New Methodology for Estimating Emissions from Residential Wood Combustion

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ABSTRACT

The Emissions Inventory and Analysis Group (EIAG) of the U.S. Environmental Protection Agency's (EPA's) Office of Air Quality Planning and Standards is in the process of updating the methodology it uses to estimate emissions from residential wood combustion (RWC) for the National Emissions Inventory (NEI). The reasons for doing this are: 1) to account for appliances not accounted for in the old methodology (e.g., outdoor hydronic heaters), 2) to make the NEI methodology easier for state, local, and tribal agencies (S/L/T) to input their own location-specific knowledge (e.g., wood density, estimates of amount of wood burned per appliance, appliance populations per county, etc.) into the estimation methodology, 3) to correct some known deficiencies in the existing NEI methodology, and 4) to make the methodology easier for some users of the NEI (e.g., emission modelers) to extract appliance population data from the NEI.

EPA worked with a group of state, local, and regional planning organization representatives to create the new methodology. This paper describes the new methodology and introduces a Microsoft Access Tool that was developed to allow S/L/T agencies to calculate annual emissions from RWC sources in the future. The Tool is designed to allow users to update county-level input parameter (based on local survey or like information) and then easily recalculate county-level emissions by running a query.

INTRODUCTION

Residential wood combustion (RWC) appliances like fireplaces, fireplace inserts, woodstoves, and hydronic heaters are significant sources of air pollution in the United States - especially during winter months. RWC emits large amounts of fine particulate matter (PM), volatile organic compounds (VOCs), and hazardous air pollutants that in several studies have been shown to contribute to poor human health, air quality, and visibility. RWC $PM_{2.5}$ emissions make up about 7 percent of the national inventory mass according to the 2002 National Emission Inventory (NEI) on an annual basis; however, local areas can experience much higher concentrations in the air during the heating season.[1]

In recent years, sales and use of residential woodstoves have been increasing due to rising costs of home heating fuel. In addition and over the past 5-years, sales of outdoor hydronic heaters (OHH) are also strong in the Northern U.S. where they are used as the primary heating source for

some homes. These outdoor wood boilers are essentially unregulated by Federal air pollution regulations and emit, on an average per hour basis, about four times as much fine PM as conventional woodstoves and about 12 times as much as U.S. Environmental Protection Agency (EPA)-certified stoves.[2] These OHHs have not been included in past inventories because, until recently, there were not very many of them in operation.

EPA's NEI includes emissions data from RWC, which in large part, are submitted by state, local, and tribal (S/L/T) agencies to EPA for inclusion in the NEI. However, when a state does not submit RWC emissions data, the EPA estimates those emissions. For the 2002 NEI, approximately one-half of the states did not submit emissions data from RWC even though EPA estimates that this category contributes significantly in many areas to annual $PM_{2.5}$ and VOC emissions on an annual basis.

The Emissions Inventory and Analysis Group (EIAG) is in the process of updating the methodology it uses to estimate emissions from RWC for the NEI. The EIAG assembled a task force consisting of members of state and local air pollution agencies. See table for names and contact information. Members of the task force are identified in this paper in the Acknowledgements. The reasons for doing this are: 1) to account for appliances not accounted for in the old methodology (e.g., outdoor hydronic heaters), 2) to make the NEI methodology easier for states, local agencies, and tribes to input their own location-specific knowledge (e.g., wood density, estimates of amount of wood burned per appliance) into the estimation methodology, 3) to correct some known deficiencies in the existing NEI methodology, and 4) to make the methodology easier for modelers and others of like mind to pull appliance population data from the NEI. In addition, the 2002 NEI methodology used to estimate the percent of conventional wood stoves versus EPA certified woodstoves was determined in the late 1990's and is in need of updating. Also, the percentage of certified woodstoves can vary widely geographically due to local regulations or local woodstove change out programs.

Our approach to performing this update is to develop a MS Access Tool that houses county-level activity and parameters with queries that allows recalculation of emissions. The Tool has been developed to:

- Include previously ignored appliance types, like outdoor hydronic heaters, pellet stoves, wax logs, and indoor wood furnaces.
- Provide more transparency.
- Allow flexibility.
- Allow stakeholders to substitute their own tool inputs
- Allow easy updates for future years.
- Use consistent and new Source Classification Codes (SCCs).
- Make use of readily available data.
- Be available from the internet.

Table 1 lists the appliance categories and updated SCCs for RWC sources. The first column of Table 1 indicates which source categories were included in the RWC Tool developed for this project. Note that these SCCs are different from the codes used in the 2002 NEI. The SCC

update was developed by the RWC work group to add missing appliance types and to avoid double counting of emissions.

