Subpart AAA—Standards of Performance for New Residential Wood Heaters

REVISED DRAFT REVIEW DOCUMENT

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List of Acronyms

Air Quality Management District	AQMD
American Recovery and Reinvestment Act	ARRA
Best Demonstrated Technology	BDT
British Thermal Unit	BTU
California Air Resource Board	CARB
Canadian Standards Association	CSA
Canada Wide Standard	CWS
Carbon Dioxide	CO_2
Carbon Monoxide	CO
Clean Air Act	CAA
Code of Federal Regulations	CFR
Energy Information Administration	EIA
Environment Canada	EC
(U.S.) Environmental Protection Agency	EPA
European Union	EU
Hearth, Patio and Barbecue Association	HPBA
International Organization for Standardization	ISO
National Ambient Air Quality Standards	NAAQS
New Source Performance Standards	NSPS
Northeast States for Coordinated Air Use Management	NESCAUM
Oxygen	O_2
Outdoor Wood-fired Hydronic Heater	OWHH
Particulate Matter	PM
Pellet Fuels Institute	PFI
Renewable Portfolio Standard	RPS
Total Hydrocarbons	THC
Volatile Organic Compound	VOC
Western States Air Resources Council	WESTAR

List of Units

Grams per hour	g/hr
Grams per joule of heat delivered	g/J
Grams per kilogram of wood consumed	g/kg
Grams per megajoule	g/MJ
Hour	hr
Kilowatt	kW
Kilowatt-hours	kWh
Inches	in
Millimeters	mm
Pounds per cubic foot	lbs/ft^3
Pounds per million British Thermal Units	lbs/MM BTU
Micrograms per cubic meter	$\mu g/m^3$
Tons Per Year	TPY

1.0 SUBPART AAA AND THE NSPS PROGRAM

The U.S. Environmental Protection Agency (EPA) has initiated a review of the New Source Performance Standards (NSPS) for new residential wood heaters. These standards are codified at 40 CFR Part 60, subpart AAA. These standards were proposed in 1987 and promulgated in 1988. The primary purpose of this review document is to summarize available information on residential wood heating, including developments in technology and alternative heating methods. The document also summarizes information about implementation of the existing program and suggestions EPA has heard regarding potential improvements to Subpart AAA or development of additional NSPS.

This chapter describes the NSPS program mandated by the Clean Air Act (CAA) and the NSPS review requirements and introduces the major elements of the review document that are presented in the following chapters. We acknowledge that information on test methods, emissions, etc. are not complete, and we are continuing to gather this information to the extent practicable. Rather than preparing another draft of this review document, we intend to summarize the expected additional information and data in technical memoranda for the docket to support any revision to the current NSPS or development of additional NSPS.

1.1 What is the NSPS program?

Section 111 of the CAA, "Standards of Performance for New Stationary Sources," requires EPA to establish federal standards of performance for new sources for source categories which cause or contribute significantly to air pollution, which may reasonably be anticipated to endanger public health or welfare. If it is not feasible to prescribe or enforce a standard of performance, the Administrator may instead promulgate a design, equipment, work practice, or operational standard, or combination thereof, which reflects the best technological system of continuous emission reduction, taking into consideration the cost of such emission reduction, and any other non-air quality, health, and environmental impact and energy requirements the Administrator determines has been adequately demonstrated. This level of control is commonly referred to as best demonstrated technology (BDT). To determine BDT, EPA uses available information and considers the incremental costs and emissions reductions for different levels of control to determine the appropriate emission limits representative of BDT. The NSPS apply to sources which have been constructed or modified since the proposal of the individual standard. Since December 23, 1971, the Administrator has promulgated 88 such standards and associated test methods. The NSPS have been successful in achieving long-term emissions reductions in numerous industries by assuring controls are installed on new, reconstructed, or modified sources.

Section 111(b)(1)(B) of the CAA requires EPA to periodically (every eight years) review an NSPS unless it determines "that such review is not appropriate in light of readily available information on the efficacy of such standard." If needed, EPA must revise the standards of performance to reflect improvements in methods for reducing emissions. Numerous stakeholders have suggested that the current body of evidence justifies that the review and revision of the current residential wood heater NSPS are needed to capture the improvements in performance of such units and to expand applicability to include additional wood-burning residential heating devices that are in the U.S. market and/or available abroad. Also, numerous stakeholders have suggested that EPA develop additional NSPS to regulate other residential wood burning devices and devices that burn other fuels.

1.2 Why was subpart AAA developed?

The development of the wood heater regulations began in the mid-1980's as a response to the growing concern that wood smoke contributes to ambient air quality-related health problems. Several state and local governments developed their own regulations for wood heaters. Then, in response to a lawsuit filed by the State of New York and the Natural Resources Defense Council, EPA agreed to conduct a wood heater NSPS rulemaking, with a schedule calling for final action by January 31, 1988. The standard was developed using a regulatory negotiation process with the key stakeholders (the wood heating industry, state governments, and environmental and consumer groups) under the Federal Advisory Committee Act.

In 1987, EPA listed the residential wood heater source based on its determination that wood heaters cause, or contribute significantly to, air pollution, which may reasonably be anticipated to endanger public health or welfare, (52 FR 5065, February 18, 1987). EPA also proposed regulations for residential wood heaters (52 FR 4994, February 18, 1987). The final standards were promulgated on February 26, 1988 (53 FR 5860). At the time the original NSPS was proposed, EPA estimated that a typical pre-NSPS conventional wood heater emits about 60 to 70 g/hr of particulate matter (PM), and that a wood heater complying with the NSPS would emit at least 75 to 86 percent less than conventional wood heaters.[1]

1.3 What are the requirements of the current NSPS?

NSPS, which are codified in 40 CFR (Code of Federal Regulations) part 60, apply to new and modified units. NSPS also apply to "reconstructed" units, as defined by the General Provisions to part 60. However, the current residential wood heater regulation is structured so that modification and reconstruction by itself cannot make a unit an affected facility. Subpart AAA defines a wood heater as an enclosed, wood burning appliance capable of and intended for space heating or domestic water heating that meets all of the following criteria:

1. An air-to-fuel ratio in the combustion chamber averaging less than 35-to-1 as determined by the test procedure prescribed in §60.534 performed at an accredited laboratory;
2. A usable firebox volume of less than 0.57 cubic meters (20 cubic feet);
3. A minimum burn rate of less than 5 kg/hr (11 lb/hr) as determined by the test procedure prescribed in §60.534 performed at an accredited laboratory; and
4. A maximum weight of 800 kg (1,760 lb), excluding fixtures and devices that are normally sold separately, such as flue pipe, chimney, and masonry components that are not an integral part of the appliance or heat distribution ducting.

There are several exemptions to the NSPS:

- Wood heaters used solely for research and development purposes
- Wood heaters manufactured for export (partially exempt)
- Coal-only heaters
- Open masonry fireplaces constructed on site
- Boilers
- Furnaces
- Cookstoves.

The wood heater NSPS (also referred to as the wood stove NSPS) is somewhat unique in that it applies to mass-produced consumer items and compliance for model lines can be certified "pre-sale" by the manufacturers. A traditional NSPS approach that imposes emissions standards

[1] 52 FR 4996, February 18, 1987.

and then requires a unit-specific compliance demonstration would have been very costly and inefficient. Therefore, the NSPS was designed to allow manufacturers of wood heaters to avoid having each unit tested by allowing, as an alternative, a certification program that is used to test representative wood heaters on a model line basis. Once a model unit is certified, all of the individual units within the model line are subject to labeling and operational requirements. Manufacturers are then required to conduct a quality assurance program to ensure that appliances produced within a model line conform to the certified design and meet the applicable emissions limits. There are also provisions for EPA to conduct audits to ensure compliance.

Standards limiting PM emissions from wood heaters were phased in and differ according to whether a catalytic combustor is used. The Phase 1 standards were very similar to the Oregon State standards that had been in existence for a few years. The Phase II standards are more stringent and had to be met within two years of promulgation. The Phase II standards are still in effect. Models equipped with a catalytic combustor cannot emit more than a weighted average of 4.1 g/hr of PM. Models that are not equipped with a catalytic combustor cannot emit more than a weighted average of 7.5 g/hr of PM. The lower initial emission limit for the catalytic combustor-equipped models incorporates an expected deterioration rate for the catalysts such that after 5 years the emissions are similar. [Note that Washington State developed regulations in 1998 that require new models sold in Washington to meet 2.5 g/hr and 4.5 g/hr limits, respectively. According to the Hearth, Patio and Barbecue Association (HPBA), 90 percent or more of the affected units sold in the U.S. today meet the Washington State emission levels [sales-weighted percentage].[2, 3]

At proposal, EPA considered alternative formats for the standard, including a g/kg of wood consumed format, a heat output format (g/J), and the addition of an efficiency standard. The g/J format was rejected because it would have required heat output to be measured. At the time (1987), EPA felt that available heat output measurement methodologies were relatively imprecise as well as costly. EPA also felt that the main benefit of the g/kg format would be to reduce possible bias created by the g/hr format for low burn rates, but that this concern could be addressed in the selection of the emission limits and the weighting scheme and setting emission

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[2] John Crouch, Director, Public Affairs of HPBA, to Karen Blanchard, OAQPS/EPA. Letter to EPA regarding survey conducted by HPBA regarding the industry's 2004 shipments.
[3] Crouch, J., Wood, G., 2009, "Percentage of wood stoves shipped in 2004 that already meet the Washington State Standard [>85%]", Email Conference, October 9-21, 2009.

caps. EPA concluded that the g/hr format was the least complex choice, was consistent with Oregon and Colorado regulations at the time, and provided more accurate information than the other formats on actual rates of particulate loading into the ambient air.[4]

The purpose of an efficiency format would be to provide comparative information for consumers, although concerns were raised during development of the original NSPS about the true significance of such data and the costs to obtain it. In the end, the decision was made to allow the manufacturer to select either a measured efficiency value or a default efficiency value and include the information on the temporary (pre-purchase) product label [aka "hang tag"]. The NSPS contains default efficiency values of 72 percent for catalyst wood heaters and 63 percent for noncatalyst wood heaters.[5] EPA left a placeholder in the regulation (see 40 CFR 60.534(d)) for an efficiency test method, but one has not been proposed to date. On June 1, 2007, EPA approved the use of Canadian Standards Association (CSA) B415.1 as a means of measuring efficiency that could be used in lieu of the default values. Nevertheless, all certified stoves have used the default efficiency values on their product labels to date. See section 5.3.2 for more discussion of potential test methods that might be needed if the NSPS standards were revised.

1.4 What are the major developments since the original NSPS was promulgated?

Interest in wood heat has surged again as the cost of other heating options has increased in recent years. Also, interest has surged as consumers look for ways to "get off the grid" and "off the oil and gas pipelines" due to economic, national security, and climate considerations. Wood heat technology has advanced significantly since the existing NSPS were developed over 20 years ago. New technologies for residential wood heating devices are commercially available in the U.S. that perform at significantly lower g/hr emission rates than required under the current NSPS. Furthermore, even greater performance potentially can be achieved by technologies employed in Europe. Stakeholders have also expressed concern to EPA about a broad range of residential wood heating technologies that are not addressed by the current NSPS. These include masonry heaters; pellet stoves that are exempt via the NSPS air-to-fuel ratio (which was primarily intended to exempt open fireplaces); and indoor and outdoor wood boilers, furnaces,

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[4] 53 FR 5001, February 18, 1987.
[5] 53 FR 5012, February 18, 1987.

and heaters. There is also interest in regulating non-"heater" devices such as fireplaces, cook stoves, and pizza ovens. A description of these units is provided in chapter 2.0.

