



Guidance for Quantifying and Using Emission Reductions from Voluntary Woodstove Changeout Programs in State Implementation Plans





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LIST OF ABBREVIATIONS

B(a)P	Benzo(a)Pyrene
CAA	Clean Air Act
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
g/kg	grams per kilogram
HCl	Hydrogen Chloride
NAAQS	National Ambient Air Quality Standards
NEI	National Emissions Inventory
NO _x	Nitrogen Oxides
PAH	Polycyclic Aromatic Hydrocarbon
PM	Particulate Matter (PM ₁₀ and PM _{2.5})
PM ₁₀	PM 10 micrometers or less in aerodynamic diameter
PM _{2.5}	PM 2.5 micrometers or less in aerodynamic diameter
POM	Polycyclic Organic Matter
RWC	Residential Wood Combustion
SIP	State Implementation Plan
SO _x	Sulfur Oxides

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(Note: As used in this document, the terms "we", "us" and "our" refer to EPA. The terms "you" and "your" refer to a State/local or tribal air pollution control agency.)

Section A: Background Information

1. What is the purpose of this guidance?

The purpose of this document is to provide you with guidance on quantifying Residential Wood Combustion (RWC) emission reductions from woodstove changeout programs. You may wish to use the emission reductions resulting from implementing a woodstove changeout to help meet the goal of attaining the PM NAAQS.

2. How does this guidance relate to existing Clean Air Act requirements?

This document provides guidance to State/local or tribal air pollution control agencies and the general public on how woodstove changeout programs to reduce RWC emissions may be used to meet SIP requirements. SIP requirements can be found in Sections 110(a)(2) and 172(c) of the CAA. This document does not substitute for those provisions, nor is it a regulation itself. It does not impose binding, enforceable requirements on any party. Further, it does not assure that EPA will approve all instances of its application, and thus the guidance may not apply to a particular situation based upon the circumstances. The EPA and State and local decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where appropriate. Any decisions by EPA regarding a particular SIP demonstration will be made based on the statute and applicable regulations, and only following notice and opportunity for public review and comment. Therefore, interested parties are free to raise questions and objections about the appropriateness of the application of this guidance to a particular situation; EPA will, and States and localities should, consider whether or not the recommendations in this guidance are appropriate in that situation. This guidance is a living document and may be revised periodically without public notice. The EPA welcomes public comments on this document at any time and will consider those comments in any future revisions of this guidance document.

Readers of this document are cautioned not to regard statements recommending the use of certain procedures as either precluding other procedures or information, or providing guarantees that using these procedures will result in actions that are fully approvable. As noted above, EPA cannot assure that actions based upon this guidance will be fully approvable in all instances, and all final actions may only be taken following notice and opportunity for public comment.

3. For the purposes of this guidance, what is considered a woodstove?

Woodstoves are freestanding devices designed to burn cordwood to heat a specific room or zone of a house. For the purposes of this guidance document, the term woodstove also

includes fireplace inserts. A fireplace insert is essentially a woodstove that is installed in an existing fireplace.

4. What pollutants are emitted by woodstoves in normal intended use?

RWC emissions are highly variable and are a function of many wood characteristics and operating practices. RWC emissions generally contain some combination of gases (principally CO and CO₂, and some quantity of toxic compounds including, B(a)P, POM, PAH, and others), and fine particles (PM_{2.5}) which are composed of tiny unburned particles of ash and toxic elements. There are also minor amounts of components such as HCl, SO_x, and NO_x. In general, conditions that promote a fast burn rate and a higher flame intensity enhance secondary combustion and thereby lower emissions. Secondary combustion is especially important in wood burning because of the high volatile matter content of wood, typically 80 percent by dry weight. Conversely, higher emissions will result from a slow burn rate and a lower flame intensity. Such generalizations apply particularly to the earlier stages of the burning cycle, when significant quantities of combustible volatile matter are being driven out of the wood. Later in the burning cycle, when all volatile matter has been driven out of the wood, the charcoal that remains burns with relatively few emissions¹.