Table 1. Appliance Types and Source Category Codes for RWC Sources.

Included	SCC	Fuel	Appliance Type	Comment
Yes	2104008100	Wood	Fireplace: general	
	2104008110	Wood	Fireplace: open	Conventional fireplace with open hearth
	2104008120	Wood	Fireplace: enclosed (or otherwise modified)	Enclosed with glass doors or other modifications to a conventional fireplace such as devices to boost efficiency (heat exchangers)
	2104008130	Wood	Fireplace: qualified for EPA voluntary program	
	2104008200	Wood	Woodstove: fireplace inserts; general	Fireplace inserts are similar to freestanding woodstove but they sit inside a fireplace. Other types of inserts should use SCC = 2104008120
Yes	2104008210	Wood	Woodstove: fireplace inserts; non EPA-certified	
Yes	2104008220	Wood	Woodstove: fireplace inserts; EPA-certified; non-catalytic	
Yes	2104008230	Wood	Woodstove: fireplace inserts; EPA-certified; catalytic	
	2104008300	Wood	Woodstove: freestanding, general	
Yes	2104008310	Wood	Woodstove: freestanding, non-EPA certified	
Yes	2104008320	Wood	Woodstove: freestanding, EPA certified, non-catalytic	
Yes	2104008330	Wood	Woodstove: freestanding, EPA certified, catalytic	

Included	SCC	Fuel	Appliance Type	Comment
	2104008340	Wood	Woodstove: freestanding, masonry heater	
	2104008400	Wood	Woodstove: pellet-fired, general	Freestanding or fireplace insert
	2104008410	Wood	Woodstove: pellet-fired, non-EPA certified	Freestanding or fireplace insert
	2104008420	Wood	Woodstove: pellet-fired, EPA certified	Freestanding or fireplace insert
	2104008500	Wood	Furnace: Indoor, general	
Yes	2104008510	Wood	Furnace: Indoor, cordwood-fired, non-EPA certified	
	2104008520	Wood	Furnace: Indoor, cordwood-fired, EPA certified	
	2104008530	Wood	Furnace: Indoor, pellet-fired, general	
	2104008540	Wood	Furnace: Indoor, pellet-fired, non-EPA certified	
	2104008550	Wood	Furnace: Indoor, pellet-fired, EPA certified	
	2104008600	Wood	Hydronic heater: general, all types	
Yes	2104008610	Wood	Hydronic heater: outdoor	
	2104008620	Wood	Hydronic heater: indoor	
	2104008630	Wood	Hydronic heater: pellet-fired	
	2104008640	Wood	Hydronic heater: meets NESCAUM phase II standards	
	2104008700	Wood	Outdoor wood burning device, NEC	Fire-pits and chimeas
Yes	2104009000	Firelog	Total: All Combustor Types	
	2104010000	Biomass; All Except Wood	Total: All Combustor Types	

OVERVIEW

Calculation Methodology

The emissions from RWC are calculated using the equation below.

$$E_y = u \times EF_y \times CF_y \quad \textbf{(Eq. 1)}$$

where:

E_y = annual emissions (ton/year) for a specific appliance (or SCC)
u = annual activity (tons of fuel burned)
EF_y = emission factor (tons of pollutant emitted/mass of fuel used)
CF_y = control factor

$_y$ is a specific pollutant

Note that CF_y was assumed to be 1 for all appliances because emission improvements for RWC are represented by improved appliance designs. These were accounted for by applying appropriately adjusted emission factors. Each of the terms in the equation and their sources are explained further below.

Activity (u)

Methodologies for determining the activity varied by the type of RWC appliance. Activity for the majority of appliance types was derived from census data.

Fireplaces, Inserts, and Woodstoves
For the first method, which applies to fireplaces, fireplace inserts, and woodstoves, activity in terms of tons of fuel burned was calculated based on several factors as shown in the equation below.

$$u = P \times AP \times BR \times D \quad \textbf{(Eq. 2)}$$

where:

P = Number of occupied housing units in a county in 2005
AP = Percentage of occupied housing units for a specific appliance category (e.g., catalytic woodstoves used as main heating equipment, fireplaces without inserts used as supplemental heating equipment, etc.)
BR = Burn rate (cords/year)
D = average density of the wood fuel burned

Outdoor Hydronic Heaters, Indoor Furnaces, and Pellet Stoves
A second method, which applies to outdoor wood burning devices, indoor furnaces, and pellet stoves, estimates the number of appliances per county based on state level proportioned to the number of woodstoves per county. Activity is calculated using the following formula.

