VOLUME III: CHAPTER 16

OPEN BURNING

April 1999

Prepared by:
Eastern Research Group, Inc.

Prepared for:
Area Sources Committee
Emission Inventory Improvement Program

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Eastern Research Group
P.O. Box 2010
Morrisville, North Carolina 27560

ACKNOWLEDGEMENT

This document was prepared by Eastern Research Group, Inc. for the Area Sources Committee of the Emission Inventory Improvement Program and for Charles Mann of the Air Pollution Prevention and Control Division, U.S. Environmental Protection Agency. Members of the Area Sources Committee contributing to the preparation of this document are:

Charles Mann, Air Pollution Prevention and Control Division, U.S. Environmental Protection Agency
Carolyn Lozo, California Air Resources Board
Kwame Agyei, Puget Sound Air Pollution Control Agency
Kim Cornelison, Louisiana Department of Environmental Quality
Mark Eastburn, Delaware Department of Natural Resources
Charles Masser, Air Pollution Prevention and Control Division, U.S. Environmental Protection Agency
Jack Sipple, Delaware Department of Natural Resources and Environmental Control
Karla Smith Hardison, Texas Natural Resource Conservation Commission
Sally Otterson, Washington Department of Ecology
Lee Tooly, Emission Factor and Inventory Group, U.S. Environmental Protection Agency
Jim Wilkinson, Maryland Department of the Environment

Also contributing to the preparation of this document is Tahir Khan of Chemical Emission Management Services of Ontario, Canada

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1

INTRODUCTION

This chapter describes the procedures and recommended approaches for estimating emissions from open burning of residential municipal solid waste, land clearing debris, and yard wastes. Section 2 of this chapter contains descriptions of open burning subcategories, their associated pollutants, and restrictions to their occurrence. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation methods for each of the open burning subcategories, and Section 5 presents alternative emission estimation techniques. Quality assurance and quality control procedures are described in Section 6. Data coding procedures are discussed in Section 7, and Section 8 lists all references cited in this chapter.

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2

SOURCE CATEGORY DESCRIPTION

Open burning is the purposeful burning of materials in outdoor areas such as forests and yards. The types of open burning included in this chapter are fires that: (1) result from anthropogenic activities; and, (2) are intentionally set in order to dispose of non-hazardous wastes by burning. This category excludes burning in dedicated combustion devices and buildings, and fires that are accidental, such as forest wildfires or structure fires. Open burning subcategories included in this chapter are open burning of residential municipal (household) solid wastes (MSW), land clearing wastes, and yard wastes. In many cases, however, the approaches for preparing emission estimates for some of the accidental fires may be very similar to the approaches presented here for intentional fires.

2.1 OPEN BURNING SUBCATEGORIES

A description of each of the anthropogenic open burning subcategories is provided in the following text:

- **Residential Municipal Solid Wastes (MSW).** Residential MSW is the nonhazardous refuse produced by households. MSW includes paper, plastics, metals, wood, glass, rubber, leather, textiles, and food wastes. Open burning of MSW at municipal landfills was prohibited by federal law in 1979 (40 CFR 257), therefore, burning of residential MSW is practiced only by private individuals. Most municipalities and some states have laws that prohibit on-site burning of residential MSW. Open burning of residential MSW is a concern mostly in rural areas, where burning is seen as an easier or cheaper alternative to landfilling.

- **Land Clearing Wastes.** The clearing of land for the construction of new buildings and highways often results in debris consisting of trees, shrubs, and brush. This debris may be burned in place but it is usually collected in piles for burning. The burning of land clearing wastes may be practiced by private individuals, corporations, and government agencies (e.g., highway construction department). There are no federal laws restricting the open burning of land clearing wastes, although state or local laws may exist.

- **Yard Wastes.** Yard waste burning is the open burning of materials such as grass clippings, leaves, and trimmings from trees and shrubs. Yard waste burning

takes place where the waste is generated (i.e., residences, parks, institutions such as universities or hospitals, office complexes or other areas where grounds maintenance generates this type of waste) or waste disposal sites where wastes have been collected. Although there are no federal regulations restricting the open burning of yard wastes, many municipalities prohibit or restrict the burning of yard wastes, and promote composting as an alternative.

Previous efforts to estimate emissions from open burning, such as the 1990 base year State Implementation Plan (SIP) inventories for ozone precursors, estimated emissions for the subcategories described in the document *Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone* (EPA, 1991). The open burning subcategories described in that document are forest fires, slash/prescribed burning, agricultural burning, structure fires, rural residential MSW burning, rural commercial/institutional MSW burning, and industrial MSW burning. This chapter does not include agricultural burning prescribed burning, forest fires, structure fires, rural commercial/institutional or industrial MSW. Forest fires and structure fires are outside of this chapter's scope, because these fires are not intentionally set. Emission estimation methods can be found in Chapter 18, Accidential Fires, of this volume. Unless there is evidence of open burning of MSW by commercial/institutional or industrial generators within the inventory area, that source does not need to be included in an inventory.

Open burning practices have changed considerably since the factors in the *Procedures* document were prepared, and the reader should keep in mind that they will likely continue to change. For example, landfilling and recycling policies will affect burning practices. Materials that were previously burned may be landfilled or recycled, resulting in a decrease in open burning emissions. On the other hand, if a landfill closes, raises fees, or no longer accepts certain types of wastes that are combustible, residents may choose to dispose of the material by burning, legally or illegally, resulting in an increase in open burning emissions.

2.2 FACTORS INFLUENCING EMISSIONS

2.2.1 PROCESS FACTORS

Emissions from open burning depend mainly on the type of waste, type of fire, and fuel loading (the weight of the material to the measured volume of the material or the area burned). Residential MSW may include paper, plastics, and other man-made products. Wastes from land clearing and yard debris consist almost entirely of naturally occurring vegetative materials. Emission factors presented in this chapter will reflect the difference in the materials burned for each type of burning. In some cases, different emission factors will be provided for many

different types of fuels for the same type of fire. For example, land clearing emission factors are provided for different vegetation types and burning configurations.

In the case of land clearing burning, the combustion process is important because the different phases of combustion greatly affect the amount of emissions produced. The phases of the combustion process include preheating, flaming and smoldering. Preheating is the first stage, where water and highly volatile hydrocarbons are volatilized. Flaming combustion is the rapid oxidation of the fuel cellulose, lignin, and volatile hydrocarbons, usually consuming fine fuels and surface fuels. As less oxygen is available either from the fuel or from the atmosphere, flaming combustion is harder to maintain and smoldering occurs. Emissions occur at all phases, but individual pollutants are emitted in different proportions during different phases and emissions are related to the rate of fuel combustion (Peterson and Ward, 1993).

AP-42 Section 13.1, Table 13.1-3 (EPA, 1995a) presents emission factors for the flaming and smoldering phases of combustion of forest materials, and a more general factor for the entire fire. The emission factors labeled “fire” for a material type should be used for area source inventories.

The configuration of the burned material will also affect emissions. Land clearing wastes may be piled, collected in windrows (material heaped or collected in rows), or spread out at the time of burning. Land clearing waste burning emission factors are available for different fuel configurations, and these should be used when fuel configuration information is available. When fuel configuration information is not available, recommendations for appropriate emission factors are provided in Sections 4 and 5 in the descriptions of specific methods.

Open burning emissions are also affected by combustion efficiency. Combustion efficiency is the proportion of the waste that is actually burned out of the total amount of waste that is subjected to burning. In a more detailed approach to estimating emissions, it may be appropriate to estimate combustion efficiency. Although combustion efficiency is not discussed in the method descriptions in this section, the inventory preparer may decide that it should be included in emissions calculations.

A fuel loading factor is the final component of an emissions calculation for land clearing burning. Fuel loading factors are provided for these burning types in the descriptions of the preferred and alternative methods.

2.2.2 OTHER FACTORS

Weather affects open burning practices. During extremely dry periods, most regions prohibit any type of open burning, even though it is allowed during normal weather periods. An inventory of open burning emissions for a dry period should result in lower than normal

emission levels. Weather-related catastrophes may cause an increase in open burning emissions. For example, a region may temporarily suspend restrictions on burning of land clearing debris after a hurricane has occurred and a lot of trees have been downed.

2.2.3 CONTROL TECHNIQUES

The most effective control technique for open burning emissions is to ban open burning and require disposal of the wastes by other methods. Composting of land clearing or yard wastes, increasing household waste pickups in an area, or improving recycling rates will reduce burning of these wastes. Another means of disposal is by combustion or incineration in a dedicated furnace or incinerator with emissions control devices. Although incineration also results in emissions, they are generally much lower per unit of mass than emissions from open burning.

Air curtain incinerators may be used to control emissions from open burning. An air curtain incinerator consists of a burn pit and a device that blows air across and into the pit. The effectiveness of these devices in controlling emissions, compared to burning the wastes in a pit without the blower, has been questioned, but they do decrease the amount of time required to burn the waste.

3

OVERVIEW OF AVAILABLE METHODS

Emissions from open burning are estimated by multiplying activity data and emission factors. Emission factors for open burning categories are available from a number of sources. The primary source is *AP-42*, but other EPA documents and documents produced by the USDA Forest Service are good information resources. Emission factors are provided in the preferred methods section of this chapter for each source category, but inventory preparers can use emission factors from other sources if the factors better characterize local conditions.

Activity data used with an emission factor should be specific to the inventory area. One of the particular difficulties with this source category is the frequent lack of activity information. This category requires a number of variables for the emission equation, and some of those variables may not be well defined or available. Inventory preparers will need to be prepared to make well-educated assumptions in some cases. Preferred and alternative methods in this chapter differ mainly in how activity data are collected, and how detailed and area-specific those data are.

Each method has advantages and disadvantages in terms of the expense and labor required by the method and the resulting quality of the emission estimate. The inventory preparer must select a method based on the desired accuracy of the emissions inventory and the resources available to develop the inventory.

There are many factors to consider when deciding which open burning subcategories to inventory in a particular area. The selection of the subcategories depends on the data quality objectives (DQOs) of the inventory, the burning practices that take place in the inventory area, the temporal scale of the inventory, and the pollutants of interest. Some types of open burning may simply not be practiced in an area (e.g., prescribed burning of forests in a strictly urban area), or there may be regulations that prohibit or discourage its use. If an inventory is for a specific season or period of the year, it may be that some types of open burning do not occur during that period, although they occur during other seasons of the year. When an inventory is to be pollutant specific, the inventory preparer should determine if any of the open burning subcategories are sources of emissions of that pollutant. If so, the preparer must decide if the emissions are likely to be significant enough, relative to other sources of that pollutant in the inventory area, to warrant inclusion in the emissions inventory.

3.1 PLANNING

As noted above, open burning may not be practiced or may not be a source of significant emissions in all inventory areas. During the planning stage of the inventory, the open burning subcategories discussed in this chapter should be investigated before they are included in the inventory or methods are chosen to estimate emissions from them. If a type of open burning takes place during the time period of interest for the inventory and if the potential emissions could provide a detectable addition to the total area source emissions, the subcategory should be included in the inventory, and an appropriate estimation method chosen based on the potential level of emissions, inventory budgets, and schedules. However, if a type of open burning is rarely, if ever, practiced in the inventory area, or all or most of the activity occurs outside of the inventory period, then there is no need to estimate emissions from this category. Also, before an estimation method can be chosen, inventory personnel should have researched and made certain that the source of activity information recommended for the estimation method is available and is at a sufficient level to satisfy the DQOs of the inventory. The following paragraphs list the agencies and organizations that can be contacted for the preliminary data collection step.