5. What is a woodstove changeout program?

A woodstove changeout is typically a voluntary program initiated by a State or local government entity (often a public health agency) to promote the use of cleaner burning heating appliances. A variety of incentives are used – such as cash rebates or other financial incentives, combined with public outreach and education, to encourage consumers to replace their old, inefficient and high polluting woodstoves with new clean burning EPA-certified^a woodstoves, or other heating appliances such as pellet stoves,^b or gas/electric stoves or fireplaces, or masonry heaters. Sometimes, the State or local government may decide to use statutory or regulatory means to prevent or limit the use of uncertified woodstoves, such as episodic bans on burning of uncertified woodstoves or graduated permit fees. In such circumstances, a woodstove changeout program may be instituted as a means to ease the burden on consumers but this does not make the changeout program itself mandatory.

The most effective changeout campaigns include an education component to ensure that EPA-certified woodstoves are properly installed, operated and maintained to achieve the lowest possible emission rates. Often, the agency sponsoring the changeout makes arrangements with metal scrap recycling dealers to recycle the uncertified woodstoves surrendered during the changeout, or they are destroyed in accordance with any Federal, State, or local laws governing disposal of hazardous or potentially hazardous substances (i.e., creosote). For the purposes of taking emissions reduction credit under this guidance, the State or locality should insure that the uncertified stoves surrendered in the changeout are accounted for (recycled for scrap metal or

^a Meets the 40 C.F.R. Part 60 Subpart AAA New Source Performance Standards (“NSPS”) for woodstoves.

^b Pellet woodstoves are fueled with sawdust, wood products, and other biomass materials compressed into pellets. Some pellet stove models are subject to the 1988 New Source Performance Standards (NSPS), while others are exempt due to a high air-to-fuel ratio (i.e., greater than 35-to-1).

destroyed), as they have value on the resale market and could be put back in service. This is a crucial step in the process of conducting a changeout if the State or locality wishes to remove the uncertified stove's emissions from the State or locality's emission inventory and use the emissions reductions in their SIP.

For more information about the practical considerations and the partnership possibilities for conducting a changeout in your State, EPA has developed a website: <http://www.epa.gov/woodstoves/index.html>.

6. What are the benefits of a woodstove changeout program?

The primary purpose of this guidance is to provide information to help you quantify emission reductions resulting from woodstove changeouts. This guidance specifically addresses emission reductions of PM_{2.5}, however PM₁₀ emission reductions can also be calculated using the same methods and credit can be granted. In addition, there are other important benefits associated with reductions in RWC emissions including:

- Reductions in the emissions of toxic air pollutants resulting in improved indoor and outdoor air quality and public health.
- Reductions in emissions of carbon monoxide and carbon dioxide.
- Reductions in haze caused by PM_{2.5} resulting in improved visibility.
- Reductions in fuel consumption with greater energy efficiency and less maintenance, which results in cost savings to the stove owner.
- Reductions in creosote buildup in chimneys, resulting in lower risk of fire in the home.

Section B: Basic Criteria for Using RWC Emissions Reductions

7. What are the basic criteria for using emission reductions in SIPs?

To be approved as a measure that provides additional emission reductions in a SIP, a control measure reducing RWC emissions cannot interfere with other requirements of the CAA, and would need to be consistent with SIP attainment and maintenance requirements. Specifically, the control measure must provide emission reductions that meet the criteria described below.

(a) Quantifiable - The emission reductions from a control measure to reduce RWC emissions are quantifiable if they can be reliably and replicably measured. Emission reductions must be calculated for the time period for which the reductions will be used. Appendix B provides you with a sample method for quantifying emission reductions. You can also submit your own quantification protocol which we will review and make a determination as to the appropriateness of its use on a case-by-case basis.

(b) Surplus – The emission reductions from a control measure to reduce RWC emissions are generally surplus if they are not otherwise relied on to meet other applicable air quality attainment and maintenance requirements. In addition, to be considered surplus the emissions

from woodstoves must be a part of all applicable SIP emissions inventories. This includes current and future inventories projected for attainment or maintenance of the NAAQS.

(c) Federally Enforceable – Since woodstove changeout programs are voluntary, the State would need to make an enforceable commitment in its SIP to monitor, assess, report and make up, in a timely manner, any shortfall in emissions reductions should the expected reductions from the changeout program not materialize. Consistent with EPA’s voluntary measures policy described below, when the program is voluntary on the part of sources – the program is considered a “voluntary measure.”