$$u = AN \times BR \times D \quad \textbf{(Eq. 3)}$$

where:

AN = Number of appliances in county
BR = Burn rate (cords/year)
D = average density of the wood fuel burned

Number of Occupied Housing Units in 2005

Since appliance profiles were estimated in terms of the percentage of occupied housing units by appliance type, it is important that county population also be based on number of occupied housing units. However these had to be calculated because intercensal estimates of the number of occupied housing units by county were not available for 2005 from the U.S. Census – only annual estimates of the total number of units by county. It was important to account for this difference because the occupancy rate varies greatly throughout the country [e.g., from 98.5 percent in Anoka County, Minnesota to 23 percent in Franklin County, Pennsylvania].[3]

The 2005 intercensal estimate was used to determine the number of housing units in each county and then multiplied by the ratio of occupied housing units to total housing units from the 2000 census to find an estimate of the number of occupied housing units in 2005. The only exception to this procedure was the county of Broomfield, Colorado, which was established in 2001 and therefore was not in the 2000 census. The percentage of occupied housing units for Boulder County was substituted for Broomfield because in 2000 it was mostly contained in Boulder County.

The number of occupied housing units by county appears in the Tool in the table named County Populations.

Development of Appliance Profiles

County-level appliance profiles for RWC sources were estimated for each appliance type listed as included in Table 1. In order to estimate county level appliance profiles, several steps were needed because county specific appliance counts for the entire nation were not available. Our goal was to use easily accessible and publically available data to estimate county-level activity by appliance type for the entire United States, and let that be the default. Then use state or local data as submitted to improve on the default values.

Fireplace and Wood Stove

The American Housing Survey (AHS) conducts national and metropolitan area surveys on the Nation's housing, including household characteristics and heating equipment and fuels.[4] Both the national and metropolitan statistical area (MSA) surveys are conducted during a 3- to 7-month period. The national survey, which gathers information on housing throughout the country, conducts interviews at about 55,000 housing units every 2 years, in odd-numbered years. The metropolitan area survey consists of 47 metropolitan areas, where householders are interviewed every 6 years.[5] Data is gathered for about 14 metropolitan areas on an even numbered year until all 47 metropolitan areas are surveyed. Table 2 lists the MSAs surveyed in the AHS and the last year a survey was completed in each area. Table 3 provides the 2005 AHS appliance counts by region.

Table 2. MSAs Gathered in the AHS.

MSA	Year of AHS
Anaheim-Santa Ana, CA PMSA	2002
Atlanta, GA MSA	2004
Baltimore, MD MSA	1998
Birmingham, AL MSA	1998
Boston, MA-NH CMSA	1998
Buffalo, NY CMSA	2002
Charlotte, NC-SC MSA	2002
Chicago, IL PMSA	2003
Cincinnati, OH-KY-IN PMSA	1998
Cleveland, OH PMSA	2004
Columbus, OH MSA	2002
Dallas, TX PMSA	2002
Denver, CO MSA	2004
Detroit, MI PMSA	2003
Fort Worth-Arlington, TX PMSA	2002
Hartford, CT MSA	2004
Houston, TX PMSA	1998
Indianapolis, IN MSA	2004
Kansas City, MO-KS MSA	2002
Los Angeles-Long Beach, CA PMSA	2003
Memphis, TN-AR-MS MSA	2004
Miami-Ft. Lauderdale, FL CMSA	2002
Milwaukee, WI PMSA	2002
Minneapolis-St. Paul, MN-WI MSA	1998
New Orleans, LA MSA	2004
New York-Nassau-Suffolk-Orange, NY PMSAs	2003
Norfolk-Virginia Beach-Newport News, VA-NC	1998
Northern NJ PMSAs	2003
Oakland, CA PMSA	1998
Oklahoma City, OK MSA	2004
Philadelphia, PA-NJ PMSA	2003
Phoenix, AZ MSA	2002
Pittsburgh, PA MSA	2004
Portland, OR-WA PMSA	2002
Providence-Pawtucket-Warwick, RI-MA PMSAs	1998
Riverside-San Bernardino-Ontario, CA PMSA	2002
Rochester, NY MSA	1998
Sacramento, CA PMSA	2004
St. Louis, MO-IL MSA	2004
Salt Lake City, UT MSA	1998
San Antonio, TX MSA	2004
San Diego, CA MSA	2002
San Francisco, CA PMSA	1998
San Jose, CA PMSA	1998

MSA	Year of AHS
Seattle-Everett, WA PMSA	2004
Tampa-St. Petersburg, FL MSA	1998
Washington, DC-MD-VA MSA	1998

Table 3. Example of Regional 2005 AHS Data in Thousands and Percentage.

