SECTION 7.1

RESIDENTIAL WOOD COMBUSTION

(Revised October 2015)

EMISSION INVENTORY SOURCE CATEGORY
Miscellaneous Processes/Residential Fuel Combustion

EMISSION INVENTORY CODES (CES CODES) AND DESCRIPTION
610-600-0230-0000 (82115) Residential Wood Combustion - Wood Stoves
610-602-0230-0000 (82123) Residential Wood Combustion - Fireplaces
610-604-0230-0000 (47225) Residential Wood Combustion – Unspecified

BACKGROUND

This methodology is used to estimate the criteria pollutant emissions from the various types of residential wood combustion for each county throughout the state. This document contains emissions estimates for wood-burning fireplaces and wood stoves (which includes fireplace inserts and pellet stoves). However, no annual emission estimation method has been derived, or included here, for the category "Residential Wood Combustion (Unspecified)." In addition, this methodology does not include emissions estimates for fireplaces or other similar devices that burn natural gas. Significant changes have occurred since the last edition of this methodology, dated July 1997. These include changes to equations, emission factors, activity data, annual emissions, and temporal profile estimates.

SOURCES

The types of devices that burn wood in a typical residence are fireplaces, wood-burning stoves, fireplace inserts, and pellet stoves. The most common wood-burning device in a home is the fireplace. A fireplace is generally a masonry or prefabricated (metal) enclosure with the side facing the interior of the house left open and a chimney to exhaust the flue gas. The combustion air can be supplied from the outside air or from the inside air.

Wood stoves are enclosed stand-alone devices that vent exhaust gas through an existing chimney or flue. Wood stoves radiate heat from their exterior surfaces and they are commonly used in residences as space heaters. They are used both as the primary source of residential heat and to supplement conventional heating systems. Wood stoves control burning or burn time by restricting the amount of air that can be used for combustion (U.S. EPA, 1996a). This methodology estimates emissions for four different types of wood stoves: (1) the conventional wood stove; (2) the noncatalytic wood stove; (3) the catalytic wood stove; and (4) the pellet stove.

Conventional wood stoves do not have any emission reduction technology or design features and, in most cases, were manufactured before July 1, 1986 (U.S. EPA, 1996a). Noncatalytic wood stoves do not contain catalysts but they do have emission reducing technology or features. Older, noncatalytic wood stoves reduce emissions by directing unburned hydrocarbons and carbon monoxide (CO) into a secondary chamber, where mixing with fresh, preheated makeup air enhances further combustion (U.S. EPA, 1996a). Newer noncatalytic wood stoves have three internal characteristics that create a good environment for complete combustion: firebox insulation; a large baffle to produce a longer, hotter gas flow path; and pre-heated combustion air introduced through small holes above the fuel in the firebox. The baffle and some other internal parts of a non-catalytic stove need replacement periodically as they deteriorate with the high heat of efficient combustion (WHO, 2013).

Catalytic wood stoves are equipped with a ceramic or metal honeycomb device, called a combustor or converter that is coated with a noble metal such as platinum or palladium. The catalyst material reduces the ignition temperature of the unburned hydrocarbons and CO in the exhaust gases, which allows these pollutants to be burned at normal stove operating temperatures. As these pollutants burn, the temperature inside the catalyst increases to a point where the ignition of the gases is essentially self-sustaining (U.S. EPA, 1996a). All catalytic stoves have a lever-operated catalyst bypass damper which is opened for starting and reloading. The catalytic honeycomb degrades over time and must be replaced, but its durability is largely in the hands of the stove user. The catalyst can last more than six seasons if the stove is used properly, but if the stove is over-fired, garbage is burned and regular cleaning and maintenance are not done, the catalyst may break down in as little as two years (WHO, 2013).

Residential wood stoves are classified as Phase I, Phase II and Pre-Phase I. Phase II stoves are those certified to meet the July 1, 1990, EPA standards; Phase I stoves meet only the July 1, 1988, EPA standards; and Pre-Phase I stoves do not meet any of the EPA standards (U.S. EPA, 2006). Some Pre-Phase I stoves may use older catalytic technology; however, for the purposes of this methodology, we make the conservative assumption that all Pre-Phase I stoves are conventional devices.

Fireplace inserts can be described as wood stoves that fit into the firebox of a fireplace. These devices are used to heat a house, or a portion of the house. Inserts are generally more effective at providing heat than a fireplace. They radiate the heat to the interior house space, or with the aid of a fan, circulate air around the insert and vent the heated air into the house. Since fireplace inserts share operating and combustion characteristics with wood stoves, the same emission factors are used for both fireplace inserts and wood stoves (HPBA, 2009a; U.S. EPA, 1996a; WHO, 2013).

Pellet stoves are fueled with pellets of sawdust, wood products, and other biomass materials pressed into manageable shapes and sizes. These stoves have active air flow systems and unique grate designs to accommodate pelleted fuel. Some pellet stove models are subject to the 1988 New Source Performance Standards (NSPS), while others are exempt due to a high air-to-fuel ratio (i.e., greater than 35-to-1) (U.S. EPA, 1996a).

EMISSION ESTIMATION METHODS

The previous 1997 version of this methodology contained two types of emissions estimates: (1) San Joaquin Valley (SJV) emissions based on 1993 data; and (2) emissions for the remainder of the state based on 1991 data. For both the 1991-based and 1993-based inventories, energy needs and activity data were estimated using the thermal properties of a typical residence and county-specific heating degree days.

For the latest revision (based on 2005 data), the methodology was updated to reflect more recent survey data, emission factors, and calculation approaches. Methodologies are provided for activity data based on two approaches:

- Preferred Method - Local Residential Wood Combustion Survey data; and
- Alternative Method - United States Census Bureau American Housing Survey data.

These methods are described below.

PREFERRED METHOD – Activity Data from Local Surveys

Since the previous version of this methodology, several districts have conducted surveys to compile local activity data when adopting rules that impact residential wood combustion (BAAQMD, 2007; OMNI, 2003; OMNI, 2006; PCAPCD, 2007; SJVUAPCD, 1997, 2008, 2010; SMAQMD, 2007). These survey data can be used to estimate emissions from wood-burning fireplaces, wood stoves, fireplace inserts, and pellet stoves, when deemed appropriate.

1.0 WOOD-BURNING FIREPLACES

1.1 Determine the number of wood-burning fireplaces that are actually used.

Equation 1: $FP_{all} = [H_{total}]*[P_{fp}]*[P_{fp,u}] *[M_{fp}]$

Where

FP_{all} = Number of fireplaces that are actually in use
H_{total} = Number of occupied housing units in the county (divided by air basin, if needed)
P_{fp} = Percent of homes with a fireplace
$P_{fp,u}$ = Percent of homes with a fireplace that was actually used during the burn season
M_{fp} = Average number of fireplaces per home (to account for multiple fireplaces in some homes) = 1.1, default (OMNI, 2003)

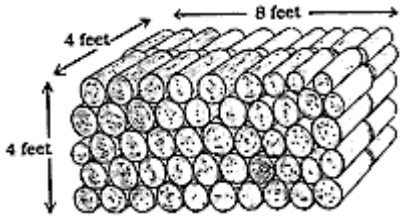
Appendix A contains the default and region-specific non-default values for the variables.

1.2. Determine the amount of wood burned in fireplaces.

For fireplaces, we assume that three types of fuel are burned: (1) cord wood; (2) bundle wood; and (3) wax/sawdust manufactured logs (e.g., Duraflame, Pine Mountain, Hearthlog, etc.). Provided below are methods for estimating the consumption rates for the different fireplace fuels.

1.2.1. Fireplaces – Cord Wood & Bundle Wood

A standard cord of wood is defined as a stack of wood with a volume of 128 cubic feet (4 ft. x 4 ft. x 8 ft.)



Bundle wood is typically purchased from a retail store, either packaged in a box or wrapped in plastic. Fireplaces burn cord wood and bundle wood for aesthetic purposes and for heating purposes. This methodology assumes wood consumption rates that include both cord wood and bundle wood. In addition, it is assumed that fireplaces burn more wood when they are used for heating purposes, as compared to aesthetic purposes (Houck, 2001a). This is a change from the previous methodology where it was assumed that all homes with fireplaces had the same consumption rate (0.28 cords/home/year).

Provided below is a method to determine the percentage of fireplaces used for aesthetic and heating purposes, and the associated wood consumption rate for each of these uses. For fireplaces, the total amount of wood consumed is based on the number of individual fireplace units, rather than the number of *homes* that have fireplaces. This is done to maintain consistency with the units for the estimated consumption rate.