One category of wood heating that has undergone significant growth is that of wood heaters/boilers or hydronic heaters. [Note that these units are technically called heaters rather than boilers because they typically are not pressurized and do not boil the liquid.] Hydronic heaters are typically located outside the buildings they heat in small sheds with short smokestacks. These appliances burn wood to heat liquid (water or water-antifreeze) that is piped to provide heat and hot water to occupied buildings, such as homes. Often they are also used to provide heat for barns and greenhouses and to provide warm water for swimming pools. Hydronic heaters may be located indoors, and they may use other biomass as fuel (such as corn or wood pellets). Old units typically have a water jacket surrounding the firebox, which can quench the combustion temperature and result in large amounts of smoke.

In response to concerns about emissions from these units (e.g., study findings of high $PM_{2.5}$ concentrations in proximity to an outdoor wood boiler indicate $PM_{2.5}$ levels that are likely to exceed the 24-hour NAAQS[6]), EPA has developed a hydronic heaters voluntary program to encourage manufacturers to reduce impacts on air quality through developing and distributing cleaner, more efficient hydronic heaters. EPA developed the voluntary program because it could bring cleaner models to market faster than the traditional federal regulatory process. Phase 1 emission level (0.60 pounds per million British Thermal Unit (lbs/MM BTU) heat input) qualifying units are approximately 70 percent cleaner than typical unqualified units. After March 31, 2010, units that only meet the Phase 1 emission level will no longer be considered "qualified models". Phase 2 emission level (0.32 lb/MM BTU heat output) qualifying units are approximately 90 percent cleaner than typical unqualified units. Typically, qualified models have improved insulation, secondary combustion, separation of the firebox from the water jacket, and the addition of a heat exchanger. Environment Canada (EC) is also looking towards regulating wood-burning hydronic heaters and forced-air furnaces. In addition to the voluntary program, EPA provided technical and financial support for the Northeast States for Coordinated Air Use Management (NESCAUM) to develop a model rule which several states have adopted to

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[6] Smoke Gets in Your Lungs: Outdoor Wood Boilers in New York State. Revised March 2008. Report Prepared by: Judith Schreiber, Ph.D. and Robert Chinery, P.E. Page 12.

regulate those units. Note that the model rule is a starting point for regulatory authorities to consider and there may be site-specific concerns that may necessitate additional actions, e.g., local terrain, meteorology, proximity of neighbors and other exposed individuals. Thus, some regulatory authorities have instituted additional requirements, including bans in some townships.

EPA has also developed a similar voluntary partnership program for low-mass fireplaces (engineered, pre-fabricated fireplaces) and site-built masonry fireplaces. Under this program, cleaner burning fireplaces are ones that qualify for the Phase 1 emissions level of 7.3 g/kg (approximately 57 percent cleaner than unqualified models) or the original Phase 2 emissions level of 5.1 g/kg (approximately 70 percent cleaner than unqualified models.) Typically, qualified units have improved insulation and added secondary combustion to reduce emissions. Some manufacturers have added closed doors to reduce the excess air and thus improve combustion. Note that the fireplace voluntary program "Phase 1" and "Phase 2" emission levels are not the same as the Subpart AAA "Phase 1" and "Phase 2" levels. Also, note that EPA is currently conducting a dispersion modeling analysis of fireplace emissions and may lower the Phase 2 voluntary qualifying level.

In addition to changes in technology, there has been increasing recognition of the health impacts of particle pollution, of which wood smoke is a contributing factor. Wood smoke contains a mixture of gases and fine particles that can cause burning eyes, runny nose, and bronchitis. Exposure to fine particles has been associated with a range of health effects including aggravation of heart or respiratory problems (as indicated by increased hospital admissions and emergency department visits), changes in lung function and increased respiratory symptoms, as well as premature death. Populations that are at greater risk for experiencing health effects related to fine particle exposures include older adults, children and individuals with pre-existing heart or lung disease.[7] Residential wood smoke contains fine particles and toxic air pollutants (e.g., benzene and formaldehyde). Each year, smoke from wood stoves and fireplaces contributes over 420,000 tons of fine particles throughout the country – mostly during the winter months. Nationally, residential wood combustion accounts for 44 percent of total stationary and

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[7] EPA Burn Wise (Consumer - Health Effects). See: http://www.epa.gov/burnwise/healtheffects.html..

mobile polycyclic organic matter (POM) emissions and 62 percent of the 7-polycyclic aromatic hydrocarbons (PAH), which are probable human carcinogens and are of great concern to EPA.[8]

There are a number of communities where residential wood smoke can increase particle pollution to levels that cause significant health concerns (e.g., asthma attacks, heart attacks, premature death). Several areas with wood smoke problems either exceed EPA's health-based standards for fine particles or are on the cusp of exceeding those standards. For example, residential wood smoke contributes 25 percent of the wintertime pollution problem in Keene, New Hampshire. In places such as Sacramento, California, and Tacoma, Washington, wood smoke makes up over 50 percent of the wintertime particle pollution problem.[9]

In 2006, EPA issued revised NAAQS for particulate matter[10] to provide increased protection of public health and welfare.[11] The 2006 standards tightened the 24-hour fine particle standard (using $PM_{2.5}$ as the indicator for fine particles) from 65 micrograms per cubic meter ($\mu g/m^3$) to 35 $\mu g/m^3$, and retained the level of the annual fine particle standard at 15 $\mu g/m^3$. EPA also retained the existing 24-hour PM_{10} standard of 150 $\mu g/m^3$ to continue to provide protection against effects associated with exposure to thoracic coarse particles. Areas that are designated as not attaining the standards, must take steps to reduce PM emissions in order to reach attainment. EPA is currently reviewing the PM NAAQS. (See the EPA webpage for the latest information on this effort and more information on the pollutants of concern.) Some states have argued that more stringent standards for new wood heating devices would provide a much needed tool for states and local communities to use in addressing the growth of pollution from these sources.[12]

There is also concern about the health effects of other pollutants found in wood smoke. In addition to PM, wood smoke contains harmful chemical substances such as carbon monoxide

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[8] Strategies for Reducing Residential Wood Smoke. EPA Document # EPA-456/B-09-001, September 2009. Prepared by Outreach and Information Division, Air Quality Planning Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. pp. 4-5.

[9] See footnote 8.

[10] Particles less than 10 micrometers in diameter (PM_{10}) pose a health concern because they can be inhaled into and accumulate in the respiratory system. Particles less than 2.5 micrometers in diameter ($PM_{2.5}$) are referred to as "fine" particles and are believed to pose the greatest health risks. Because of their small size (approximately 1/30th the average width of a human hair), fine particles can lodge deeply into the lungs.

[11] PM Standards. EPA webpage. See: http://www.epa.gov/air/particlepollution/standards.html.

[12] Arthur Marin, Executive Director of NESCAUM and Dan Johnson, Executive Director of WESTAR, to Steve Page, Director OAPQS/EPA. April 28, 2008. Letter requesting that EPA review, update, and expand the residential wood heater NSPS.

(CO), formaldehyde and other organic gases, and nitrogen oxides (NO_x). Health effects from CO include:

- Interferes with the blood's ability to carry oxygen to the brain, which impairs thinking and reflexes
- Causes heart pain
- Linked to lower birth weights and increased deaths in newborns
- Can cause death.

Health effects from formaldehyde and other organic gases include:

- Irritate eyes, nose, and throat
- Inflame mucous membranes, causing irritation of the throat and sinuses
- Interfere with lung function
- Can cause allergic reactions
- Cause nose and throat cancer in animals, and may cause cancer in humans.

Nitrogen oxides can irritate eyes and respiratory system, may damage the immune system by impairing ability to fight respiratory infection; and affect lung function.[13]

Residential wood combustion emissions contain potentially carcinogenic compounds including PAHs, benzene, and dioxin, which are toxic air pollutants, but their effects on human health via exposure to wood smoke have not been extensively studied.[14]

Individual state and local agencies also have continued to take independent steps to combat wood smoke pollution from new and existing units. As described in chapter 4.0, these regulations range from performance standards, burn bans during high pollution events, and construction limits or prohibitions. In addition, voluntary programs that encourage good burning practices, which have a significant impact on emissions, are common. EPA, some state and local agencies, and other stakeholders, including the HPBA, have been active in promoting wood stove changeout programs to replace older, dirtier stoves with lower-emitting EPA-certified stoves, pellet stoves, or other cleaner burning appliances.

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[13] Department of Ecology, State of Washington, Brochure on Wood Smoke and Your Health. September 2008. See: http://www.ecy.wa.gov/pubs/91br023.pdf.
[14] EPA Burn Wise (Health Effects of Breathing Wood Smoke). See: http://www.epa.gov/burnwise/pdfs/woodsmoke_health_effects_jan07.pdf.

In the over 20 years that the NSPS have been in effect, stakeholders have gained experience in complying with the requirements of the program. As a result, stakeholders have suggested changes to the certification scheme to better implement the program, such as developing an electronic system for submittals and approval. Stakeholders have also questioned the effectiveness of some of the existing audit procedures. In addition, test methods continue to evolve. While the NSPS left a placeholder for development of an efficiency standard, one has not been developed by EPA. However, Canadian and European efficiency methods are currently available and can be reviewed for their applicability to the NSPS. [As noted earlier, EPA approved the CSA B415.1 as an alternative for wood heater efficiency testing.] Also, EPA Method 28 OWHH (outdoor wood-fired hydronic heating appliances) for testing the emissions of hydronic heaters has not been vetted via the *Federal Register* process. Other issues that have been identified for test methods and subsequent emissions calculations relate to emissions averaging (burn rate weightings, hot start vs. cold start), caps, and catalyst degradation. These and other issues related to certification, test methods, and quality assurance/quality control are discussed in chapter 5.0.

1.5 What are the issues driving the subpart AAA review process?

EPA has received several requests to conduct a review of the residential wood heating NSPS, including a joint letter from the Western States Air Resources Council (WESTAR) and NESCAUM[15] that urges EPA to update and develop regulations relating to a variety of wood combustion devices. The authors cite concerns that many communities are measuring ambient conditions above or very close to the new $PM_{2.5}$ NAAQS. They state that in many instances, emissions from wood smoke are a significant contributor to those high $PM_{2.5}$ levels. Other states, environmental groups, and HPBA have also recommended several changes to the NSPS. The HPBA OWHH Manufacturers Caucus wrote EPA to express their unanimous support for EPA to develop a federal regulation for OWHH.[16]

Specific requests include the following topics:

- Tighten emission standards based on current performance data
- Address other pollutants of concern

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[15] See footnote 12.
[16] September 27, 2007 letter.

- Review the format of standard, including the possibility of adding requirements to document the efficiency of the unit
- Close applicability "loopholes" such as air-to-fuel ratios, and size and weight cutoffs in the definition of wood heater
- Add other wood heating devices such as pellet stoves, hydronic heaters, and masonry heaters to the NSPS
- Regulate fireplaces and other non-"heater" devices (e.g., cook stoves)
- Regulate heating devices that burn fuel other than wood (e.g., other solid biomass, coal)
- Revise test methods
- Streamline certification process to use electronic data submittals/reviews
- Consider use of International Organization for Standardization (ISO)-accredited labs and ISO-accredited certifying bodies
- Improve compliance assurance/enforceability and quality assurance/quality control
- Make the rule more consumer-friendly by making more information readily available on-line.

As expected, stakeholder positions vary on these topics.

This document summarizes the available information gathered for the NSPS review so far. If EPA proceeds with a revised rulemaking on some or all of these issues, EPA would issue proposed amendments to subpart AAA for public review and comment. EPA may also propose additional NSPS for non-heaters and non-wood combustion devices.