Heating Category	Appliance type	Total	Northeast	Midwest	South	West
Main Heating	Wood Stove	896	150	143	304	299
Main Heating	Fireplace with Inserts	131	14	22	47	47
Main Heating	Fireplace without Inserts	59	10	0	22	27
Pleasure Heating	Wood Stove	985	258	181	260	286
Pleasure Heating	Fireplace with Inserts	655	74	99	220	263
Pleasure Heating	Fireplace without Inserts	391	30	70	133	157
Secondary Heating	Wood Stove	3,096	920	635	626	915
Secondary Heating	Fireplace with Inserts	4,323	486	829	1,673	1,334
Secondary Heating	Fireplace without Inserts	4,080	371	643	1,686	1,381
All Houses	**Total**	**108,871**	**20,337**	**24,955**	**39,722**	**23,858**
Main Heating	Wood Stove	0.82%	0.74%	0.57%	0.77%	1.25%
Main Heating	Fireplace with Inserts	0.12%	0.07%	0.09%	0.12%	0.20%
Main Heating	Fireplace without Inserts	0.05%	0.05%	0.00%	0.06%	0.11%
Pleasure Heating	Wood Stove	0.90%	1.27%	0.73%	0.65%	1.20%
Pleasure Heating	Fireplace with Inserts	0.60%	0.36%	0.40%	0.55%	1.10%
Pleasure Heating	Fireplace without Inserts	0.36%	0.15%	0.28%	0.33%	0.66%
Secondary Heating	Wood Stove	2.84%	4.52%	2.54%	1.58%	3.84%
Secondary Heating	Fireplace with Inserts	3.97%	2.39%	3.32%	4.21%	5.59%
Secondary Heating	Fireplace without Inserts	3.75%	1.82%	2.58%	4.24%	5.79%

The AHS provides RWC appliance information for three different appliance types: fireplaces with inserts, wood stoves, and fireplaces without inserts. In addition, AHS data provide information on the purpose of each household heating appliance. These are separated into three categories of heating appliances use - main, secondary, or pleasure.

The following are the definitions used by the AHS to differentiate between different types of equipment ownership, by usage characteristics.

- Main heating equipment – Only one type of equipment was reported as the "Main heating equipment," as understood by survey respondents. More than one category of "Other heating equipment," which includes both pleasure and secondary heating equipment, could be reported for the same household.

- Supplemental heating equipment – This is additional heating equipment for a heated area of the housing unit. (AHS Appendix A. http://www.census.gov/hhes/www/housing/ahs/definitions.html.) For example, if a home is usually heated with main equipment which is oil or natural gas, and the homeowner uses a fireplace at times in winter, the fireplace is considered to be supplemental equipment.

- Parallel heating equipment – This is additional heating equipment for an area not heated by the main heating equipment.[6] For example, if the main house is heated with a wood stove, and a garage is heated by an electric heat pump, the heat pump would be considered parallel heating equipment.

The following are the definitions used by the AHS to differentiate between different types of RWC Appliances.

- Fireplaces without inserts - refers to glass door fire screens or fire backs inserted in the back of the fireplace to passively reflect heat.

- Fireplaces with inserts - have a fan-forced air circulation system to force the heat into the room.

- Wood stove - refers to any range or stove that burns solid fuel including wood burning, pot belly, and Franklin stoves.

These population percentages were applied to county-level occupied housing units as described above in order to estimate the number of appliances in each county.

The Hearth and Patio Association estimates the proportion of EPA certified wood stoves and inserts to uncertified wood stoves and inserts.[7] In 1999 the estimate was 92 percent uncertified, 5.7 percent certified using a non-catalytic design, and 2.3 percent certified using a catalytic design. EPA estimates an annual growth rate of 1 percent of certified stoves in operation so a case could be made for altering the mix of appliances slightly depending on the age of the latest Hearth and Patio report.[8] One estimate of the ratio in 2005 may be as much as 20 percent certified. For this study, we used a distribution of 80 percent uncertified, 15 percent certified, and 5 percent certified catalytic for both fireplace inserts and woodstoves.

Fireplaces without inserts were assumed to burn cordwood 78.3 percent of the time, and wax/sawdust firelogs 21.7 percent of the time, and the AHS data was split between the two relevant SCCs accordingly. This was based on the proportion of estimated cordwood equivalent for firelogs to cords consumed in fireplaces without inserts in the 2002 NEI documentation.[1] The most recent analysis performed by E.H. Pechan & Associates, Inc. (Pechan) resulted in an improvement that we plan to implement in the 2008 version of this tool. The updated distribution between cordwood and wax/sawdust firelogs is assumed to be 86.5 percent cordwood and 13.5 percent wax/sawdust firelogs. This was based on survey data reflecting the number of households which use wax firelogs exclusively.[9]

These appliance profiles are in the Tool as a table called Appliance Profiles.