3.1.1 MUNICIPAL SOLID WASTE (MSW) BURNING

County sanitation, health, and fire departments are most likely to monitor open burning of household wastes. One of these departments or local or state air agencies should be able to indicate whether this type of open burning occurs frequently in the inventory area. In most cases, this activity is not legal or requires a permit.

Factors most likely to increase activity for this subcategory are the lack of garbage pickup, high costs for pickup or disposal, or drop off points that are difficult to reach. Inventory planners should consider these factors when deciding if the subcategory is important to include in their inventory, and if it may become more or less important in the future. If yard waste burning emissions are also being estimated, information about yard waste pickup and composting programs should be collected at the same time as information about MSW.

3.1.2 LAND CLEARING WASTE BURNING

Permits for the burning of land clearing wastes may be issued by local or state air agencies, local fire departments, or local health departments. Other sources of information concerning land clearing activity would be landfill personnel, state departments of transportation (DOT) when a significant proportion of the clearing is for roads, and local planning departments. The number of burning permits issued should provide an indicator of the scale of the activity in this source subcategory. These same agencies should also know if there are restrictions on burning at certain times of the year, or if there were restrictions during the specific inventory period. For

instance, burning for this subcategory and others such as yard wastes can be banned during droughts. On the other hand, catastrophic events such as tornadoes, floods or hurricanes may result in burning of debris even though such burning is ordinarily banned. These agencies should also be aware of alternative disposal methods such as landfilling or composting that are practiced in their area.

Data collection for the land clearing waste subcategory and the prescribed burning subcategory should be coordinated, because these two burning types will sometimes be reported together. These burning types will also rely on similar fuel loading data and will use the same emission factors.

3.1.3 YARD WASTE BURNING

State and local regulations and programs that provide pickup for leaves and other yard debris, or encourage composting of the material should be identified. Rules prohibiting or limiting open burning of yard wastes and the organization that enforces those rules should be identified. In 1996, 23 states had rules banning yard wastes from landfills (EPA, 1996b). Solid waste agencies should be contacted about rules currently in place for an inventory area. Composting programs are meant to reduce the burden on landfills and are typically run by local departments in charge of solid waste. These departments may also track reductions in burning and non-compliance with non-burning rules.

Inventory planners should also define the potential scope of the activity during the inventory time period and in the inventory area. Factors that may increase yard waste burning activity are high costs for pick up or tipping at local landfills, or not having a local landfill that will accept the waste. Some areas may limit burning to leaves and grass clippings only, or prohibit burning during certain times of the year, such as the summer months, or during droughts. Yard waste burning may take place primarily in the rural areas outside of the inventory area, or may take place during a different season than the inventory time period. Estimating emissions from this subcategory may not be necessary if there is little evidence of activity during the inventory time period and area.

Information collection about the collection or composting of yard wastes should be coordinated with the information collection for MSW.

3.2 AVAILABLE METHODS AND DATA REQUIREMENTS

The following sections outline the preferred and alternative methods for this source category. Sections 4 and 5 of this chapter provide detailed descriptions of the methods.

3.2.1 MUNICIPAL SOLID WASTE BURNING

Table 16.3-1 presents the preferred and alternative methods for estimating emissions from open burning of municipal solid wastes. Emission factors from the most recent *AP-42* section on open burning, Chapter 2, Section 5, and an EPA document titled, *Evaluation of Emissions from the Open Burning Of Household Waste in Barrels*, (EPA, 1997), are used in all of the methods for this burning type. Methods for estimating residential burning of MSW vary in the way that activity data are collected. The preferred method requires a local estimate of the amount of waste burned. The first alternative method takes into account that it may be more convenient to estimate the fraction of waste generated that is not burned than it is to estimate the fraction of waste that is burned. The method provides an approach for estimating the amount of waste open burned in an area, using either locally-generated estimates of the total amount of MSW generated, or a national average per capita waste generation. The amount of waste known to be disposed of through landfilling, composting, incineration or other disposal methods is subtracted from this total, and the remainder is assumed to be open burned. The second alternative method uses emissions data from another area (similar area or an area that contains the inventory area) or tons of waste burned in another area extrapolated to the inventory area.

3.2.2 LAND CLEARING WASTE BURNING

The preferred and alternative methods for estimating emissions from the open burning of land clearing wastes are shown in Table 16.3-2. Emission calculations for all methods are based on determining the fuel type in order to estimate the fuel loading, and the emission factor. Data collection issues, assumptions and factors for fuel loading are provided in Section 4 of this chapter. The preferred method develops activity data through permit data for land debris burning. Estimates of the average tons of fuel burned in the permitted burns will need to be collected from state or local experts. The preferred method uses information that is specifically collected for the inventory area. The first alternative method estimates activity data by estimating the acres of land cleared, estimating the waste generated by the land clearing, and subtracting the waste that is known to be disposed of through other means, such as landfilling or composting. The second alternative method extrapolates emissions or the amount of waste burned from a similar area. Scaling the emissions or activity can be done by comparing rules between the two areas, and either population growth or building activity.

TABLE 16.3-1

SUMMARY OF AVAILABLE METHODS FOR MUNICIPAL SOLID WASTE BURNING

METHOD DESCRIPTION	ACTIVITY DATA REQUIRED
PREFERRED Collect a local estimate of MSW open burned. Calculation: Amount of waste burned in inventory area * Emission factor	- Tons of waste burned in inventory area
ALTERNATIVE 1 Collect a local estimate of the total amount of MSW generated in the inventory area (or estimate using the national per capita waste generation rate) and the amount of MSW that is disposed of by other means (landfilling, incineration). Calculation: (Amount of waste generated in inventory area - Amount of waste disposed of by other means in inventory area) * Emission factor	- Tons of waste generated in inventory area - Tons of waste disposed of by other means (other than open burning) in inventory area
ALTERNATIVE 2 Obtain data (emissions or amount of waste burned) from an area that is similar to the inventory area, extrapolate the data to the inventory area based on the ratio of the rural population of the inventory area to the rural population of the similar area, and multiply by an emission factor. Calculation: (Rural population of inventory area/Rural population of similar area) * Emissions from similar area	- Emissions data from similar area (or tons of waste burned and emission factors) - Ratio of rural population of similar area to inventory area

TABLE 16.3-2

SUMMARY OF AVAILABLE METHODS FOR LAND CLEARING WASTE BURNING

METHOD DESCRIPTION	ACTIVITY DATA REQUIRED
PREFERRED Collect local activity and fuel loading data. Calculation: Permits for land clearing waste burns in inventory area * Fuel loading factor for each burn * Emission factor	- Permits for land clearing burns - Fuel loading factor (ton/burn) - Fuel type (for determining fuel loading and emission factor)
ALTERNATIVE 1 Collect the total number of acres cleared and a local fuel loading factor, subtract the amount of debris that is disposed of by means other than burning. Calculation: [(Acres of land cleared * Fuel loading factor) - Amount of debris disposed of by other means] * Emission factor	- Acres of land cleared in inventory area - Fuel loading factor (ton/acre) - Debris disposed of by other means in inventory area (tons)
ALTERNATIVE 2 Obtain data (emissions or amount of waste burned) from an area that is similar to the inventory area, extrapolate the data to the inventory area based on a scaling surrogate.	- Activity or emissions from a similar area - The scaling surrogate is a ratio between the similar area and the inventory area based on population growth, acres cleared, or building permits

3.2.3 YARD WASTE BURNING

The preferred and alternative methods for estimating emissions from open burning of yard wastes are presented in Table 16.3-3. The preferred approach is to identify and use locality-specific data, if it is available. This approach, however, may not be an option, and three alternatives are also available. The first alternative is to survey a subset of the inventory area, and scale that estimate up to the larger inventory area. The second alternative is to use information from a similar area and extrapolate the data to the inventory area. Suitable information would be collected using the methods described under the preferred or first alternative methods. The third alternative is to develop a local generation rate that can be scaled to the inventory area, corrected by estimates of the material that is landfilled or composted.

3.3 ADJUSTMENTS FOR CONTROLS

Air curtain incinerators are the only devices currently used to control emissions from open burning. In an air curtain incinerator, a rotating mass ("curtain") of high velocity, high temperature air is circulated across an open chamber or pit in which burning occurs. The continued air flow over-oxygenates the fire and increases turbulence, resulting in more complete combustion. The effectiveness of air curtain incinerators in reducing emissions has not been fully established. Available factors for burning with air curtain incinerators are provided in Section 4.

Other controls on open burning emissions are regulations that prohibit or restrict open burning, and recycling practices in the inventory area. These controls are reflected in lower activities.

3.4 SPATIAL ALLOCATION

Spatial allocation of the activity data may be necessary in some cases. Spatial allocation is the assignment of an activity level or emission estimate to a smaller or larger geographic area than the area for which it was prepared. Allocation requires the identification of a surrogate indicator that can be used for extrapolation or scaling. In addition to scaling or extrapolating emissions or activity from one area to another, emissions or activity may need to be allocated within the inventory area. When a method uses a spatial surrogate, preferred and alternative surrogates are described as part of the method. Some spatial allocation surrogates would be land use in the area, distribution of rural population, and building permit activity.

TABLE 16.3-3

SUMMARY OF AVAILABLE METHODS FOR YARD WASTE BURNING

METHOD DESCRIPTION	ACTIVITY DATA REQUIRED
PREFERRED Actual measurements of burned material, or existing locality-specific information, either from previous study or local expert.	- Waste generated that is burned
ALTERNATIVE 1 Use a study of a subset of the inventory area using permits to burn and violations of burning rules to estimate extent of burning. Scale to larger inventory area. Calculation: (Permits + Violations) * Fuel loading * Scaling factor * Emission factor	- Permits to burn - Violations of burning rules - Estimates of fuel loading for each burn - Scaling factors for inventory area
ALTERNATIVE 2 Obtain data (emissions or amount of waste burned) from an area that is similar to the inventory area, extrapolate the data to the inventory area based on a scaling surrogate. Calculation: Yard waste burned in a similar area/Scaling factor for similar area * Scaling factor for inventory area * Emission factor	- Waste burned for a similar area (defined by population and land use) - Scaling factors for inventory area and similar area
ALTERNATIVE 3 Develop a local per residence or per acre yard waste generation rate. Estimate total waste generation and subtract the waste that is landfilled or composted. Calculation: (Yard waste generated in small area)/(Scaling factor for smaller area) * (Scaling factor for inventory area) * Emission factor	- Yard waste generation for small area within the inventory area - Scaling factor (rural residences, acres of rural residential land use)

3.5 TEMPORAL RESOLUTION

Open burning emissions can be seasonal or influenced by weather conditions. Land clearing waste and yard waste burning may occur only during certain times of the year, and may not take place during the season of interest for a particular inventory. For that reason, it has been emphasized in this chapter that the preparer must investigate the seasonal aspect of the activity before collecting other emission calculation data for these burning types. All of the burning types covered in this chapter may be limited or banned because of seasonal drought or wind conditions. These conditions should also be investigated before committing resources to inventory data collection.