2.0 DEVICES AND FUELS

This chapter discusses two types of devices: heaters and non-heaters. Indoor and outdoor wood heating devices are described in sections 2.1 through 2.5. An indoor wood heating device is a space heater intended to heat a space directly. Indoor wood heating devices include freestanding wood stoves (or wood heaters), pellet stoves, masonry heaters, fireplace inserts, and forced air furnaces. Outdoor wood heating devices have also become popular in recent years. These devices, known as outdoor wood heaters, outdoor wood boilers, or water stoves are typically located outside the buildings they heat in small sheds with short smokestacks. Other wood burning devices that are not used for directly heating a space are also described in this chapter. These include low-mass fireplaces, open masonry fireplaces, fire pits, chimineas, cook stoves, and pizza ovens and are described in section 2.6 and 2.7.

This chapter then explores issues associated with fuels used to run these devices, e.g., factors that affect emissions, availability of operating practices and/or design features that ensure optimal combustion, and emerging developments in fuel technology. This chapter also briefly addresses issues associated with burning non-wood fuels, such as other solid biomass, coal, and natural gas. Note that several efforts are on-going to better characterize the emissions. However, those efforts are not expected to be completed in time for inclusion in this draft document.

2.1 Wood Stoves

2.1.1 Definition

EPA-certified wood stoves are enclosed combustion devices that meet the definition of a wood heater specified in subpart AAA and are demonstrated by the manufacturer and approved by EPA to meet the subpart AAA requirements. Because most of the chemical compounds in wood smoke are combustible, high temperatures (< 1000° F) can loosen the bonds of these chemical compounds and “burn” both combustible gases and particles in wood smoke. In contrast, a catalytic combustor lowers the temperature at which particles and gases begin to burn. Existing EPA-certified stoves either use a catalyst technology or “advanced” combustion design to meet the NSPS emissions standards

2.1.2 Operation

There are two general types of wood stoves, catalytic and non-catalytic. Catalytic stoves use catalytic combustors, and non-catalytic stoves use secondary air staged combustion, baffles, and higher temperatures. In catalytic stoves the exhaust is typically passed through a coated ceramic honeycomb converter (other designs are also available) inside the stove, where the smoke gases and particles in the smoke ignite and burn. The catalytic combustor lowers the required temperature to burn wood efficiently from 1,200^{o}F to 500°F - 600^{o}F; to produce a long, slow, controlled combustion that burns off the smoke that otherwise would leave the chimney as dirty, wasted fuel. The catalyst must be maintained because it degrades over time and must eventually be replaced. [17]

According to the catalytic stove industry, the durability of catalysts has improved substantially since they were first used in stoves manufactured in the early years of the NSPS. The Catalytic Hearth Coalition is currently conducting performance testing of used catalysts to document current durability. Manufacturers have worked to design their stoves to protect catalyst performance (e.g., keep the catalyst separate from the flame, install reliable temperature monitors to keep the stove below high heats that could damage the catalyst) and make the catalyst easier to monitor and change, when needed. The manufacturers also have undertaken consumer outreach and education campaigns to ensure that stove owners are aware of the need for proper operation and maintenance. The owner has the incentive for proper operation and maintenance in that when the catalytic stove is operating properly, efficiency is higher and the quantity of wood burned is less, saving money and time. [18]

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[17] Hearth.com Articles – Choosing and Using Your Wood Stove. See: http://hearth.com/econtent/index.php/articles/choosing_and_using_wstove.
[18] Summary of Discussion and Action Items from 8/18/09 Catalytic Hearth Coalition-EPA Wood Stove NSPS Review Meeting. Prepared by EC/R, Inc. September 3, 2009.

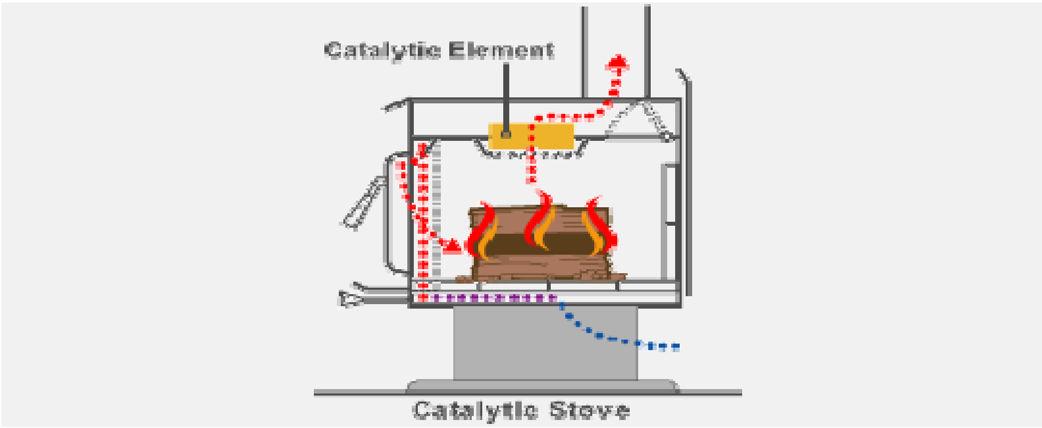

Figure 1. Cross section of a catalytic stove, showing combustion air/exhaust flow patterns, the catalytic element, and the bypass damper.

Non-catalytic stoves do not use a catalyst, but instead have three internal characteristics that create a good environment for complete combustion. These devices are referred to as advanced combustion stoves or slow combustion heaters. These stoves include a heavily insulated firebox, which keeps the heat in, creating a hot environment that encourages more complete combustion; a large baffle to produce a longer, hotter gas flow path; and pre-heated combustion air introduced through small holes above the fuel in the firebox.[19] For manufacturers to achieve the right combinations of time, temperature, and turbulence to reduce emissions has required a lot of trial-and-error. For example, the angles and quantity of secondary air have commanded much attention. Durability issues have also been raised with these stoves, as improper operation can damage key components related to burning efficiency and emissions production. However, in the case of both stove types, one simple test of good performance is to check for the presence of smoke from the stack. Except for startup and when fuel is added, there should be no visible emissions. If there are, the stove owner should be alerted to potential problems with the stove and/or operation of the unit. Common concerns regarding both catalyst and non-catalyst stoves are deteriorated gaskets in doors at 3-5 years and warped baffles and doors at 12-15 years, etc. Also, the use of unseasoned wood can seriously diminish the performance of the stoves, resulting in poor combustion efficiency and visible emissions.

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[19] Woodheat.org (wood stoves). See: http://www.woodheat.org/technology/woodstoves.htm.

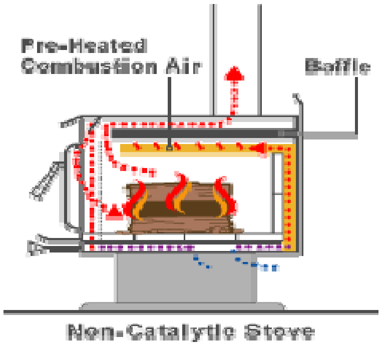

Figure 2. Cross section of a non-catalytic stove, showing combustion air/exhaust flow patterns, large baffle and high level combustion air supply.

2.1.3 Heating Efficiency

New catalytic stoves and advanced combustion stoves have advertised efficiencies of 70 percent to over 80 percent.[20] [21] Heating efficiency testing[22] is performed using full loads of seasoned cordwood, and is designed to measure how much of the heat value contained in the wood is extracted and delivered into the living space. When testing for heating efficiency, the following criteria are examined:

- Combustion Efficiency: the load is weighed going in, and the particulate emissions and ashes are weighed after the fire to determine how effectively a given firebox design burns the fuel to extract the available heat.
- Heat Transfer Efficiency: this testing is performed in calorimeter rooms equipped with temperature sensors. Similar temperature sensors are installed in the exhaust flue. The degree-changes in the room and flue are monitored for the duration of the test fires to determine how much of the heat extracted by the fire is delivered into the room, as compared to the heat lost up the flue.

Many models have recently been tested to qualify for the new IRS tax credit for high efficiency biomass heaters.

[20] The Chimney Sweep, Wood Stove Comparison Page (heating efficiency). See; http://www.chimneysweeponline.com/wscompe.htm.
[21] Wood Stoves – Catalytic. See: http://www.vermontcastings.com/content/products/productline.cfm?category=16&sc=18.
[22] The Chimney Sweep, Wood Stove Comparison Page (heating efficiency). See; http://www.chimneysweeponline.com/wscompe.htm.

As described in section 2.8, there are also steps that the stove owner can take to ensure proper installation, maintenance and operation that increase wood burning efficiency (as well as safety and emissions performance).

2.1.4 BTU Output

A common measure of heat output of a stove is the British Thermal Unit, and a BTU/hr rating tells how much heat is produced per hour. All things being equal, wood stoves with higher BTU/hr ratings will produce more heat than lower-rated appliances. However, there are a number of different measures of BTU. One is based on the heat output generated during an EPA emissions test, which tests worst case conditions (i.e., "smoky" conditions) and results in a relatively low BTU rating. Some manufacturers also determine the maximum BTU performance using a short-duration fire with a full load of wood and the draft control cranked wide open. Neither measure is indicative of normal operation. The third measure of BTU content is based on measuring BTUs with the draft control set for an all-night burn (partially open), to determine the average BTU output of one full load of wood over an 8-hour burn.[23] BTU content also varies based on the size of the stove, with larger stoves generally producing more available heat. According to one vendor, the maximum BTU rate for wood stoves ranges from 35,000 BTU to 120,000 BTU, but the 8-hour (or 6-hour for smaller stoves) average burn rate ranges from 18,000 BTU to 63,000 BTU.[24] Another manufacturer stated that typical operation of a 70,000 BTU/hour wood stove in a cold climate was only 18,000 BTU/hour ("medium low") for more than 90 percent of the time.[25]

2.1.5 Cost

The cost of a new wood stove, including installation, can vary, depending on the make, model, and options for venting to the outdoors. A basic model can usually be purchased and installed for approximately $1,000- $3,000.[26] Smaller models with fewer features and EPA-

[23] The Chimney Sweep (Understanding BTU ratings). See: http://www.chimneysweeponline.com/hobtucmp.htm.
[24] The Chimney Sweep (Comparing BTU ratings). See: http://www.chimneysweeponline.com/wscomp8.htm.
[25] Dan Henry, during September 29, 2009, teleconference of ASTM Task Group.
[26] HPBA Wood Stove Changeout Campaign. See: http://www.woodstovechangeout.org/index.php?id=57.

exempt models are available for less than $400, but not all are certified to operate in all states (e.g., California and Washington)[27] and some may or may not meet EPA regulations.

2.1.6 Emissions Data

Emissions are a function of burn rate, pollution control technology, and operating conditions. Figure 3 shows the relative emissions of fine particles from heating devices on a per BTU heat output basis. As can be seen, EPA-certified wood stoves on average emit approximately 70 percent less fine particles ($PM_{2.5}$) than uncertified stoves.