Under an existing EPA policy (“Incorporating Emerging and Voluntary Measures in a SIP”^c) the State is responsible for assuring that the reductions credited in the SIP occur. The State would need to make an enforceable SIP commitment to monitor, assess and report on the emission reductions resulting from the voluntary measure and to remedy any shortfalls from forecasted emission reductions in a timely manner. Given the uncertainty involved with voluntary and emerging measures, we believe it is appropriate in most cases to limit the amount of emissions reductions you can take credit for in your SIP. The presumptive limit is 6 percent^d of the total amount of emission reductions required for attainment or maintenance demonstration purposes. The limit is presumptive in that EPA believes it may approve measures into a SIP in excess of the presumptive six percent where a clear and convincing justification is made by the State as to why a higher limit should apply in their case. Any request for a higher limit will be reviewed by EPA on a case-by-case basis.

(d) Permanent - The emission reduction must be permanent throughout the term that the emission reduction is used. Documentation of stove replacement, including proof that the stove replaced was destroyed or recycled, is key to meeting this requirement and is your responsibility if you wish to take credit for woodstove changeout emissions reductions in your SIP.

(e) Adequately Supported - The State (or responsible agency) must demonstrate that it has adequate funding, personnel, and other resources to implement the control measure (in this case a woodstove changeout program) on schedule.

8. What additional considerations should you be aware of ?

(a) All uncertified woodstoves surrendered as a part of the changeout, for which you wish to take credit for in your SIP, should be located within the nonattainment area boundary in question. You may be able to get credit for replacing woodstoves outside of the nonattainment area boundary if you can reliably demonstrate that the emissions from these woodstoves are

^c See <http://www.epa.gov/ttn/oarpg/t1pgm.html>

^d The six percent reduction does not apply to an area’s total emission inventory, but only to the increment that is necessary to achieve attainment or maintenance. To determine this increment, you must subtract the level of emissions consistent with attaining the NAAQS from the projected attainment year inventory, reflecting the benefits of all federal/state regulations that will be adopted and implemented.

contributing to nonattainment or are adversely affecting maintenance of the PM air quality standards.

(b) All EPA-certified woodstoves installed as a part of the changeout should be professionally installed. Improper installation can render a woodstove unsafe and cause it to operate with much less efficiency which may result in higher rather than lower emissions. You should keep track of the number of new certified stoves installed during a changeout program so that you will be able to update your emissions inventory and be able to calculate post-changeout emissions reductions.

9. Are RWC emissions part of the State's or locality's emission inventory?

In order to take credit for these emissions reductions, you will need to insure that an adequate and up to date inventory of PM_{2.5} emissions from woodstoves exists for the area in question. In addition, the crediting of emission reductions must also be consistent with the assumptions in the emission inventory upon which the attainment or maintenance demonstration is based. If they are not already in the SIP inventory, no credit can be given for RWC emissions reductions unless the SIP inventory baseline is reassessed to include such emissions at their current level.

Section C: Quantifying Woodstove Changeout Emissions Reductions

10. How do you quantify emission reductions from a woodstove changeout?

There are several sources of uncertainty involved with quantifying emissions reductions from a woodstove changeout program. Appendices A and B discuss these uncertainties and Appendix B provides an example calculation. Generally, the annual emission reductions from woodstove changeout programs are based upon the number of uncertified stoves that are replaced annually by EPA-certified stoves (or equivalent) minus the number of EPA-certified stoves presently in the stove inventory. In some cases, EPA-certified woodstoves may be replaced by pellet stoves or other devices such as gas or electric stoves or fireplaces that are lower emitting in terms of PM than the device they replaced. This situation can and should be accounted for in the inventory and the subsequent emission reduction calculations. If any uncertified woodstoves remain in the inventory after the implementation period of the changeout program, those emissions must also be included in the post-changeout emissions total.

Section D: Monitoring and Recordkeeping

11. What monitoring and record keeping should occur to document woodstove changeout emissions reductions?

(A) For each changeout program generating emissions reductions, the responsible party (the State or local air agency in most cases) should monitor and record the following information for each time period for which an emissions reduction is generated (or other information capable of demonstrating the emissions reductions):

(1) the number of uncertified woodstoves surrendered (scrapped or destroyed) during the changeout program,

(2) a demonstration that either these woodstoves were located in a nonattainment or maintenance area for the pollutant for which emission reductions were determined, or if not located in the nonattainment area that their emissions contribute to nonattainment or adversely affect maintenance of the PM air quality standards.