3.5.1 SEASONAL APPORTIONING

The preferred method for allocating open burning emissions is to use local season-specific activity data. An alternative is to collect estimates of seasonal activity percentages from local experts.

3.5.2 DAILY RESOLUTION

Open burning can be expected to take place seven days a week.

3.6 OTHER FACTORS INFLUENCING EMISSIONS ESTIMATES

Natural disasters may affect open burning practices and the resulting emissions. Natural disasters such as hurricanes, tornadoes, or floods may generate wastes, and open burning rules may be suspended to dispose of those wastes. These special conditions should be identified as part of the planning process for an inventory.

3.7 PROJECTING EMISSIONS

A discussion about developing growth factors and projecting emission estimates can be found in Section 4 of Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development*. Projecting emissions for this source category usually will take into account only changes in burning activity because rules for reducing emissions are most likely to reduce activity. Burning of land clearing wastes may be affected by controls if air curtain incineration is used. Emission factors specific to this device should be used to calculate emissions in this case.

Activity and emissions can vary substantially from year to year for open burning types. Sources of variation will depend on the burning type, but some factors apply to all burning types:

- Change in population, either in total or as a population shift from urban to rural areas;
- Changes in cost or location of landfills or other methods of waste disposal; and
- Implementation of new laws that affect types of open burning.

Yard waste composting programs may reduce burning for this waste type.

4

PREFERRED METHOD FOR ESTIMATING EMISSIONS

Because the data collection for this source category can be difficult, the preferred methods presented here are in the form of a set of guidelines for identifying data sources and using assumptions in order to develop reasonable estimates. There is no universal data source that can be used for every inventory to estimate emissions for this source category. When lists of potential data sources are given as part of a method, one or more of these data sources may need to be contacted.

AP-42 is the primary source of emission factors for all of the types of burning covered here. Additional emission factors are presented in Ward, et al. (1989), and two EPA Control Technology Center reports, EPA (1996) and EPA (1997). There are only limited factors in these references for burning of land clearing wastes, but factors developed for prescribed burning can be used for the land clearing subcategory.

Drawbacks to using the preferred methods are that the activity information can be difficult to collect; the process may be expensive in terms of time and effort; and the resulting information may still be based on estimates of activity, rather than measured amounts of materials burned. However, previous estimates of this category were often based on dated waste generation rates, and emission estimates for the category may not have reflected current burning practices. Collecting local, period-specific data and applying reasonable assumptions should provide a much better estimate of the scale and importance of the category relative to the inventory area's air pollution problems.

As with all area source inventory categories, documentation should be maintained for data collected, assumptions, information contacts, and calculations. Because this source category does require making assumptions in order to develop activity levels, the basis for all assumptions should be well documented.

Costs and labor efforts are highest the first time that the preferred methods are used. Subsequent updates to the inventory may be done using a local activity adjustment factor, if a suitable scaling surrogate can be identified. Also, subsequent inventories should take advantage of the data handling and quality assurance/quality control (QA/QC) routines that were put into place

the first time the method was used. See discussions of surveys for area sources in Volume I of the EIIP series and in Chapter 1 of this volume for more information.

4.1 PREFERRED METHODS

4.1.1 MUNICIPAL SOLID WASTE BURNING

The preferred method for estimating emissions from burning MSW is to collect estimates of open burning of MSW, in weight units, from state or local experts, or a survey of a subset of the inventory area. The subset should be representative of the activity throughout the entire inventory area. For the preferred method, the information is collected specifically for the inventory area and the inventory time period. See the discussion of the alternative methods if this level of information is not available.

If activity data are available for a subset of the inventory area, then information will need to be identified that can be used to scale the activity to the entire inventory area. Section 3.1.2 of this chapter discusses factors that influence activity for this source category, such as a lack of garbage pickup services, high costs for pickup or disposal, or drop off points that are difficult to reach. The alternative scaling factor is rural population.

Emission Factors

Emission factors for open burning MSW come from two sources, *AP-42* (EPA, 1995a) and an EPA document *Evaluation of Emissions from the Open Burning Of Household Waste in Barrels*, (EPA, 1997).[1] The recommended emission factors are listed in Table 16.4-1, and the source of each factor is indicated in the table. *AP-42* factors are based on a 1967 study of emissions from two test burns of MSW (Gerstle and Kemnitz, 1967). No detail is provided about the make up of the MSW in that article. The emission factors are expressed in units of the emission rate for the entire refuse weight.

The more recent EPA factors are also based on two test burns, out of four done for the study. Differences between the two test burns are described in the next paragraph. The proportions of waste types are provided in the report. These emission factors are expressed in units of the emission rate for only the fuel that actually burned.

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[1] *Evaluation of Emissions from the Open Burning of Household Waste in Barrels*, is available from the Clean Air Technology Center (CATC), on the EPA TTN Website, at: http//www.epa.gov/ttncatc1/products.html#aptecrpts.

TABLE 16.4-1

EMISSION FACTORS FOR OPEN BURNING OF MUNICIPAL REFUSE (EPA, 1997 AND EPA, 1995a)

Pollutant	Emissions (lb/ton entire refuse weight)	Emissions (lb/ton actually burned)	Emission Factor Source
Sulfur Oxides	1.0		AP-42 (EPA, 1995a)
Carbon Monoxide	85		AP-42 (EPA, 1995a)
Methane	13		AP-42 (EPA, 1995a)
Nitrogen Oxide	6		AP-42 (EPA, 1995a)
VOCs[a]		8.556	EPA, 1997
PM_{10}		38	EPA, 1997
$PM_{2.5}$		34.8	EPA, 1997
Chlorobenzenes		0.0008484	EPA, 1997
Benzene		2.48	EPA, 1997
Acetone		1.88	EPA, 1997
Styrene		1.48	EPA, 1997
Phenol		0.28	EPA, 1997
Dichlorobenzenes		0.00032	EPA, 1997
Trichlorobenzenes		0.00022	EPA, 1997
Tetrachlorobenzenes		0.000148	EPA, 1997
Pentachlorobenzene		0.000106	EPA, 1997
Hexachlorobenzene		0.000044	EPA, 1997
Total Polycyclic Aromatic Hydrocarbons (PAHs)[b]		0.132	EPA, 1997

TABLE 16.4-1

(CONTINUED)

Pollutant	Emissions (lb/ton entire refuse weight)	Emissions (lb/ton actually burned)	Emission Factor Source
Acenaphthylene		0.022	EPA, 1997
Naphthalene		0.036	EPA, 1997
Phenanthrene		0.0146	EPA, 1997
Total Polychlorinated dibenzo-p-dioxins (PCDD)		0.000076	EPA, 1997
Total Polychlorinated dibenzo furans (PCDF)		0.0000122	EPA, 1997
Total Polychlorinated biphenyls (PCB)		0.00572	EPA, 1997
Hydrogen chloride (HCl)		0.568	EPA, 1997
Hydrogen cyanide (HCN)		0.936	EPA, 1997

[a] The component VOCs measured for this factor include acetone, which is not considered a reactive VOC for ozone inventories (40 CFR 51.100). Reactive VOC can be calculated by subtracting the separate acetone emission factor in this table from the listed VOC factor. The other component VOCs measured are: 1,3-butadiene, 2-butanone, benzene, chloromethane (methyl chloride), ethyl benzene, naphthalene, styrene, and toluene. More detail about measurements of VOC is available in the source document.

[b] Total PAH includes emissions from acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, dibenzo(ah)anthracene, fluoranthene, fluorene, indeno(123cd)pyrene, naphthalene, phenanthrene, pyrene. Individual emission factors for acenaphthylene, naphthalene, and phenanthrene were provided in the source document and are listed in this table.

The mix of household wastes burned in the 1997 EPA study was based on a survey done by the New York State Department of Environmental Conservation's Division of Solid Waste and is based on waste stream characterizations for New York State. Sample waste mixes were prepared for the study for an "avid recycler," who removed the paper from the mix, and a

"non- recycler," which included all household wastes. Both samples included noncombustables. Emission factors for test burns using the non-recycler's waste are those recommended here. Test burns of the non-recycler's waste resulted in about 50 percent of the total waste burned. The non-recycler's waste included about 20 percent noncombustables, such as glass or metal.

The reader should note important differences in how the emission factors from the two documents can be used. The *AP-42* factors should be applied to the estimated total waste subjected to burning. However, the factors from the 1997 EPA document should be applied to the estimated amount of waste that actually burns. This means that when using factors from the 1997 EPA document, the amount of waste that actually burned must be estimated based on the estimate of the amount of waste subjected to burning. The proportions of waste actually burned to total waste from the 1997 EPA document, discussed above, are recommended.

Example 16.4-1 shows how the emission factors may be used, and what assumptions have to be made.

Example 16.4-1

Estimating emissions from open burning of household waste in County A:

Survey results

A survey has been completed of 1,000 households in a rural portion of County A in the inventory area. The survey area covered only locations where no public or private garbage pickup services are available, determined through telephone conversations with County A's Planning Department. An average household size is 2.5 people determined from U.S. Census Bureau statistics. Average waste generation for a household is 6.75 lbs per day, and 1.38 lbs of the waste is noncombustible material. Thus, combustable waste per household is 5.37 lb/day. Sixty seven of the 1,000 households use burn barrels to dispose of combustable household waste.

Survey scaling

U.S. Census Bureau data lists 17,502 households in the rural portion of County A, and 2,636 of the households are in areas where public or private garbage pickup services are available. This study assumes that only the remainder, 14,866 households, are likely to open burn their waste. Of that number, 6.7 percent (from the survey) are expected to actually burn their household waste: 996 households.

Emissions calculations for CO and PM

Both of the following waste calculations assume that households that open burn generate the average amount of household waste, noncombustable material is not put in the burn barrels, and that all of the combustable was subjected to burning and not recycled.

Example 16.4-1 (continued)

The emissions calculation using an *AP-42* factor uses total combustable waste. Total combustable waste for County A:

Total Waste Burned (lb/day)	=	996 * 5.37 lb/day
	=	5349 lb/day
	=	2.68 ton/day
CO emissions	=	85 lb CO/ton total waste burned * 2.68 ton/day
	=	227.8 lb CO/day

The emissions calculation using a factor from EPA (1997) uses waste actually burned. Fifty percent of the waste subjected to burning, burned in tests reported in *Evaluation of Emissions from the Open Burning Of Household Waste in Barrels*, (EPA, 1997). Twenty percent of that was noncombustable. In County A, 50 percent of the total household waste generated by household is:

Waste Actually Burned (lb/day)	=	6.75 lb/day * 50%
	=	3.38 lb/day

The waste actually burned for County A is:

Waste Actually Burned (lb/day)	=	996 * 3.38 lb/day
	=	3366 lb/day
	=	1.68 ton/day

Emissions calculation using factors from EPA (1997):

$PM_{2.5}$ emissions	=	34.8 lb $PM_{2.5}$/ton waste actually burned * 1.68 ton/day
	=	58.5 lb $PM_{2.5}$/day

Activity Level Data Collection

Potential information sources for MSW open burning activity are:

- State solid waste agencies -- these agencies track waste types, generation of wastes and their treatment and disposal.

- Local or state air quality agencies -- these agencies should have information about the rules in place concerning open burning, and they may track violations of the rules, and generate estimates of the activity.