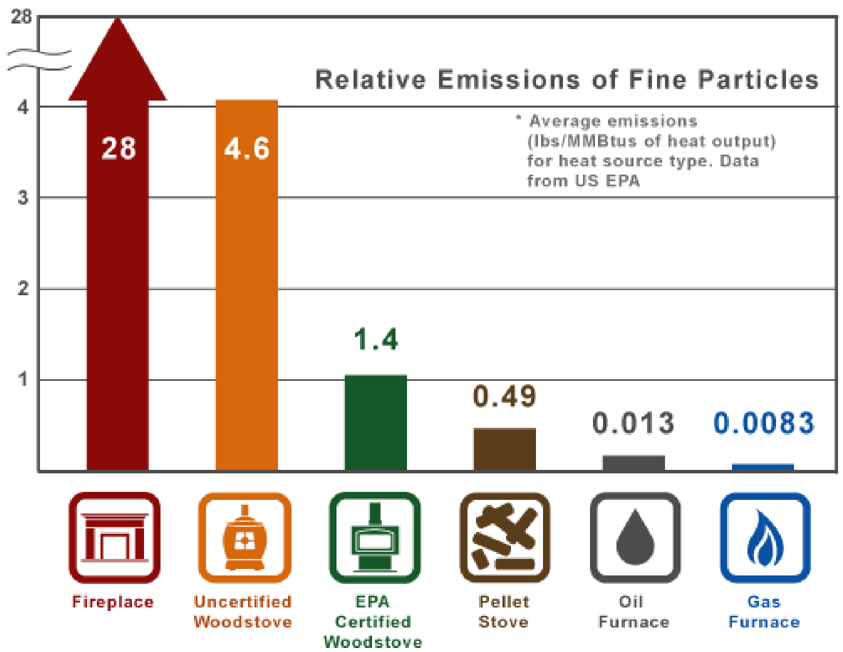

Figure 3. Fine Particle Emissions.[28]

The NSPS has been extremely successful in encouraging the development of good particulate matter control technology in residential wood stoves. There are over 800 certified wood stove models in EPA's compliance database, most of which are certified at emissions levels well below the current EPA standards. In addition, over 90 percent of certified units (on a sale-weighted basis) are reported to meet the more stringent Washington State standards (2.5 g/hr

Comment [KR1]: Is this what you meant? I couldn't read the handwriting on the comment.

[27] On-line vendor. (Website address removed pending EPA investigation of compliance with Subpart AAA.)
[28] EPA Fuel Comparison AP-42.

of PM for catalytic stoves and 4.5 g/hr of PM for all other solid fuel burning devices. See chapter 4.0 for more information.)

2.2 Pellet Stoves

2.2.1 Definition

A pellet stove is defined as any wood burning heater which operates on wood-pellet fuel. Wood pellets are tightly compacted and dense and have relatively low moisture content. The combination of fuel quality and precise metering of the fuel and air cause the pellets to burn more efficiently than cordwood. Types of pellet fuels include compressed sawdust, paper products, forest residue, wood chips and other waste biomass, ground nut-hulls and fruit pits, corn, and cotton seed. Pellet burning stoves look similar to wood stoves; however, they are usually smaller.[29] Approximately 800,000 homes in the U.S. are using wood pellets for heat, in freestanding stoves, fireplace inserts and furnaces.[30]

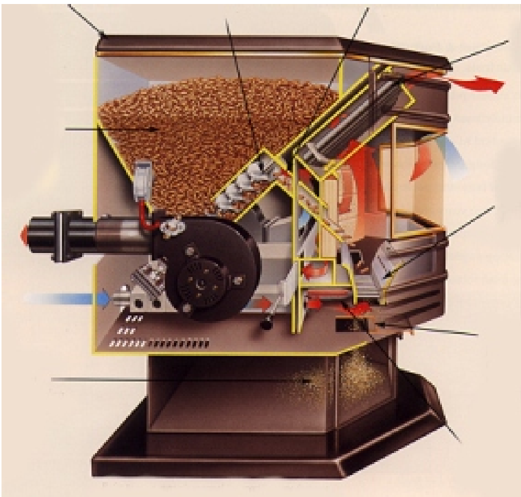

Figure 4. Cross section of pellet stove.

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[29] Outdoor Wood Stoves (pellet wood stoves). See: http://www.outdoorswoodstoves.com/wood-pellet-stoves.
[30] Pellet Fuel Institute (What is pellet fuel?). See: http://www.pelletheat.org/3/residential/index.html.

2.2.2 Operation

A typical pellet stove uses computers and circuit boards to automate most of its functions. This automation is a convenience factor for the consumer. Most models have multiple burn settings and use thermostats to control how much pellet fuel should be burned to maintain a certain heat output or a certain temperature. A load of around 30 lbs to 130 lbs (depending on the size of the pellet stove) of pellets is loaded into a device called a hopper which holds the pellets. The operator sets an internal thermostat which controls a feed device that delivers regulated amounts of fuel from the hopper to the heating chamber. Combustion air is supplied from outside via a fan motor, and the combustion by-products are exhausted out of a small vent pipe located on the top of or behind the stove. A separate fan draws room air through a heat exchanger heated by combustion. The fan delivers heat back into the home by blowing air through heat exchangers in the stove and out into the home.[31]

2.2.3 Heating Efficiency

Pellet stoves have higher combustion and heating efficiencies than ordinary wood stoves or fireplaces, i.e., their efficiencies range between 75 percent and 90 percent.[32] A variation seems to be due to the amount of excess air used, i.e., too much excess air lowers the efficiency and infuses fly ash re-entrainment.

2.2.4 BTU Output

Each pound of pellets produces about 5,000 BTUs. Like other heating devices, pellet stoves should be sized to account for the size of the space to be heated in addition to factors such as average winter temperature and level of insulation in the structure. Most pellet stoves have an output in the range of 8,000 to 90,000 BTU's per hour.[33] Most pellet stoves have a very large turn-down ratio and still maintain good combustion.

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[31] Hearth.com ("Checking it out - understanding pellet fuel and what to look for in appliances"). See: http://hearth.com/what/pellet/pellet1.html.
[32] CARB Wood Burning Handbook (heating efficiencies). See: http://www.arb.ca.gov/cap/handbooks/wood_burning_handbook.pdf.
[33] Wood Heat Stoves and Solar (pellet stoves). See: http://woodheatstoves.com/pellet-stoves-c-293_302.html.

2.2.5 Cost

Pellet stoves can cost between $1,700 and $3,000. However, a pellet stove is often cheaper to install than a cordwood-burning heater. Many pellet stoves can be direct-vented and do not need an expensive chimney or flue. As a result, the installed cost of the entire system may be less than that of a conventional wood stove. The cost of pellet fuel currently ranges from $120-200 per ton. Note that pellet stoves need electricity to run their fans, controls, and pellet feeders. Under normal usage, they consume about 100 kilowatt-hours (kWh) or about $9 worth of electricity per month. [34] Because a power outage would mean that the stove would not work, some models have battery backup units. Alternatively, some homeowners may opt to install a gas-powered generator to take over when the main supply fails.[35]

2.2.6 Emissions Data

According to Figure 3, above, pellet stoves generate 0.49 pounds of $PM_{2.5}$ per million BTU heat output. Alternatively, most units emit less than 1 gram per hour of PM.[36] Two studies carried out in 1990[37,38] evaluated the emissions from six different EPA-certified pellet stoves and determined the emission factors published in the 1996 EPA AP-42 document. Two other studies, whose results are discussed in Houck et al., 2000, evaluated emissions from a 1990 pellet stove under four different burn rates.[39] One of these studies showed that 84 percent of total PM emissions from pellet stoves are PM_{10}. That same study showed that approximately 81 percent of the PM emissions were smaller than 2.5 microns. The remaining study evaluated the difference in emissions between the newer under-feed and top-feed pellet stoves using both hardwood and softwood pellets. This study also provided factors to determine the elemental, organic, and carbonate carbon contents of the PM emissions. Particulate matter emissions

[34] U.S. DOE Energy Savers (pellet fuel). See: http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12570
[35] The Encyclopedia of Alternative Energy and Sustainable Living. See: http://www.daviddarling.info/encyclopedia/P/AE_pellet_stove_buying.html.
[36] CARB Wood Burning Handbook (pellet stoves). See: http://www.arb.ca.gov/cap/handbooks/wood_burning_handbook.pdf.
[37] Barnett, S.G. and Roholt, R.B., 1990, "In-home Performance of Certified Pellet Stoves in Medford and Klamath Falls, Oregon", OMNI Environmental Services Inc. report to the U.S. Department of Energy, DOE/BP-04143-1.
[38] Barnett, S.G., Houck, J.E. and Roholt, R.B., 1991, "In-home Performance of Pellet Stoves in Medford and Klamath Fallas, Oregon", presented at A&WMA 84th Annual Meeting, Vancouver, BC, June 16-21.
[39] Houck, J.E., Scott, A.T., Purvis, C.R., Kariher, P.H., Crouch, J., Van Buren, M.J., 2000, "Low Emission and High Efficiency Residential Pellet-fired Heaters", Proceedings of the Ninth Biennial Bioenergy Conference, Buffalo, NY, October 15-19, 2000.

generated by top-feed models were largely made up of elemental carbon, topping out at 88 percent of the total PM emissions at the highest burn rate. In under-feed models, entrained ash accounted for 26 and 8 percent of the PM emissions at a medium burn rate for softwood and hardwood pellets, respectively. Finally, the elemental carbon composition of particles emitted from a cordwood stove ranged from 10 to 20 percent with less than one percent inorganic ash, much lower than the pellet stoves. This difference in chemical make-up of the emissions shows that "total PM emissions are not accurate surrogates for emissions of specific organic compounds such as those identified as 'air toxics'."

Other fuels can be used in pellet stoves as well, including shelled corn, switch grass, wheat, barley, sunflower seeds, and cherry pits, although EPA currently does not take into account fuels other than wood when certifying stoves under the current NSPS. One study completed by OMNI Environmental, Inc. tested the emissions from five different stoves that could burn corn. Table 1 presents the results.

Table 1. Emission Results from Corn-burning Stoves.

	Burn Rate (kg/hr)	Emission Rate (g/hr)	Moisture Content (DB)	g/MJ	Emission Factor (g/kg)
Stove 1	1.0	4.8	9%	0.41	4.8
Stove 2	1.6	3.1	14%	0.17	1.93
Stove 3	1.2	2.8	11%	0.20	2.33
Stove 4	1.0	2.4	9%	0.12	1.40
Stove 5	1.1	1.7	9%	0.13	1.54
Average	1.18	2.76	10%	0.20	2.40

These results show that while these corn-burning stoves would potentially pass EPA's certification standard of 7.5 grams of PM emitted per hour, corn does not, on average, burn cleaner than wood pellets, which emit, on average, 1 gram per hour of particulate emissions.[40]

2.3 Masonry Heaters

2.3.1 Definition

According to the Masonry Heater Association of North America, a masonry heater is defined as a site-built or site-assembled, solid-fueled heating device constructed mainly of masonry materials in which the heat from intermittent fires burned rapidly in its firebox is stored

[40] OMNI-Test Laboratories, Inc., 2008, "Particulate Emissions Results from Burning Shelled Corn in Pellet-Fired Room Heaters".

in its massive structure for slow release to the building. Well-designed and maintained masonry heaters have the potential to produce heat with relatively low emissions. However, masonry heaters are relatively slow to respond to temperature changes due to the large mass of the units.

Masonry heaters meet the design and construction specifications set forth in ASTM E 1602-3, "Guide for Construction of Solid Fuel Burning Masonry Heaters." A masonry heater has the following characteristics:

- A mass of at least 800 kg
- Tight fitting doors that are closed during the burn cycle
- A chimney
- An overall average wall thickness not exceeding 250 mm
- Under normal operating conditions, the external surface of the masonry heater (except immediately surrounding the fuel loading door(s)), does not exceed 110°C (230°F)
- The gas path through the internal heat exchange channels downstream of the firebox includes at least one 180 degree change in flow direction, usually downward, before entering the chimney
- The length of the shortest single path from the firebox exit to the chimney entrance is at least twice the largest firebox dimension.[41]

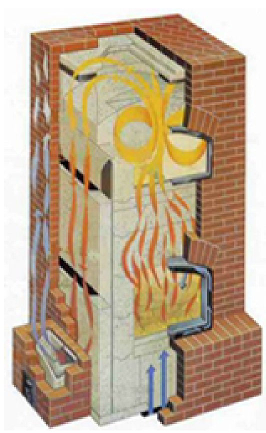

Figure 5. Cross section of a masonry heater.[42]

[41] The Masonry Heater Association of North America (MHA masonry heater definition). See: http://www.mha-net.org/docs/def-mha.htm.
[42] Keystone Masonry Ltd. See: http://keystonemasonry.ca/masonrystoves.htm.