Equation 2: $FP_{aes} = [FP_{all}]*[P_{fp,cord}]*[P_{fp,aes}]$

Equation 3: $F_{aes} = [FP_{aes}]*[N_{cord,aes}]*[W_{cord}]$

Where

FP_{aes}	=	Number of fireplaces being used primarily for aesthetic purposes
FP_{all}	=	Number of fireplaces that are actually in use
$P_{fp,cord}$	=	Percent of fireplaces that burn cord wood = 88%, default (Houck, 2001b)
$P_{fp,aes}$	=	Percent of fireplace use that is described as aesthetic
F_{aes}	=	Amount of cord wood burned in fireplaces for aesthetic purposes, tons wood/year
$N_{cord,aes}$	=	Number of cords burned in fireplaces – aesthetics = 0.069 cords/fireplace/year, default (Houck, 2001a)
W_{cord}	=	Weight of an average cord of wood = 1.54 tons/cord, default (OMNI, 2006)

Equation 4: $FP_{heat} = [FP_{all}]*[P_{fp,cord}]*[P_{fp,heat}]$

Equation 5: $F_{heat} = [FP_{heat}]*[N_{cord,heat}]*[W_{cord}]$

Where

FP_{heat}	=	Number of fireplaces being used primarily for heating purposes
FP_{all}	=	Number of fireplaces that are actually in use
$P_{fp,heat}$	=	Percent of fireplace use that is for heating purposes (non-aesthetic)
F_{heat}	=	Amount of cord wood burned in fireplaces for heating purposes, tons wood/year
$N_{cord,heat}$	=	Number of cords burned in fireplaces – heating = 0.656 cords/fireplace/year, default (Houck, 2001a)
W_{cord}	=	Weight of an average cord of wood = 1.54 tons/cord, default (OMNI, 2006)

Appendix A contains the default and region-specific non-default values for the variables.

1.2.2. Fireplaces - Manufactured Wax/Sawdust Logs

Manufactured Wax/Sawdust Logs (e.g., Pine Mountain, Hearthlog, etc.) are made from a mixture of sawdust, wax, and binders. Statewide sales data can be used to determine California's total consumption, which can then be distributed among the various counties, air basins, and districts (i.e., each COABDIS combination) (OMNI, 2006). Provided below is a method to determine the manufactured log consumption rate for fireplaces.

Equation 6: $H_{fp,ml} = [H_{total}]*[P_{fp}]*[P_{fp,u}]*[P_{fp,ml}]$ for each COABDIS combination

Equation 7: $F_{ml} = ([H_{fp,ml,\text{each COABDIS}}]/[H_{fp,ml,\text{statewide total}}])*[\text{CA Mfrd. Log Sales}]$

Where

$H_{fp,ml}$	=	Number of homes with fireplaces that primarily burn manufactured logs
H_{total}	=	Number of occupied housing units in the county (divided by air basin, if needed)
P_{fp}	=	Percent of homes with a fireplace
$P_{fp,u}$	=	Percent of homes with a fireplace that was actually used during the burn season
$P_{fp,ml}$	=	Percent of active fireplaces that primarily burn manufactured logs = 12%, default (Houck, 2001b)
F_{ml}	=	Amount of manufactured logs burned in fireplaces, tons/year
$H_{fp,ml,\text{each COABDIS}}$	=	Number of homes with fireplaces that primarily burn manufactured logs for each county/air basin/district combination
$H_{fp,ml,\text{statewide total}}$	=	Statewide total for all homes with fireplaces that primarily burn manufactured logs (sum of all $H_{fp,ml,\text{each COABDIS}}$)
CA Mfrd. Log Sales	=	Total sales of manufactured logs in California, tons/year

Appendix A contains the default and region-specific non-default values for the variables.

2.0. WOOD STOVES

2.1. Determine the number of homes with wood stoves that are actually used.

Equation 8: $H_{w,u} = [H_{total}]*[P_w]*[P_{w,u}]$

Where

$H_{w,u}$	=	Number of homes with wood stoves that are actually in use
H_{total}	=	Number of occupied housing units in the county (divided by air basin, if needed)
P_w	=	Percent of homes with a wood stove
$P_{w,u}$	=	Percent of homes with a wood stove that was actually used during the burn season

Appendix A contains the default and region-specific non-default values for the variables.

2.2. Determine the amount of wood burned in wood stoves.

For wood stoves, we assume that only cord wood is burned, because survey data indicate that wood stove owners do not purchase bundles of wood (OMNI, 2003). In addition, wax/sawdust manufactured logs are not recommended for use in wood stoves (HPBA, 2009b). There are three types of wood stoves that are addressed in this methodology:

(1) Conventional Wood Stoves
(2) Phase II Catalytic Wood Stoves
(3) Phase II Non-Catalytic Wood Stoves

Provided below are methods for estimating the consumption rates for wood stoves.

2.2.1. Wood Stoves - Cord Wood

This methodology assumes that all wood stoves in use burn cord wood. In addition, it is assumed that wood stoves are used for heating purposes only. Provided below is a method to determine the cord wood consumption rate for wood stoves.

Total Cord Wood Consumption for All Wood Stoves

Equation 9: $F_w = [H_{w,u}]*[N_{cord}]*[W_{cord}]$

Where

F_w = Total amount of cord wood burned in wood stoves, tons wood/year
$H_{w,u}$ = Number of homes with wood stoves that are actually in use
N_{cord} = Number of cords burned in wood stoves, cords/home/year
W_{cord} = Weight of an average cord of wood = 1.54 tons/cord (OMNI, 2006)

Cord Wood Consumption for Conventional Non-Catalytic Wood Stoves

Equation 10: $F_{w,con} = [F_w]*[100\% - P_{ph}]$

Where

$F_{w,con}$ = Amount of cord wood burned in conventional wood stoves, tons wood/year
F_w = Total amount of cord wood burned in wood stoves, tons wood/year
P_{ph} = Percent of wood stoves that are Phase II

Note: It is assumed that all wood stoves purchased prior to 1 July 1990 are conventional non-catalytic units and all wood stoves purchased on or after 1 July 1990 are Phase II EPA-certified units (catalytic and non-catalytic). Therefore, the estimated percentage of conventional wood stoves is [100% - P_{ph}].

Cord Wood Consumption for Phase II Catalytic Wood Stoves

Equation 11: $F_{w,cat} = [F_w]*[P_{ph}]*[P_c]$

Where

$F_{w,cat}$ = Amount of cord wood burned in Phase II catalytic wood stoves, tons wood/year
F_w = Total amount of cord wood burned in wood stoves, tons wood/year
P_{ph} = Percent of wood stoves that are Phase II
P_c = Percent of wood stoves that are catalytic

Note: It is assumed that all wood stoves purchased prior to 1 July 1990 were conventional non-catalytic units. Therefore, the percentage of catalytic wood stoves was only applied to Phase II wood stoves purchased on or after 1 July 1990.

Cord Wood Consumption for Phase II Non-Catalytic Wood Stoves

Equation 12: $F_{w,ncat} = [F_w]*[P_{ph}]*[100\% - P_c]$

Where

$F_{w,ncat}$ = Amount of cord wood burned in Phase II non-catalytic wood stoves, tons wood/year
F_w = Total amount of cord wood burned in wood stoves, tons wood/year
P_{ph} = Percent of wood stoves that are Phase II (i.e., purchased after 1 July 1990)
P_c = Percent of wood stoves that are catalytic
Appendix A contains the default and region-specific non-default values for the variables.

3.0. FIREPLACE INSERTS

3.1. Determine the number of homes with fireplace inserts that are actually used.

Equation 13: $H_{fi,u} = [H_{total}]*[P_{fi}]*[P_{fi,u}]$

Where
$H_{fi,u}$ = Number of homes with fireplace inserts that are actually in use
H_{total} = Number of occupied housing units in the county (divided by air basin, if needed)
P_{fi} = Percent of homes with a fireplace insert
$P_{fi,u}$ = Percent of homes with a fireplace insert that was actually used during the burn season
Appendix A contains the default and region-specific non-default values for the variables.

3.2. Determine the amount of wood burned in fireplace inserts.

For fireplace inserts, we assume that three types of fuel are primarily burned: (1) cord wood; (2) bundle wood; and (3) compressed sawdust logs which are 100% sawdust and wood shavings with no wax or binders (e.g., Pres-to Logs, Eco-Logs, etc.).

Similar to wood stoves, there are three types of fireplace inserts that are addressed in this methodology:

(1) Conventional Fireplace Inserts
(2) Phase II Catalytic Fireplace Inserts
(3) Phase II Non-Catalytic Fireplace Inserts

Emissions for fireplace inserts are reported under EIC 610-600-0230-0000, the general wood stove category. Provided below are methods for estimating the consumption rates for fireplace inserts.

3.2.1. Fireplace Inserts - Cord Wood

This methodology assumes that fireplace inserts burn cord wood for heating purposes only. Provided below is a method to determine the cord wood consumption rate for fireplace inserts.