- Local health sanitation departments -- these departments manage waste pickup and disposal, and may have estimates of the amount of household waste (MSW) burned, or estimates of the entire amount generated.

- Local fire and public safety departments -- these departments may track reports of violations of open burning rules. Reports may include burning of MSW, yard wastes and land clearing wastes.

4.1.2 LAND CLEARING DEBRIS

Land clearing debris burning and prescribed burning are similar processes and burn similar fuels. However, only land clearing debris burning is covered in this chapter. In some cases, the distinction between the two subcategories will be the source of the activity data and the purpose of the burning. Some inventories may combine these two subcategories. Care should be taken not to double count activity between land clearing debris burning and prescribed burning.

Land clearing debris is typically piled and then burned, but can also be applied to material collected in windrows, or to broadcast debris (material left undisturbed before burning) over an area. The term slash is used for the debris that is left after logging or clearing.

The preferred method for estimating emissions from burning land clearing debris is to collect permit data for land debris burning from the permitting agency. Estimates of the average tons of fuel burned in the permitted burns of land clearing debris (the fuel loading per burn) will need to be collected from state or local experts. In some cases, the permit may contain enough information to estimate an average or typical amount of fuel burned. However, this method may need to be supplemented with information such as the number of acres cleared for a sample of permits, which would be collected from planning departments or building permits. This method uses information specifically collected for the inventory area.

The amount of land clearing wastes burned can vary from year to year, usually depending on local building and development, and by how much of the material cleared is either sold or disposed of in some other manner. Other factors that may increase activity levels are natural events such as tornadoes or insect infestations that create fallen wood that needs to be disposed of.

Activity Level Data Collection

Potential information sources for land clearing debris burning activity are:

- Local or state air quality agencies -- These agencies should have information about the rules in place concerning debris burning. They may be responsible for permits and may track violations of the rules, and generate estimates of the activity.

- Federal, state and local forest service and agricultural extension agents -- Some land clearing may result from the harvest of commercial timber, or removal of stands of timber that have become diseased. The remaining material may be disposed of by burning. See comments about sources of information about fuel loading.

- Local planning departments -- These departments track building permits and development of land that will result in clearing, and register changes in land use.

- State or local transportation departments -- These departments can estimate the amount of clearing that took place for building new roads. If clearing did take place, the transportation department may also have records that can be used to estimate how much of the clearing debris was landfilled, composted, or burned. State solid waste agencies -- These agencies may track or estimate land clearing debris generation, and may maintain records about what happens to the debris. These agencies are most likely to enforce rules about illegal dumping of wastes, and may have estimates of the amount of waste illegally dumped that is from land clearing.

- Local health and sanitation departments -- These departments may have estimates of the amount of land clearing debris generated, or estimates of the amount burned. In some cases, these departments may be responsible for some of the debris burning. These agencies should also be contacted about land clearing debris that is landfilled or composted.

- Local fire and public safety departments -- These departments may track reports of violations of burning rules. Reports may include burning of MSW, yard wastes and land clearing wastes, with no clear distinction between types.

Many areas require that permits be obtained before burning land clearing debris. Although the permits may not include any estimates of the amount of waste burned, local experts may provide some estimates of typical size piles, or the amount of land cleared for each pile of debris. If

permit information is not available, if not all burning requires a permit, or if the information needed for fuel loading is not available, this method cannot be used.

Emission Factors

At the time of this writing, there are no emission factors available that have been developed specifically for land clearing debris burning. The emission factors for prescribed burning from the most recent *AP-42* section on Wildfires and Prescribed Burning, Chapter 13, Section 1, the factors for unspecified forest residues in Table 2.5-2 of the *AP-42* Open Burning section (Chapter 2, Section 5), factors developed by Ward, et al. (1989) for logging slash, factors from the EPA CTC study (EPA, 1996) or emission functions from Peterson and Ward (1993) are recommended. Inventory preparers will have to decide which of these factors best suit the activity data that has been collected for the inventory area, and the local fuel types. The *AP-42* section on prescribed burning and Ward, et al. (1989) include factors for two phases of the burn, termed the flame and the smolder. The flame stage is the initial fire, involving the smaller sized and dryer fuels. The smolder phase occurs after the initial flame, and consumes larger sized fuels and fuels that were initially not dry. Using these emission factors would imply a level of detail rarely possible in area source emission estimates. Therefore, other factors provided for "fire" burns that represent the average emission rate for the flame and smolder phases should be used for area source inventory calculations. Assume that the emission factor for non-methane TOC is entirely VOC.

A bench-scale study of emissions from typical land clearing debris materials has been done by the US EPA Control Technology Center (CTC) (EPA, 1996b), which reports emissions of CO, NO, total hydrocarbons (THC), $PM_{2.5}$, PM_{10}, and some HAPs. Emission factors for CO, CO_2, methane, non-methane hydrocarbons (NMHC), total PM, $PM_{2.5}$, PM_{10}, and NO from *AP-42*, Ward, et al. (1989) and the CTC report are compiled in Table 16.4-2. Emission factors have been converted to pounds per ton of fuel for this table. Emission factors from *AP-42* are more general and should be used in most cases. However, the Ward et al. (1989) factors and EPA (1996b) factors can be used if the fuel configurations and material burned descriptions match that being burned in the inventory area.

Emission factors and emission functions are also available for some HAPs. Factors from the EPA (1996b) report are presented in Table 16.4-3, and emission functions from Peterson and Ward (1989) are presented in Table 16.4-4. The EPA (1996b) factors are for piled debris burning. The Peterson and Ward (1993) emission functions were developed to estimate emissions for air toxics from prescribed burning emission factors for carbon monoxide (EFCO), methane ($EFCH_4$), or total particulates (EFPM). In this way, if one of these pollutants' emission factors varies because of different fuel classifications or combustion phases, pollutants estimated using the functions in Table 16.4-4 will also reflect that difference.

TABLE 16.4-2

LAND CLEARING BURNING CRITERIA POLLUTANT EMISSION FACTORS

EF Source	Fuel Configuration	Material Burned	Pollutants, lb/ton							
			CO	CO2	Methane	NMHC	Total PM	$PM_{2.5}$	PM_{10}	NO
Ward, et al 1989	Piled	Coniferous Slash	153.20	3,271.20	11.40	8.00	20.40	10.80		
	Piled	Woody Debris	185.40	3,143.40	21.72	15.20	36.40	23.40		
AP-42, 13.1	Piled	Logging Slash	74.00		3.60		12.00	8.00	8.00	
AP-42, 13.1	Broadcast	Logging Slash Hardwood	224.00		12.20	12.80	36.00	22.00	24.00	
AP-42, 13.1	Broadcast	Logging Slash Conifer - Short Needle	350.00		11.20	7.00	34.00	24.00	26.00	
AP-42, 13.1	Broadcast	Logging slash Conifer - Long Needle	254.00		11.40	8.40	40.00	26.00	26.00	
AP-42, 2.5	unspecified	Forest Residues	140.00		5.60	18.00	16.00			
Ward, et al 1989	Broadcast	Douglas-Fir Hemlock Slash	312.40	3,082.40	11.00	7.20	29.60	21.80		
	Broadcast	Hardwood Slash	256.20	3,072.20	13.20	10.80	37.40	22.40		
	Broadcast	Long-Needle Pine Slash	178.40	3,201.80	8.20	6.40	39.60	22.00		
	Broadcast underburn	Mixed Conifer Slash	201.40	3,165.40	12.80	9.80	29.00	18.80		
	Broadcast	Juniper	163.00	3,231.00	12.00	10.40	28.30	18.70	20.40	
EPA 1996b	Test burn[a]	Land Clearing Debris (TN)	46.00			32.00		28.26	33.62	0.74
	Test burn[a]	Land Clearing Debris (TN)	32.00			12.00		20.08	20.50	0.10
	Test burn[a]	Land Clearing Debris (FL)	38.00			18.00		3.50	15.50	0.06
	Test burn[a]	Land Clearing Debris (FL)	30.00			8.00		9.12	9.32	0.18

TABLE 16.4-2

(CONTINUED)

EF Source	Fuel Configuration	Material Burned	Pollutants, lb/ton							
			CO	CO2	Methane	NMHC	Total PM	$PM_{2.5}$	PM_{10}	NO
EPA 1996b	Test burn with blower[a]	Land Clearing Debris (TN)	24.00			14.00		24.14	24.46	
	Test burn with blower[a]	Land Clearing Debris (TN)	22.00			12.00				0.50

Sources: Ward, et al. (1989); EPA (1995a); EPA (1996b)

[a] Factors from this source were derived from individual laboratory test burns. Test debris was collected in Tennessee (TN) and Florida (FL). Two reported test burns were undertaken using blowers to simulate air curtain incinerators. These are marked on the table as 'Test burn with blower'. See the reference document for further description of the study.

TABLE 16.4-3

LAND CLEARING BURNING HAP EMISSION FACTORS (EPA, 1996b)

Compound (lb/ton)	Material Source and Fuel Configuration					
	No Blower				With Blower	
	TN	TN	FL	FL	TN	TN
2-butanone(methyl ethyl ketone)	0.084	0.072	0.080	0.032	0.060	0.038
Ethyl benzene	0.074	0.058	0.042	0.018	0.054	0.070
Styrene	0.152	0.140	0.080	0.034	0.118	0.172
Cumene	0.038	0.007	0.004	Nd	Nd	0.036
Phenol	0.075	0.167	0.130	0.088	0.024	0.190
Dibenzofuran	0.010	0.004	0.008	0.005	0.003	0.009

[a] Factors from this source were derived from individual laboratory test burns. Test debris was collected in Tennessee (TN) and Florida (FL). Two reported test burns were undertaken using blowers to simulate air curtain incinerators. These are marked on the table as 'with blower'. See the reference document for further description of the study.

[b] Nd - not detected.

Fuel Types

Fuel types described here are the same as those that would be burned in prescribed burning, so descriptions of fuel types developed for prescribed burning can be used for land clearing burning as well. Land clearing waste will typically not include live fuels. Fuel types are made up of varying quantities of the following materials (Peterson and Ward, 1993):

- Woody fuels -- include branches, logs, stumps and limbs.
- Duff -- matted layers of partially decomposed organic matter and high organic content soils such as humus or peat.
- Litter -- Fallen leaves and needles, twigs, bark, cones, and small branches that have not decayed to the extent of loosing their identity.

TABLE 16.4-4

HAP EMISSION FUNCTIONS TO BE USED FOR LAND CLEARING BURNING (PETERSON AND WARD, 1993)

Pollutant	Emission Factor Function (lb/ton) [a]
Formaldehyde (HCHO)	(0.0137*EFCO)-0.0358
Acetaldehyde (C_2H4O)	0.315*EFHCHO
Acrolein (C_3H_4O)	(0.0029*EFCO)+0.1398
1,3-Butadine (C_4H_6)	0.00213*EFCO
Benzene (C_6H_6)	0.00592*EFCO
Toluene ($C_6H_5CH_3$)	0.00588*EFCO
o-Xylenes	0.00089*EFCO
m,p-Xylene	0.00161*EFCO
n-Hexane (C_6H_{14})	0.00017*EFCO
Polynuclear Organic Material (POM)	0.000345*EFPM
Methyl Chloride (CH_3Cl)	8.8 to 11.4[b]
Carbonyl sulfide (COS)	0.267

[a] EFCO - carbon monoxide emission factor (lb/ton)
EFHCHO - formaldehyde emission factor as calculated with formaldehyde function (lb/ton)
EFPM - particulate matter emission factor (Total PM) (lb/ton)
[b] Flaming factor is presented

Example fuel models are listed in Appendix A. In a detailed study of emissions from burning land clearing waste, emissions from varying quantities of each of the materials listed above would be considered as part of the total emissions. However, fuel type groupings that are useable for area source calculations are much more generalized, such as those listed in Table 16.4-2.

