum of Three Heating Equipment Categories	Wood as a Heating Fuel	Usable Fireplace
	Stove	Fireplace with Insert	Fireplace w/o Insert			
Anaheim-Santa Ana, 2002	2450	32,150	54,900	89,500	42,800	531,600
Riverside-San Bernardino- Ontario, 2002	24,700	67,100	88,100	179,900	138,400	572,800
Los Angeles-Long Beach, 1999	29,400	85,700	186,400	301,500	172,700	1,121,300
Los Angeles- Long Beach, 2003	14,800	74,900	173,200	262,900	149,200	1,121,500
Los Angeles-Long Beach, 2002	18,450	77,600	176,500	272,550	155,075	1,121,450

Table 4 notes:
AHS Definitions of Term: Usable fireplace. Excludes the following: fireplaces that have been blocked off or whose chimney or flue has been filled, decorative or artificial fireplaces and wood stoves, even if shaped like a fireplace, like a Franklin stove. Free-standing fireplaces are included in this item.

Because besides cordwood (1) the AHS stove category includes other solid fuels (coal, coke, and wood pellets), (2) the AHS fireplace with inserts category includes pellets, piped gas and bottled gas fuels, and (3) the AHS fireplace without insert category includes piped gas and bottled gas fuels, an adjustment in the AHS numbers by appliance category is required to account for these fuels and to derive the cordwood- and wood

pellet-fueled appliance numbers separately. The fact that the sum of all occupied housing units using stoves, fireplaces with inserts and the fireplaces without inserts for heating exceeds the number of occupied housing units that use wood for heating shown in Table 4 illustrates the significant use of other fuels (notably, gas) in these appliances.

Several minor points also need to be noted in developing an estimate of the number of wood-burning appliances. (1) For 2002, the number of total occupied units for the South Coast counties listed in AHS documents differ slightly from the number of households numbers provided by the SCAQMD Emission Inventory Group. The differences are small on a relative basis and should not substantially effect the development of the RWC emission inventory. (2) The AHS definitions of "fireplaces with inserts" and "fireplaces without inserts" provided in the definitions appendix of the AHS reports[1-6] (shown as Table 3 notes here) are not consistent with normal use of these terms nor are they representative of the actual AHS interview questions.[7] Fortunately, upon review of the questionnaire, it is the author's opinion that the results of typical interviewee's response to the AHS questionnaire provides "fireplaces with insert" and "fireplace without insert" numbers reasonably close for the two appliance categories if the definitions generally understood in the hearth industry were applied. (3) It needs to be emphasized that the number of fireplaces used for heating purposes is much smaller than the total number of fireplaces actually used as many fireplaces are used for "aesthetic" purposes. The AHS questionnaire specifically asks, "Do you consider [your] fireplace to be heating equipment?" Fireplaces used for aesthetics are typically used less frequently. (4) Because surveys have shown that many fireplace users use both manufactured wax/firelogs and cordwood, the contribution of wax/firelog and cordwood have been separated for this study. The importance of wax/fiber firelogs is illustrated in a 1994/1995 survey that showed that 30% of fireplace users, used both manufactured wax/fiber firelogs and cordwood and 12% used wax/fiber firelogs exclusively[8]. (5) In contrast, because the sale and use of densified manufactured fuels (not to be confused with wax/fiber manufactured fuels) is very small as compared to the use of cordwood, particularly outside the Pacific Northwest[9], and their characteristic emission factors were determined to be only slightly lower than cordwood[10,11], their usage will not be separated from cordwood as it will have an insignificant effect. Additionally, detailed records for their use in the southern California do not exist. (6) The number of masonry heaters (not to be confused with masonry fireplaces) is very small in the SCAB or SSAB and their contribution to RWC there is insignificant. It has been estimated that there were 11,262 masonry heaters in North America with only 955 of them in the entire southwestern portion of the U.S. in 2002[12]. (7) Similarly, wood-fired centralized heaters (forced air furnaces, indoor boilers and outdoor boilers –sometimes referred to as hydronic heaters) will not contribute significantly to the RWC emission inventory in the SCAB or SSAB. Their use is associated with rural, forested, cold climates. The number in use would be extremely small in the SCAB or SSAB and while on a case-by-case basis their air quality impact may be observable, their contribution to the RWC emission inventory as a category is insignificant. (8) Wood-fired cook stoves have sometimes been used as a heating appliance. A review of the AHS surveys covering the SCAB and SSAB areas revealed that the use of wood as a cooking fuel was so small as to be below the ability to quantify with the surveys. (9) As previously noted, the term "stove" as used in the AHS includes stoves fueled by coal and coke. The ratio of occupied units reporting using wood as a fuel as compared to the sum of coal and coke was 728 to 1 in all of Los Angeles, Orange, Riverside, and San Bernardino counties. A correction in stove numbers for coal or coke use is unnecessary.

Using the data compiled in Tables 3 and 4 as a starting point, estimates have been made of the number of (1) freestanding stoves that burn cordwood, (2) freestanding stoves that burn wood pellets, (3) fireplaces with inserts that burn cordwood (4) fireplaces with inserts that burn pellets (5) fireplaces without inserts that burn cordwood and are used for heating purposes, and (6) fireplaces without inserts that burn cordwood (including wax fiber firelogs) that are used for aesthetic purposes. (The terms fireplaces with inserts and fireplace inserts are used interchangeably.) Finally, making the necessary assumption that per capita ownership does not change

significantly within each of the four counties, the appliance numbers for the four categories have further been proportion based on population into the SCAB and SSAB boundaries.

Due to the fact that some homes have more than one woodburning appliance, multiple ownership needs to be taken into consideration in the calculation of total number of appliances used (Tables 5 and 6)

Table 5. Multiple ownership factors.