Total Cord Wood Consumption for All Fireplace Inserts

Equation 14: $F_{fi,cord} = [H_{fi,u}]*[N_{cord}]*[W_{cord}]$

Where
$F_{fi,cord}$ = Total amount of cord wood burned in fireplace inserts, tons wood/year
$H_{fi,u}$ = Number of homes with fireplace inserts that are actually in use
N_{cord} = Number of cords burned in fireplace inserts, cords/home/year
W_{cord} = Weight of an average cord of wood = 1.54 tons/cord (OMNI, 2006)

Cord Wood Consumption for Conventional Non-Catalytic Fireplace Inserts

Equation 15: $F_{fi,con} = [F_{fi,cord}]*[100\% - P_{ph}]$

Where

$F_{fi,con}$ = Amount of cord wood burned in conventional fireplace inserts, tons wood/year
$F_{fi,cord}$ = Total amount of cord wood burned in fireplace inserts, tons wood/year
P_{ph} = Percent of fireplace inserts that are Phase II

Note: It is assumed that all fireplace inserts purchased prior to 1 July 1990 are conventional non-catalytic units and all fireplace inserts purchased on or after 1 July 1990 are Phase II EPA-certified units (catalytic and non-catalytic). Therefore, the estimated percentage of conventional fireplace inserts is [100% - P_{ph}].

Cord Wood Consumption for Phase II Catalytic Fireplace Inserts

Equation 16: $F_{fi,cat} = [F_{fi,cord}]*[P_{ph}]*[P_c]$

Where

$F_{fi,cat}$ = Amount of cord wood burned in Phase II catalytic fireplace inserts, tons wood/year
$F_{fi,cord}$ = Total amount of cord wood burned in fireplace inserts, tons wood/year
P_{ph} = Percent of fireplace inserts that are Phase II
P_c = Percent of fireplace inserts that are catalytic

Note: It is assumed that all fireplace inserts purchased prior to 1 July 1990 were conventional non-catalytic units. Therefore, the percentage of catalytic fireplace inserts was only applied to Phase II fireplace inserts purchased on or after 1 July 1990.

Cord Wood Consumption for Phase II Non-Catalytic Fireplace Inserts

Equation 17: $F_{fi,ncat} = [F_{fi,cord}]*[P_{ph}]*[100\% - P_c]$

Where

$F_{fi,ncat}$ = Amount of cord wood burned in Phase II non-catalytic fireplace inserts, tons wood/year
$F_{fi,cord}$ = Total amount of cord wood burned in fireplace inserts, tons wood/year
P_{ph} = Percent of fireplace inserts that are Phase II (i.e., purchased after 1 July 1990)
P_c = Percent of fireplace inserts that are catalytic

Appendix A contains the default and region-specific non-default values for the variables.

3.2.2. Fireplace Inserts - Bundle Wood

Bundle wood is typically purchased from a retail store, either packaged in a box or wrapped in plastic. Depending on the type of survey data available, bundle wood may be included with cord wood or it may be broken out separately. This methodology assumes that 9.4% of fireplaces burn bundle wood in addition to cord wood, based on average survey results (OMNI, 2003). However, this percentage may change if more detailed usage data are available. Average survey results may also be used to estimate the average consumption rate for bundles of wood (OMNI, 2003). Provided below is a method to determine the bundle wood consumption rate for fireplace inserts.

Total Bundle Wood Consumption for All Fireplace Inserts

Equation 18: $F_{fi,bundle} = [H_{fi,u}]*[P_{fi,bundle}]*[N_{bundle}]*[W_{bundle}]$

Where

$F_{fi,bundle}$ = Amount of bundle wood burned in fireplace inserts, tons wood/year
$H_{fi,u}$ = Number of homes with fireplace inserts that are actually in use
$P_{fi,bundle}$ = Percent of fireplace inserts that burn bundle wood = 9.4%, default (OMNI, 2003)
N_{bundle} = Number of bundles burned in fireplaces, bundles/home/year
W_{bundle} = Weight of an average bundle of wood = 0.024 ton/bundle (assuming 1 bundle = 1/64 of a cord or 1ft.x1ft.x2ft.) (OMNI, 2003)

Appendix A contains the default and region-specific non-default values for the variables.

Bundle Wood Consumption for Conventional Non-Catalytic Fireplace Inserts

Equation 19: $F_{fi,con,b} = [F_{fi,bundle}]*[100\% - P_{ph}]$

Where

$F_{fi,con,b}$ = Amount of bundle wood burned in conventional fireplace inserts, tons wood/year
$F_{fi,bundle}$ = Total amount of bundle wood burned in fireplace inserts, tons wood/year
P_{ph} = Percent of fireplace inserts that are Phase II

Note: It is assumed that all fireplace inserts purchased prior to 1 July 1990 are conventional non-catalytic units and all fireplace inserts purchased on or after 1 July 1990 are Phase II EPA-certified units (catalytic and non-catalytic). Therefore, the estimated percentage of conventional fireplace inserts is [100% - P_{ph}].

Bundle Wood Consumption for Phase II Catalytic Fireplace Inserts

Equation 20: $F_{fi,cat,b} = [F_{fi,bundle}]*[P_{ph}]*[P_c]$

Where

$F_{fi,cat,b}$ = Amount of bundle wood burned in Phase II catalytic fireplace inserts, tons wood/year
$F_{fi,bundle}$ = Total amount of bundle wood burned in fireplace inserts, tons wood/year
P_{ph} = Percent of fireplace inserts that are Phase II
P_c = Percent of fireplace inserts that are catalytic

Note: It is assumed that all fireplace inserts purchased prior to 1 July 1990 were conventional non-catalytic units. Therefore, the percentage of catalytic fireplace inserts was only applied to Phase II fireplace inserts purchased on or after 1 July 1990.

Bundle Wood Consumption for Phase II Non-Catalytic Fireplace Inserts

Equation 21: $F_{fi,ncat,b} = [F_{fi,bundle}]*[P_{ph}]*[100\% - P_c]$

Where

$F_{fi,ncat,b}$ = Amount of bundle wood burned in Phase II non-catalytic fireplace inserts, tons wood/year
$F_{fi,bundle}$ = Total amount of bundle wood burned in fireplace inserts, tons wood/year
P_{ph} = Percent of fireplace inserts that are Phase II
P_c = Percent of fireplace inserts that are catalytic

Appendix A contains the default and region-specific non-default values for the variables.

3.2.3. Fireplace Inserts – Compressed Wood Logs

Compressed Wood Logs are made from 100% compressed sawdust and wood shavings (e.g., Pres-to Logs, Eco-Logs, etc.). Survey data are available to estimate average consumption rates for compressed wood logs (OMNI, 2003). The use of compressed wood logs is very limited, when compared to the other fuels, and emissions from compressed wood logs often represent a

negligible part of the emissions inventory. For that reason, this methodology estimates an overall consumption rate, rather than allocating the compressed wood log usage among different types of fireplace inserts (conventional, catalytic, non-catalytic). Provided below is a method to determine the overall compressed wood log consumption rate for fireplace inserts.

Equation 22: $F_{fi,cwl} = [H_{fi,u}]*[P_{fi,cwl}]*[N_{cwl}]*[W_{cwl}]$

Where

$F_{fi,cwl}$ = Amount of compressed wood logs burned in fireplace inserts, tons/year
$H_{fi,u}$ = Number of homes with fireplace inserts that are actually in use
$P_{fi,cwl}$ = Percent of fireplace inserts that burn compressed wood logs
N_{cwl} = Number of compressed wood logs burned in fireplace inserts, logs/home/year
W_{cwl} = Weight of an average compressed wood log = 5 lbs/log or 0.0025 tons/log (OMNI, 2003)

Appendix A contains the default and region-specific non-default values for the variables.

4.0 PELLET STOVES

4.1 Determine the number of homes with wood-burning pellet stoves that are actually used.

Equation 23: $H_{ps,u} = [H_{total}]*[P_{ps}]*[P_{ps,u}]$

Where

$H_{ps,u}$ = Number of homes with pellet stoves that are actually in use
H_{total} = Number of occupied housing units in the county (divided by air basin, if needed)
P_{ps} = Percent of homes with a pellet stove
$P_{ps,u}$ = Percent of homes with a pellet stove that was actually used during the burn season

Appendix A contains the default and region-specific non-default values for the variables.

4.2. Determine the amount of wood burned in pellet stoves.

The methodology assumes that all pellet stoves in use burn only one type of fuel – compressed wood pellets. Survey data are available to estimate average consumption rates for sacks of pellets (OMNI, 2003). Provided below is a method to determine the consumption rate for sacks of pellets used in pellet stoves:

Equation 24: $F_{ps} = [H_{ps,u}]*[N_{sacks}]*[W_{sack}]$

Where

$H_{ps,u}$ = Number of homes with pellet stoves that are actually in use
F_{ps} = Amount of pellets burned in pellet stoves, tons/year
N_{sacks} = Number of sacks of pellets burned in pellet stoves, sacks/home/year
W_{sack} = Weight of an average sack of pellets = 40 lbs/sack or 0.02 tons/sack (HPBA, 2009c)

Appendix A contains the default and region-specific non-default values for the variables.

Emissions for pellet stoves are reported under EIC 610-600-0230-0000, the general wood stove category.