The product of these appliance profile percentages with the number of occupied housing units in a county was used to find the total number of appliances in the county for the majority of appliance types.

Outdoor Hydronic Heaters and Indoor Furnaces

For OHHs and indoor furnaces, a different approach was used to find the number of appliances. Sales data was able to provide estimates of the number of appliances within each county.

Outdoor Hydronic Heaters

For Outdoor Hydronic Heaters, the population of these appliances were obtained by using sales data compiled by Northeast States for Coordinated Air Use Management (NESCAUM) that was provided by Hearth, Patio, and Barbeque Association. The counties populations were estimated by multiplying the state totals by the fraction of woodstoves in the county relative to the state. Sales data were available for all 50 states.

For outdoor hydronic heaters, state level sales data by distributing the sales within the state to all counties not in MSAs. This distribution was in proportion to the number of occupied housing units. The counties in the MSAs were not included in the distribution to avoid assigning high numbers of these units, which are typically found in more rural environments, to cities, based solely on population density.

Indoor Furnaces

For indoor furnaces, sales data was able to provide county level estimates of the number of appliances.[8] The number of appliances for both indoor furnaces and outdoor hydronic heaters is listed in the table Other Appliance Populations in the Tool.

Sales of indoor furnaces were very strong in the 1970's and 1980's, with the strongest sales in the upper Midwest, the Great Lake states, and New York and Pennsylvania. After 1988 when the EPA's NSPS Woodstove rule was promulgated, sales of indoor furnaces have been weak. (Roy Huntley email to Frank Divita of Pechan). Sales in the southern states and in the Pacific Northwest have traditionally not been strong.

Several approaches were used to estimate the county level appliance population of indoor furnaces. For the Mid-Atlantic Northeast Visibility Union (MANE-VU) states (Maine, Vermont, New Hampshire, Massachusetts, Connecticut, New York, Delaware, Maryland, New Jersey, Pennsylvania, Rhode Island, and the District of Colombia), we used the MANE-VU report to obtain the number of furnaces.[9] The MANE-VU report provides the number of centralized heaters/furnaces by state. This figure includes both indoor furnaces and OHH, so taking the difference between this figure and the NESCAUM data for OHH, we were able to estimate the number of indoor furnaces by state. We then allocated these units to the county level by ratioing the state total by the fraction of woodstoves in the county.

For Minnesota, we used information in a recent report from Minnesota Department of Natural Resources that provided the number of furnaces by five Minnesota regions.[10] Furnaces were allocated to the county level by ratioing the state total by the fraction of woodstoves in the county.

For the rest of the Great Lakes states (Wisconsin, Michigan, Illinois, Indiana, and Ohio), we generated an average factor from the Minnesota report (38 furnaces per 100 woodstoves) for the number of furnaces per woodstove and used the number of woodstoves in each county to estimate the number of furnaces.

For the rest of the states, we developed a factor from the 2000 Oregon/Washington/Idaho survey provided by the Oregon Department of Environmental Quality (DEQ). The survey provided the percentages of device type by region for 4 of the 5 Oregon regions (we were unable to use data from the southeast region due to incomplete central furnace data). The central region furnace data as assumed to be represented by indoor furnaces and we therefore used the ratio of the percent of furnaces to the percent of woodstoves by the 4 regions. The average of the ratios was used to determine the number of furnaces in the remaining state not mentioned above. As a last step, we assumed no outdoor furnaces in counties that are in climate zones 4 and 5

Burn Rates

Burn rate estimates with the level of detail needed for inventory purposes was difficult to come by. National average burn rates were assumed based on the U.S. Department of Agriculture (USDA) Forest Service documents from Midwest or Great Plainstate surveys performed in the 1990s (publications available from http://www.ncrs.fs.fed.us/pubs/). Burn rate was differentiated by appliance type (woodstove, fireplace, fireplace with insert, furnace/boiler, and firepit) and burning purpose (Main, Secondary, and Pleasure). The Access Tool includes the average number of cords of wood burned in a year by appliance type. It was assumed that these burn rates are based on most of the appliances not being EPA certified. To account for the greater efficiencies of EPA certified appliances, a discount factor of 79.4 percent was applied. This means that if an uncertified stove burns 7 cords of wood in a season, a certified stove would burn only 5.55 cords of wood.