Area,Year,Reference	Stove	Fireplace Insert	Fireplace w/o Insert
California, 2002, Reference 13	1.1	1.1	1.1
West/Mountain, 2004, Reference 14	1.1	-	1.1
U.S.,1988, Reference 15	1.1	1.1	1.2
Mean	1.1	1.1	1.1

Table 6. Total stoves, fireplaces with inserts and fireplaces without inserts used for heating in the Los Angeles region in 2002.

Metropolitan Area, 2002	Stoves	Fireplace Inserts	Fireplaces w/o Inserts
Anaheim-Santa Ana	2695	35,365	60,039
Riverside-San Bernardino-Ontario,	27,170	73,810	96,910
Los Angeles-Long Beach	20,295	85,360	194,150

Woodstoves

An estimate of the fraction of wood-burning stoves that were pellet stoves were made based on the review of the available literature (Table 7). This fraction was applied to the total number to wood-burning stoves used in each southern California metropolitan area (Table 6). The number of cordwood stoves and number of pellet stoves in each of the metropolitan areas were thus calculated (Table 8).

Table 7. Fraction of wood-burning stoves that were pellet stoves.

Area, Year, Reference	Fraction
U.S., 2003, references 16-18	0.0544
California, 2002, reference 13	0.0782
U.S., 2002, reference 19	0.0731
San Joaquin Valley, 1999, reference 20	0.126
San Joaquin Valley 2002, reference 21	0.174
West-Mountain, 2004, reference 14	0.133
Mean	0.11

Table 8. Total cordwood stoves and total pellet stoves used for heating in the Los Angeles region in 2002

Metropolitan Area, 2002	Cordwood Stoves	Pellet Stoves
Anaheim-Santa Ana	2395	296
Riverside-San Bernardino-Ontario	24,181	2989
Los Angeles-Long Beach	18,062	2232

Fireplace Inserts

The number of gas-fueled fireplace inserts, the number of cordwood-fueled fireplace inserts and the number of pellet-fueled fireplace inserts that were used for heat were calculated for the three metropolitan areas from the total number of fireplace inserts shown in Table 6. The fraction of fireplaces that were gas-fueled on a national basis was used to estimate the number of gas-fueled fireplaces that were in the Los Angles region. Because the number of fireplace inserts that are gas-fueled are influenced by the number of homes that have piped or bottle gas hook-ups, the ratio of the of fraction of households in the Los Angeles region that use gas for any purposes, (i.e. have hook-ups) to the national average (Table 9) and the ratio of the fraction of households that use gas as their main heating fuel (Table 10) were calculated to provide two independent ways to adjust the national average to the Los Angeles region. The mean of the two values was used. Adjustment factors for the San Joaquin Valley to the Los Angeles region and for California as a whole to the Los Angeles region are also included in Table 10 as they are needed in the calculation of fireplace without insert numbers in the next section.

Table 9. Fraction of households that used gas (piped or bottled) for any purpose in 2002.

Area, Reference	Fraction of Households
U.S., References 5 and 6	0.701
Anaheim-Santa Ana, Reference 1	0.915
Riverside-San Bernardino-Ontario, Reference 2	0.958
Los Angeles-Long Beach, References 3 and 4	0.952
Population Weighed Los Angeles Region	0.946
National to Los Angeles Region Adjustment Factor 1.36	

Table 10. Fraction of households that used gas as their main heating fuel in 2000 (Reference 22).

Area	Population	Fraction of Households with Gas as Their Main Heating Fuel
U.S.	281,421,906	0.577
California	33,871,648	0.743
San Joaquin Valley	3,302,792	0.710 (Population weighted avg.)
San Joaquin Co.	563,598	0.703
Stanislaus Co.	446,997	0.700
Merced Co.	210,554	0.624
Fresno Co.	799,407	0.638
Madera Co.	123,109	0.616
Kings Co.	129,461	0.774
Kern Co	661,645	0.788
Tulare Co.	368,021	0.805
Los Angeles Region	15,620,450	0.782 (Population weighted avg.)
Orange Co.	2,846,289	0.770
Riverside Co	1,542,387	0.804
San Bernardino Co.	1,709,434	0.838
Los Angeles Co	9,519,338	0.772
California to Los Angeles Region Adjustment Factor 1.05		
San Joaquin Valley to Los Angeles Region Adjustment Factor 1.10		
National to Los Angeles Area Adjustment Factor 1.36		

Table 11 shows the calculation of the fraction of fireplaces with inserts that were gas-fueled in the Los Angeles region. Table 12 shows the estimate of the fraction of fireplace inserts that were pellet fueled. Table 13 shows the total number of cordwood-fueled, gas-fueled and pellet-fueled fireplace inserts that were used for heating in the Los Angeles region. The values were calculated from the number of fireplaces inserts used in the Los Angeles region for heating shown in Table 6 and the fraction that are of gas-and pellet-fueled shown in Tables 11 and 12.

Table 11. Fraction of fireplace inserts that were gas-fueled in the Los Angeles region in 2002.

Total Number of Households in the U.S. 2002, references 5 and 6	106,051,500
Fraction of Households Nationally that Own a Wood-Fired Fireplace Insert 2002, reference 18	0.058
Multiple Ownership Factor	1.1
Number of Total Wood-Fired Inserts in 2002	6,766,086
Total Number of Gas-Fueled Inserts sold as of 2002, references 16 and 17	559,483
Fraction of Total Fireplace Inserts Nationally that Are Gas-Fueled	0.076
National to Los Angeles Area Adjustment Factor	1.36
Fraction of Total Fireplace Inserts in the Los Angeles Area that were Gas-Fueled in 2002	0.104

Table 12. Fraction of wood-burning fireplace inserts that were pellet-fueled in 2002.

Number of Total Wood-Fired Inserts Nationally in 2002	6,766,086
Total Number of Pellet-Fueled Inserts Sold Nationally as of 2002, references 16 and 17	200,000
Fraction of Wood-Fueled Inserts in 2002 that were Pellet-Fueled	0.029

Table 13. Total gas-fueled, cordwood-fueled and pellet-fueled fireplace inserts used for heating in the Los Angeles region in 2002.