Fuel Loading

Fuel loading estimates are necessary in order to use the emission factors, which are based on the weight of the material burned. Specifically, the debris that is burned will be a function of the total biomass on the area, minus any wood or other material logged or harvested, amount of wood that may be collected as fuelwood, and the amount of wood or other material that is landfilled, composted or allowed to decay. For an area source inventory, generalized estimates

can be made for fuel loading, although if specific information is easily available, it is preferred. The most conservative estimate will assume that all material is burned. However, in areas where there is usable timber, where rules restrict burning, or other disposal methods exist, information about logging, landfilling, composting or firewood use should be collected.

The preferred approach for estimating fuel loading for land clearing debris is to use estimates made specifically for the burns that have taken place. If a state forestry service requires a smoke management report for land clearing debris, or has good compliance in a voluntary program, then that data can be collected and used. If tonnages or volumes of land clearing debris are not reported, then alternatives can be local estimates of the species types and debris amounts that would be typical for the area. Regional estimates for fuel loading can also be used. The U.S. Forest Service compiles forest resource data about forest area, volume, removals, residues and timber product outputs, by region/subregion, ownership class, and species group which could be useful in defining fuel loading for land clearing activity.[2] Forest Service Technical Reports may include enough information to develop a regional estimate of the amount of debris that typically remains after logging or clearing.

State forestry agencies may compile similar data, and may be able to estimate the amount of material cut for lumber or fuelwood and the amount burned. Landfill operators should have records of the amount of land clearing debris that has been brought in to the landfill. In the absence of reliable estimates, assume that all of the debris in an area that is cleared is burned. However, this latter approach will overestimate emissions.

Other potential resources for fuel loading information are state forestry departments in other states. Data collected in a neighboring state for prescribed burning estimates may have enough similarity to the target state's forest types and disposal practices to be useable for an inventory.

Another alternative for estimating fuel loading is to use a procedure drawn from the Intergovernmental Panel of Climate Change (IPCC, 1994). This procedure can be used when the land cleared is logged before clearing and all useable timber on the cleared land is removed before burning the remainder. The amount of timber that is harvested for commercial use may be available through forest service statistics or state economic reports. Estimates of typical timber yields for an area may also be available from state forest service experts or U.S. Forest Service reports. The procedure uses a factor applied to the amount of logged wood to account for the

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[2] An example publication is *Forest Statistics of the United States, 1992, Metric Units*, (USDA, 1994) which has forest area statistics by state, and per hectare estimates of logging residues by subregion and wood type (hardwood or softwood). These publications are produced by regional forest experiment stations, and more recent publications may be available on the regional stations' Web sites through the Internet.

unharvested portion (limbs, small trees, etc.) of the total biomass that was cleared. This factor is called an expansion ratio, since it expands the measured amount of wood that is removed as logs to calculate the amount of material that remains.

The expansion will take two steps. Because commercial timber may be measured by volume, the first step is to convert the volume of harvested wood to weight units, using the values provided in Table 16.4-5. The table gives density conversion factors for hardwoods and softwoods by typical forest type within a region. The generalized factors represent a weighted average density of the three most common (in terms of volume) softwood or hardwood species within the forest type. Forest types are identified by the primary tree species or tree species groups, but will include other tree species that are typically found in that biome. Local or state forestry service personnel should be able to identify a typical forest type for an area. *AP-42* Appendix A also contains more general conversion factors. The more detailed factors in Table 16.4-5 are preferred.

The second step is to expand the amount of commercial timber harvested to represent the amount that was left behind. Default ratios for expanding harvested timber amounts to unharvested biomass are (IPCC, 1994):

- Undisturbed forests 1.75
- Logged forests 1.90
- Unproductive forests 2.00

Undisturbed forests are, or are close to being, in a natural, undisturbed state. These forests would not commonly be cleared. Logged forests are those that have been logged or cleared previously, and are regrowing, but not fully regrown (a forest may take one hundred years or more to return to the state of an undisturbed forest). Unproductive forests have been overused or poorly managed and may have reduced amounts of usable timber. When the forest type is unknown, the more conservative expansion ratio for unproductive forests should be used as a default.

The calculation is:

$$\text{Unharvested biomass} = \text{Commercially Harvested Timber}(ft^3) * \text{Wood Type Density}\ (lb/ft^3) * \text{Expansion Ratio} \qquad (16.4\text{-}3)$$

This amount can be assumed to be entirely burned, or can be corrected for the amount which is estimated to be disposed of in other ways: landfilled, composted, or used as fuelwood. The remainder is assumed to be open burned.

TABLE 16.4-5

FACTORS TO CONVERT WOOD VOLUME (CUBIC FEET) TO WEIGHT (POUNDS) (EPA, 1995)

Region	Forest Type	Density Conversion Factors	
		Softwood	Hardwood
Southeast and South Central	Pines	31.8	39.9
	Oak-Hickory	33.4	39.9
	Oak-Pine	32.6	39.9
	Bottomland Hardwoods	28.7	36.2
Northeast and Mid Atlantic	Pines	23.6	33.8
	Spruce-Fir	23.0	32.8
	Oak-Hickory	23.3	39.7
	Maple-Beech-Birch	24.0	37.4
	Bottomland Hardwoods	28.7	36.2
North Central and Central	Pines	26.3	33.1
	Spruce-Fir	21.9	30.0
	Oak-Hickory	26.0	39.4
	Maple-Beech	23.2	35.9
	Aspen-Birch	23.1	29.0
	Bottomland Hardwoods	28.7	36.2
Rocky Mountain and Pacific Coast	Douglas Fir	29.5	23.7
	Ponderosa Pine	26.0	23.7
	Fir-Spruce	21.8	23.7
	Hemlock-Sitka Spruce	27.1	27.0
	Lodgepole Pine	26.4	23.7
	Larch	31.7	27.0
	Redwoods	26.0	36.2
	Hardwoods	26.5	24.0

If only the number of acres cleared is known, then Table 16.4-6 provides a default fuel loading value from *AP-42* for forest residues after harvest, from IPCC (1994) for grasslands, and example fuel loading values from Ward et al. (1989). The example values for fuel loading were developed from tests in the Pacific North West for mostly hardwood, mostly long-needle pine, or mixed conifer forest types.

Emissions Calculations

Emissions calculations for emissions from burning land clearing debris use the following general equation:

$$\text{Emissions} = \text{Area Burned (acres)} * \text{Fuel Loading (tons/acre)} * \text{Emission Factor}$$

TABLE 16.4-6

FUEL LOADING FACTORS -- FOR LAND CLEARING DEBRIS

Source	Debris Type	Fuel Loading	
		(ton/acre)	(Mg/hectare)
AP-42	Unspecified forest residues	70	157
Ward, et al., 1989	Hardwood slash	66	149
	Long-needle pine slash	21	46
	Mixed conifer slash	54	121
IPCC, 1994	Grasslands	4.5	10

In some cases, estimates of the tons of material burned will be substituted for the acres burned and fuel loading factors.

4.1.3 YARD WASTES

Yard wastes include grass clippings, leaves, and tree and brush trimmings from residential, institutional, and commercial sources. Planning and data collection for this source subcategory should include research on local and state rules about open burning of these materials, the disposal of yard wastes in landfills, and composting programs that may be in place for the inventory area. Some localities prohibit open burning of yard wastes, and in that case, emissions from this source subcategory may be negligible. On the other hand, localities may

collect yard wastes and dispose of the waste by burning. Estimating emissions in that case would require an estimate of the yard waste collected by the locality, conversion of volume measurements to weight, assumptions about the predominant materials in the waste, and emission factors for the materials.

The preferred approach for this burning type is to collect locality-specific activity information from a local expert. Sanitation and health departments, local recycling and composting programs, and fire and public safety officials may track local generation or incidences of burning and have estimates of the proportions of the yard waste that landfilled, composted and burned.

In most cases, yard waste amounts will be estimated in units of volume, rather than weight. This unit conversion can be problematic, because densities of grass clippings, leaves, or tree and brush clippings can vary from tens of pounds to hundreds of pounds per cubic yard, depending on the material, compaction and moisture content. The preferred approach for converting volumes to weight is to derive a local estimate for yard wastes in the area. Local refuse haulers that collect materials for composting programs may keep track of weights of incoming loads and the volumes of the trucks. For example, if the volume capacity and tare weight (empty weight) of a truck are known, and gross weights (filled weight) of several loads have been recorded, then the volume to weight ratio can be calculated:

$$\text{Ratio} = (\text{Gross} - \text{Tare})/\text{Volume} \qquad (16.4\text{-}5)$$

Where:

Ratio	=	Volume to weight ratio (yd^3/tons)
Gross	=	Average filled truck weight (tons)
Tare	=	Empty weight of truck (tons)
Volume	=	Volume of truck (yd^3)

There are major uncertainties in this approach, since the types of materials are unknown and it is unknown whether the truck is full or not. However, the material in the truck has most likely been compacted, and the resulting weight estimate can be taken as a conservative upper limit for yard waste density. As a comparison, MSW weighs between 1,100 and 1,400 lb/cu yd when compacted, and 100 and 200 lb/cu yd when uncompacted (NSWMA, 1985).

Emission factors for leaf burning (unspecified), weeds, and forest residues in *AP-42* Tables 2.5-5 and 2.5-6 in Section 2.5 Open Burning, can be used to calculate emission estimates and are shown in Table 16.4-10. The EPA Office of Solid Waste and Emergency Response estimates that as a “ballpark” composition of yard waste, average composition by weight is 50 percent grass, 25 percent brush, and 25 percent leaves (EPA, 1996). These proportions will vary according to season, region and climate, and it may be that only one type of yard waste is

burned, such as leaves in the fall. Alternatively, the conservative assumption of using the higher emission factor between the two sets of factors can be made.

Emissions Calculations

A general emission calculation for yard waste burning is:

$$\text{Emissions} = \left(\begin{array}{c}\text{Yard}\\ \text{Waste}\\ \text{(tons)}\end{array} * \begin{array}{c}\%\\ \text{Grass}\\ \text{Composition}\end{array} * \begin{array}{c}\text{Weeds}\\ \text{Emission}\\ \text{Factor}\end{array}\right) + \left(\begin{array}{c}\text{Yard}\\ \text{Waste}\\ \text{(tons)}\end{array} * \begin{array}{c}\%\\ \text{Brush}\\ \text{Composition}\end{array} * \begin{array}{c}\text{Forest}\\ \text{Residue}\\ \text{Emission}\\ \text{Factor}\end{array}\right) + \left(\begin{array}{c}\text{Yard}\\ \text{Waste}\\ \text{(tons)}\end{array} * \begin{array}{c}\%\\ \text{Leaf}\\ \text{Composition}\end{array} * \begin{array}{c}\text{Leaf}\\ \text{Emission}\\ \text{Factor}\end{array}\right) \qquad (16.5\text{-}2)$$

Yard waste is the total estimated amount of yard waste burned. If they are available, the proportions of grass, brush or leaves can be used to subdivide that total to be applied to the weed, forest residue or leaf emission factors, respectively. If the waste type proportions are not known, the equation becomes:

$$\text{Emissions} = \begin{array}{c}\text{Yard}\\ \text{Waste}\\ \text{(Tons)}\end{array} * \text{Emission Factor}$$

Where the emission factor used is the highest for the pollutant shown on Table 16.4-7.