Wax/Sawdust firelogs also heat more efficiently than wood, and it is estimated that their use displaces more than their volume in wood that would have been burned. Therefore, the burn rates for wax/sawdust firelogs were reduced from those of fireplaces without inserts by a factor of 4.49, which accounts for the increased volume of wood that would be burnt to release the equivalent amount of heat.[11, 12]

County level climate zone were used to adjust burn rate profiles to account for the fact that less wood is burned in warmer states. The Commercial Buildings Energy Consumption Survey (CBECS) climate zones are groups of climate divisions, as defined by the National Oceanic and Atmospheric Administration (NOAA), which are regions within a state that are as climatically homogeneous as possible. Each NOAA climate division is placed into one of five zones based on its 30-year average heating degree-days (HDD) and cooling degree-days (CDD) for the period 1971 through 2000.[13] Climate zone is listed in the County Population table. Burn rates for all SCCs in the national default were multiplied by the ratio of the average British thermal unit (Btu) consumption to heat a house each climate zone to the average Btu consumption in climate zone 1. The ratios were 0.30 for climate zone 5, 0.44 for climate zone 4, and 0.77 for climate zone 3.[8]

Modifications by S/L/T agencies with more detailed information may be made by appending a new burn profile to the Burn Rates table in the Access Tool and changing the burn profile number of the appropriate counties in the County Populations table. Each burn rate profile should address all the RWC SCCs that are considered by this Tool, and can distinguish between Main, Secondary, and Pleasure burn rates. In the event that appliance populations and burn rates are not distinguished by burn type (main, secondary, or pleasure), insert the overall average burn rate in the burn type for which appliance populations are calculated. For example, in Minnesota, appliance populations were all put under the secondary burn type, consequently, burn rates were only populated in the secondary burn type.

Wood Density

To compute average density of wood by county, we use the density of oven dried wood because emission factors developed by EPA are based on oven dried wood mass units. Dried wood density data was obtained from the U.S. Forest Service for various wood species.[14] The Forest Service developed a database (called the timber products output) that contained survey results of sawmill operators that includes the volume of wood by species for several different categories of use - one of the uses being fuel wood.

Using the oven dried density by species multiplied by the per-species volumes gave a per species weight which was summed to calculate the total weight for the county. This was then divided by the total volume of wood in the county to get the average density by county. This average is stored in the Density by County table under the pounds per cubic feet (lbs/ft^3) column. If a county specific density was not available, regional averages were used instead.

The calculated density by county from the Forest Service data was then converted to tons/cords. Officially a cord is defined as a stack of wood 4 feet wide, 8 feet long, and 4 feet tall or 128 ft^3. However, to account for air spaces in the stack, we assumed 80 ft^3 per cord instead.

For wax firelogs, density was assumed to not vary from county to county, and a density of 4.005 tons per cord was used. This was based on the volume of a typical 5 pound firelog. For wax firelogs, a cord was assumed to be actually 128 ft^3 because air spaces assumptions are applicable. The density figure was arrived at based on a Duraflame wax/sawdust firelog, which was measured to have a volume of ~138 cubic inches or ~.0799 cubic feet. From this a density of ~62.58 lb/ft^3 was derived. Assuming that for this source type, the equivalent of one cord was 128 cubic feet, we arrived at a density of ~8010 lb/cord or 4.005 tons/cord.

The wood density by county is in the Tool as in the table Density by County. S/L/T agencies can update the appropriate counties with the density of cordwood consumed, filling in not only the Density (lbs/ft^3), but converting and filling in the Density (tons/cord) column by multiplying by the factor: (80 ft^3/cord)/(2000 lbs/ton). The data_source column should be updated appropriately as well. When updating or revising the wood density, users should be sure to use oven-dried density numbers.

Emission Factors

The emission factors used are expressed as tons of pollutant produced for every ton of wood burned. The emission factors were reviewed by the task force and for the most part are the same as the ones used in past inventories. Some minor changes were implemented. The most significant change was to the VOC emissions factor. The old factor was from AP-42 and it was 229 lb VOC /ton of wood burned. The new factor is 18.9 lb VOC/ton of wood burned and it was pulled from the Mid-Atlantic Regional Air Management Association report. The complete list of the revised emission factors is in the tool.

DESCRIPTION AND USE OF THE RWC TOOL

The RWC Tool was developed in Microsoft Access to allow S/L/T agencies to calculate annual emissions from RWC sources. The Tool is designed to allow users to update county-level input parameter (based on local survey or like information) and then calculate county-level emissions by running a query named "Create Calculated Inventory" to generate a table called Calculated Inventory. Figure 1 provides the flow of the RWC Tool calculations. The shaded boxes in Figure 1 show calculated values which the non-shaded boxes show data inputs.