Metropolitan Area	Gas-Fueled Fireplace Insert	Total Wood-Fueled Fireplace Insert	Pellet-Fueled Fireplace Insert	Cordwood-Fueled Fireplace Insert
Anaheim-Santa Ana	3678	31,687	919	30,768
Riverside-San Bernardino-Ontario	7676	66,134	1918	64,216
Los Angeles-Long Beach	8877	76,483	2218	74,266

Fireplaces Without Inserts

The total number of usable fireplaces owned and the total number of fireplaces that were used for heating in the three metropolitan areas are shown in Table 4. The fraction of fireplaces that were gas-fueled (Table 14) and the fraction that were not used (Table 15) allowed for the number of fireplaces (both gas-fueled and cordwood-fueled) that were (1) owned, (2) that were not used, (3) that were used for heating, and (4) that were used for aesthetics to be calculated/tabulated (Tables 16 and 17). Because the use of gas-fueled fireplaces is more convenient than the use of cordwood-fueled units a different adjustment factor reflecting the difference was used when calculating the fraction that were used versus not used for cordwood and gas-fueled fireplaces, respectively. (See Table 15.)

Table 14. Fraction of fireplaces without inserts that were gas-fueled**.**

Area, Reference, Year	Fraction that Were Gas-Fueled	Adjustment for Los Angeles Region (See Table 10)	Fraction Predicted to be Gas-Fueled in Los Angeles Region
San Joaquin Valley, 1999, reference 20	0.20	1.10	0.22
San Joaquin Valley, 2002, reference 21	0.22	1.10	0.24
California, 2002, reference 13	0.29	1.05	0.30
California, 2001, reference 23	0.26	1.05	0.27
Mean			0.26

Table 15. Fireplace without insert usage.

Area, Reference, Year	Usage Category	Fraction by Category	Fraction Not Used
San Joaquin Valley, 2002, reference 21	Almost Every Day	0.16	
	Several Times a Week	0.20	
	Several Tines a Month	0.14	
	Rarely	0.28	
	Never	0.22	0.22
San Joaquin Valley, 1999, reference 20	Daily	0.12	
	4-6 Times a Week	0.10	
	1-3 Times a Week	0.24	
	Less than Once a Week	0.22	
	Never	0.32	0.32
California, 2002, reference 13	Used Last Year? Yes	0.77	
	Used Last Year? No	0.23	0.23
U.S., 2002, reference 19	Almost Every Day	0.15	
	1 or 2 Times a Week	0.23	
	1 or 2 Times a Month	0.24	
	1 or 2 Times a Season	0.17	
	Almost Never/Never	0.19	0.19
U.S., 1994-1995, reference 8	5-7 Times per week	0.11	
	3-4 Times per Week	0.10	
	1.2 Times per Week	0.18	
	1-2 Times per Month	0.13	
	1-2 Times per Season	0.17	
	Don't Use	0.31	0.31
West/Mountain, 2004, reference 14	1-2 Times or More Per Month (value for gas-fueled in parenthesis)	0.51 (0.65)	
	1-2 Times per Season (value for gas-fueled in parenthesis)	0.15 (0.15)	
	Almost Never/Never (value for gas-fueled in parenthesis)	0.34 (0.20)	0.34
Mean of "Not Used" Category (value for gas-fueled in parenthesis)			0.27 (0.20)

Table 16 Fireplaces without inserts by category in the Los Angeles region in 2002 (part 1).

Metropolitan Area	Total Fireplaces Owned	Total Wood-Burning Fireplaces Owned	Total Gas-Fueled Fireplaces Owned	Wood-burning Fireplaces Not in Use	Gas-Fueled Fireplaces Not in Use
Anaheim-Santa Ana	584,760	432,722	152,038	116,835	24,147
Riverside-San Bernardino-Ontario	630,080	466,259	163,821	125,890	26,018
Los Angeles-Long Beach	1,233,430	912,738	320,692	246,439	50,933

Table 17 Fireplaces without inserts by category in the Los Angeles region in 2002 (part 2).

Metropolitan Area	Wood-Burning Fireplaces in Use	Gas-Fueled Fireplaces in Use	Wood-Burning Fireplaces Used for Heating	Gas-Fueled Fireplaces Used for Heating	Wood-Burning Fireplaces Used for Aesthetics	Gas-Fueled Fireplaces Used for Aesthetics
Anaheim-Santa Ana	315,887	127,891	40,827	19,212	275,060	108,679
Riverside-San Bernardino-Ontario	340,369	137,803	65,899	31,011	274,470	106,792
Los Angeles Long Beach	666,229	269,759	132,022	62,128	534,207	207,631

Summary of Wood-Burning Appliances in the SCAB and Coachella Valley Portion of the SSAB

To obtain the final estimate of the number of wood-burning appliances owned and used by appliance category in the SCAB and SSAB several other adjustments need to be made to the numbers obtained for the three MSA's derived primarily from American Housing Survey reports. These adjustments are for: (1) The fraction of each of the three MSA's population that are in the SCAB and SSAB, respectively – Table 18. (2) The fraction of cordwood heaters that are certified catalytic, certified non-catalytic or pre-EPA certification conventional units – Table 19. (3) The fraction of cordwood stoves and fireplace inserts that are not in use – Table 20. (The fraction of fireplaces without inserts not in use has already been taken into consideration due to the inherent difference in the database for fireplaces without inserts as compared to the stove and fireplace insert database. The fireplace without insert numbers for those not in use are shown in Table 16.) (4) Wood-burning units that are in vacant houses – Table 21. Tables 22, 23, and 24 are compilations of intermediate data used in the calculations. The summary of wood-burning appliances both owned and used in the SCAB and the SSAB are provided in Tables 25 and 26, respectively.