TABLE 16.4-7

YARD WASTE BURNING EMISSION FACTORS (EPA, 1995a)[a]

Yard Waste Type	Particulate[b]	Carbon Monoxide	TOC[c]	
			Methane	Nonmethane
	lb/ton	lb/ton	lb/ton	lb/ton
Leaf Species Unspecified	38	112	12	28
Forest Residues, Unspecified	17	140	5.7	19
Weeds, Unspecified	15	85	3	9

[a] Emission factors in this table have been given a rating of D in AP-42.
[b] The majority of particulate is submicrometer in size.
[c] Average TOC emissions are reported for leaf burning are 29% methane, 11% other saturates, 33% olefins, 27% other (aromatics, acetylene, oxygenates). For forest residues and weeds, average TOC values are 22% methane, 7.5% other saturates, 17% olefines, 15% acetylene, 38.5% unidentified. Unidentified TOC are expected to include aldehydes, ketones, aromatics, and cycloparaffins.

5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

Alternative methods require less effort and less cost than the preferred methods, but may result in less detail or estimates that are less specific to the area. The choice of a preferred over an alternative method will be determined by the DQOs and budget of the inventory. For this source category in particular, the significance of this source to total area emissions should be considered when choosing methods.

During the planning stage of the inventory, research should be done to identify data sources, rules affecting the source category, or other factors that might influence emissions from the source category. See Section 16.4.1, Planning, for more specific issues.

5.1 MUNICIPAL SOLID WASTE BURNING

5.1.1 FIRST ALTERNATIVE METHOD

The first alternative method for estimating emissions from burning MSW is to collect estimates of total MSW generation in the inventory area from local experts, and subtract the amount of MSW that is disposed of by methods other than open burning. The remaining amount of waste is assumed to be burned. In this case, the waste generation information and the disposal information are specific to the inventory area.

Sources of information for total MSW generation or estimates of the landfilling, incineration or recycling activity in the area would be many of the same information sources listed in Section 4 of this document for MSW open burning: state solid waste agencies, local sanitation agencies, and local health departments. Other sources could be civil engineering departments in universities, local or state planning departments, or environmental public interest groups.

If no estimates of local activity are available, then estimates will need to be generated. The information needed is:

- Estimated total MSW generated in the inventory area;

- Estimated amount of the MSW that is landfilled, either in the inventory area or outside of the area; and

- Estimated amount incinerated, composted, recycled, or otherwise disposed of.

Typical densities of MSW are:

Loose refuse: 100 to 200 lb/cu yd (NSWMA, 1985)
Compacted waste: 1,100 to 1,400 lb/cu yd (EPA, 1995a)

The general equation for estimating the MSW burned is:

$$\begin{matrix}\text{MSW}\\ \text{Open}\\ \text{Burned}\end{matrix} = \begin{matrix}\text{Total}\\ \text{MSW}\\ \text{Generated}\end{matrix} - \left(\text{MSW Landfilled} + \begin{matrix}\text{MSW Disposed of}\\ \text{Using Other Methods}\end{matrix}\right) \qquad (16.5\text{-}2)$$

Other methods of disposal for MSW will be any incineration, composting, or recycling that takes place in the area. Some MSW will also be disposed of by open dumping. Activity for open dumping will be difficult to estimate because it is typically illegal, but state solid waste agencies may be able to provide estimates. Local estimates for total MSW generated are preferred, but calculating estimates based on population-based generation rates are suitable for this source category. The recommended population-based waste generation rate is 3.77 lb MSW generated per person per day, or 0.69 tons MSW generated per person per year (EPA, 1996a).

These generation rates are from the Office of Solid Waste's (OSW) annual report on the characterization of MSW in the US and are for 1994.[1] Waste make up, by material type, is listed in Table 16.5-1. Total MSW reported in the OSW annual report is the MSW that enters the waste stream to be landfilled, incinerated, recycled or composted where the composted material is collected then treated. The estimate includes wastes from households, commercial establishments, and other sources. It does not include the portion that may be open burned or disposed of by other means. Thus, it can be assumed that the per capita MSW generation estimate is an underestimate of the total that is generated in the US. However, within a particular area, the national average per capita generation rate could be either an over- or an

[1] The EPA Office of Solid Waste and Emergency Response maintains an Internet World Wide Web page at: http://www.epa.gov/epaoswer, and can be reached by telephone through the RCRA hotline at 1-800-424-9346 or 1-800-553-7672, or by mail at RCRA Information Center, U.S. EPA, 401 M Street, SW (5305W), Washington, D.C. 20460.

TABLE 16.5-1

GENERATION OF MUNICIPAL SOLID WASTE, BY MATERIAL 1994 (EPA, 1996a)

Materials	lb/person/day
Paper and paperboard	1.71
Glass	0.28
Metals	0.33
Plastics	0.42
Rubber and leather	0.13
Textiles	0.14
Wood	0.31
Other	0.08
Food Trimmings	0.30
Yard trimmings	0.64
Miscellaneous inorganic wastes	0.07
Total MSW Generated	**4.41**
MSW Generated minus Yard trimmings	**3.77**

under-estimation. Yard waste should be reported separately, and is discussed in Section 16.5.5 of this chapter.

Estimates of the amount of MSW that is landfilled, and MSW that is disposed of using other methods may have already been collected for the landfill source category emissions estimate described in Chapter 15 of this document. Public health departments, local sanitation departments and individual active landfills may need to be contacted for this information. Activity data for this source category differs from the landfill source category in that landfill activity data includes waste generated before and during the inventory year, and this source category only requires information about the inventory year. Another correction to the landfill source category activity data may be to remove the estimated amounts of wastes other than MSW. These wastes would be land clearing debris and yard wastes, or industrial wastes, if such wastes are accepted at the landfill.

Emission Factors

The emission factors discussed in Section 4 of this document for municipal waste are recommended. These factors are listed in Table 16.4-4.

5.1.2 SECOND ALTERNATIVE METHOD

The second alternative method for estimating emissions from municipal solid waste burning uses either the activity data collected or the emission estimates that were calculated for another, similar area. The original data should have been collected using the preferred method, but can be data from a different year than that of the current inventory, so long as the similarity between areas is maintained. The data are scaled to the inventory area using a surrogate factor. If activity data are used, the preferred method emission factors are employed to calculate emission estimates.

An alternative to collecting activity from a similar inventory area is to use the per household waste generation factor reported in the EPA report, *Evaluation of Emissions from the Open Burning Of Household Waste in Barrels*, (EPA, 1997). This report is discussed in Section 4.1.2 of this chapter. The waste generation factor used in this report was based on a survey done by the NY State Department of Environmental Conservation's Division of Solid Waste.
Table 16.5-2 lists the material types and amounts generated by the surveyed average household of four people. This area is effected by a bottle bill, where beverage containers can be returned for a deposit. This per household waste generation rate is in contrast to the waste generation estimates presented in Table 16.5-1, which is based on the waste total generated by households, commercial establishments and other sources.

TABLE 16.5-2

GENERATION OF HOUSEHOLD WASTE, BY MATERIAL (EPA, 1997)

Materials	lb/household/day
Paper and paperboard	6.7
Glass/Ceramics	1.1
Metals	1.1
Plastics	0.8
Textiles/Leather	0.4
Wood	0.1
Food Waste	0.6
Total Waste Generated	**10.8**

The best match between two areas would be for areas that have the same demographic and waste handling situations. During the preparation of emission estimates for the original area, the significant matching factors for activity should have been identified. These factors may include: deposits on glass, plastic and aluminum beverage containers; the presence of a rural, less dense population; lack of refuse haulers; the distance between residences and the landfill; the cost of hauling; and the population's income. If such factors can be identified, they can be used to match inventory areas. Many cities and counties maintain demographic information and information about services that could be useful. The U.S. Census Bureau also reports rural population numbers for many counties.[2] The extent of detailed information collected will depend on the DQO of the inventory, the importance of the source category, and resources available.

[2] U.S. Census Bureau data are available on CD-ROMs, paper reports, and can be viewed on the Internet on: http://venus.census.gov/cdrom/lookup. Summary files under the Census Summary Tape File 3 (STF3) listing on the Internet site will include population, households, household income, education level and other population and housing statistics by county and by census tract. The Summary Tape File 1A CD-ROM will have the same data, as will the Census printed reports, *Summary Population and Housing Characteristics*, CPH-1 for county-level data, and *Population and Housing Characteristics for Census Tracts and Block Numbering Areas*, CPH-3.

Rural population is the primary factor for matching inventory areas, and can also be used to scale the emissions or the activity from the original area to the inventory area. Example 16.5-2 shows a typical scaling calculation:

Example 16.5-2

County A has a total population of 38,759, of which 33,951 people are considered rural residents, from U.S. Census data. Using the first alternative method, it has been estimated that 593 tons of MSW is burned in County A. County B has a total population of 181,835, of which 27,078 people are rural residents.

The scaling equation is:

$$\text{County B MSW Emissions} = \frac{\text{County B Rural Populaion}}{\text{County A Rural Population}} * \text{County A MSW Burned}$$

$$\text{County B MSW Burned} = \frac{\text{27,078 Rural Residents}}{\text{33,951 Rural Residents}} * \text{593 tons MSW Burned}$$

$$= \text{473 tons MSW Burned}$$

Emission Factors

The emission factors discussed in Section 4 of this document for municipal waste are recommended. These factors are listed in Table 16.4-4.

5.2 LAND CLEARING WASTE BURNING

Methods for this burning type all use the emission factors discussed in Section 4, and vary only in the specificity of the activity data and fuel loading factors used to the inventory area. The information sources for activity and fuel loading that are listed in Section 4 for this type of burning can be used for the alternative methods listed below.

5.2.1 FIRST ALTERNATIVE METHOD

The first alternative method is to estimate the amount of debris burned by collecting estimates of debris generated by the land cleared in the inventory area during the inventory time period, and subtracting the amount of debris that is disposed of by other methods.

Activity data is developed for this method in three steps:

- Estimate the amount of land cleared in the inventory area during the inventory time period;
- Estimate the amount of debris generated for a typical acre of cleared land and multiply by the acres of land cleared; and
- Estimate the amount of debris that is not burned -- either landfilled, composted, or if possible estimates of debris that is illegally dumped, and then subtract from the estimated total amount of debris generated.

See the listing of information sources under land clearing activity level data collection in Section 4 of this chapter. Planning departments and DOTs should be contacted for information about the amount of land cleared, and if possible, whether the debris was burned and if the land was logged first, which would reduce the amount of debris. Forest service offices can be contacted for information about the type of plant cover that would be burned in a particular area. State solid waste agencies or environmental agencies may be able to provide estimates of how much land clearing debris is illegally landfilled. State solid waste, landfill operators, and local sanitation agencies should have estimates of the amounts of land clearing debris that were accepted at local landfills during the inventory period. The cost of hauling this type of debris over great distances would be prohibitive. Debris generated far from a landfill is probably not sent to a landfill.