2.3.2 Operation

Masonry heaters include a firebox, a large masonry mass, and long-twisting smoke channels that run through the masonry mass. Interior construction consists of a firebox and heat exchange channels built from refractory components that can handle temperatures of over 2,000°F. Hot gases are generated during combustion of a fuel load in the firebox, and they pass through the channels, saturating the masonry mass with heat. The masonry mass then radiates heat into the area around the masonry heater for 12 to 20 hours. The main difference between conventional fireplaces and masonry heaters is that the latter are used primarily as heating units, as opposed to the primarily aesthetic purposes of the former. While the walls of masonry heaters get saturated with heat and reach average surface temperatures in the range between 100-150°F, the outside surface of the walls of conventional fireplaces never get warm.

Unlike most other types of wood heating devices, a masonry heater is able to heat a home all day without having to burn wood continuously. Masonry heaters are often used in fuel-poor locations, since masonry heaters can use sticks, kindling, and other dry vegetable matter to provide heat.[43]

2.3.3 Heating Efficiency

A small hot fire built once or twice a day releases heated gases into the long masonry heat tunnels. The masonry absorbs the heat and then slowly releases it into the house over a period of 12–20 hours. As a result, masonry heaters commonly reach a combustion efficiency of 90 percent.[44]

2.3.4 BTU Output

A small masonry heater usually has an output between 8,000 – 10,000 BTU's per hour. A small to medium masonry heater usually has an output of approximately 14,000 BTU's per hour. A medium masonry heater usually has an output of approximately 26,000 BTU's per hour. Larger masonry heaters usually have outputs of approximately 55,000 BTU's per hour. In most

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[43] Stovemaster (masonry heaters: planning guide for architects, home designers and builders). See: http://www.stovemaster.com/files/masonry.pdf.
[44] U.S. DOE Energy Savers (masonry heaters). See: http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12570

cases, 30,000 BTU's per hour is the upper limit for possible heat output for a single-story masonry heater.[45]

2.3.5 Cost

A masonry heater usually costs $4,000- $5,000 more than a simple masonry fireplace, which translates to a price range from around $10,000 to $25,000. Because of its high efficiency compared to masonry fireplaces, manufacturers estimate that a masonry heater will pay for itself within approximately 10 years.[46]

2.3.6 Emissions Data

The Masonry Heater Caucus of the HPBA has prepared a report titled "A Report on the Particulate Emissions Performance of Masonry Heaters – Definitions, Data, Analysis, and Recommendations."[47] The report includes a summary of available test data. Using a variety of test procedures, fueling protocols and fuel types, emission measurement methodologies, laboratory and in-situ measurements, the resultant average particulate emissions have ranged from 1.4 to 5.8 grams of particulate per kilogram of fuel burned. The average of the averages for this data is 2.9 g/kg. The current AP-42 emission factor for masonry heaters is 2.8 g/kg.

The authors of the report stress that it is important to measure emissions over the length of the heating period (several hours) vs. just over the time combustion is occurring. ASTM is currently working on developing a consensus test method for masonry heaters.

2.4 Fireplace Inserts

2.4.1 Definition

A fireplace insert is defined as a wood stove that has been modified by its manufacturer to fit within the firebox of an existing open-mouthed fireplace. An insert consists of a firebox surrounded by a cast iron or steel shell; and it must be installed in an existing fireplace with a

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[45] Alliance of Masonry Heater & Oven Professionals (sizing for your heating requirements). See: http://www.masonryheaters.org/AMHOPguide.php.
[46] Fireplaces & Wood Stoves (masonry fireplaces). See: http://www.fireplacesandwoodstoves.com/indoor-fireplaces/masonry-fireplaces.aspx.
[47] A Report on the Particulate Emissions Performance of Masonry Heaters – Definitions, Data, Analysis, and Recommendations. Prepared for the Masonry Heater Caucus of the HPBA by Robert Ferguson, Ferguson, Andors and Company. February 13, 2008.

working chimney. Inserts are used to enhance the efficiency and appearance of existing wood burning fireplaces.[48] There are fireplace inserts that burn cordwood and pellets.

2.4.2 Operation

Air from the room flows between the firebox and shell to create and provide warmth. The outer shell ensures that most of the heat from the firebox is delivered to the room instead of being released into the masonry structure.[49]

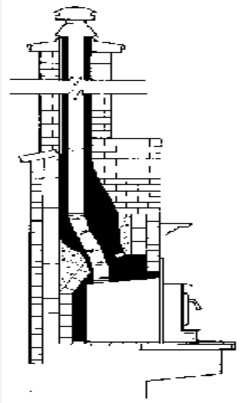

Figure 6. Cross section of a fireplace showing a properly installed fireplace insert with venting.

2.4.3 Heating Efficiency

EPA-certified fireplace inserts provide approximately the same efficiency as EPA-certified wood stoves. However, there is less radiant heat to the room than a freestanding wood stove. For safety and proper drafting, a stainless steel chimney liner is typically required when retrofitting into an existing open masonry fire hearth.

2.4.4 Cost

A quality fireplace insert usually costs between $1,200- $2,200. Installing a fireplace insert runs from $400 for a direct connection to $2,000 or more for a complete relining.[50]

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[48] HPBA (fireplace inserts). See: http://static.hpba.org/fileadmin/factsheets/product/FS_FireplaceInsert.pdf.
[49] Woodheat.org (fireplace inserts: the cure for cold fireplaces). See: http://www.woodheat.org/technology/inserts.htm.

2.4.5 BTU Output

According to one vendor, the maximum BTU of fireplace inserts ranges from 56,000 BTU to 97,000 BTU, but the 8-hour average burn rate ranges from 20,000 BTU to 44,000 BTU.[51]

2.4.6 Emissions Data

Emissions are comparable to wood stoves and pellet heaters, depending on the type of insert.

2.5 Central Heating Systems

A central heating system uses a network of air ducts or water pipes to distribute heat to an entire house. Furnaces heat air, which is forced through ducts with a fan. Boilers heat water that is pumped through pipes to heat floors or radiators. Central heating with wood-fired furnaces and boilers is less common than it used to be. This is because houses are more energy efficient and easier to heat with stoves and fireplaces that also provide an esthetic experience. Another reason is that advanced technologies have not been used in furnaces and boilers until recently, so their efficiency is low related to other heating options.[52]

There are both indoor and outdoor wood-fired forced air furnaces on the market. These furnaces may burn either cordwood or pellets and some are equipped with electric, oil, or natural gas backup systems. Some units are also equipped to burn coal. Forced air furnaces provide filtered, thermostatically controlled heat distributed throughout the home's heating ducts. These units are designed to heat an entire house, (2,500 square feet) with heat ratings ranging up to 160,000 BTUs.[53]

The increased popularity of in-floor radiant heating with a network of pipes installed below the floor surface has led to an increase in the use of wood-fired boilers. These boilers can also be used to heat domestic water, as well as provide heating for the house and adjacent

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[50] Hearth.com Articles: Fireplace Inserts, A Short Introduction. See: http://hearth.com/econtent/index.php/articles/insert_intro.
[51] The Chimney Sweep (comparing insert BTU ratings). See: http://www.chimneysweeponline.com/wicompha.htm..
[52] Canada Mortgage and Housing Corporation. A Guide to Residential Wood Heating. Revised 2008. Page 19.
[53] Energy King brochure. http://www.energyking.com/PDF/385-365-480_Furnace_8-09.pdf.

buildings. Because of the popularity of these units, also known as hydronic heaters, the remainder of this section focuses on wood boilers. Note that most hydronic heaters are not actually "boilers" in that they are not pressurized and do not boil the liquid.

Hydronic heaters heat liquid (water or water-antifreeze) that is piped to a nearby building (usually a home), providing both heat and hot water to the structure. An outdoor wood-fired boiler, which is sometimes called an outdoor wood heater, is an example of a hydronic heater. These heaters can be located inside or outside of the building to be heated. An outdoor hydronic heater resembles a small shed with a short smokestack. An indoor hydronic heater typically is located in the basement, but some are located in the living area. Most hydronic heaters are sold for use in rural, cold climate areas where wood is readily available; however, they can be found throughout the United States. In addition to burning cordwood, hydronic heaters may use other biomass as fuel, such as corn or wood pellets or other fuels such as oil or coal.

An old-style outdoor hydronic heater burns wood to heat the firebox which is surrounded by a water jacket. The hydronic heater cycles water through the jacket to deliver hot water through underground pipes to occupied buildings such as homes, barns and greenhouses. When the water temperature in the water jacket reaches the desired temperature, an air damper closes off air, smoldering the fire and cooling the unit until the temperature drops and the air damper opens, creating an on/off cycle. Systems are available that can switch to oil or gas if the fire goes out.

Outdoor hydronic heaters have an output in the range of 115,000 BTUs per hour to 3.2 million BTU's per hour. Residential hydronic heaters tend to provide heat at a rate of less than 1 million BTUs per hour. Depending on the size of the unit, outdoor hydronic heaters cost between $8,000 and $18,000.

In January 2007, EPA launched a voluntary program to reduce hydronic heater emissions. Under the first phase of the program, certain participating manufacturers designed units that are approximately 70 percent cleaner than pre-program models. To qualify, these models meet a smoke emissions level of 0.60 pounds per million Btu heat input. After March 31, 2010, models that only meet the Phase 1 emission level will no longer be considered "qualified". Phase 2 heaters, starting October 2008, are cleaner than the Phase 1 models. Qualified Phase 2 models meet smoke emission levels of 0.32 pounds per million BTU heat output. That is approximately 90 percent cleaner than pre-program models. Indoor hydronic heaters and units fueled by other biomass, such as wood pellets, sawdust and corn, also may qualify as Phase 2 models. Coal, oil and gas heaters currently are not included. To date, 10 models have qualified at the Phase 2 level. [54]

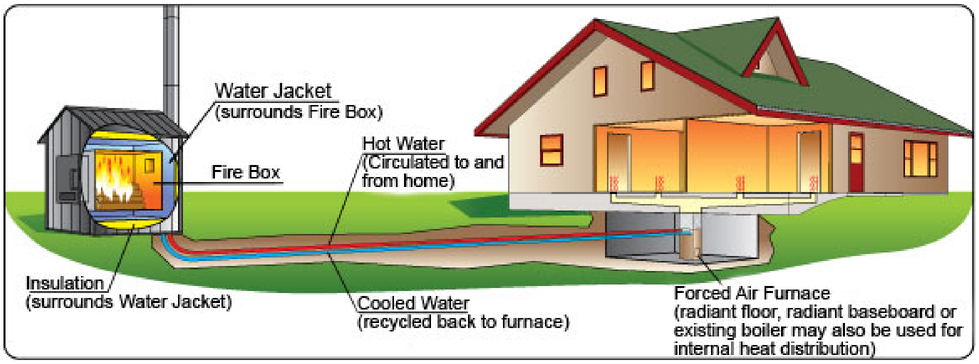

Figure 7. Diagram of an outdoor hydronic heater and its underground piping to a house.[55]

2.6 Fireplaces

Most conventional masonry and low-mass, factory-built fireplaces are not efficient at producing usable heat, and many sources do not consider them to be prudent heating devices. Typically, over 90 percent of the heat generated by a fireplace is lost out the chimney. In addition, many of these fireplaces can be sources of smoke, indoors and out.[56] According to Figure 3, fireplaces generate 28 pounds of $PM_{2.5}$ per million BTU heat output. Instead of true heating devices, most fireplaces should be considered aesthetic devices, used to provide ambience. Some local areas are prohibiting new wood-burning fireplaces because of air quality concerns and concerns on wasting a valuable natural resource for ambience. However, improvements in their design and operation are possible for areas that allow their use. The Hearth Patio and Barbecue Association has suggested that if EPA chooses to regulate fireplaces, EPA should consider listing fireplaces as a separate source category with a separate NSPS since they are typically not “heaters”.