Table 18. Metropolitan area to air basin conversions.

Metropolitan Area	Counties	Fraction to SCAB	Fraction to SSAB
Anaheim-Santa Ana	Orange	1	0
Riverside-San Bernardino-Ontario	Riverside and San Bernardino	0.7645	0.09765
Los Angeles-Long Beach	Los Angeles	0.96907	0

Table 19. Fraction of cordwood heaters (freestanding stoves plus fireplace inserts) by type.

Area, Year, Reference	Type	Fraction
Minnesota, 2002-2003, Reference 24 (Used)	Conventional Pre-EPA Certification	0.76
	Certified Catalytic	0.07
	Certified Non-Catalytic	0.17
U.S. 2003, References 16-18 (Owned)	Conventional Pre-EPA Certification	0.79
	Certified Catalytic	0.07
	Certified Non-Catalytic	0.14

Table 20. Fraction of cordwood stoves and fireplace inserts not in use.

Area, Year, Reference	Fraction of Stoves Not Used		Fraction of Fireplace Inserts Not Used	
Minnesota, 2002-2003, reference 23	0.18	conv. 0.22	0.039	conv. 0.044
		cert. cat. 0.057		cert. cat. 0
		cert. non-cat. 0.061		cert. non-cat 0
California, 2002, reference 13	0.17		0.03	
San Joaquin Valley, 1999, reference 20	0.14		-	
U.S., 2002, reference 19	0.15		-	
West/Mountain Region, 2004, reference 14	0.13		-	
Mean	0.15		0.03	

Table 21. Adjustment factor for ownership due to vacant housing.

Area, Year	Total Housing Units	Occupied Units (Households)	Adjustment Factor
Anaheim-Santa Ana, 2002	995,600	937,500	1.062
Riverside-San Bernardino-Ontario, 2002	1,229,500	1,187,500	1.035
Los Angeles – Long Beach, 1999	3,278,500	3,269,300	-
Los Angeles – Long Beach, 2003	3,318,500	3,310,200	-
Los Angeles –Long Beach, 2002	3,308,500	3,300,000	1.002

Table 22. Summary of wood-burning stove ownership and usage by metropolitan area and air basin.

Metropolitan Area/Air Basin	Number Owned – Cordwood				Number Used – Cordwood				Number Owned	Number Used
	Total	Conv.	Cat.	Non-Cat.	Total	Conv.	Cat.	Non-Cat.	Pellet	Pellet
Anaheim Santa Ana	2845	2196	189	460	2395	1820	168	407	314	296
Riverside-San Bernardino-Ontario	28,004	21,615	1858	4531	24,181	18,378	1693	4111	3094	2989
Los Angeles-Long Beach	20,249	15,630	1343	3276	18,062	13,727	1264	3070	2232	2232
SCAB	43,877	33,868	2916	7099	38,384	29,172	2687	6525	4842	4744
SSAB	2735	2111	181	442	2361	1794	165	401	302	292

Table 23. Summary of wood-burning fireplace insert ownership and usage by metropolitan area and air basin.

Metropolitan Area/Air Basin	Number Owned –Cordwood				Number Used –Cordwood				Number Owned	Number Used
	Total	Conv.	Cat.	Non-Cat.	Total	Conv.	Cat.	Non-Cat.	Pellet	Pellet
Anaheim Santa Ana	34,829	26,752	2356	5721	31,687	24,082	2218	5387	974	919
Riverside-San Bernardino-Ontario	70,843	54,415	4791	11,637	66,134	50,262	4629	11,243	1995	1918
Los Angeles-Long Beach	79,317	60,924	5365	13,028	76,483	58,127	5354	13,002	2218	2218
SCAB	165,852	127,392	11,218	27,242	156,363	118,836	10,945	26,582	4648	4534
SSAB	6918	5314	468	1148	6459	4908	450	1098	195	187

Table 24. Summary of wood-burning fireplace without insert ownership and usage by metropolitan area and air basin.

Metropolitan Area/Air Basin	Owned	Used	Used for Heating	Used for Aesthetics
Anaheim-Santa Ana	432,722	315,887	40,827	275,060
Riverside-San Bernardino-Ontario	466,259	340,369	65,899	274,470
Los Angeles-Long Beach	912,738	666,229	132,022	534,207
SCAB	1,673,684	1,221,721	219,146	1,002,576
SSAB	45,530	33,237	6435	26,802

Table 25. Wood-burning appliances in the SCAB and SSAB.

Category	SCAB		SSAB	
	Owned	Used	Owned	Used
Total Wood-Burning Appliances (Wood Heaters + Fireplaces w/o Inserts	1,897,745	1,431,490 427,915[a] 1,002,576[b]	55,680	42,536 15,734[a] 26,805[b]
Wood Heaters (Cordwood + Pellet	224,061	208,769	10,150	9299
Cordwood Heaters (Stoves + Inserts)	214,571	199,491	9653	8820
Pellet Heaters (Stoves + Inserts)	9490	9278	497	479
Total Stoves (Cordwood + Pellet)	48,719	43,128	3037	2653
Cordwood Stoves (Conv. + Cat. + Non-Cat.)	43,877	38,384	2735	2361
Conventional Stoves	33,868	29,172	2111	1794
Certified Catalytic Stoves	2916	2687	181	165
Certified Non-Catalytic Stoves	7099	6525	442	401
Pellet Stoves	4842	4744	302	292
Fireplace Inserts (Cordwood + Pellet)	170,500	160,897	7113	6646
Cordwood Fireplace Inserts (Conv. + Cat. + Non-Cat.)	165,852	156,363	6918	6459
Conventional Inserts	127,392	118,836	5314	4908
Certified Catalytic Inserts	11,218	10,945	468	450
Certified Non-Catalytic Inserts	27,242	26,582	1148	1098
Pellet Inserts	4648	4534	195	187
Fireplace w/o Inserts	1,673,684	1,222,721 219,146[a] 1,002,576[b]	45,530	33,237 6435[a] 26,805[b]

[a]Used for heating
[b]Used for aesthetics, no heaters are considered used for aesthetics, fireplaces only are included in this category.