5.0 EMISSIONS CALCULATIONS

After fuel consumption data are determined as described above, emissions are calculated using the following general equation:

Equation 25: E = [EF]*[F]/2000 lbs/ton

Where

E	=	Emissions, tons/year
F	=	Amount of fuel burned, tons/year
EF	=	Emission Factor, lbs pollutant/ton fuel burned

Table 1 contains default values for emission factors. These factors have been updated to reflect data used by U.S. EPA to develop the 2002 National Emission Inventory (NEI) and information from other wood combustion studies. It is important to note that U.S. EPA emission factors assume that Total PM, PM_{10} and $PM_{2.5}$ are all equivalent. This is not consistent with ARB's designated particulate size fractions for residential wood combustion ([PM_{10}] = 0.935*[Total PM]; [$PM_{2.5}$] = 0.9001*[Total PM]). To ensure consistency with ARB size fractions, emission factors have been adjusted to correspond to the appropriate size fraction. For example, if U.S. EPA provided an emission factor for the PM_{10} size fraction, we determined the corresponding $PM_{2.5}$ emission factor by applying the ratio of size fractions ($PM_{2.5}/PM_{10}$ = 0.9001/0.935). Using this approach, $PM_{2.5}$ emission factors are 96.3% of PM_{10} emission factors.

Table 2 contains 2005 estimated fuel use and emissions for fireplaces. Table 3 contains 2005 estimated fuel use and emissions for wood stoves (including wood stoves, fireplace inserts, and pellet stoves). Detailed data on fuel use and emissions are presented in Appendix A.

Table 1 Residential Wood Combustion Emission Factors

		EMISSION FACTORS (lbs/ton fuel burned)						
Device Description	**Fuel Type**	**CO**	**NO_X**	**$PM_{2.5}$**	**PM_{10}**	**SO_2**	**VOC / ROG**	**NH_3**
Fireplace	Cord Wood, Bundles	149 [4]	2.6 [2]	22.7 [7]	23.6 [1]	0.4 [2]	18.9 [4,8]	1.8 [3]
Fireplace	Manufactured Log	137 [4]	6.5 [4]	46.4 [7]	48.2 [4]	4.2 [4]	33.8 [4]	0.004 [4]
Woodstove: Conventional (non-EPA certified)	Cord Wood	230.8 [5]	2.8 [5]	29.5 [7]	30.6 [5]	0.4 [5]	53 [5]	1.7 [3]
Woodstove: Phase II EPA certified, Non-Catalytic	Cord Wood	140.8 [5]	2.28 [4]	14.1 [7]	14.6 [5]	0.4 [5]	12 [5]	0.9 [3]
Woodstove: Phase II EPA certified, Catalytic	Cord Wood	104.4 [1]	2 [5]	19.6 [7]	20.4 [5,9]	0.4 [5]	15 [5]	0.9 [3]
Fireplace Inserts: Conventional (non-EPA certified)	Cord Wood, Bundles	230.8 [5]	2.8 [5]	29.5 [7]	30.6 [5]	0.4 [5]	53 [5]	1.7 [3]
Fireplace Inserts: Phase II EPA certified; Non-Catalytic	Cord Wood, Bundles	140.8 [5]	2.28 [4]	14.1 [7]	14.6 [5]	0.4 [5]	12 [5]	0.9 [3]
Fireplace Inserts: Phase II EPA certified; Catalytic	Cord Wood, Bundles	104.4 [1]	2 [5]	19.6 [7]	20.4 [5,9]	0.4 [5]	15 [5]	0.9 [3]
Fireplace Inserts: All	Compressed Wood Log	201.2 [6]	2.8 [5]	25.0 [7]	26.0 [6,7]	0.4 [5]	15.1 [6]	1.7 [3]
Pellet Stove	Pellets	15.9 [4]	3.8 [4]	2.9 [7]	3.06 [4]	0.32 [4]	0.04 [4]	0.3 [3,4]

References and Notes:

1. 2002 National Emission Inventory (Pechan, 2006; Broderick, 2005)
2. U.S. EPA AP-42 Section 1.9 (U.S EPA, 1996b)
3. U.S. EPA Emission Inventory Improvement Program (EC/R, 2002; EIIP, 2004)
4. Mid-Atlantic Regional Air Management Association (MARAMA) study (Houck, 2006)
5. U.S. EPA AP-42 Section 1.10 (U.S EPA, 1996a) and Houck, J.E., J. Crouch, and R.H. Huntley. 2001. *Review of Wood Heater and Fireplace Emission Factors.*
6. Oregon Department of Energy study (Barnett, 1992). Note: ARB PM Speciation Profile #424 was used to convert from Total PM to PM_{10} (ARB, 2005).
7. This emission factor was adjusted to match ARB's particulate size fractions.
8. U.S. EPA 2005 NEI Technical Support Document (U.S. EPA, 2010)
9. For wood stoves classified as "Catalytic - Phase II", U.S. EPA AP-42 lists a PM_{10} emission factor of 16.2 lb/ton. Since the deterioration of the catalyst in these stoves can result in higher emissions, ARB staff are using the more conservative AP-42 emission factor for "Catalytic – All" wood stoves (20.4 lb/ton).
10. The EIIP document did not include an ammonia emission factor for Phase II Catalytic wood stoves. Therefore, it was assumed that the ammonia emission factor for Phase II Non-Catalytic wood stoves was appropriate for Phase II Catalytic wood stoves.
11. The Oregon Dept. of Energy study did not include NO_X or SO_2 emission factors for fireplace inserts burning compressed wood logs. Therefore, it was assumed that the emission factors for conventional fireplaces with inserts were appropriate for estimating emissions.
12. [Total PM] = [PM_{10}]/[0.935]; [Total Organic Gases, TOG] = [ROG]/0.4385 [ARB Speciation Profile #424]
13. "Outdoor wood burning devices" include chimeneas, patio firepits, etc. For these devices, it was assumed that the emission factors for fireplaces without inserts were appropriate for estimating emissions.
14. Ammonia emission factors were generally estimated by using a molar ratio of ammonia to carbon monoxide, based on emissions data from the combustion of forest fuels (EC/R, 2002; EIIP, 2004).

The emission factors provided in Table 1 are based on the mass of fuel burned and they may not provide an accurate basis for comparison among different types of wood burning devices or different fuels. For example, the emission factors for manufactured logs may be higher than for cord wood, but fireplace users may burn only one manufactured log to provide the same type of fire that would otherwise require several pieces of cord wood. Similarly, the emission factors for wood stoves may be higher than those for fireplaces, but wood stoves are much more efficient for heating purposes and studies show that certified wood stoves produce lower emissions per unit of heat delivered when compared to fireplaces or conventional stoves (Houck, 1998; Houck, 2005).

6.0 SAMPLE CALCULATIONS

Estimating Annual Emissions for Residential Fireplaces: El Dorado County (Mountain Counties)

In 2005, El Dorado County had 65,962 houses (14,220 in the Lake Tahoe Air Basin and 51,742 houses in the Mountain Counties Air Basin). A survey was conducted in 2001 that gathered data for the Sacramento Valley area, including El Dorado County (OMNI, 2003). Based on that survey data, the emission calculations for wood-burning fireplaces are provided below for the Mountain Counties Air Basin portion of El Dorado County:

From Equation 1, determine the number of fireplaces that are actually being used in El Dorado County (Mountain Counties Air Basin portion):

$$FP_{all} = [H_{total}]*[P_{fp}]*[P_{fp,u}] *[M_{fp}]$$

Based on survey data, 39% of homes in El Dorado County have fireplaces and 71% of those fireplaces are being used (OMNI, 2003). Also, the average number of fireplaces per home is 1.1, to account for the fact that some homes have multiple fireplaces (OMNI, 2003).

$$FP_{all} = [51,742]*[39\%]*[71\%]*[1.1] = 15,760 \text{ fireplaces in use}$$

For cord wood and bundle wood, use Equations 2 and 4 to determine the number of fireplaces being used for aesthetic and heating purposes:

$$FP_{aes} = [FP_{all}]*[P_{fp,cord}]*[P_{fp,aes}]$$
$$FP_{heat} = [FP_{all}]*[P_{fp,cord}]*[P_{fp,heat}]$$

Survey data indicate that 56% of the fireplaces in El Dorado County are used for aesthetic purposes and the remaining 44% are used for heating purposes (OMNI, 2003). Also, it is estimated that 88% of fireplaces burn primarily cord wood (Houck, 2001b).

$$FP_{aes} = [15,760 \text{ fireplaces}]*[88\%]*[56\%]$$
$$= 7,767 \text{ fireplaces used for aesthetic purposes}$$

$$FP_{heat} = [15,760 \text{ fireplaces}]*[88\%]*[44\%]$$
$$= 6,102 \text{ fireplaces used for heating purposes}$$

Use Equations 3 and 5 to determine the amount of cord wood and bundle wood burned in fireplaces for aesthetic and heating purposes:

$F_{aes} = [FP_{aes}]*[N_{cord,aes}]*[W_{cord}]$
$F_{heat} = [FP_{heat}]*[N_{cord,heat}]*[W_{cord}]$

The methodology for U.S. EPA's 2002 National Emission Inventory assumes that two different consumption rates should be used for fireplaces burning cord wood: 0.656 cords/fireplace/year for heating and 0.069 cords/fireplace/year for aesthetic purposes (Houck, 2001a; Pechan, 2006). The average weight for a cord of wood is assumed to be 1.54 tons/cord (OMNI, 2006).