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[54] EPA Burn Wise: Partners – Program Participation. See: http://www.epa.gov/burnwise/participation.html.
[55] HBPA. Outdoor Wood Furnaces. See: http://www.hpba.org/government-affairs/old-website-archive/issues-legislation/outdoor-wood-furnaces.
[56] Fireplaces (basic information). See: http://www.epa.gov/air/fireplaces/basicinfo.html.

2.6.1 Low-mass Fireplaces

A low-mass fireplace is defined as any fireplace and attached chimney, as identified in ASTM E 2558-7, "Determining Particulate Matter Emissions from Fires in Low-Mass Wood-burning Fireplaces," that can be weighed (including the weight of the test fuel) on a platform scale. They are mass produced and provide home builders with a lower-cost option for homeowners. Low-mass fireplaces differ from high-mass masonry heaters, which typically weigh over two tons and use short, hot fires to heat the large mass that then radiates the heat to the room for hours.

In 2009, EPA initiated a voluntary program for manufacturers of low-mass, wood-burning fireplaces (and masonry fireplaces, described in section 2.6.2) to encourage the manufacture and sale of cleaner units. Additionally, the voluntary program was designed to provide an alternative management tool for air quality managers in non-attainment areas. The program is still in the early stages of implementation but already, the voluntary program has encouraged the development of several cleaner burning technologies. EPA does not promote the sale of wood-burning fireplaces over other devices; however EPA does encourage those who buy a fireplace to buy the cleanest model. In addition, the program focuses on educating new and current fireplace users on the health effects of wood smoke, what to look for when purchasing a fireplace, and how to properly operate and maintain their fireplace. To participate in the fireplace program, manufacturers commit to develop cleaner models, approximately 57 percent cleaner than typical models available on the market for Phase 1 emission level qualification and approximately 70 percent cleaner for Phase 2 emission level qualification.[57] As with all combustion appliances, the technology improvements involve time, temperature and turbulence in the right combinations to improve combustion. The fireplaces qualified under the voluntary program are using some of the concepts used in improvements to non-catalytic wood stoves and some are using glass doors to reduce the excess air. Several components of the voluntary program that are awaiting implementation include a modeling study and future adjustment of Phase 2 emission limits to better address air quality management needs. Note that "Phase 1" and

[57] Burn Wise. Consumers - Choosing Appliances - Choosing the Right Fireplace. See: http://www.epa.gov/burnwise/fireplaces.htm.

"Phase 2" voluntary qualification levels are not equivalent to "Phase 1" and "Phase 2" certification levels for woodstoves regulated under the current Subpart AAA.

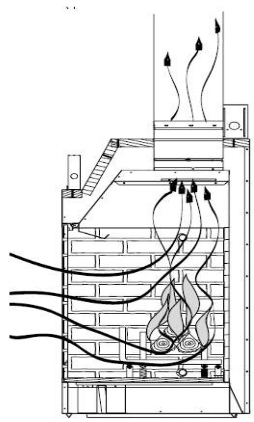

Figure 8. Cross section of a low mass fireplace.[58]

2.6.2 Masonry Fireplaces

Masonry fireplaces are traditional fireplaces that are created using materials such as brick, cement blocks, or natural stones. Most forms of the traditional fireplace can be properly identified as a masonry fireplace.

There are several ways to increase the efficiency of a masonry fireplace. A fireplace can be constructed with a slanted back, allowing the fireplace to radiate heat into the room more effectively. Other beneficial steps include:

- Using insulating brick to construct a fireplace.
- Adding a fan-driven heat exchanger to a fireplace, to enable the fire to warm the air rather than just radiating heat on objects in the room.
- Using glass doors for fireplaces, because they allow more air control for combustion when burning wood. Glass doors are currently required for all masonry fireplaces in California.[59] Note that operators should follow the owner's manual carefully because not all glass doors are designed to be closed while the wood is burning. That is, some glass

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[58] Quadra-Fire (low mass open burning fireplace). See: http://www.ecy.wa.gov/programs/air/outdoor_woodsmoke/Woodsmokeworkgroup/PowerPoint/Dan_Henry_Rev_D.ppt.
[59] Hearth.com Articles (introduction to fireplaces). See: http://hearth.com/econtent/index.php/articles/intro_fireplaces

doors are designed only to reduce escape of the heated room air out the chimney after the fire is out.

On July 4, 2009, EPA extended the low mass fireplace voluntary program to include masonry fireplaces. As described in the previous section, to participate in the fireplace voluntary program, manufacturers commit to develop cleaner models, approximately 57 percent cleaner than typical models available on the market for Phase 1 emission level qualification and approximately 70 percent cleaner for Phase 2 emission level qualification.

Masonry fireplaces typically start at around $4,000 and can top out at $10,000 to $20,000 depending on size, stone type, and whether a full masonry chimney is being installed.[60] Although the review document is focusing on new appliances, it is worth noting that retrofit catalysts for masonry fireplaces that have the potential to reduce emissions by 70 percent are now available.[61]

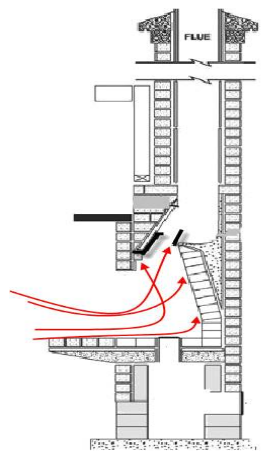

Figure 9. Cross section of a masonry fireplace.[62]

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[60] Fireplaces and Wood Stoves (masonry fireplaces). See: http://www.fireplacesandwoodstoves.com/indoor-fireplaces/masonry-fireplaces.aspx
[61] Clear Skies Unlimited. See: http://www.clearskiesunlimited.com/.
[62] Quadra-Fire (masonry open burning fireplace). See: http://www.ecy.wa.gov/programs/air/outdoor_woodsmoke/Woodsmokeworkgroup/PowerPoint/Dan_Henry_Rev_D.ppt.

2.7 Cook Stoves, Pizza Ovens, Outdoor Fireplaces

Wood-burning ovens range from relatively primitive cook stoves used in developing countries for everyday cooking, to state-of-the art Aga wood stoves. This group of devices also includes pizza ovens and other outdoor stoves, as well as outdoor fireplaces called chimineas. In developing countries, using cook stoves burning wood or other forms of biomass is a common form of cooking because of the high expense and scarcity of alternate energy sources. A simple cook stove can be made of mud or other local materials, making them relatively inexpensive to make. While, cooking with wood is not typical for most U.S. residents, there is a market for antique wood stoves and top-of-the-line wood stoves and ovens for home cooks. Also, numerous stakeholders have expressed concern that some manufacturers are allegedly using the cook stove exemption as a means to circumvent the NSPS requirements.

Wood cook stoves often look similar to conventional gas or electric stoves, but they are bigger because of the need to hold wood. They have the oven at the bottom and cooking ranges on the top of the oven. Wood cook stoves are made of high quality cast iron, which can withstand the heat produced by the fire and will not show external signs of wear and tear.[63] In some cases, cook stoves are actually wood heaters, with ovens and cooking surfaces included. For example, one model advertises that it warms up to 1,800 square feet.[64] Top-of-the-line Aga wood-burning stoves can cost from $6,000 to $7,000, with other stoves retailing less than $3,000.[65]

Pizza ovens are typically made out of clay adobe, refractory fire bricks or some sort of masonry mass that is heat resistant and can withstand prolonged high heat conditions. An outdoor pizza oven can cost between $1,500 for a small kit, to $3,800 for a large one. Kits usually start around $2,000.[66]

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[63] The Benefits of Wood Cook Stoves. See: http://www.specialtyansweringservice.net/articles/interior-decorating/The-Benefits-of-Wood-Cook-Stoves_19766/

[64] Heartland Appliances Woodburning Stoves. See: http://www.heartlandapp.com/en/Products/WoodburningCookstoves/Woodburning/Reservoir/1903.Oval_with_Reservoir.htm.

[65] Lehman's. See: http://www.lehmans.com/store/Stoves___Cook_Stoves___Wood_Burning_Cook_Stoves?Args=&page_number=1.

[66] Why Opt For an Outdoor Pizza Oven? See: http://ezinearticles.com/?Why-Opt-For-an-Outdoor-Pizza-Oven?&id=2585450.

Chimineas are popular outdoor ornaments. A fire is built inside the oven to a temperature of approximately 750°F, and as the fire burns, the oven walls absorb heat. To maintain the desired temperature, wood is added as needed. When the dome chamber inside is hot enough, the fire is allowed to die down. Chimineas may be made from cast iron, terra cotta or clay. The clay or terra cotta units are best used during the summer and stored during the winter, as the oven can crack when heated in cold temperatures. Chimineas range in price from $150 to $250 for a very basic, low-end model. High-end models, with features such as safety grills and pitched chimney stacks to contain ash and embers, start at around $500. Only firewood should be used in a chiminea unless the manufacturer specifies that other fuels can be burned.[67]

When a larger fire is wanted, consumers sometimes use a grated cylinder style outdoor fireplace. Grated cylinder style units have a simple, open design: a bottom basin for the fire, a grate for cooking food, open grating surrounding the basin, and a lid. Many models have wheels, allowing the fireplace to be easily moved. A grated cylinder style outdoor fireplace starts at $100 and uses wood, or sometimes either natural gas or propane for its fuel. [68]

On a larger scale, there is a permanent outdoor fireplace. Similar to a traditional indoor fireplace, the outdoor fireplace can be an extension of the house or patio, or it can be completely free-standing. Some outdoor fireplace models include a drainage system to divert rainwater away from the fire. The available styles range from simple firepits within stone wall enclosures to more elaborate units that include a mantel and hearth.[69] It is important to note that a number of local areas have concerns about the air quality impacts of these devices and the waste of valuable natural resources for recreational burning.

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[67] Fireplaces and Wood Stoves (Outdoor Fireplaces). See: http://www.fireplacesandwoodstoves.com/outdoor-fireplaces/

[68] See footnote 67.

[69] See footnote 67

Figure 10. Picture of a wood cook stove (A), pizza oven (B), and chiminea (C).[70,71,72]

2.8 Fuels and Efficiency

EPA, the states, vendors, and trade associations all promote good burning practices to enhance the safety and efficiency of wood-burning appliances. These measures also reduce fuel costs for the consumers. Before buying a wood-burning appliance, the consumer should make sure it is sized properly for the intended space and use. Many consumers purchase units much larger than they need and, in turn, use the unit at its least efficient and most smoky, choked down operating mode. EPA recommends that the unit be professionally installed to ensure safe and efficient operation. Also, an integral part of the wood-heating unit is the venting system, which should be designed to deliver an adequate draft to reduce wood consumption, produce more usable heat, and reduce maintenance from inefficient fires. Finally, proper maintenance in the form of regular chimney cleaning is essential.

EPA offers the following practical steps in building fires to obtain the best efficiency and to minimize emissions from a conventional wood stove.

- Split the wood and season it outdoors through the hot, dry summer for at least 6 months before burning it. Properly seasoned wood is darker, has cracks in the end grain, and sounds hollow when smacked against another piece of wood.
- Store wood outdoors, stacked neatly off the ground with the top covered.
- Burn only dry, well-seasoned wood that has been split properly.

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[70] http://www.kountrylife.com/content/gal16.htm
[71] http://homepages.callplus.net.nz/~b.gubb/pizza_oven.html
[72] http://paulbunyansfirewood.com/chiminea.htm

- Start fires with clean newspaper and dry kindling.
- Burn hot, bright fires (unless the unit is a catalytic wood stove that is designed for low burn rates).
- Let the fire burn down to coals, then rake the coals toward the air inlet (and wood stove door), creating a mound. Do not spread the coals flat.
- Reload your wood stove by adding at least three pieces of wood each time, on and behind the mound of hot coals. Avoid adding one log at a time.
- Use smaller fires in milder weather.
- Regularly remove ashes from the wood stove into a metal container with a cover and store outdoors.