(3) the estimated emissions from the uncertified woodstoves for the pollutants of interest,

(4) the estimated emissions from the woodstoves (or other appliances) that replaced the uncertified stoves.

(B) All information to be monitored and recorded in accordance with this guidance for existing SIP requirements should be maintained by the responsible party for a period of no less than five years, and available for inspection.

12. What kind of validation and reconciliation should occur for emission reductions in SIPs approved as a voluntary measure?

The SIP submission for a voluntary measure should contain a description of the evaluation procedures and time frame(s) in which the evaluation of SIP reductions will take place. Once the voluntary control measure is in place, emission reductions should be evaluated to validate the actual emission reductions. You should submit the results of your evaluation to EPA in accordance with the schedule contained in the SIP. If the review indicates that the actual emission reductions are not consistent with the estimated emission reductions, then the amount of credit should be adjusted appropriately and applicable remedial measures should be taken. See the EPA's "Incorporating Emerging and Voluntary Measures in a SIP" policy for further information regarding validation and reconciliation procedures and timing for such measures: http://www.epa.gov/ttn/oarpg/t1/memoranda/evm_ievm_g.pdf.

13. What types of penalties can be assessed for not complying with CAA requirements?

Use of this guidance does not relieve the responsible party of any obligation to comply with all otherwise applicable CAA requirements, including those pertaining to the crediting of emission reductions in your SIP for attainment or maintenance plans. To receive SIP credit for emissions reductions under a voluntary program such as this the State must make an enforceable reconciliation commitment to address any shortfall in emissions reductions which then becomes the provision in the SIP subject to enforcement.

Violations of CAA requirements are subject to administrative, civil, and/or criminal enforcement under Section 113 of the CAA, as well as to citizen suits under Section 304 of the

CAA. The full range of penalty and injunctive relief options would be available to the Federal or State government (or citizens) bringing the enforcement action.

Section E: Including Woodstove Changeout Programs in SIPs

14. What must a State submit to EPA on the woodstove changeout program to meet the statutory and regulatory requirements for incorporating a source specific control measure in a SIP?

The State must submit to EPA a written document that:

- (A) Identifies and describes the woodstove changeout campaign and its implementation schedule to reduce RWC emissions within a specific time period;
- (B) Contains a quantification methodology to estimate the emission reductions from the woodstove changeout campaign. You can follow the quantification methodology provided in Appendix B of this document or you can submit your own. If you submit your own quantification methodology for quantifying the emission reductions, you must provide all relevant technical support documentation. You must rely on the most recent information available at the time the SIP is developed;
- (C) Contains federally enforceable requirements for the responsible party (the State) to monitor and record the appropriate information;
- (D) Enforceably commits to evaluate and report the resulting emission reductions of the measure as applicable;
- (E) Enforceably commits to remedy any SIP emission shortfall in a timely manner if the measure does not achieve estimated emission reductions; and
- (F) Meets all other requirements for SIP revisions under sections 110 and 172 of the CAA.

15. How can the estimated emission reductions be used for SIP purposes?

For your SIP attainment or maintenance strategy, you should use the emission reductions which are expected from the implementation of a woodstove changeout program by applying the following criteria:

- a) Only those reductions that occur, or are expected to occur, prior to the area's attainment date are creditable.
- b) If the changeout program takes place prior to the attainment date, for example in the spring of the attainment year, but the emissions reductions aren't fully realized until the

next heating season which ends the following year after the attainment date has past, you may need an extension of the attainment date if those emissions reductions are necessary to attain the standard. If the extension is approved, all creditable reductions resulting from the changeout program that occur before the new attainment date will be considered in this instance.

- c) Reductions from an ongoing changeout campaign that occur past the area's attainment date, or its extension, can be used to support the maintenance plan for the area once it is redesignated to attainment, provided the old uncertified stoves surrendered during the changeout are scrapped or otherwise removed from service, the number of new stoves being installed is tracked, and the responsible agency continues a public outreach program to educate the public on the proper techniques for efficiently burning wood.