Refer to the land clearing portion of Chapter 4 for more information about information sources and choosing fuel loading and emission factors.

5.2.2 SECOND ALTERNATIVE METHOD

The second alternative method for estimating emissions from burning land clearing waste uses either the activity data collected or the emission estimates that were calculated for another, similar area. Review the discussion of fuel types and fuel loadings for land clearing debris burning in Section 4.2.3. The original data can be collected using either the preferred or the first alternative methods. The data can also be from a different time period than that of the inventory, so long as the similarity between areas is maintained. The data is scaled to the inventory area using a surrogate factor. If activity data is used, the preferred method emission factors are used to calculate emissions.

Areas should be matched by comparing disposal rules, disposal methods, and costs for disposing of land clearing waste, and land cover types. Land covers should share enough common qualities so that the fuel loading is similar. Areas can also be compared by looking at land use

patterns. Clearing that is done for roads and commercial development will clear more per acre of the land than that done for residential development.

Two types of scaling factors can be used for this source subcategory. If most of the land clearing is for residential building, population growth can be used. If land clearing has been done for roads, commercial development and residential building, the acres cleared should be used to scale activity from the original area to the inventory area. Alternatively, the number of residential and commercial building permits may be used to scale activity between the two areas.

Emission estimates are calculated using the same equations and emission factors as the preferred method.

5.3 YARD WASTE BURNING

Alternative methods for this type of burning differ from the preferred approach in that they use less specific activity information and require more assumptions. Please review the discussion of the types of material burned, conversion factors for, and other factors that affect data collection and calculations under the discussion of the preferred method.

5.3.1 FIRST ALTERNATIVE METHOD

The first alternative method uses records of permits and violations of rules prohibiting yard waste burning. If records are maintained of permits and violations, then an estimate of yard waste burning from the permits and reported violations may be possible. Assumptions necessary to transform reports of violations into an estimate of activity are estimates of the typical volume and material for piles of yard waste, and scaling surrogates in order to scale reports of burning from one small portion of the inventory area to the rest of the inventory area.

5.3.2 SECOND ALTERNATIVE METHOD

The second alternative method for estimating emissions from burning yard waste uses either the activity data collected or the emission estimates that were calculated for another, similar area. Review the discussion of yard waste activity and limits on activity in Section 4.2.5. The data is scaled to the inventory area using a surrogate factor. If activity data is used, the preferred method emission factors are employed in the emission estimation calculations.

The area used as a data source should be matched to the inventory area using similarities in rules, waste disposal practices (such as composting programs and yard waste pickup programs) and population density. Activity or emission estimates should be scaled using population.

5.3.3 THIRD ALTERNATIVE METHOD

The third alternative method uses a local per acre waste generation rate, multiplied by residential land use, and corrected with the amounts of yard waste that are estimated to be landfilled or composted for the inventory area. Like the first alternative method discussed above, this method relies on sampling a small portion of activity, and scaling it up for the entire inventory area. The local generation rate is an estimate of what a typical maintained acre produces in grass, trimmings, and leaves during either a year or during the inventory period. Detailed information is unlikely, and gross assumptions will have to be made. Only one contact should be necessary in order to develop a generation rate. Potential contacts are:

- Sanitation or health department personnel in areas where yard wastes are collected separately from other wastes.

- The grounds maintenance crews of a landscaped park, or an institution with grounds that may be similar to residential lots can be contacted for estimates of the waste generated over a typical time period.

Volumes or weight amounts of the wastes collected for a known area can be averaged to a typical acre. See Section 4.2.4 for more information about converting volume measures of yard waste to weight measures. The per acre yard waste generation rate is applied to the amount of the inventory area that is defined as residential, commercial and institutional land use. Local planning departments or tax offices should be able to provide land use information.

The total yard waste generated for the inventory area is corrected by subtracting the amount of waste that is collected and disposed of, or composted in the area. These estimates may be available from health or sanitation departments, landfill operators, waste collection departments, or local recycling and composting programs. It should be assumed that a certain amount of yard waste is composted on-site where it was generated. Local recycling and composting programs may be able to supply estimates of on-site composting. The remaining waste is assumed to be burned.

There are considerable uncertainties in the scaling and correction steps of this approach. The assumption necessary to use the per acre yard waste generation rate to the inventory area will be an assumption of typical lot size.

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6

QUALITY ASSURANCE/QUALITY CONTROL

Data collection and data handling for this source category should be planned and documented in the Quality Assurance Plan. Quality assurance (QA) and quality control (QC) methods may vary based on the data quality objectives for the inventory.

When using survey methods and other detailed methods that require data collection from permits, or reports of violations, then the survey method, sample design, data collection, and data handling steps should be documented in the Quality Assurance Plan. Refer to the discussion of survey planning and survey QA/QC in Chapter 1, *Introduction to Area Source Emission Inventory Development*, of this volume, and Volume VI, *Quality Assurance Procedures*, of the Emission Inventory Improvement Program (EIIP) series. When using other methods, data handling for activity, fuel loading factors, and emission factors should be planned and documented in the Quality Assurance Plan. For all methods, the basis for choosing fuel loading factors, and emission factors should be documented. Methods that use surrogate scaling factors should also include an explanation of why those factors were chosen.

Potential pitfalls when preparing estimates for this source category are the potential overlap and double counting of the open burning subcategories, use of the wrong fuel loading factor, the choice of inappropriate scaling factors, or unit conversion errors.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

There are not large variations in the Data Attribute Rating System (DARS) scores between preferred and alternative methods for most of the open burning source categories discussed in this chapter. Emissions for all of the open burning source categories are estimated using activity, fuel loading, and emission factors, and values for these parameters vary widely for very similar circumstances; this means that for most of these source categories, estimates based on careful and detailed collection of data for these three parameters may still be far from the actual emissions.

Emission factor scores provided here reflect emission rate variations dependent on differences in the materials burned, burning types (smoldering vs. flaming), and whether the factors are averages of direct measurements or ratios. Activity factor scores reflect variability in the

amount of available fuel that actually burned, fuel loading, and spatial and temporal variability introduced when data from one area is scaled or extrapolated to the inventory area.

The effort required in collecting high quality activity information for these open burning source categories and the inherent difficulty in obtaining good quality emission estimates, even when detailed information has been collected, should be considered when planning the inventory and choosing an estimation method.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The DARS scores for emission estimation methods for municipal solid waste burning are shown in Tables 16.6-1 through 16.6-3; for land clearing waste burning, in Tables 16.6-4 through 16.6-6; and for yard waste burning Table 16.6-7 through 16.6-10. A range of scores is given for many of the methods to account for the applicability of the available emission factors to the materials that are actually being burned in the inventory area, the specificity of fuel loading factors used, and different approaches for collection and scaling of activity data for a particular method. DARS scores for these methods and for these source categories can be improved if the uncontrolled variables that affect emissions can be limited.

6.2 SOURCES OF UNCERTAINTY

There are many sources of uncertainty in estimating emissions from open burning source categories. Historically, emissions from this source category have been difficult to estimate because of the lack of cost-efficient data collection methods and the large number of variables that affect emissions. Methods presented here provide some more streamlined approaches, but at a cost of less area-specific estimates. The data quality objectives for a particular inventory and the priority of the open burning source category in the inventory should be used as a guide when choosing inventory methods.

Although the methods presented here generally use only emission factors, fuel loading factors, and activity factors, many other parameters operate when burning actually takes place. Details for these other parameters, which include fuel moisture, type of combustion, and the amount of fuel that is actually burned, are not available at the level required in an area source inventory. The variance that may exist between burning that takes place in the inventory area and the burning measured to develop emission factors or fuel loadings cannot be defined without a detailed study outside of the usual scope of an area source inventory.

In many cases, methods presented in this chapter recommend that data collected by survey or other detailed methods such as permits or burning violation reports should be done for only a subset of the inventory area or should be collected for another similar area. These data will need

to be scaled to the entire inventory area using a scaling surrogate. In all cases, scaling data from another area will add uncertainty to the estimate of activity. If burning practices are well matched from the data source area to the inventory area, this uncertainty is reduced; but if burning practices are not similar, choosing an appropriate surrogate factor becomes more important. In the case of the yard waste burning methods that use scaling, the inventory preparer is expected to identify an appropriate scaling surrogate. Selecting the best scaling surrogate will depend on the reasons that people burn and the material that they burn. Examples of appropriate scaling surrogates for this subcategory of open burning are the number of rural residences, residential lot size, or household income.

TABLE 16.6-1

MSW BURNING
PREFERRED METHOD: LOCAL ESTIMATE

Attribute	Scores		
	Factor[a]	Activity	Emissions
Measurement	0.4	0.4 - 0.6	0.16 - 0.24
Source specificity	0.6	0.7	0.42
Spatial congruity	0.7	0.7 - 0.9	0.49 - 0.63
Temporal congruity	0.5	0.7	0.35
Composite	0.55	0.63 - 0.73	0.36 - 0.41

[a] Emission factors are from AP-42 with a factor rating of D.

TABLE 16.6-2

MSW BURNING
ALTERNATIVE METHOD 1: ESTIMATED TOTAL MINUS LANDFILLED AMOUNT

Attribute	Scores		
	Factor[a]	Activity	Emissions
Measurement	0.4	0.4	0.16
Source specificity	0.6	0.6	0.36
Spatial congruity	0.7	0.7	0.49
Temporal congruity	0.5	0.7	0.35
Composite	0.55	0.6	0.34

[a] Emission factors are from AP-42 with a factor rating of D.

TABLE 16.6-3

MSW BURNING
ALTERNATIVE METHOD 2: SCALING OF DATA FROM A SIMILAR AREA

Attribute	Scores		
	Factor[a]	Activity	Emissions
Measurement	0.4	0.4	0.16
Source specificity	0.6	0.5 - 0.6	0.3 - 0.36
Spatial congruity	0.7	0.6	0.42
Temporal congruity	0.5	0.7	0.35 - 0.35
Composite	0.55	0.55 - 0.58	0.31 - 0.32

[a] Emission factors are from AP-42 with a factor rating of D.

TABLE 16.6-4

LAND CLEARING WASTE BURNING
PREFERRED METHOD: LOCAL ACTIVITY AND FUEL LOADING DATA

Attribute	Scores		
	Factor[a]	Activity	Emissions
Measurement	0.4 - 0.7	0.7	0.28 - 0.49
Source specificity	0.5 - 0.8	0.7 - 0.9	0.35 - 0.72
Spatial congruity	0.7	0.9	0.63
Temporal congruity	0.8	0.6 - 0.8[b]	0.48 - 0.64
Composite	0.6 - 0.75	0.73 - 0.83	0.44 - 0.62

[a] Score depends on the factor used. Refer to source material for emission factors Current AP-42 factors get the lower score.
[b] Fuel loading may vary by season, it is unlikely that it will be taken into account for these estimates. The higher score is for data specific to the inventory time period, the lower score is given if data has been collected for a different season, or for an entire year, when seasonal emissions must then be apportioned.