As shown in Table 4, the RWC Tool consists of several tables of parameters used to calculate emissions associated with burning. Each are described below.

Figure 1. RWC Tool Data Flow Diagram.

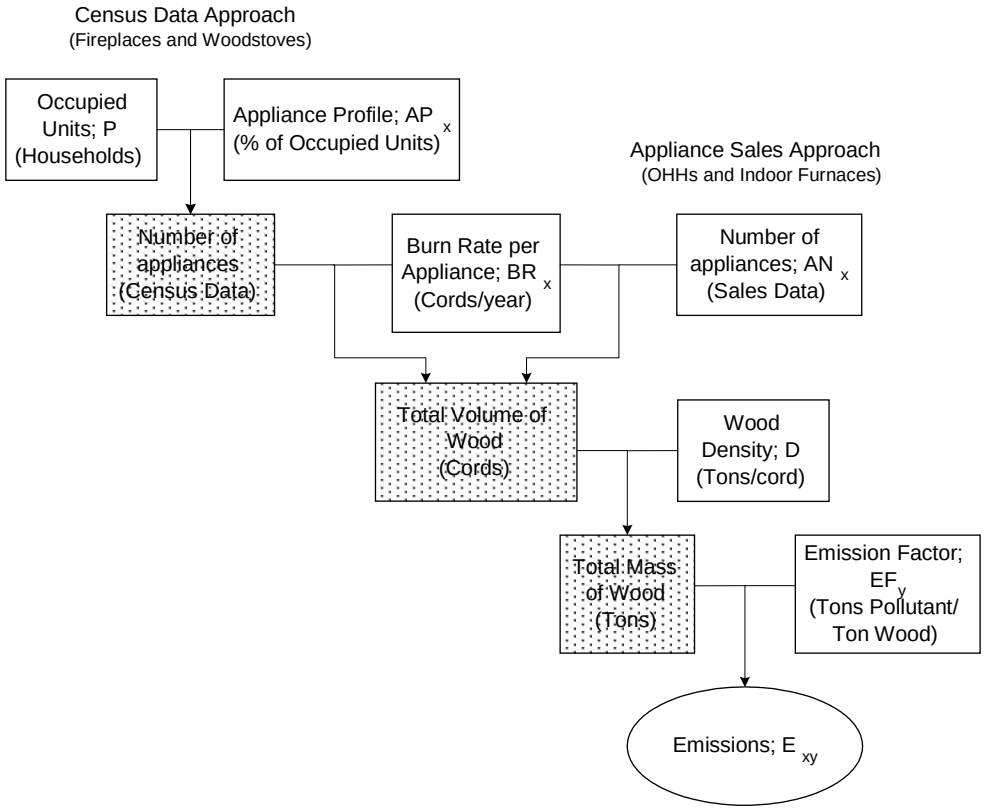

Table 4. Listing and Descriptions of the Tables Included in the RWC Tool.

Table Name	Table Description
County Populations	Entries contain the county, the number of occupied housing units in 2005, the appliance profile, the burn profile, and the climate zone.
Appliance Profiles:	Entries contain the appliance profile, the SCC, the burn purpose (Main, Secondary, or pleasure) and the percentage of households with an appliance of the type corresponding to the SCC.
Burn Rates	Entries contain the burn profile, the SCC, the burn purpose, and the cords burned per year per appliance.
Density by County	Entries contain the county, the density in lb/ft^3, the density in tons/cord, and the data source.
Other Appliance Populations	Entries contain the county, the SCC, the burn purpose, and the number of appliances in the county with an appliance of the type corresponding to the SCC.
Emission Factor by SCC	Entries contain the SCC, the Pollutant, the emission factor with units, the emission factor converted to tons pollutant/tons of wood combusted, and the data source for the emission factor.

County Populations - This table lists the number of occupied housing units in each county in the United States. These estimates are based on the 2005 intercensal estimate of total housing units and the percentage of units occupied in 2000. If state or local agencies have performed counts of the number of occupied households per county, these numbers can be substituted into the county populations table and the query will recalculate the emissions accordingly. More accurate counts of the occupied housing units can be submitted to EPA along with a data source for reference, and they will be used to replace the current estimates.

Appliance Profiles - The Appliance Profiles table has a number of existing appliance profiles. Each profile provides the percentage of occupied households which utilize each type of wood burning appliance (SCC) and burn purpose combination.