Section F: Contact Information

16. Whom should you contact for additional information?

State agencies, local agencies, the regulated community and members of the public with questions concerning a case-specific application of this guidance should contact the EPA Regional Office with responsibility for air quality planning in the area where the woodstove changeout is planned. A contact list of EPA Regional Offices is available at the following web address: <http://www.epa.gov/epahome/locate2.htm>. The individuals responsible for SIP programs in each office can be found by going to the Regional office website and either using the Quick Finder function at the top of each homepage, or by searching on SIP.

For general questions regarding this guidance please contact Gary Blais of EPA's Office of Air Quality Planning and Standards at (919) 541-3223

Appendix A: PM Emissions Factors for a Selection of Woodstoves

Emissions estimates are important for developing emissions control strategies, such as voluntary woodstove changeout programs. While data from source-specific emission tests or continuous emission monitors are usually preferred for estimating emissions, those data are not always available and can be expensive to obtain. In situations where area-wide emissions estimates for a specific source category – not individual site – are desired, the risks of using a poor estimate are low, and the costs of more extensive methods are unattractive, then the use of less expensive estimation methods such as emissions factors may be satisfactory and appropriate.

If after assessing the risks and costs associated with using emissions factors, sources and regulatory authorities determine use of emissions factors to be acceptable, then we offer the following information.

Emissions factors are representative values that attempt to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of a pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e., a population average). In the case of RWC, our emissions factors are expressed in terms of pounds of pollutant per ton of wood burned.

Currently, the most credible and most widely used source for emissions factors is the EPA's Compilation of Air Pollutant Emission Factors (*AP-42*). Unfortunately, the AP-42 emissions factors for woodstoves are based on old test data. For example, no particulate data for cordwood or pellet stoves collected more recently than 1992 are included. As of July 1, 1992, all wood heaters sold are required to be "Phase II" certified. Consequently, emissions factors of only the earlier models of Phase II certified cordwood stoves and pellet stoves contribute to the particulate values compiled in AP-42^c. It is generally recognized in the hearth industry that the performance of both Phase II certified cordwood stoves and pellet stoves has improved considerably since the earliest models. Also, because most of the testing on which AP-42 woodstoves emissions factors are based occurred around the time the NSPS was being developed (1988-1990), there were not many tests on very old stoves which are believed by many in the hearth industry to have much higher emissions.

OAQPS is considering recommendations to improve AP-42 made by Omni Environmental Services (Omni) in a May 26, 2005 report entitled "[PM_{2.5} Emission Reduction Benefits of Replacing Conventional Uncertified Woodstoves with Certified Woodstoves or Modern Pellet Stoves.](#)" Omni has been funded numerous times by EPA to help prepare emissions factors and emission inventory guidance for woodstoves as well as by the HPBA. EPA is currently

^c Some Phase II cordwood stoves were manufactured and sold before the 1992 requirement became effective and are included in the AP-42 compilation, but approximately 1 million stoves have been sold since then.

reviewing the complete body of test data and Omni's recommended adjustments. EPA's preliminary conclusions are that the logic of the recommendations is sound. It is expected that the emissions factors for uncertified stoves will likely increase while the values for newer certified stoves will decrease, and thus the emissions reductions due to changing out old stoves for new stoves will increase, but the exact magnitudes are pending completion of the review of the data and possible additional emissions testing.

Omni's recommended adjustments to the National average value take into account the "dampened-down" conditions and more frequent start-ups characteristic of stove use in more mild climates such as the mid-Atlantic states and the Southeast than the colder climates typical of the AP-42 data. Also, Omni recommends adjusting the AP-42 emissions factor for Phase II certified stoves to account for the improvement in stove emissions performance since the AP-42 tests of the late 1980's. The third adjustment would be to increase the efficiency value for certified non-catalytic stoves (68% current default value) to reflect the fact that less wood is consumed and fewer emissions are produced even if all else is equal. Omni also recommends similar adjustments be made for catalytic stoves but not as great due to factoring in catalyst degradation.

Although it is not an "emissions factor" adjustment per se, another significant adjustment to woodstove emission estimates that EPA is already planning for is to adjust the wood density factor based on better information on representative moisture content. That is, the conversion factor (1.16 tons/cord) that many States and EPA used in their inventory development (including the 2002 NEI) is low and in the future EPA will revise our methods to have a higher conversion factor, perhaps as high as 1.8. We may use state-specific conversion factors, but we know the 1.16 current nationwide factor is based on oven-dried wood which is not representative of wood combusted for residential use. The example calculation in Appendix B uses 1.4 tons/cord, a number derived from the MANE-VU RWC survey.