F_{aes} = [7,767 fireplaces]*[0.069 cords/fireplace/year]*[1.54 tons/cord]
= 825 tons burned/year for aesthetic purposes
F_{heat} = [6,102 fireplaces]*[0.656 cords/fireplace/year]*[1.54 tons/cord]
= 6,165 tons burned/year for heating

Using Equation 25, calculate emissions from fireplaces burning cord wood:
E = [EF]*[F]/2000 lbs/ton

From Table 1, the PM2.5 emission factor is 22.7 lbs PM2.5/ton burned

E = [22.7 lbs PM2.5/ton]*[825 tons burned/year]/2000 lbs/ton
= 9 tons PM2.5/year for aesthetic purposes
E = [22.7 lbs PM2.5/ton]*[6,165 tons burned/year]/2000 lbs/ton
= 70 tons PM2.5/year for heating

For manufactured logs, use Equations 6 and 7 to determine the number of fireplaces being used for aesthetic and heating purposes:
Equation 6: $H_{fp,ml} = [H_{total}]*[P_{fp}]*[P_{fp,u}]*[P_{fp,ml}]$

It is estimated that 12% of homes that use their fireplace primarily burn manufactured logs (Houck, 2001b).

$H_{fp,ml}$ = [51,742 homes]*[39%]*[71%]*[12%]= 1,719 homes for El Dorado County (Mountain Counties Air Basin portion)

$H_{fp,ml,statewide\ total}$ = 377,085 homes statewide

Equation 7: $F_{ml} = ([H_{fp,ml,each\ COABDIS}]/[H_{fp,ml,statewide\ total}])*[CA\ Mfrd.\ Log\ Sales]$
F_{ml} = ([1,719 homes]/[377,085 homes])*[60,825 tons/yr] = 277 tons burned/year

Using Equation 25, calculate emissions from fireplaces burning manufactured logs:
E = [EF]*[F]/2000 lbs/ton

From Table 1, the $PM_{2.5}$ emission factor is 46.4 lbs $PM_{2.5}$/ton burned
E = [46.4 lbs $PM_{2.5}$/ton]*[277 tons burned/year]/2000 lbs/ton = 6.4 tons $PM_{2.5}$/year

Total emissions from fireplaces in El Dorado County (Mountain Counties Air Basin portion):
E = 9 + 70 + 6 = 86 tons $PM_{2.5}$/year

Table 2: Fireplaces – 2005 Fuel Use and Emissions Estimates

			FUEL USE (Tons/Yr)			2005 EMISSIONS (Tons/Year)						
AB	Dis	County (Air Basin)	Cord Wood	Mfrd. Logs	Total All Fuels	CO	NO_X	$PM_{2.5}$	PM_{10}	SO_2	ROG	NH_3
GBV	GBU	Alpine	161	7	168	12	0	2	2	0	2	0
GBV	GBU	Inyo	1,719	73	1,792	133	2	21	22	0	17	2
GBV	GBU	Mono	1,858	79	1,937	144	3	23	24	1	19	2
LC	LAK	Lake	4,053	172	4,226	314	6	50	52	1	41	4
LT	ED	El Dorado (LT)	1,921	77	1,998	148	3	24	25	1	19	2
LT	PLA	Placer (LT)	811	33	843	63	1	10	10	0	8	1
MC	AMA	Amador	3,259	138	3,398	252	5	40	42	1	33	3
MC	CAL	Calaveras	3,037	129	3,166	235	4	37	39	1	31	3
MC	ED	El Dorado (MC)	6,990	281	7,271	540	10	86	89	2	71	6
MC	MPA	Mariposa	1,190	51	1,240	92	2	15	15	0	12	1
MC	NSI	Nevada	6,566	279	6,845	508	9	81	84	2	67	6
MC	NSI	Plumas	2,896	123	3,019	224	4	36	37	1	29	3
MC	NSI	Sierra	422	18	440	33	1	5	5	0	4	0
MC	PLA	Placer (MC)	1,459	59	1,518	113	2	18	19	0	15	1
MC	TUO	Tuolumne	3,606	153	3,760	279	5	45	46	1	37	3
MD	AV	Los Angeles (MD)	367	374	741	53	2	13	13	1	10	0
MD	KER	Kern (MD)	2,351	86	2,437	181	3	29	30	1	24	2
MD	MOJ	Riverside (MD)	39	34	72	5	0	1	1	0	1	0
MD	MOJ	San Bernardino (MD)	819	708	1,527	110	3	26	27	2	20	1
MD	SC	Riverside (MD)	23	20	43	3	0	1	1	0	1	0
NC	MEN	Mendocino	8,223	349	8,573	637	12	102	105	2	84	7
NC	NCU	Del Norte	2,549	108	2,657	197	4	31	33	1	26	2
NC	NCU	Humboldt	10,404	442	10,846	805	15	128	133	3	106	9
NC	NCU	Trinity	1,886	80	1,966	146	3	23	24	1	19	2
NC	NS	Sonoma (NC)	4,720	141	4,861	361	7	57	59	1	47	4
NCC	MBU	Monterey	17,909	760	18,669	1,386	26	221	230	5	182	16
NCC	MBU	San Benito	2,513	107	2,619	194	4	31	32	1	26	2
NCC	MBU	Santa Cruz	18,841	800	19,641	1,458	27	233	242	5	192	17
NEP	LAS	Lassen	2,876	122	2,998	223	4	36	37	1	29	3
NEP	MOD	Modoc	980	42	1,022	76	1	12	13	0	10	1
NEP	SIS	Siskiyou	5,504	234	5,737	426	8	68	71	2	56	5
SC	SC	Los Angeles (SC)	12,031	12,045	24,076	1,721	55	416	432	28	317	11
SC	SC	Orange	5,907	6,024	11,931	853	27	207	215	14	158	5
SC	SC	Riverside (SC)	2,965	2,564	5,530	397	12	93	97	6	71	3
SC	SC	San Bernardino (SC)	2,855	2,469	5,325	382	12	90	93	6	69	3
SCC	SB	Santa Barbara	10,276	1,066	11,342	839	17	141	147	4	115	9
SCC	SLO	San Luis Obispo	17,360	737	18,098	1,344	25	214	223	5	177	16
SCC	VEN	Ventura	32,306	1,372	33,678	2,501	46	399	414	9	328	29
SD	SD	San Diego	5,683	5,189	10,872	779	24	185	192	12	141	5
SF	BA	Alameda	49,507	2,477	51,983	3,858	72	620	644	15	510	45
SF	BA	Contra Costa	94,221	2,316	96,536	7,178	130	1,124	1,168	24	930	85
SF	BA	Marin	8,479	806	9,285	687	14	115	119	3	94	8
SF	BA	Napa	8,995	310	9,305	691	13	109	114	2	90	8
SF	BA	San Francisco	6,181	1,112	7,294	537	12	96	100	4	77	6
SF	BA	San Mateo	16,689	1,897	18,586	1,373	28	234	243	7	190	15
SF	BA	Santa Clara	70,647	2,643	73,290	5,444	100	864	897	20	712	64
SF	BA	Solano (SF)	19,433	564	19,997	1,486	27	234	243	5	193	17
SF	BA	Sonoma (SF)	31,913	952	32,866	2,443	45	385	400	8	318	29
SJV	SJU	Fresno	49,461	715	50,176	3,734	67	578	601	11	479	45
SJV	SJU	Kern (SJV)	29,189	422	29,611	2,204	39	341	355	7	283	26
SJV	SJU	Kings	5,752	83	5,835	434	8	67	70	1	56	5
SJV	SJU	Madera	7,325	106	7,430	553	10	86	89	2	71	7
SJV	SJU	Merced	12,920	187	13,106	975	17	151	157	3	125	12
SJV	SJU	San Joaquin	69,428	1,003	70,431	5,241	94	812	843	16	673	62
SJV	SJU	Stanislaus	41,253	596	41,849	3,114	56	482	501	10	400	37
SJV	SJU	Tulare	29,252	423	29,675	2,208	39	342	355	7	284	26
SS	IMP	Imperial	876	59	935	69	1	11	12	0	9	1
SS	SC	Riverside (SS)	807	698	1,506	108	3	25	26	2	19	1
SV	BUT	Butte	11,548	464	12,012	892	17	142	147	3	117	10
SV	COL	Colusa	894	36	930	69	1	11	11	0	9	1