ANNUAL WOOD CONSUMPTION BY APPLIANCE TYPE

To calculate the wood burning activity (mass of dry fuel burned per year) for each appliance type, the number of units of each appliance type (Table 25) that were used were multiplied by the average mass of cordwood or pellets burned annually in them. The mass of wax/fiber firelogs were estimated separately from: (1) sales records[25] and population characteristics of California[26] and (2) a household survey conducted in the San Francisco, San Joaquin Valley and Sacramento areas[13].

The first step in determining the mass of cordwood burned was estimating the average number of cords burned per appliance type in the SCAB and SSAB. The survey conducted by Sierra Research in 1986 was the key document used for this determination[27] (Table 26). The cordwood heater number is the weighted average of the "woodstove" plus "stove-like insert" numbers compiled by the survey. The SCAB values were estimated from 318 wood-burning households in the South Coast Air Basin. The SSAB values were estimated by taking the weighted average from 24 wood-burning households in desert portion of Los Angeles County, nine wood-burning households in the desert portion of Riverside County and from 102 households in the San Diego Air Basin. The data from the desert portions of Los Angeles and Riverside counties and the San Diego Air Basin were used due to the geographic proximity and similar mild climates of these areas to the SSAB area. The desert portion of San Bernardino County was not used as it may contain some homes in a significantly cooler climate.

The second step was to assign efficiency to each wood-burning heater type (Table 27). This was done to adjust the annual cordwood usage for wood heaters shown in Table 26 that were for pre-EPA certified wood heaters to cordwood usage for certified catalytic and certified non-catalytic cordwood heaters as well as for pellet heaters since less fuel will be used in these devices for the same heat demand due to their higher efficiencies[28-31]. Because there are numerous methods for measuring and conventions for reporting efficiency a "best professional judgment" value rather than a true mean was used for these calculations.

The next step was to compile the tree species used for fuel. The percent of fuel by tree species was determined by conducting a phone interview with ten wood vendors in southern California and averaging their responses with the survey results obtained from the interview with 318 wood-burning households in the South Coast Air Basin that was part of the 1986 Sierra Research study[27] (Table 28). The dry cord weight for wood by tree type was obtained from various sources, referenced and compiled in Table 29.

From the relative fraction of each tree type used for fuel in southern California and from the. characteristic weight of a dry cord of each of the tree types, a weighted cord mass for a cord of wood was calculated as 3081 lbs (1400 kg) on a dry basis. It was assumed that wood in the urban/other category was made up of wood from tree types in the same relative proportions as in the identified portion.

The mass of wax/fiber firelogs burned in 2002 in both the SCAB and SSAB is tabulated in Table 30. The average of the wax/fiber firelog mass calculated by the two methods previously discussed is shown in Table 30 and is used in the subsequent calculations. In these calculations the mass of firelogs sold in 1999 was assumed to be equal to that sold between Sept. 1998 and Sept 1999 and the average weight of firelogs was calculated as 4.95 lbs. The 4.95 lb average was calculated from the estimate that 34% of the firelogs sold are 6 lb logs, 32% are 5 lb logs, 32% are 3.5 lb logs, and an insignificant number are other sizes[32]. The firelog moisture of 2.2% shown in Table 30 was the average obtained from wax/fiber firelog moistures reported by a number of studies[33].

The annual fuel consumption (activity) per appliance type is tabulated in Table 31. The activities for five appliance types were compiled: (1) conventional pre-EPA certification cordwood heaters, (2) EPA-certified non-catalytic cordwood heaters, (3) EPA-certified catalytic cordwood heaters, (4) pellet heaters, and (5) fireplaces without inserts. Activity for fireplaces was further divided into cordwood and wax/fiber firelog usage. The term heater is the sum of freestanding stoves and fireplace inserts. The activity was divided into these categories to be consistent with emission factor groupings that when multiplied by the activities will provide the emission inventory.

Table 26. Average cords burned per year by appliance type.

Air basin	Cordwood heaters (cordwood stoves + fireplace inserts) (cords/year)	Fireplaces without inserts (cords/year)
SCAB	0.95	0.52
SSAB	1.00	0.64

Table 27. Wood-burning appliance efficiencies (%).

Appliance Type	AP-42	EPA-600/R-98-174a	NSPS Default	Sonoma Co. Rept.	Value Used Here
Conv. pre-EPA cert.	54	54	-	-	54
EPA-cert. Non-cat.	68	68	63	57.4-70.1[a]	65
EPA-cert Cat.	68	72	72	-	70
Pellet	56[b], 68[c]	78	78	-	75

[a]Range for multiple tests on a single model wood stove with different burn rates
[b]Older uncertified pellet stove
[c]Older EPA certified pellet stove

Table 28. Cordwood by tree type in southern California.