Until EPA makes a decision about the need for revising AP-42, we recommend using those RWC emissions factors found in Table A-1 (below) from the Emission Inventory Improvement Program (EIIP), Volume III, Chapter 2, revised final report of January 2001². The EIIP document is considered by EPA to be the most up to date guidance for the development of emissions inventories for most source categories, including RWC. Residential woodstoves are classified as Phase I, Phase II and Pre-Phase I. Phase II stoves are those certified to meet the July 1, 1990, EPA standards; Phase I stoves meet only the July 1, 1988, EPA standards; and Pre-Phase I stoves do not meet any of the EPA standards but in most cases do necessarily meet the Oregon 1986 certification standards. If a stove is certified there will be a label on the back. AP-42 contains PM₁₀ emissions factors for catalytic and non-catalytic woodstoves in each of these classifications, but only emissions factors for Phase II are presented here. Information on how the AP-42 emissions factors were developed can be found in the AP-42 woodstoves section (<http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s10.pdf>).

At the time of this writing, no factors for PM_{2.5} are available. If PM_{2.5} emissions estimates are required for an inventory, you may assume that all of the PM₁₀ is PM_{2.5} (EPA, 1997). Emissions

estimated using this assumption should not be perceived to be of the same level of quality as many of the factors found in AP-42, and if new AP-42 factors for RWC became available, they should supersede emissions factors that are presented here. EPA, the hearth industry trade association (HPBA), and other stakeholders are currently exploring the issue of revising emissions factors for woodstoves, including developing factors specifically for PM_{2.5}.

Table A-1 : Adjusted PM₁₀ Emissions Factors for RWC (lb/ton)^a

Process Description	PM ₁₀ Emissions Factors
Residential Total Woodstoves and Fireplaces ^b	34.6
Residential Fireplaces ^c	34.6
Residential Woodstoves – Catalytic Phase II	16.2
Residential Woodstoves – Noncatalytic Phase II	14.6
Residential Woodstoves – Conventional	30.6
Residential Woodstoves – Pellet / Certified ^d	4.2
Residential Woodstoves – Pellet / Exempt ^e	8.8
Masonry Heaters ^f	5.6

- a *State's Workbook, Methodologies for Estimating Greenhouse Gas Emissions*. U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation. Washington, D.C.
- b These emission factors are for fireplaces and should be used when information separating wood burning equipment types is not available.
- c Exempt from the 1988 New Source Performance Standards for woodstoves because of air: fuel ratio > 15:1 and/or minimum burn rate > 5 kg/hr.
- d Certified pursuant to the 1988 New Source Performance Standards for woodstoves.
- e Exempt from the 1988 New Source Performance Standards for woodstoves because of air: fuel ratio >35:1.
- f Exempt from the 1988 New Source Performance Standards for woodstoves because of weight > 800 kg.

Appendix B: General Approach for Determining Emissions Reductions

The purpose of this appendix is to provide a general approach for calculating the net emissions reductions potential from a voluntary woodstove changeout campaign. You may develop your own methodology if you so choose. You are also encouraged to refer to Chapters 3 and 4 of the EIIP document referred to in Appendix A for a detailed discussion on the available emissions estimation methodologies for RWC.

The general approach is to first, determine the PM_{2.5} emissions from all RWC in the area in question for the pre-changeout condition. The first step in this process is to develop an emissions inventory and the preferred method of gathering emissions inventory data for RWC is the survey method. The alternative method is to estimate activity factors for RWC using residential wood data compiled by state or federal agencies, and apportioned using data from the U.S. Census Bureau and the U.S. Energy Information Administration³. The preferred source of information on residential wood burning is the state energy office, or state forest service. Available information may include estimates of wood burned for residential heating at the state, regional or county level. If the state energy office does not have information on residential wood burning, other sources of information for area-wide wood use, or per household wood use should be identified. USDA Forest Service regional experiment stations may compile information that may be useful. Inventory personnel should try to collect the most detailed and area-specific information possible.