See the following EPA website for more information: http://www.epa.gov/burnwise/bestburn.html. Operation may vary depending on the type of appliance. Read and follow the manufacturer's recommendations in the Owner's Manual.

2.8.1 Cordwood

The type of wood used affects the quality of the burn. The heat value of any firewood depends on its density, resin, ash and moisture content. Other characteristics to consider when purchasing firewood include ease of splitting, ease of starting, amount of smoking and coaling qualities, number of knots and pitch content. Of these characteristics, the most important is the moisture content. Moisture content affects the heat output, and how clean firewood burns. The optimal amount of moisture content should be between 15 and 20 percent. Firewood with a moisture content higher than 20 percent will burn, but it will be difficult to light and keep burning and will emit a lot of unwanted emissions, with much of its energy content exiting the chimney. This is primarily because, when there is too much moisture in the firewood, the heat produced will go towards drying out the moisture in the wood instead of producing heat. When wood is first cut down from a live tree, the moisture content ranges from 40 to 60 percent. In order for the wood to be burned more efficiently, the wood needs to be seasoned (dried). All firewood seasoned to the same moisture content contain approximately 8,000 to 9,500 BTU for fully dried wood and 5,500 to 8,500 BTU for air-seasoned wood per pound.[73] Seasoning wood usually requires that it be split and air-dried for at least 6 months, and often more. For example, oak requires over 12 months of seasoning before it is ready to burn.[74] Firewood is usually stored and stacked as "cords" in sheds. A cord is the official measurement of firewood; a full cord measures 4 ft. x 4 ft. x 8 ft.[75]

Generally, firewood is categorized into two types, hard wood and soft wood. Hard wood species contain a higher total heating value per unit of volume, and therefore tends to burn for longer periods of time than soft wood and produces better "coaling." Coaling is the phenomenon of wood "burning down" to a bed of glowing, hot embers. This makes hard wood more suitable for the winter. Types of hard wood include oak, beech, hickory, and maple. A rule of thumb often used for estimating heat value of firewood is: "One cord of well-seasoned hard wood (weighing approximately two tons) burned in an airtight, draft-controlled wood stove with a 55-65 percent efficiency is equivalent to approximately 175 gallons of #2 fuel oil or 225 therms of natural gas consumed in normal furnaces having 65-75 percent efficiencies." Soft woods, on the other hand, produce a fast-burning, cracking blaze, and are less dense and contain less total heating value per unit of volume. Though they still provide a good amount of warmth, soft woods are better suited for the spring and fall, when the heat demand has moderated. Types of soft wood include aspen, spruce, pine and firs.[76] Below, Table 2 compares important characteristics of hard and soft wood. Because of its higher heat value, hard wood tends to be more expensive than soft wood. A cord of mixed hard wood can range from $50 to more than $250, with the typical range being around $120 to $180.[77]

Table 2. Hard woods and soft woods comparison.[78]

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[73] ODA Measurement Standards Division (firewood facts). See: http://www.oregon.gov/ODA/MSD/fuel_facts.shtml.
[74] Ezine Articles (how to choose the best fuel for your wood stove). See: http://ezinearticles.com/?How-to-Choose-the-Best-Fuel-For-Your-Wood-Stove&id=1367202.
[75] Woodheat.org (what is a cord?). See: http://www.woodheat.org/firewood/cord.htm.
[76] See footnote 73.
[77] IdeaMarketers (preparing wood stove fuel). See: http://www.ideamarketers.com/?wood_stove_&articleid=535263.
[78] Oregon Department of Agriculture (firewood ratings and info). See: http://mb-soft.com/juca/print/firewood.html

Species	Relative Heat	Easy to Burn	Easy to Split	Heavy Smoke?	Throw Sparks?	General Rating	Aroma	Weight of Seasoned Cord (lbs)	Heat Produced per Cord (MBTU)
Hard Woods									
Black Ash	Med	Yes/Fair	Yes	No	No/Few	Excellent	Minimal	2,992	19.1
Red Oak	High	Yes/Poor	No	No	No/Few	Excellent	Fair	3,757	24.0
Beech	High	Yes/Poor	Yes	No	No/Few	Excellent	Minimal	3,757	24.0
White Birch	Med	Yes/Good	Yes	No	No/Moderate	Excellent	Minimal	3,179	20.3
Yellow Birch	High	Yes/Good	Yes	No	No/ Moderate	Excellent	Minimal	3,689	23.6
Hickory	High	Yes/Fair	Bad	No	No/ Moderate	Excellent	Good	4,327	27.7
Red or Soft Maple	Med	Yes	No	No	No	Good		2,924	18.7
Sugar Maple	High	Poor	No		Few	Good	Good	3,757	24.0
Soft Woods									
Easter White Pine	Low	Med/ Excellent	Yes	Med	No/ Moderate	Fair	Good	2,236	14.3
Spruce	Low	Yes	Yes	Med	Yes	Poor		2,100	14.5
Douglas Fir	High	Yes	Yes	Yes	No	Good			
Balsam Fir	Low					Poor		2,236	14.3
White Cedar	Med/Low	Yes/ Excellent	Yes	Med	Some	Good	Excellent	1,913	12.2

2.8.2 Pellet Fuel

Pellet stoves require the use of pellets instead of standard wood logs. Pellet fuels include compressed sawdust, paper products, forest residue, wood chips and other waste biomass, ground nut-hulls and fruit pits, corn, and cotton seed. Pellet fuels must conform to certain specifications. To assure predictable fuel amounts and prevent fuel jamming, pellet dimensions must be a maximum of 1 ½" long and a diameter of ¼" or $^{5}/_{16}$". The density of a pellet must be a minimum of 40 lbs/ft^3 to provide consistent hardness and energy content. The amount of fines from pellets passing through $^{1}/_{8}$" screen should be no more than 0.5 percent by weight, so that there is a limited amount of sawdust from pellet breakdown to avoid dust while loading and problems with pellet flow during operation. There should be less than 300 parts per million of salt content to avoid stove and vent rusting. Ash content determines the maintenance frequency of ash removal from a pellet stove. Premium grade wood pellets have less than 1 percent ash content, while standard grade pellets have up to 3 percent ash content. Pellets from other biomass typically have greater ash content (and thus higher emissions).

Pellet fuels offer certain advantages over conventional wood logs. Pellets are convenient to store because of their compact nature. In addition, their compact size also allows them to be loaded easier, because they allow for precisely regulated fuel feeds. Last, since some pellets are made from renewable materials, using biomass pellets can reduce costs and problems of waste disposal.[79] The Pellet Fuels Institute (PFI) is currently establishing pellet quality standards and appliance manufacturers are expected to specify the quality suitable for their appliances.

2.8.3 Coal

After declining for decades, burning coal for residential heating is making a comeback and sales of coal-burning devices are up. Over time, cleaner and more easily distributed forms of heating fuel, e.g., natural gas, electricity and oil, displaced coal, and residential use dropped from 50 million tons in 1950 to 2.8 million tons by 1975 and then to less than 500,000 tons by 2000. Coal consumption for residential use hit a low of 258,000 tons in 2006. But then, it jumped 9 percent in 2007 and another 10 percent more in the first eight months of 2008. However, even with this increase in demand, residential use of coal in the United States represents less than 1 percent of all coal use.[80]

According to stove dealers, coal stoves offer fuel cost savings compared to other fuels. One dealer reports the unit cost per million BTUs of burning coal at $5.20, compared to $6.50 for cordwood, $10.71 for wood pellets, $12.00 for natural gas, and $18.03 for fuel oil. Depending on the model, coal stoves can deliver up to 85,000 BTU's which is sufficient to heat a home of up to 1800 square feet. Coal stoves can also be used to supplement an existing heating system.[81]

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[79] Hearth.com (the fuel). See: http://hearth.com/what/pellet/pellet1.html.
[80] Friends of Coal. See: http://www.friendsofcoal.org/news/155-burning-coal-at-home-is-making-a-comeback-.html
[81] Reading Stove Company. See: http://www.readingstove.com/

2.8.4 Manufactured Firelogs

Manufactured logs, typically made of compressed sawdust or other organic matter, potentially provide a cleaner alternative to wood for open-hearth fires, when used according to manufacturers' instructions. Note that this depends on the size of the homeowner's typical cordwood fire. That is, burning a single firelog may result in less emissions compared to a large typical fire of multiple cordwood logs in a cold climate area but may not be a reduction for a small fire of only one or two cordwood logs in a mild climate. However, not all varieties are suitable for wood stoves and fireplace inserts; consumers should check the guidelines on the wrapper to ensure compatibility with the wood heating device being used.[82]

There are two types of manufactured firelogs: densified firelogs and wax-sawdust firelogs. Densified firelogs, which are intended to serve as a substitute for cordwood, have been recently introduced in North America, but have a longer history in Europe. Logs made from densified wood residue are manufactured using an extrusion process and are composed of hardwood residue (thus, using recycled material) with a controlled particle size and moisture content. A hollow core allows the log to burn more efficiently. The product comes out of the extruder in a continuous piece and is mechanically sawn into logs. This method of producing logs made from densified wood residue requires no petroleum-based, chemical or other additives.

Emission tests sponsored by the Canadian government showed that densified wood logs produce fewer fine particles when burned compared to the same quantity of conventional wood. When the logs were burned in a certified stove, the emission rate was almost 58 percent lower than the rate for the conventional logs. The particle emissions rate dropped from 8.5 g/h to 3.6 g/h.[83]

Wax-sawdust firelogs are used exclusively in fireplaces. They require no kindling, and are designed for one-at-a-time use. Several sizes of firelogs are commercially available, but those with a burn duration of about 3 to 4 hours, which is the typical fireplace usage period, are most popular. Wax-sawdust firelogs are composed of approximately 40 percent to 60 percent

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[82] Puget Sound Clean Air Agency (manufactured logs). See: http://www.pscleanair.org/actions/woodstoves/mfglogs.aspx.
[83] Environment Canada Publication: Densified Logs Reduce the Impact of Residential Wood Heating. See: http://www.qc.ec.gc.ca/dpe/Anglais/dpe_main_en.asp?innov_fiche_200503.

wax with the remaining portion sawdust. Waxes obtained from petroleum refineries are typically used. The heat content of wax-sawdust firelogs is much higher than that of cordwood (15,700 BTU/lb for wax-sawdust firelogs as compared to 8,900 BTU/lb for Douglas fir) and their moisture content is much lower (3 percent as compared to 20 percent for well-seasoned cordwood).[84]

A number of studies have evaluated the reduction in particulate and CO emissions achievable with wax-sawdust firelogs as compared with cordwood. These studies used emission rates (g/hr) rather than emission factors (g/kg fuel) or emissions per unit of heat (g/MJ) to compare emissions. This was done because the heat content for wax-sawdust firelogs is different from cordwood firelogs and their prescribed usage (one log burned at a time without the use of kindling) is also different from cordwood. The results of all studies showed substantial emissions reductions when the firelogs were used in accordance with the manufacturer's instructions, i.e., one firelog at a time and compared versus a typical multiple cordwood log fire. See note above that some cordwood fires may be small and thus firelogs may not reduce emissions versus such small fires. The average reduction in particulate emissions for the studies was 69 percent, and the average reduction in CO emissions was 88 percent. The primary reason for the PM reductions is the reduction in the mass of material burned. Because virtually all particles emitted from cordwood and firelogs burned in fireplaces are sub-micron in diameter, reductions documented for total PM emissions are also representative of reductions in PM_{10} and $PM_{2.5}$ particles.[85] Some air pollution agencies have concerns that users may not follow the manufacturer's instructions to only burn one firelog at a time and thus negate the potential emission reductions. Uncertainties in the test protocol raise additional concerns regarding the potential emission reductions from the use of manufactured logs.