Firewood Dealers	City	Almond/ Fruitwood	Ash	Cedar	Eucalyptus	Juniper	Maple	Oak	Orange	Pine/ Fir/ Tamarack	Walnut	Urban/ Other
Holiday Firewood	Pasadena	60%	0%	0%	0%	0%	0%	20%	0%	0%	0%	20%
Southern California Tree & Landscape	Torrance	0%	0%	0%	25%	0%	0%	0%	0%	25%	0%	50%
Tru Inc.	Rancho Cucamonga	0%	0%	0%	75%	0%	0%	0%	0%	0%	0%	25%
Jones Firewood Yard	Hawthorne	15%	0%	20%	15%	0%	0%	10%	0%	40%	0%	0%
Gallagher Firewood	North Hollywood	0%	40%	0%	15%	0%	5%	10%	0%	0%	10%	5%
Woodshed Firewood Co.	Orange	15%	0%	0%	0%	5%	0%	15%	15%	5%	0%	45%
Freeburn Firewood	Pomona	0%	0%	0%	70%	0%	0%	10%	0%	0%	0%	20%
A & L Firewood & Landscape	Newport Beach	0%	0%	0%	75%	0%	0%	20%	0%	0%	0%	5%
All Seasons Firewood	Pasadena	0%	0%	0%	30%	0%	0%	40%	0%	20%	0%	10%
Treeco Inc. Products & Services	Brea	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Survey[a]	South Coast Basin	7.5%	0%	1.6%	18.8%	0%	0%	19.5%	0%	25%	0%	55.8%
Average		8.9%	3.6%	2.0%	29.4%	0.5%	0.5%	13.1%	1.4%	10.5%	0.9%	30.5%

[a] Survey of 318 wood-burning households.

Table 29. Cord weight by tree type and weight of average area cord.

	Almond/ Fruitwood	Ash	Cedar	Eucalyptus	Juniper	Maple	Oak	Orange	Pine/ Fir/ Tamarack	Walnut	Urban/ Other
Dry Weight Per Cord (lb/cord)	3000	2867	1812	3568	2625	3267	3253	3227	2245	2600	2846
Percent of total wood	8.9%	3.6%	2.0%	29.4%	0.5%	0.5%	13.1%	1.4%	10.5%	0.9%	30.5%
Contribution to Dry Weight Per Area Average Cord (lb/cord)	266	104	36	1050	12	15	427	44	235	24	869
			Average Dry Weight Per Cord			3081 lb	(1400 kg)				

Table 29 notes:
Cord weights obtained from: (1) Firewood Ratings and Info: http://mb-soft.com/juca/print/firewood.html, (2) correspondence with southern California firewood dealers, Fuelwood Facts: (3) Oregon State University Extension Service, (4) Wood Weights and Values: http://72.14.203.104/search?q=cache:vsfr1FesUIoJ:www.consumerenergycenter.org/homeandwork/homes/inside/heatandcool/fireplaces.html+eucalyptus+cord+weight&hl=en&gl=us&ct=clnk&cd=2&client=firefox-a, (5)Wood Fuel for Heating, University of Missouri Extension, http://muextension.missouri.edu/explore/agguides/forestry/g05450.htm.

Table 30. Wax/fiber firelog activity.

Parameters – Calculation Method 1	Value
Total firelogs sold nationally Sept. 98 to Sept. 99	103,738,112 logs
Average weight of a firelog	4.95 lbs (2.25 kg)
Fraction of total firelogs sold in U.S. that were sold in California	0.22
Mass of firelogs sold in California 1999	51,350,365 kg
Households in California 1999	11,213,201
Households in California 2002	11,707,270
Households in SCAB 2002	4,846,728
Households in SSAB 2002	125,042
Mass of firelogs used in SCAB 2002	22,195,380 kg
Mass of firelogs used in SSAB 2002	572,624 kg
Calculation Method 2	
Average number of firelogs used per fireplace that is used in San Francisco, San Joaquin Valley and Sacramento areas	16 logs
Fraction of fireplaces that are used that use firelogs at least sometimes in San Francisco, San Joaquin Valley and Sacramento areas	0.42
Number of fireplaces used in SCAB 2002	1,222,721 fireplaces
Number of fireplaces used in SSAB 2002	33,237 fireplaces
Mass of firelogs used in SCAB 2002	18,487,541 kg
Mass of firelogs used in SSAB 2002	502, 543 kg
Average of Method 1 and Method 2 Results	
Mass of firelogs used in SCAB 2002	20,341,461 kg
Mass of firelogs used in SSAB 2002	537,584 kg
Mean moisture content of firelogs	2.2%
Dry mass of firelogs used in SCAB 2002	19,893,949 kg
Dry mass of firelogs used in SSAB 2002	525,757

Table 31. Annual fuel consumption (activity) by appliance type.

Appliance Type	SCAB – mass dry fuel 2002 (kg)	SSAB – mass dry fuel 2002 (kg)
Conventional pre-EPA certification wood heaters	1.97×10^8	9.38×10^6
EPA certified non-catalytic wood heaters	3.66×10^7	1.74×10^6
EPA certified catalytic wood heaters	1.40×10^7	6.64×10^5
Pellet heaters	8.89×10^6	4.82×10^5
Fireplaces without inserts	8.90×10^8 cordwood 1.99×10^7 firelogs	2.98×10^7 cordwood 5.26×10^5 firelogs

ANNUAL PARTICULATE EMISSIONS BY WOOD-BURNING APPLIANCE TYPE

Table 32 lists the particulate emission factors used in the calculation of the emission inventories. It should be noted that all particulate emission factors are in the form of "Method 5H equivalents" and total particulate emissions are treated equivalent to $PM_{2.5}$ emissions since well over 90% of residential wood combustion particulate emissions are submicron in size. It should also be noted that the emission factors for wood heaters and fireplace have been refined considerably from those appearing in EPA's

AP-42 document[33-35]. The AP-42 emission factors are flawed for several reasons: (1) They lack currency. The certified cordwood heater and pellet heater data included in AP-42 were for the very earliest original pellet heaters and certified catalytic and non-catalytic cordwood heaters. Current models have considerably reduced emissions. (2) The emission factors for conventional pre-EPA certification cordwood heaters are heavily biased to their operation in extremely cold climates. (The database was made up of stoves primarily in the Whitehorse, Yukon, the high elevation community of Crested Butte, Colorado, upstate New York and Vermont, and the high desert community of Klamath Falls, Oregon.) Higher emission factors will be characteristic of wood heater use under oxygen starved ("dampered down') conditions and shorter fires with a higher relative fraction of kindling start up conditions typical in more mild climates such as characteristic of the SCAB and SSAB. (3) The AP-42 data are based on a limited number of studies. A much larger database is available to establish emission factors[33-35]. Two other additional notes on emission factors should also be made. First, the emission factor for EPA certified catalytic wood heaters is estimated to be higher than for EPA certified non-catalytic wood heaters, even though new catalytic models generally have lower emission than non-catalytic models, due to normal degradation of catalytic activity with use. Second, even though the wax/fiber firelog emission factor is higher than cordwood, the use of wax/fiber firelogs typically produce less emissions than cordwood since they contain a higher heat content and less mass is burned to produce a satisfactory fireplace fire.