The next variable to consider is the emissions factors for the woodstoves in the inventory. An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., pounds of pollutant per ton of wood burned). The emissions factors used for the preferred method are also used for the alternative method.

After the changeout takes place, determine the RWC PM_{2.5} emissions and subtract the post-changeout emissions from the pre-changeout emissions to arrive at the net emission reduction.

Some owners of uncertified woodstoves, and even some owners of certified woodstoves or pellet stoves, may decide to switch to natural gas, propane or electric space heating appliances during the Changeout campaign. Particulate matter emissions are assumed to be extremely small or nonexistent for these devices and thus are not accounted for in this calculation but you are free to account for them if you choose. Also, some owners of wood burning heating appliances may choose to stop using them entirely as a result of the Changeout campaign and rely instead on their primary heating source. This outcome should be reflected in the activity data in the post-changeout condition. The following general equation can be used to determine emissions of any source category:

$$E = A \times EF \times (1-ER/100)$$

where:

- E = emissions;
- A = activity rate
- EF = emissions factor, and
- ER = overall emission reduction efficiency, %

For RWC, the activity rate is usually expressed in cords of wood used per day and is provided either as a single constant or as a range, and should be determined as you develop your emissions inventory. Emissions factors are reported in mass of pollutant per mass of dry wood, therefore cords need to be converted into mass. The mass of wood in a cord varies with wood species with the most significant factor being the difference in the mass of hardwood (deciduous trees) versus softwood (coniferous trees). The conversion values reported in the literature range from approximately 1.2 tons/dry cord to about 1.8 tons/dry cord. Your State forestry and energy offices are good sources for this information in your area. The Emission Inventory Improvement Program's 2005 emission inventory conference^f featured some informative presentations on developing RWC surveys and inventories which might also help you in determining wood fuel usage.

The emissions factors for RWC were covered in the previous appendix. That leaves us with the final part of the equation, overall or net efficiency. The net efficiency of a woodstove is the product of combustion efficiency and heat transfer efficiency. Table B-1 contains wood stove efficiencies taken from AP42.¹ It is by no means a complete and comprehensive list but rather is a summary of woodstove net efficiencies by broad categories.

EPA also maintains a list of EPA-certified woodstoves at:

<http://www.epa.gov/Compliance/resources/publications/monitoring/caa/woodstoves/certifiedwood.pdf> which includes an efficiency "rating" from each manufacturer for all the stoves in this list. It is not apparent whether this rating is a net efficiency, combustion efficiency, or heat transfer efficiency therefore use these ratings with caution if you intend to calculate emissions for individual stove models. Consult the manufacturer first to determine the net efficiency.

^f See <http://www.epa.gov/ttn/chief/conference/ei14/>

Table B-1 Summary of Woodstove Net Efficiencies^a

Wood Heater Type	Source Classification Code	Net Efficiency (%)
Conventional Woodstove	21-04-008-051	54
Non-catalytic Woodstove	21-04-008-050	68
Catalytic Woodstove	21-04-008-030	68
Pellet Stoves ^b	21-04-008-053	68
Pellet Stoves ^c	21-04-008-053	56
Masonry Heaters	21-04-008-055	58

^a Net efficiency is a function of both combustion efficiency and heat transfer efficiency. The percentages shown here are based on data collected from in-home testing.

^b Certified pursuant to 1988 NSPS

^c Exempt from 1988 NSPS (i.e., air-to-fuel ratio >35:1)

Example Calculation : Annual PM_{2.5} Reduction from a Hypothetical 1500-Stove Changeout in the Mid-Atlantic Region

The following is presented as an example of how to calculate emissions reductions and is based on a hypothetical changeout in the Mid-Atlantic region of the United States involving 1500 uncertified (“conventional”) woodstoves. It is assumed that the following mix of new certified appliances are used to replace the 1500 conventional woodstoves: 1000 certified non-catalytic woodstoves, 400 certified catalytic woodstoves, and 100 pellet woodstoves. The average national annual cordwood usage value of 1.75 cords/stove/year⁴ is assumed and the mass conversion factor is assumed to be 1.4 tons/cord⁵.

For this example, the basic equation is modified since we are interested in the improvement in emissions based on the change in efficiency from old conventional stoves to newer more efficient stoves. Therefore, the equation becomes:

$$E = A \times EF \times (NE_{conv}/NE_{new})$$

where:

- E = emissions;
- A = activity rate: (wood fuel usage X mass conversion)
- EF = emissions factor, and
- NE_x = Net efficiency of the stove
- Activity Rate = (Cord Use) X (Cord-to-Mass Conversion).