Table 2: Fireplaces – 2005 Fuel Use and Emissions Estimates

AB	Dis	County (Air Basin)	FUEL USE (Tons/Yr)			2005 EMISSIONS (Tons/Year)						
			Cord Wood	Mfrd. Logs	Total All Fuels	CO	NO_X	$PM_{2.5}$	PM_{10}	SO_2	ROG	NH_3
SV	FR	Sutter	4,023	162	4,184	311	6	49	51	1	41	4
SV	FR	Yuba	2,975	120	3,094	230	4	37	38	1	30	3
SV	GLE	Glenn	1,284	52	1,336	99	2	16	16	0	13	1
SV	PLA	Placer (SV)	6,854	658	7,513	556	11	93	97	3	76	6
SV	SAC	Sacramento	33,252	3,194	36,446	2,696	54	452	469	13	368	30
SV	SHA	Shasta	9,216	370	9,586	712	13	113	118	3	93	8
SV	TEH	Tehama	3,027	122	3,149	234	4	37	39	1	31	3
SV	YS	Solano (SV)	3,282	315	3,598	266	5	45	46	1	36	3
SV	YS	Yolo	4,386	421	4,807	356	7	60	62	2	49	4
		Totals (tons/year) =	**842,407**	**60,825**	**903,233**	**66,926**	**1,293**	**10,981**	**11,406**	**296**	**8,989**	**758**
		Totals (Annual Avg. tons/day) =	**2,308**	**167**	**2,475**	**183**	**4**	**30**	**31**	**1**	**25**	**2**

Emission Inventory Code (EIC): 610-602-0230-0000
[Total PM] = [PM_{10}]/[0.935], per ARB particulate matter profile code #424
[$PM_{2.5}$] = [Total PM]*[0.9001] = [PM_{10}]*[0.9001/0.935] = [PM_{10}]*[0.963], per ARB particulate matter profile code #424
[Total Organic Gases, TOG] = [ROG]/0.4385, per ARB organic profile code #549

Table 3: All Wood Stoves – 2005 Fuel Use and Emissions Estimates

(includes Wood Stoves, Fireplace Inserts, and Pellet Stoves)

AB	Dis	County (Air Basin)	FUEL USE (Tons/Yr)						2005 EMISSIONS (Tons/Year)						
			Cord Wood: Convntl.	Cord Wood: Phase II, Non-Catalytic	Cord Wood: Phase II, Catalytic	Comp. Wood Logs	Pellets	Total for All Fuels	CO	NO_X	$PM_{2.5}$	PM_{10}	SO_2	ROG	NH_3
GBV	GBU	Alpine	115	72	26	0	0	212	20	0	2	3	0	4	0
GBV	GBU	Inyo	1,225	767	276	1	0	2,268	210	3	26	27	0	39	2
GBV	GBU	Mono	1,324	830	298	1	0	2,452	227	3	28	29	0	42	2
LC	LAK	Lake	5,148	3,251	1,134	3	0	9,535	882	12	110	114	2	164	6
LT	ED	El Dorado (LT)	3,732	2,148	722	5	114	6,721	621	9	77	80	1	117	4
LT	PLA	Placer (LT)	1,575	906	305	2	48	2,836	262	4	33	34	1	49	2
MC	AMA	Amador	4,270	2,717	921	2	0	7,910	732	10	91	95	2	136	5
MC	CAL	Calaveras	6,660	4,250	1,423	2	0	12,335	1,142	16	142	147	2	213	8
MC	ED	El Dorado (MC)	13,579	7,818	2,628	18	414	24,456	2,260	31	282	292	5	427	16
MC	MPA	Mariposa	1,534	969	338	1	189	3,030	264	4	33	34	1	49	2
MC	NSI	Nevada	9,992	6,336	2,176	4	0	18,507	1,713	23	213	221	4	319	12
MC	NSI	Plumas	4,129	2,631	887	1	0	7,648	708	10	88	91	2	132	5
MC	NSI	Sierra	301	189	68	0	0	557	52	1	6	7	0	10	0
MC	PLA	Placer (MC)	2,834	1,632	548	4	86	5,104	472	7	59	61	1	89	3
MC	TUO	Tuolumne	8,322	5,315	1,774	2	0	15,413	1,427	19	177	184	3	266	10
MD	AV	Los Angeles (MD)	998	178	88	0	0	1,264	132	2	17	17	0	28	1
MD	KER	Kern (MD)	863	428	41	0	0	1,332	132	2	16	17	0	26	1
MD	MOJ	Riverside (MD)	199	35	17	0	0	251	26	0	3	3	0	6	0
MD	MOJ	San Bernardino (MD)	4,488	799	394	0	0	5,682	595	8	76	79	1	127	4
MD	SC	Riverside (MD)	119	21	10	0	0	151	16	0	2	2	0	3	0
NC	MEN	Mendocino	11,927	7,601	2,560	4	0	22,092	2,046	28	254	264	4	381	15
NC	NCU	Del Norte	2,587	1,638	567	1	0	4,793	444	6	55	57	1	83	3
NC	NCU	Humboldt	14,467	8,960	2,204	5	0	25,635	2,416	33	298	309	5	454	17
NC	NCU	Trinity	1,343	842	302	1	0	2,489	230	3	29	30	0	43	2
NC	NS	Sonoma (NC)	2,600	3,089	1,262	0	731	7,682	589	10	73	76	2	97	4
NCC	MBU	Monterey	9,158	5,666	2,136	9	0	16,969	1,568	21	196	203	3	293	11
NCC	MBU	San Benito	1,722	1,078	389	1	0	3,190	295	4	37	38	1	55	2
NCC	MBU	Santa Cruz	12,567	7,858	2,847	9	0	23,281	2,153	29	268	279	5	402	16

Table 3: All Wood Stoves – 2005 Fuel Use and Emissions Estimates

(includes Wood Stoves, Fireplace Inserts, and Pellet Stoves)

			FUEL USE (Tons/Yr)						2005 EMISSIONS (Tons/Year)						
AB	**Dis**	**County (Air Basin)**	**Cord Wood: Convntl.**	**Cord Wood: Phase II, Non-Catalytic**	**Cord Wood: Phase II, Catalytic**	**Comp. Wood Logs**	**Pellets**	**Total for All Fuels**	**CO**	**NO_X**	**$PM_{2.5}$**	**PM_{10}**	**SO_2**	**ROG**	**NH_3**
NEP	LAS	Lassen	4,087	2,603	878	1	0	7,569	701	10	87	91	2	131	5
NEP	MOD	Modoc	698	438	157	0	0	1,293	120	2	15	15	0	22	1
NEP	SIS	Siskiyou	7,504	4,777	1,615	3	0	13,900	1,287	18	160	166	3	240	9
SC	SC	Los Angeles (SC)	32,280	5,749	2,832	0	0	40,860	4,278	55	544	565	8	911	31
SC	SC	Orange	6,015	1,071	528	0	0	7,614	797	10	101	105	2	170	6
SC	SC	Riverside (SC)	15,173	2,702	1,331	0	0	19,207	2,011	26	256	265	4	428	15
SC	SC	San Bernardino (SC)	15,650	2,787	1,373	0	0	19,810	2,074	26	264	274	4	442	15
SCC	SB	Santa Barbara	8,830	5,637	1,885	0	0	16,352	1,514	21	188	195	3	282	11
SCC	SLO	San Luis Obispo	9,552	5,928	2,208	9	0	17,697	1,636	22	204	212	4	305	12
SCC	VEN	Ventura	9,590	5,733	2,436	16	0	17,775	1,639	22	206	214	4	307	12
SD	SD	San Diego	31,486	5,608	2,762	0	0	39,856	4,173	53	530	551	8	889	31
SF	BA	Alameda	370	440	180	0	31,096	32,086	330	60	56	58	5	14	5
SF	BA	Contra Costa	10,823	12,862	5,254	0	15,272	44,211	2,550	64	324	336	8	404	20
SF	BA	Marin	13,531	16,080	6,568	0	4,042	40,220	3,068	52	383	398	8	504	22
SF	BA	Napa	4,643	5,517	2,254	0	1,619	14,033	1,055	18	132	137	3	173	8
SF	BA	San Francisco	347	412	168	0	12,052	12,979	174	24	27	28	2	13	2
SF	BA	San Mateo	4,458	5,298	2,164	0	18,696	30,617	1,149	50	152	158	5	167	10
SF	BA	Santa Clara	7,927	9,420	3,848	0	19,274	40,469	1,932	62	249	259	7	296	16
SF	BA	Solano (SF)	692	823	336	0	1,994	3,845	171	6	22	23	1	26	1
SF	BA	Sonoma (SF)	17,578	20,889	8,532	0	4,941	51,941	3,984	66	497	516	10	655	29
SJV	SJU	Fresno	9,274	4,599	438	0	0	14,311	1,417	19	173	180	3	277	10
SJV	SJU	Kern (SJV)	4,214	2,090	199	0	0	6,503	644	8	79	82	1	126	5
SJV	SJU	Kings	614	304	29	0	0	947	94	1	11	12	0	18	1
SJV	SJU	Madera	3,835	1,902	181	0	0	5,919	586	8	72	74	1	114	4
SJV	SJU	Merced	6,921	3,432	327	0	0	10,680	1,057	14	129	134	2	206	8
SJV	SJU	San Joaquin	4,351	2,158	206	0	0	6,714	665	9	81	84	1	130	5
SJV	SJU	Stanislaus	8,180	4,057	387	0	0	12,624	1,250	16	153	159	3	244	9
SJV	SJU	Tulare	17,215	8,538	814	0	0	26,567	2,630	35	322	334	5	514	19
SS	IMP	Imperial	91	16	8	0	0	115	12	0	2	2	0	3	0
SS	SC	Riverside (SS)	4,091	729	359	0	0	5,179	542	7	69	72	1	115	4
SV	BUT	Butte	22,433	12,915	4,341	30	684	40,402	3,733	52	465	483	8	705	27
SV	COL	Colusa	1,737	1,000	336	2	53	3,128	289	4	36	37	1	55	2
SV	FR	Sutter	7,814	4,499	1,512	10	238	14,074	1,300	18	162	168	3	245	9
SV	FR	Yuba	5,779	3,327	1,118	8	176	10,408	962	13	120	124	2	182	7
SV	GLE	Glenn	2,495	1,436	483	3	76	4,493	415	6	52	54	1	78	3
SV	PLA	Placer (SV)	14,852	7,005	4,874	60	3,901	30,692	2,499	41	322	335	6	473	19
SV	SAC	Sacramento	72,052	33,982	23,644	291	18,923	148,892	12,121	200	1,564	1,624	29	2,293	90
SV	SHA	Shasta	17,904	10,307	3,464	24	546	32,245	2,979	41	371	386	6	562	22
SV	TEH	Tehama	5,881	3,386	1,138	8	179	10,592	979	14	122	127	2	185	7
SV	YS	Solano (SV)	7,112	3,354	2,334	29	1,868	14,697	1,196	20	154	160	3	226	9
SV	YS	Yolo	9,503	4,482	3,119	38	2,496	19,638	1,599	26	206	214	4	302	12
		Totals (tons/year) =	**555,358**	**306,317**	**122,958**	**609**	**139,708**	**1,124,949**	**93,243**	**1,516**	**11,753**	**12,209**	**219**	**17,484**	**687**
		Totals (Ann. Avg. tons/day) =							**255**	**4**	**32**	**33**	**1**	**48**	**2**