The $PM_{2.5}$ emission inventory for SCAB and SSAB by appliance type is provided in Table 33.

Table 32. Emission factors.

Appliance Type	Emission Factor (g/dry kg fuel)
Conventional pre-EPA certification wood heaters (freestanding stoves + fireplace inserts)	33.4
EPA certified non-catalytic wood heaters (freestanding stoves + fireplace inserts)	5.85
EPA certified catalytic wood heaters (freestanding stoves + fireplace inserts)	7.55
Pellet heaters (freestanding stoves + fireplace inserts)	1.25
Fireplaces without inserts	13.0 cordwood 21.2 firelogs

Table 33. 2002 $PM_{2.5}$ Emission inventory for SCAB and SSAB by appliance type.

Appliance Type	Total $PM_{2.5}$ in SCAB 2002		Total $PM_{2.5}$ in SSAB 2002	
	kg	English tons	kg	English tons
Conventional pre-EPA certification wood heaters (freestanding stoves + fireplace inserts)	6.58×10^{6}	7.24×10^{3}	3.13×10^{5}	3.44×10^{2}
EPA certified non-catalytic wood heaters (freestanding stoves + fireplace inserts)	2.14×10^{5}	2.35×10^{2}	1.02×10^{4}	1.12×10^{1}
EPA certified catalytic wood heaters (freestanding stoves + fireplace inserts)	1.06×10^{5}	1.17×10^{2}	5.01×10^{3}	5.51×10^{0}
Pellet heaters (freestanding stoves + fireplace inserts)	1.11×10^{4}	1.22×10^{1}	6.02×10^{2}	6.62×10^{-1}
Fireplaces without inserts burning cordwood	1.16×10^{7}	1.28×10^{4}	3.87×10^{5}	4.26×10^{2}
Fireplaces without inserts burning firelogs	4.22×10^{5}	4.64×10^{2}	1.11×10^{4}	1.22×10^{1}

Summary

Tables 34 and 35 are compilations of the key data for the SCAB and SSAB for the 2002 base year. They contain the number of appliances owned and used by appliance type, the mass of fuel burned in them, and the mass of $PM_{2.5}$ emitted.

Table 34. Data summary for SCAB 2002 base year.

Appliance Type	Number owned	Number used	Mass dry fuel burned (kg)	Mass $PM_{2.5}$ emitted (kg)
Conventional pre-EPA certification wood heaters	161,260	148,008	1.97×10^8	6.58×10^6
EPA certified non-catalytic wood heaters	34,341	33,107	3.66×10^7	2.14×10^5
EPA certified catalytic wood heaters	14,134	13,632	1.40×10^7	1.06×10^5
Pellet heaters	9490	9278	8.89×10^6	1.11×10^4
Fireplaces without inserts	1,673,684	1,222,721	8.90×10^8 cw 1.99×10^7 fl	1.16×10^7 cw 4.22×10^5 fl

Table 34 notes: Heaters = freestanding stoves + fireplace inserts, cw = cordwood, fl = firelogs

Table 35. Data summary for SSAB 2002 base year.

Appliance Type	Number owned	Number used	Mass dry fuel burned (kg)	Mass $PM_{2.5}$ emitted (kg)
Conventional pre-EPA certification wood heaters	7425	6702	9.38×10^6	3.13×10^5
EPA certified non-catalytic wood heaters	1590	1499	1.74×10^6	1.02×10^4
EPA certified catalytic wood heaters	649	615	6.64×10^5	5.01×10^3
Pellet heaters	497	479	4.82×10^5	6.02×10^2
Fireplaces without inserts	45,530	33,237	2.98×10^7 cw 5.26×10^5 fl	3.87×10^5 cw 1.11×10^4 fl

Table 35 notes: Heaters = freestanding stoves + fireplace inserts, cw = cordwood, fl = firelogs

REFERENCES

1. U.S. Department of Housing and Urban Development and U.S. Department of Commerce*, American Housing Survey for the Anaheim-Santa Ana Metropolitan Area: 2002, Current Housing Reports*, issued July 2003.

2. U.S. Department of Housing and Urban Development and U.S. Department of Commerce, *American Housing Survey for the Riverside-San Bernardino-Ontario Metropolitan Area: 2002, Current Housing Reports*, issued July 2003.

3. U.S. Department of Housing and Urban Development and U.S. Department of Commerce, *American Housing Survey for the Los Angeles-Long Beach Metropolitan Area: 1999, Current Housing Reports*, issued March 2001.

4. U.S. Department of Housing and Urban Development and U.S. Department of Commerce, *American Housing Survey for the Los Angeles-Long Beach Metropolitan Area: 2003, Current Housing Reports*, issued December 2004.

5. U.S. Department of Housing and Urban Development and U.S. Department of Commerce, *American Housing Survey for the United States: 2001, Current Housing Reports*, issued October 2002.

6. U.S. Department of Housing and Urban Development and U.S. Department of Commerce, *American Housing Survey for the United States: 2003, Current Housing Reports*, issued September 2004.

7. U.S. Department of Housing and Urban Development and U.S. Department of Commerce, *American Housing Survey, 2003 National Sample – Items Booklet,* http://www.huduser.org/datasets/ahs/ahsdata03.html.