Assume Cord Use= 1.75 cord/stove/year
 Cord-to-Mass Conversion= 1.4 tons/cord

Therefore, the Activity Rate for this region is:
(1.75 cord/stove/year) X (1.4 tons/cord) = 2.45 tons/stove/year.

Using the modified equation: $E = A \times EF \times (NE_{conv}/NE_{new})$

The Pre-Changeout Emissions are:

PM_{2.5} emissions from 1500 conventional woodstoves = (Activity Rate) X (Emissions Factor) X
(54%_{eff. conv} / 54%_{eff. conv}) X 1500

Or,

(2.45 tons/stove/year) X (30.6 lb PM_{2.5}/ton) X 1500 stoves = 112,455 lb PM_{2.5}/year.

The Post-Changeout Emissions are:

PM_{2.5} emissions from 1000 non-catalytic certified woodstoves = (Activity Rate) X (Emissions
Factor) X (NE_{conv}/NE_{new}) X 1000.

Or:

(2.45 tons/stove/year) X (54 %_{eff. conv.} / 68 %_{eff. noncat.}) X (14.6 lb PM_{2.5} /ton) X 1000 stoves =
28,406 lb PM_{2.5}/year.

And:

PM_{2.5} emissions from 400 catalytic certified woodstoves = (Activity Rate) X (Emissions Factor)
X (NE_{conv}/NE_{new}) X 400.

Or:

(2.45 tons/stove/year) X (54 %_{eff. conv.} / 68 %_{eff. cat.}) X (16.2 lb PM_{2.5} /ton) X 400 stoves = 12,607
lb PM_{2.5}/year.

And,

PM_{2.5} emissions from 100 pellet woodstoves = (Activity Rate) X (Emissions Factor) X
(NE_{conv}/NE_{new}) X 100.

Or:

(2.45 tons/stove/year) X (54 %_{eff. conv.} / 68 %_{eff. pellet}) X (4.2 lb PM_{2.5} /ton) X 100 stoves = 817 lb
PM_{2.5}/year

So, the change in emissions is expressed as Pre-Changeout Emissions - Post-Changeout Emissions:

(emissions from 1500 conventional stoves) – (emissions from 1000 noncatalytic woodstoves) – (emissions from 400 catalytic certified woodstove) – (emissions from 100 pellet stoves).

Or,

(112,455 lb PM_{2.5}/yr) – (28,406 lb PM_{2.5}/yr) – (12,607 lb PM_{2.5}/yr) – (817 lb PM_{2.5}/yr) =
A net reduction of 70,625 lbs of PM_{2.5}/year from the pre-changeout condition.

Keep in mind that this calculation is very much a theoretical exercise because in reality, it is highly unlikely that there is any community with only conventional woodstoves in the inventory. More likely is that there will be some certified appliances, woodstoves and/or pellet stoves, in every inventory and some number of gas, electric or propane stoves and you will have to account for those emissions both before and after the changeout. Also, it is equally unlikely that any changeout will result in all the conventional woodstoves being replaced so the post-changeout condition will also include some conventional woodstove emissions.

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<http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s10.pdf>

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http://www.epa.gov/ttn/chief/eiip/techreport/volume03/iii02_apr2001.pdf

³ *See EPA's Emission Inventory Improvement Program Document Series - Volume 9 Particulate Emissions, Residential Combustion-Woodstoves:*

<http://www.epa.gov/ttn/chief/eiip/techreport/volume09/wdstov3.pdf>

⁴ *A Recommended Procedure for Compiling Emission Inventory National, Regional and County Level Activity Data for the Residential Wood Combustion Source Category.* Houck, J.E., Mangino, J.E., Brooks, G. and Huntley, R.H., in proceedings of the U.S. EPA's Emission Inventory Conference, Denver, CO, 2001.

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⁵ *Review of Residential Wood Combustion Data for Mid-Atlantic and New England States,* Broderick, D.R., Houck, J.E., Crouch, J. and Goldman, J., presented at U.S. EPA's 14th Annual Emission Inventory Conference, March 2005.

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