If more accurate appliance percentages for any or all such combinations are available for a state or number of counties, a new appliance profile can be created to accommodate the data. For example, if state or local woodstove change-out programs result in a higher concentration of certified woodstoves in a county or counties, this can be accounted for by editing the relative proportion of certified to uncertified woodstoves. It should be noted in the appliance_profile column which appliance profile is currently assigned to the state or counties. If improved percentages are known only for some appliance/burn type combinations, the rest should be copied from the original, otherwise all emissions from these sources will be calculated with a value of zero. After adding a new appliance profile with a new number, the appliance_profile column in the county populations table should be updated for the affected counties.

If local agencies have more accurate data, EPA should be provided with a table of both the updated and copied percentages (so as to ensure a complete profile.) The Federal information

processing standard (FIPS) of the counties to which these percentages apply should also be provided, along with a reference for the source of the updated quantities.

In the event that actual equipment populations are known, rather than percentages, the percentages must be back-calculated by dividing the number of appliances per each burn type by the county populations. This will result in a separate new appliance profile for each geographic area in which appliance populations are known. The same steps apply as above for supplementing incomplete population data with the existing profile data and providing references for data sources.

Burn Rates - The Burn Rates table contains a number of existing burn profiles. Each profile provides the cords burned per year per household for each type of wood burning appliance (e.g., SCC) and burn purpose combination.

If more accurate burn rates are known for any or all SCC/burn purpose combinations, a new burn profile can be created to accommodate this data. It should be noted in the County Populations table burn_profile column which profile is currently assigned to the state or counties. If improved burn rates are only known for some appliance/burn type combinations, the rest should be copied from the original burn profile, or the amount of wood burned, and consequently the emissions, will be calculated as zero. After the addition of a new burn profile with a new number, the affected counties should have the burn_profile column in County Populations updated.

If local agencies have more accurate data than is currently in the tool, EPA should be provided with a table of both the updated and copied burn rates in cords/year/household. The FIPS of all the counties to which these burn rates should apply should also be provided, along with a reference for the source of the updated burn rates.

If the rate at which cordwood is burned is known in terms of cubic feet rather than cords, a cord should be assumed to be 80 cubic feet of stacked dry cordwood when converting the burn rates. The same steps apply as above for supplementing incomplete burn rate data with rates from the currently used existing burn profile and providing references for data sources.

Density by County - The Density by County table contains estimates of the average density of dry cordwood that is used in residential combustion for every county. Each County has the density listed in both lbs/ft^3 and in tons/cord. The density can be updated for any county or counties and the query will recalculate the emissions accordingly.

If more accurate estimates of the average wood density exist for one or more counties, the improved data, along with a source reference can be sent to EPA. If this data is used, the data_source column in the Density by County table will be updated with this information. Please note that all densities must be for dry cordwood. Also, the conversion between lbs/ft^3 and tons/cord assumes 2000 lbs in one ton and 80 cubic feet in one cord.

Other Appliance Populations - The Other Appliance Populations table contains data on the number of appliances for SCCs which were not covered by the appliances in the American

Housing Survey. These include pellet-fire woodstoves, indoor furnaces, and outdoor hydronic heaters. Each county is listed with the number of appliances of each appliance type and burn purpose combination.

To model different estimates of the appliance population in one or more counties, this data can be entered by changing the Number of Appliances column for all affected counties. If the query is run, it will calculate the updated emissions accordingly.

If more accurate estimates of the appliance population in one or more counties are known, EPA should be provided a table of the changes or additions to the table, including all the columns that appear in the table in the tool.

Emission Factor by SCC - The Emission Factor by SCC table contains a list of the emission factors that were used to calculate emissions. It also cites the source of each emission factor. Any changes or additions to the emission factors will change the results for every county when the query is run. Users are not encouraged to change this table. Any errors noticed in the current emission factor table should be reported to EPA.

CONCLUSIONS

An updated methodology was developed as collaboration between EPA, Pechan, and a group of state, local and regional planning organization representatives. In addition, a Microsoft Access Tool was developed in a way that allows users to update county-level input parameter (based on local survey or like information) and then recalculate county-level emissions by running a query. The Tool is transparent so that inputs can be easily identified.

EPA is interested in obtaining local data that can be used to calculate RWC emissions. Improved data sources in the format used by the Access Tool can be provided to the authors via email. For everyone's convenience, Pechan has developed a template that will aid in uploading state specific data to the tool. The template can be obtained by contacting the authors of this paper. As of this writing, EPA is updating the tool for the 2008 calendar year.

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KEYWORDS

Residential wood combustion, National Emissions Inventory, woodstove emissions, fireplace emissions, wax firelog emissions