8. Vista Marketing Research, "U.S. Fireplace Fuel Usage, 1994/95 Fall/Winter Season", Prepared for Duraflame Corporation, Stockton, CA, March 1996.

9. Houck, J.E; Tiegs, P, "Convenience Fuels", Hearth and Home, December 2001,18-21.

10. Barnett, S.G.; Bighouse, R.D., "In-Home Demonstration of the Reduction of Woodstove Emission from the Use of Densified Logs", Prepared for Oregon Department of Energy and U.S. Environmental Protection Agency by OMNI Environmental Services, Inc., Beaverton, OR, July 7, 1992, DOE/BP-35836-1.

11. Bighouse, R. D.; Houck, J.E., "Evaluation of Emissions and Energy Efficiencies of Residential Wood Combustion Devices Using Manufactured Fuels", Prepared for the Oregon Department of Energy by OMNI Environmental Services, Inc., Beaverton, OR, August 23, 1993.

12. Frisch, J. President, Masonry Heater Association of North America, June 24, 2002, *personal communication*.

13. Broderick, D.; Houck, J.E., "Results of Wood Burning Survey – Sacramento, San Joaquin, and San Francisco Areas, University of California Berkeley/California Air Resources Board – GIS Study", Prepared for Hearth, Patio, and Barbecue Association by OMNI Environmental Services, Inc., Beaverton, OR, 2003.

14. U.S. Department of Energy, Energy Information Administration, *2001 Residential Energy Consumption Survey*, http://www.eia.doe/emeu/recs2001/detail_tables.html.

15. DHM Group, "2004 Consumer Attitude and Usage Survey: Hearth Products", Prepared for Hearth, Patio, and Barbecue Association, Arlington, VA, 2005.

16. Zamula, W.W. *Room Heating Equipment Exposure*, U.S. Consumer Product Safety Commission, Final Report, OMB Control, 1989, No. 3041-0083.

17. Smith, Bucklin & Associates, Inc., "Annual Surveys of Cordwood Burning Appliances Sales and Pelletized Fuel Burning Appliances Sales", 1989-1996 reports prepared for Hearth Patio Association, Arlington, VA, 1990-1997.

18. Johnson, D., October 20, 2005, Director of Market Research, Hearth, Patio and Barbecue Association, U.S. Stove, Insert and Pellet Stove Shipments, *personal communication*.

19 Simmons Market Research Bureau, Inc, *Annual Studies of Media and Markets*, Spring 2003.

20. NFO WorldGroup, "HPBA Fireplace and Freestanding Stove Usage and Attitude Study 2002", Prepared for Hearth, Patio and Barbecue Association, Arlington, VA, 2003.

21. META Information Services, "Summary Results, San Joaquin Valley Unified Air Pollution Control District Baseline Telephone Survey, January 1999", Prepared for San Joaquin Valley Unified Air Pollution Control District, 1999.

22. McGuire Research Services, Inc., "Duraflame San Joaquin Valley District Survey", Prepared for Duraflame Inc. Stockton, CA, 2002.

23. United States Census, *2000 Demographic Profiles*, http://censtats.census.gov/pub/Profiles.shtml.

24. Wu, C.Y.; Piva, R.; Broderick, D.R.; Houck, J.E.; Crouch, J. "Emissions Inventory Oriented Residential Wood Combustion Survey", In *Proceedings of 14th International Emission Inventory Conference, Transforming Emission Inventories – Meeting Future Challenges Today*, U.S. Environmental Protection Agency, Las Vegas, NV, 2005.

25. Information Resource, "Infoscan Region Profile", Prepared for Duraflame, Inc., Stockton, CA, January 2000.

26. U.S. Census Bureau, *American Fact Finder, California, Selected Housing Characteristics*, 2004.

27. Sierra Research, Inc., "Residential Wood Use in California", Prepared for the U.S. Environmental Protection Agency, EPA Contract No. 68-02-4601, October 20, 1989.

28. U.S. Environmental Protection Agency, *Compilation of Air Pollution Emission Factors – Volume 1: Stationary Point and Area Sources, AP-42, Chapter 1.10, Residential Woodstoves*, Research Triangle Park, NC, revised October 1996.

29. Houck, J.E.; Tiegs, P.E. "Residential Wood Combustion Technology Review", Volume 1, Prepared for U.S. Environmental Protection Agency by OMNI Environmental Services, Inc., Beaverton, OR, EPA-600/R-98-174a, 1998.

30. U.S. Federal, Register, "Standards for Particulate Matter", Vol. 53, No. 38, Section 60.536, February 26, 1988.

31. Tiegs, P.; Houck, J.E., "Evaluation of the Northern Sonoma County Wood-burning Fireplace and Masonry Heater Emissions Testing Protocols", Prepared for Northern Sonoma County Air Quality Management District, Healdsburg, CA, by OMNI Environmental Services, Inc. Beaverton,OR, November 30, 2000.

32. Solari, S., 2000, Duraflame, Inc. Stockton, CA, *personnel communication*.

33. Houck, J.E.; Crouch J., "Updated Emissions Data for Revision of AP-42 Section 1.9, Residential Fireplaces", Prepared for U.S. Environmental Protection Agency by OMNI Environmental Services, Inc., Beaverton, OR, 2002.

34. Houck, J.E.; Broderick, D.R., "$PM_{2.5}$ Emission Reduction Benefits of Replacing Conventional Uncertified Cordwood Stoves with Certified Cordwood Stoves or Modern Pellet Stoves," Prepared for Hearth, Patio and Barbecue Association, Arlington, VA by OMNI Environmental Services, Inc., Beaverton, OR, 2005.

35. Broderick, D.R.; Houck, J.E.; Crouch, J., "Development of a Fireplace Baseline Particulate Emission Factor Database", In *Proceedings of 14th International Emission Inventory Conference, Transforming Emission Inventories – Meeting Future Challenges Today*, U.S. Environmental Protection Agency, Las Vegas, NV, 2005.