Emission Inventory Code (EIC): 610-600-0230-0000

[Total PM] = [PM_{10}]/[0.935], per ARB particulate matter profile code #424

[$PM_{2.5}$] = [Total PM]*[0.9001] = [PM_{10}]*[0.9001/0.935] = [PM_{10}]*[0.963], per ARB particulate matter profile code #424

[Total Organic Gases, TOG] = [ROG]/0.4385, per ARB organic profile code #549

ALTERNATIVE METHOD – United States Census Bureau American Housing Survey Data

The Preferred Method described in Sections 1 through 4 above is based on survey data that have become available since 2000, primarily for areas in Northern and Central California where residential wood combustion is more prevalent. In Southern California, fewer surveys have been conducted in recent years to gather activity data for residential wood combustion. For these areas, ARB used an alternative method based on data from the U.S. Census Bureau's American Housing Survey (AHS) to estimate wood consumption. This alternative method has been used by U.S. EPA to develop nationwide emissions estimates (Houck, 2001a, 2001b). AHS reports are available for several large metropolitan areas in California and they include the number of housing units with fireplaces and stoves. Additional data (e.g., the number of homes that use wood as a heating fuel) can be obtained through the U.S. Census Bureau's American FactFinder tool.

TEMPORAL INFORMATION

Most residential wood burning occurs during the cold season (typically in the fall, winter and early spring). To determine monthly emissions throughout the year, multiply annual average emissions by the monthly temporal factors. Daily emissions (tons/day) are calculated by ARB's emission forecasting system, based on the applicable temporal profile and the season (annual average, winter, or summer). Default temporal factors are provided below:

Table 4: Default Temporal Profiles (%)

EIC	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
61060002300000	18.2	18.2	12.7	9.1	0	0	0	0	0	9.1	14.5	18.2
61060202300000	18.2	18.2	12.7	9.1	0	0	0	0	0	9.1	14.5	18.2

Several districts have established local temporal profiles that differ from the defaults shown above. These local profiles are provided below:

Table 5: Other Temporal Profiles (%)

Dis	County	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NS	SONOMA	17.8	17.8	14.3	10.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	14.3
SHA	SHASTA	17.8	17.8	14.3	10.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	14.3
SJU	FRESNO	25.2	16.6	1.1	0.5	0.4	0.5	0	0	0.2	1.7	27.5	26.3
SJU	KERN	25.7	16	2.6	0.5	0.5	0.3	0	0	0	2	23.5	28.9
SJU	KINGS	24.9	16.1	1.8	0.5	0.5	0.3	0	0	0.1	1.8	26	28
SJU	MADERA	25	16.3	1.8	0.5	0.5	0.5	0	0	0.2	1.8	27.5	25.9
SJU	MERCED	25	17.3	1.8	0.5	0.5	0.4	0	0	0.1	1.8	26.6	26
SJU	SAN JOAQUIN	23.6	16.9	1.8	0.5	0.5	0.5	0	0	0.3	1.8	28	26.1
SJU	STANISLAUS	25.4	17	1.8	0.5	0.5	0.5	0	0	0.2	1.8	25.3	27
SJU	TULARE	25	16.3	1.8	0.5	0.5	0.5	0	0	0.1	1.8	26.3	27.2

To estimate emissions for the summer and winter seasons, multiply annual average emissions by the seasonal temporal factors. Default seasonal temporal factors are 0.183 for summer (May – October) and 1.818 for winter (November – April).

The statewide temporal cycle codes for wood stoves and fireplaces are:

Table 6: Temporal Cycle Codes

District	Description	Cycle Code	Definition
Default	Hours/Day	33	Max activity 7-9 a.m. & 7-11 p.m., ave during day, low at night (resident combst)
Default	Days/Wk	7	7 day per week – uniform activity every day of the week
SJU	Hours/Day	24	24 hours per day – uniform activity during the day
SJU	Days/Wk	7	7 day per week – uniform activity every day of the week

7.0 SPECIATION PROFILES & FRACTIONS

ARB has established the following default speciation profiles for the residential wood combustion categories:

- Organic Profile Code #549
- Particulate Matter Profile Code #424

While the standard emission factors in Section 5 are generally the same for $PM_{2.5}$ and PM_{10}, there may be some cases where it is necessary to estimate PM fractions based on other emission factors. In addition, air quality modeling programs require the use of speciated data that identify individual chemicals. The speciation profiles listed above can be used to assign weight fractions and to identify the chemical species that are contained in the organic and particulate emissions. Details are provided below:

Table 7: ROG and PM Weight Fractions

EIC	Description	Weight Fraction ROG	Weight Fraction PM_{10}	Weight Fraction $PM_{2.5}$
610-600-0230-0000	Wood Stoves	0.4385*TOG	0.935*TSP	0.9001*TSP
610-602-0230-0000	Fireplaces			
610-604-0230-0000	Unspecified			

ROG = Reactive Organic Gases; TOG = Total Organic Gases; TSP = Total Suspended Particulate

References:
ARB Organic Profile Code #549, http://arb.ca.gov/ei/speciate/vv10001/profphp/orgspecvv10001_list.php
ARB PM Profile Code #424, http://arb.ca.gov/ei/speciate/vv10001/profphp/pmspecvv10001_list.php

Table 8: Organic Speciation Profile Code#549

Chemical Name	CAS#	Weight Fraction of TOG
isomers of heptane		0.1883
isomers of pentane		0.0353
methane	74828	0.511
ethane	74840	0.0057
ethylene	74851	0.0158
propane	74986	0.0055
propylene	115071	0.0105

Table 8: Organic Speciation Profile Code#549

Chemical Name	CAS#	Weight Fraction of TOG
n-butane	106978	0.0355
formaldehyde	50000	0.0423
acetaldehyde	75070	0.0393
propionaldehyde	123386	0.0619
isomers of xylene	1330207	0.0075
toluene	108883	0.0124

Reference: ARB Organic Profile Code #549,
http://arb.ca.gov/ei/speciate/vv10001/profphp/orgspecvv10001_list.php