TABLE 16.6-5

LAND CLEARING WASTE BURNING
ALTERNATIVE METHOD 1: ESTIMATE FROM TOTAL LAND CLEARED AND AMOUNT OF MATERIAL DISPOSED OF BY OTHER MEANS

Attribute	Scores		
	Factor[a]	Activity	Emissions
Measurement	0.4 - 0.7	0.30	0.12 - 0.21
Source specificity	0.5 - 0.8	0.60	0.3 - 0.48
Spatial congruity	0.70	0.70	0.49
Temporal congruity	0.80	0.6 - 0.8[b]	0.48 - 0.64
Composite	0.6 - 0.75	0.55 - 0.6	0.35 - 0.46

[a] Score depends on the factor used. Refer to source material for emission factors Current AP-42 factors get the lower score.
[b] Fuel loading may vary by season, it is unlikely that it will be taken into account for these estimates. The higher score is for data specific to the inventory time period, the lower score is given if data has been collected for a different season, or for an entire year, when seasonal emissions must then be apportioned.

TABLE 16.6-6

LAND CLEARING WASTE BURNING
ALTERNATIVE METHOD 2: EXTRAPOLATE DATA FROM A SIMILAR AREA

Attribute	Scores		
	Factor[a]	Activity	Emissions
Measurement	0.4 - 0.7	0.3 - 0.7[b]	0.12 - 0.49
Source specificity	0.5 - 0.8	0.6 - 0.9	0.30 - 0.72
Spatial congruity	0.7	0.5 - 0.7	0.35 - 0.49
Temporal congruity	0.8	0.6 - 0.8[c]	0.48 - 0.64
Composite	0.6 - 0.75	0.5 - 0.78	0.31 - 0.59

[a] Score depends on the factor used. Refer to source material for emission factors Current AP-42 factors get the lower score.
[b] Activity score depends on the method used to collect data in the similar area (see scoring for preferred and alternative one methods).
[c] Fuel loading may vary by season, it is unlikely that it will be taken into account for these estimates. The higher score is for data specific to the inventory time period, the lower score is given if data has been collected for a different season, or for an entire year, when seasonal emissions must then be apportioned.

TABLE 16.6-7

YARD WASTE BURNING
PREFERRED METHOD: LOCAL DATA

Attribute	Scores		
	Factor[a]	Activity	Emissions
Measurement	0.4	0.4 - 0.6	0.16 - 0.24
Source specificity	0.6	0.5 - 0.7	0.3 - 0.42
Spatial congruity	0.5	0.7 - 0.9	0.35 - 0.45
Temporal congruity	0.8	0.7	0.56
Composite	0.58	0.58 - 0.73	0.34 - 0.42

[a] Emission factors are from AP-42 with a factor rating of D.

TABLE 16.6-8

YARD WASTE BURNING
ALTERNATIVE METHOD 1: SMALL-SCALE SURVEY FROM PERMITS AND VIOLATIONS

Attribute	Scores		
	Factor[a]	Activity	Emissions
Measurement	0.4	0.5	0.2
Source specificity	0.6	0.5 - 0.7	0.3 - 0.42
Spatial congruity	0.5	0.5 - 0.7	0.25 - 0.35
Temporal congruity	0.8	0.8	0.64
Composite	0.58	0.58 - 0.68	0.35 - 0.4

[a] Emission factors are from AP-42 with a factor rating of D.

TABLE 16.6-9

YARD WASTE BURNING
ALTERNATIVE METHOD 2: EXTRAPOLATE FROM A SIMILAR AREA

Attribute	Scores		
	Factor[a]	Activity	Emissions
Measurement	0.4	0.4	0.16
Source specificity	0.6	0.5	0.3
Spatial congruity	0.5	0.5 - 0.6	0.25 - 0.3
Temporal congruity	0.8	0.7	0.56
Composite	0.58	0.53 - 0.55	0.32 - 0.33

[a] Emission factors are from AP-42 with a factor rating of D.

TABLE 16.6-10

YARD WASTE BURNING
ALTERNATIVE METHOD 3: ESTIMATED LOCAL YARD WASTE MINUS LANDFILLED OR COMPOSTED YARD WASTE

Attribute	Scores		
	Factor[a]	Activity	Emissions
Measurement	0.4	0.4	0.16
Source specificity	0.6	0.5 - 0.7	0.3 - 0.42
Spatial congruity	0.5	0.5 - 0.7	0.25 - 0.35
Temporal congruity	0.8	0.5	0.4
Composite	0.58	0.48 - 0.58	0.28 - 0.33

[a] Emission factors are from AP-42 with a factor rating of D.

7

DATA CODING PROCEDURES

This section describes the codes available to characterize open burning emission estimates. Consistent categorization and coding will result in greater uniformity between inventories. Inventory planning for data collection, calculations, and inventory presentation should take the data formats presented in this section into account. Available codes and process definitions may impose constraints or requirements on the preparation of emission estimates for this category.

7.1 PROCESS AND CONTROL CODES

The source category process codes for open burning operations are shown in Table 16.7-1. These codes are derived from the EPA's Aerometric Information Retrieval System (AIRS) Area and Mobile Source (AMS) source category codes (EPA, 1994). Codes have been assigned to all of the subcategories of open burning except for the burning of yard wastes. If these codes are used to store emission inventory data, it is recommended that a source category code be developed for leaf burning. Alternatively, the leaf burning emissions could be added to emissions calculated for residential open burning.

Few controls are available or likely to be used for this category. Most reductions in emissions from this source category are accomplished by reducing the amount of waste material burned. The control codes for use with AMS are shown in Table 16.7-2. The "099" control code can be used for miscellaneous control devices that do not have a unique identification code. The "999" code can be used for a combination of control devices where only the overall control efficiency is known. State and local regulations can be used as guides to estimate the extent of controls and limits on burning, and the use of control techniques and the level of efficiency that can be achieved, if controls are used. It should be assumed that controls and limits are only partially effective for this source category. The equations used to apply control efficiency, rule penetration, and rule effectiveness for area sources are discussed in Chapter 1 of this volume.

TABLE 16.7-1

AIRS AMS CODES FOR OPEN BURNING

Process Description	Source Category Code
Open Burning	26-10
All Categories	26-10-000-000
Industrial	26-10-010-000
Commercial/Institutional	26-10-020-000
Residential	26-10-030-000
Other Combustion	28-10
Managed Burning -- Slash	28-10-005-000

TABLE 16.7-2

AIRS CONTROL DEVICE CODES

Control Device	Code
Miscellaneous Control Device	099
Combination Control Device	999

8

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APPENDIX A

PRESCRIBED BURNING FUEL CATEGORIES (PETERSON AND WARD, 1993) TO BE USED FOR LAND CLEARING WASTE BURNING

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Emission rates from prescribed burning vary depending on the fuels burned. One system for categorizing the materials burned is the National Fire Danger Rating System, which uses 20 fuel models to organize fuels according to their response to weather and influence on fire behavior. Definitions of fuel components and the 20 fuel models are listed below.

FUEL COMPONENTS

1. Fine fuels less than 1 inch in diameter consisting of grasses, needles, and/or small twigs.

2. Small fuels 1 to 3 inches in diameter consisting of small branches and/or brush stems.

3. Large fuels greater than 3 inches in diameter consisting of large branches and/or logging debris.

4. Live woody fuels from live, brush plants such as chaparral, palmetto-galberry, and juniper.

5. Litter and duff from the organic layers above the mineral soil. The litter retains its original form, in contrast to duff which, by definition, is partially or fully decayed organic residue.

EXAMPLE FUEL MODELS

Brief descriptions of the NFDRS fuel models follow:

- Fuel Model A: Western grasslands vegetated by annual grasses and forbs. Brush or trees may be present, but are very sparse, occupying less than one-third of the area. Examples include cheatgrass and medusahead, open pinyon-juniper, sagebrush-grass, and desert shrub.

- Fuel Model B: Mature, dense field of brush 6 feet or more in height are represented by this fuel model. This model is for California mixed chaparral, generally 30 years or older.

- Fuel Model C: Open pine stands typify Model C fuels. Perennial grasses and forbs are the primary ground fuel, but there is enough needle litter and branchwood present to contribute significantly to the fuel loading. Some brush and shrubs may be present, but they are of little consequence. Examples are open longleaf, slash, ponderosa, Jeffrey, and sugar pine stands.

- Fuel Model D: This fuel model is specifically for the palmetto-galberry understory-pine overstory association of the southeast coastal plains.

- Fuel Model E: This model is for hardwood and mixed hardwood-conifer types after leaf fall. The primary fuel is hardwood leaf litter.

- Fuel Model F: Mature closed chamise and oak brush fields of Arizona, Utah, and Colorado are represented by Fuel Model F. It also applies to young, closed stands and to mature, open stands of California mixed chaparral.

- Fuel Model G: Fuel Model G is used for dense conifer stands where there is a heavy accumulation of litter and downed woody material. Such stands are typically overmature and may also be suffering insect, disease, wind, or ice damage--natural events that create a very heavy buildup of dead material on the forest floor. Types meant to be represented by Fuel Model G are hemlock-Sitka spruce, coast Douglas fir, and windthrown or bug-killed stands of lodgepole pine and spruce.

- Fuel Model H: The short-needed conifers (white pines, spruces, larches, and firs) are represented by Fuel Model H. In contrast to Model G fuels, Fuel Model H describes a healthy stand with sparse undergrowth and a thin layer of ground fuels.

- Fuel Model I: Fuel Model I was designed for clearcut conifer slash where the total loading of materials less than 6 inches in diameter exceeds 25 tons/acre.

- Fuel Model J: This is for clearcuts and heavily thinned conifer stands where the total loading of materials less than 6 inches in diameter is less than 25 tons per acre.

- Fuel Model K: Slash fuels from light thinnings and partial cuts in conifer stands are represented by Fuel Model K. Typically the slash is scattered about under an open overstory. This model applies to hardwood slash and to southern pine clearcuts where the loading of all fuel is less than 15 tons/acre.

- Fuel Model L: This fuel model is meant to represent western grasslands vegetated by perennial grasses. The principal species are coarser and the loadings heavier than those in Model A fuels.

- Fuel Model N: This model was constructed specifically for the sawgrass prairies of south Florida. It may be useful in other marsh situations where the fuel is coarse and reedlike.

- Fuel Model O: Model O applies to dense, brushlike fuels of the southeast. The high pocosins of the Virginia and North and South Carolina coasts are the ideal of Fuel Model O.

- Fuel Model P: Closed, thrifty stands of long needled southern pines are characteristic of P fuels.

- Fuel Model Q: Upland Alaskan black spruce is represented by Fuel Model Q. This fuel model may also be useful for jack pine stands in the Lake States.

- Fuel Model R: This model represents the hardwood areas after the canopies leaf out in the spring.

- Fuel Model S: Alaskan or alpine tundra on relatively well-drained sites is represented by Model S. Grass and low shrubs are often present, but the principal fuel is a deep layer of lichens and moss.

- Fuel Model T: The sagebrush-grass types of the Great Basin and intermountain west are characteristics of T fuels. This model might also be used for immature scrub oak and desert shrub associations in the west, and the scrub oak-wire grass in the southeast.

- Fuel Model U: Closed stands of western long-needled pines are covered by this model. Fuel Model U should be used for ponderosa, Jeffrey, sugar, and red pine stands of the Lake States.

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