Table 9: PM Speciation Profile Code #424

Chemical Name	CAS#	Weight Fraction of Total PM	Weight Fraction of PM_{10}	Weight Fraction of $PM_{2.5}$
carbon organic		0.524014	0.486306	0.535706
unknown pm		0.221475	0.274118	0.258324
aluminum	7429905	1.40E-05	4.10E-05	1.40E-05
antimony	7440360	8.00E-06	1.30E-05	1.50E-05
arsenic	7440382	3.00E-06	2.00E-06	1.00E-06
barium	7440393	0.000106	0.00012	7.00E-05
bromine	7726956	4.50E-05	4.50E-05	4.40E-05
cadmium	7440439	4.00E-06	9.00E-06	4.00E-06
calcium	7440702	0.001237	0.000736	0.000327
chromium	7440473	0	0	0
cobalt	7440484	1.00E-06	2.00E-06	1.00E-06
copper	7440508	2.00E-06	1.00E-06	0
chlorine	7782505	0.008116	0.007987	0.00783
carbon elemental	7440440	0.220351	0.207016	0.174252
gallium	7440553	0	0	0
iron	7439896	1.20E-05	9.00E-06	7.00E-06
lead	7439921	1.10E-05	1.50E-05	1.40E-05
indium	7440746	1.00E-06	3.00E-06	1.00E-06
manganese	7439965	2.50E-05	1.70E-05	1.00E-05
molybdenum	7439987	0	0	0
nickel	7440020	0	0	0
mercury	7439976	0	0	0
lanthanum	7439910	0.000104	0.000128	7.00E-05
palladium	7440053	1.00E-06	2.00E-06	0
phosphorous	7723140	0	0	0
selenium	7782492	1.00E-06	1.00E-06	1.00E-06
tin	7440315	9.00E-06	4.00E-06	0
titanium	7440326	3.00E-06	1.00E-06	3.00E-06
vanadium (fume or dust)	7440622	1.00E-06	1.00E-06	2.00E-06
silicon	7440213	1.60E-05	2.00E-06	0
silver	7440224	0	3.00E-06	3.00E-06
zinc	7440666	0.000554	0.000548	0.00056
strontium	7440246	9.00E-06	5.00E-06	2.00E-06

Table 9: PM Speciation Profile Code #424

Chemical Name	CAS#	Weight Fraction of Total PM	Weight Fraction of PM_{10}	Weight Fraction of $PM_{2.5}$
sulfur	7704349	0.002682	0.002668	0.002598
rubidium	7440177	2.00E-05	1.80E-05	1.80E-05
potassium	7440097	0.01735	0.016702	0.016685
yttrium	7440655	0	0	0
sodium	7440235	0.000674	0.000617	0.000629
zirconium	7440677	0	0	0
ammonium ion	14798039	0.000553	0.000586	0.000564
nitrates	14797558	0.00222	0.002228	0.002214
sulfates		0.007473	0.007459	0.00741
carbonate ion		0.000378	4.50E-05	2.80E-05

Reference: ARB PM Profile Code #424, http://arb.ca.gov/ei/speciate/vv10001/profphp/pmspecvv10001_list.php

GROWTH FACTORS

ARB's default growth parameters for fireplace and woodstove emissions are based on historical residential wood combustion survey data published by the U.S. Energy Information Agency's State Energy Data System (U.S. EIA SEDS) and residential wood burning forecasts from the EIA's Annual Energy Outlook (U.S. EIA, 2011). These default growth factors are used for most districts, but some districts have submitted alternative growth data based on local information and updated rules that limit growth of wood-burning appliances.

SUMMARY OF METHODOLOGY CHANGES

The previous 1997 version of this methodology estimated emissions based on 1993 data for SJV and 1991 data for the remainder of the state. This revised methodology is based on 2005 data for all regions in the state.

For fireplaces, the previous methodology assumed a single statewide average wood consumption rate of 0.28 cords/year/home. For all regions in the state, the revised methodology uses either district survey data (where available) or two default consumption rates: (1) 0.069 cords/year/fireplace for units that burn wood primarily for aesthetics purposes; and (2) 0.656 cords/year/fireplace for units that burn wood primarily for heating (Houck, 2001a). Survey data are used to determine the split between aesthetic and heating uses.

For SJV, it was determined that, prior to full implementation in 2009 of District Rule 4901, *Wood Burning Fireplaces and Wood Burning Heaters*, a higher fireplace wood consumption rate based on a 1997 district survey was more representative than the default values. Therefore, the revised methodology assumes a consumption rate of 0.91 cords/year/fireplace for 2005 (Franz, 1997), and the default rates starting in 2009 and thereafter. Appendix B presents the summary of fireplace fuel use and associated emissions in 2009 for all counties in SJV.

The previous methodology used a single PM emission factor for all fireplaces (31.1 lb/ton), based on the 1992 version of U.S. EPA AP-42. The revised methodology uses a PM_{10} emission

factor that was used for U.S. EPA's 2002 National Emission Inventory (23.6 lb/ton). U.S. EPA staff chose to use the revised emission factor, because it is based on an improved data set (34 studies and 360 test runs), as compared to the old value (based on 4 studies, and 54 test runs) (Broderick, 2005). Emission factors for other criteria pollutants have also been updated, based on the results of newer emissions tests and research studies.

For wood stoves, the previous methodology determined wood consumption rates by estimating energy needs based on the thermal properties of a typical residence and the number of heating degree days in each county. The revised methodology uses survey data to estimate wood consumption rates for each county.

The previous methodology assumed that all wood stoves were conventional units and emissions were based on the highest emission factor. The revised methodology uses survey data to estimate the percentage of wood stoves that are Phase II EPA certified units (catalytic and non-catalytic). Emission factors for certified units have been revised to reflect the lower emissions levels of the Phase II units.

The previous methodology only estimated emissions from burning cord wood in fireplaces and wood stoves. The updated version provides estimation methodologies for cord wood, bundle wood, artificial/manufactured wax/sawdust logs, compressed sawdust logs, and pellets. In addition, the types of devices now include fireplaces, wood stoves, fireplace inserts, and pellet stoves. Emissions for wood stoves, fireplace inserts, and pellet stoves are reported under EIC 610-600-0230-0000, the general wood stove category.

DIFFERENCES BETWEEN PREVIOUS AND CURRENT EMISSION ESTIMATES

The new methodology results in lower statewide PM emissions estimates for both fireplaces and wood stoves. Using the previous methodology, the projected 2005 statewide PM_{10} emission estimates were 16,000 tons/year for fireplaces and about 24,000 tons/year for wood stoves, including the effects of growth and emission reductions from district rules. With the new methodology, the 2005 statewide PM_{10} estimates decline to approximately 11,400 tons/year for fireplaces and about 12,200 tons/year for wood stoves. The 2005 statewide $PM_{2.5}$ emission estimates also decline from about 15,000 to 11,000 tons/year for fireplaces and from 23,000 to 11,800 tons/year for wood stoves. For fireplaces, these declines are primarily due to reduced wood consumption estimates and the use of lower PM emission factors. For wood stoves, emissions declined primarily because it was no longer assumed that all stoves were conventional units. A portion of the wood use was attributed to EPA-certified stoves that have lower emission rates. In addition, the overall fuel consumption rate for wood stoves decreased slightly.

The accuracy of the residential wood burning category could be increased by conducting more local surveys to document the number of wood burning devices and fuel usage. Many districts have adopted local rules that govern wood burning activities and some districts have established incentive programs to encourage the purchase of cleaner wood burning devices that produce less particulate pollution. It is expected that these efforts will result in the need to update wood burning activity data more frequently to account for equipment turnover.

As with many area source methodologies, the possibility of incorporating geographic information system data may allow more accurate depictions of local emissions inventories.

ACRONYMS AND GLOSSARY

AEO	Annual Energy Outlook
Bundle Wood	Wood that is typically purchased in small bundles from a retail store, either packaged in a box or wrapped in plastic.
CAS	Chemical Abstract Service
CES	Category of Emission Source code. A 5-digit code that has been used by ARB to identify area source categories. The CES code has been replaced by the 14-digit Emission Inventory Code (EIC).
CO	Carbon Monoxide
Compressed Wood Logs	Manufactured logs that are made from 100% compressed sawdust and wood shavings (e.g., Pres-to Logs, Eco-Logs, etc.)
Cord	A stack of wood with a volume of 128 cubic feet (4 feet x 4 feet x 8 feet)
EF	Emission Factor
EIC	Emission Inventory Code. A 14-digit code that ARB uses to identify stationary and area source categories.
Heating Degree Day	The number of heating degree days is the number of degrees that the average daily temperature is below 65°F.
NEI	National Emission Inventory
NH_3	Ammonia
NO_X	Nitrogen Oxides
NSPS	New Source Performance Standard
Phase I Stoves	U.S. EPA designation for stoves certified to meet a 5.5 grams per hour (gm/hr) for catalytic wood heaters and 8.5 gm/hr noncatalytic wood heaters particulate matter emission standards manufactured on or after July 1, 1988 or sold after July 1, 1990.
Phase II Stoves	U.S. EPA designation for stoves certified to meet a 4.1 gm/hr for catalytic wood heaters and 7.5 gm/hr for noncatalytic wood heaters particulate matter emissions standards manufactured on or after July 1, 1990 or sold after July 1, 1992.
$PM_{2.5}$	Particulate matter with an aerodynamic diameter less than or equal to a nominal 2.5 micrometers.
PM_{10}	Particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometers.
ROG	Reactive Organic Gases
SO_2	Sulfur Dioxide
TOG	Total Organic Gases
Ton	2000 pounds
TSP	Total Suspended Particulate
VOC	Volatile Organic Compound
Wax/Sawdust Logs	Manufactured logs that are made from a mixture of sawdust, wax, and binders (e.g., Pine Mountain, Hearthlog, etc.)

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July 2011

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February 2013
Added Appendix B and revised methodology text to reflect this update.

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October 2015
Added reference to footnote 9 for woodstove and fireplace inserts PM10 emission factors in Table 1, Residential Wood Combustion Emission Factors.

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