3.0 MARKET CHARACTERISTICS

3.1 Nationwide Trends and Statistics of Wood Fuel

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[84] Comparison of Air Emissions between Cordwood and Wax-Sawdust Firelogs Burned in Residential Fireplaces. James E. Houck, Andrew T. Scott, Jared T. Sorenson and Bruce S. Davis, OMNI Environmental Services, Inc. and Chris Caron, Duraflame, Inc. In Proceedings of AWMA and PNIS International Specialty Conference: Recent Advances in the Science of Management of Air Toxics, April 2000.
[85] See footnote 84.

Between 2007 and 2008, renewable energy consumption in the United States increased by 7 percent, even with a two percent decline in total energy consumption.[86] Although much of this change is accounted for by the electrical power and industrial sectors, the residential sector accounted for 8 percent of the total renewable energy consumption. In 2008, 53 percent of United States households had at least one fireplace or freestanding stove. Of these households 79 percent had at least one fireplace or stove and 21 percent had two or more.[87] Thirty-two percent of stove owners consider their wood stove as the major heat source, whereas 51 percent use their wood stove as a secondary source of heat.

Of the various renewable energy sources available, wood and derived wood fuel (such as pellets) remained the most used and clearly drives the trend, as shown in Figure 11.[88]

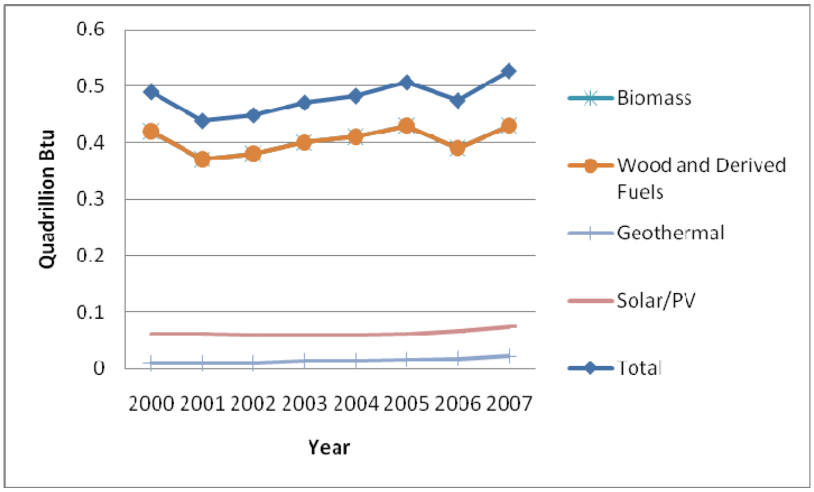


Figure 11. Breakdown of Renewable Energy Consumption from 2000-2008

The Energy Information Administration (EIA) provides an energy outlook every year, projecting the possible scenarios of fuel and energy use out to a certain date. The most current publication released by the EIA is the "Annual Energy Outlook 2009"[89] with projections out to

[86] Energy Information Administration, "Renewable Energy Consumption and Electricity Preliminary Statistics 2008", http://www.eia.doe.gov/fuelrenewable.html.
[87] Hearth, Patio & Barbecue Association, 2008, "State of the Hearth Industry Report", http://www.hpba.org/media/hpbexpo-2008/?searchterm=State%20of%20the%20Hearth
[88] Energy Information Administration, 2009, "Renewable Annual Energy 2007".
[89] Energy Information Administration, 2009, "Annual energy Outlook 2009 with Projections to 2030", DOE/EIA-0383 (2009).

the year 2030. This document evaluates the current uses of energy by various sectors and, using certain assumptions and methodologies, presents possible scenarios showing the extent of use of different fuels for residential purposes. In particular, the EIA considers the stimulus program and other rules and regulations enacted through the American Recovery and Reinvestment Act (ARRA) passed in February 2009. The ARRA provides loan guarantees, federal funding, and tax credits to encourage the use of renewable energy in place of traditional energy sources and to encourage energy efficiency.[90]

Figure 12 shows where energy is expected to be consumed in the future. "No stimulus" indicates what energy use will be like if there were no incentives and ARRA is not enacted. "Reference" reflects energy usage with ARRA in place.

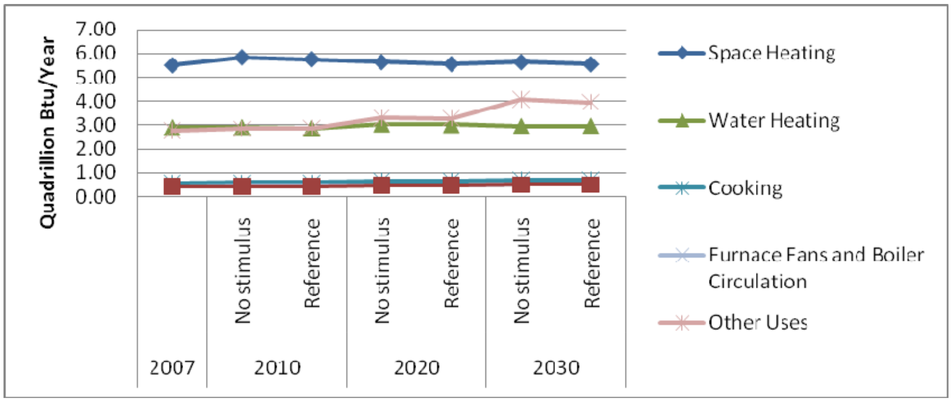


Figure 12. Total Energy Consumption by End Use.[90]

Figure 12 also shows the amount of marketed renewables expected to be used in the different scenarios. In this case "marketed renewable" includes wood fuel, solar energy, geothermal energy, and wind. The figure shows that marketed renewables make up a small portion of the total energy sources for the various end uses, and even has a small increase in the future. To show in better perspective the small increase shown in Figure 12, Figure 13 shows projections out to 2030 for the use of marketable renewables.

[90] Energy Information Administration, 2009, "An Updated Annual Energy Outlook 2009", SR/OIAF/2009-03.

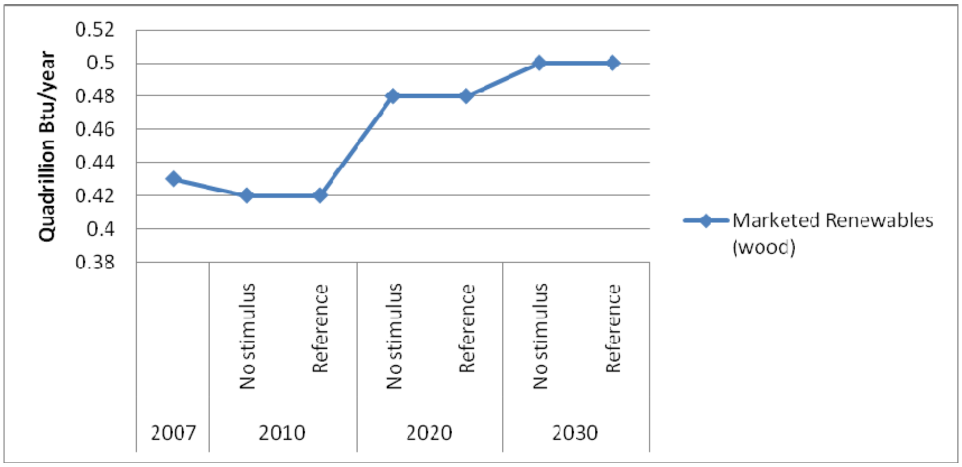


Figure 13. Residential Sector Consumption.[90]

The figure shows that the ARRA will have little impact on the use of marketed renewables. According to EIA's models and assumptions, residents in the United States will continuously increase their use of renewable energy as an energy source for their homes. Figure 14 below shows how much of the renewable energy in Figure 13 is made up of wood fuel. Wood fuel, although not a large part of marketed renewable energy, still plays a significant role in the future as a source of fuel for residents.

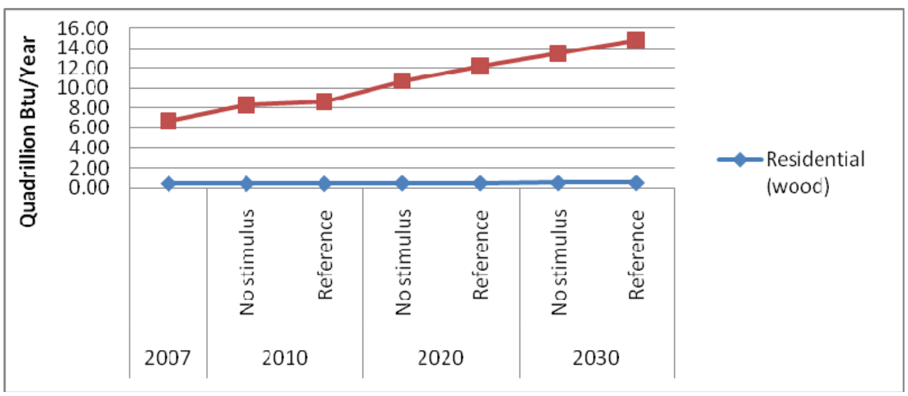
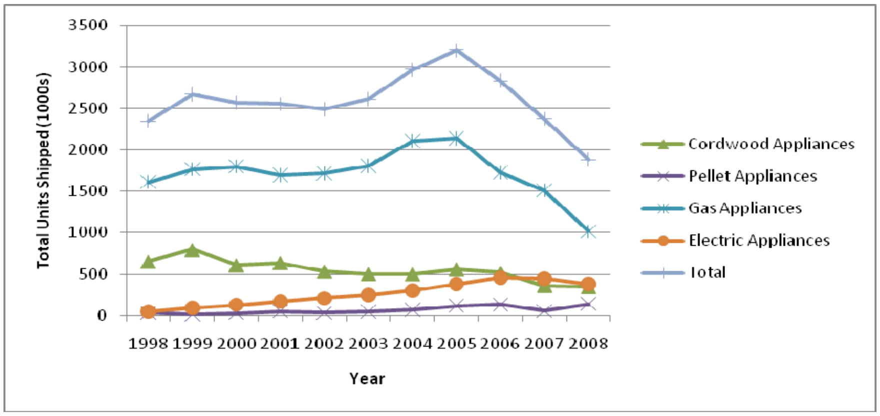


Figure 14. Breakdown of Marketed Renewable Energy.[90]

The EIA also modeled cases of low and high economic growth, and low and high oil prices, all with the same effect: marketed renewable energy and wood fuel remain a consistent, if not increasing, presence in the residential consumption of energy.

3.2 Nationwide Trends and Statistics on Wood-burning Appliances

According to the Bureau of Census, 1,976,841 households heat with wood fuel, or approximately 18 percent of occupied households.[91] According to HPBA, in 2008 141,211 freestanding pellet stoves and inserts were shipped; and 345,735 fireplaces, freestanding wood stoves and inserts using cordwood as fuel were shipped in the United States out of a total of 1,882,274 appliance shipments. Thus 18 percent were cordwood appliances and 8 percent were pellet appliances. In 2008 a 161 percent increase was seen in the purchase of pellet appliances, whereas cordwood appliances showed a 5 percent decline from shipments in 2007. Showing even steeper declines are electric appliances (15 percent decline) and gas appliances (33 percent decline)[92] (see Figure 15).



Cordwood appliances include: fireplaces, freestanding wood stoves, and inserts
Pellet appliances include: freestanding stoves and inserts
Gas appliances include: fireplaces, freestanding stoves, inserts, fireboxes and gas logs
Electric appliances include: fireplaces, freestanding stoves, and inserts

Figure 15. Total Number of Hearth Appliances Shipped in the US, 1998-2008.

In 2005 the consumption of wood for residential purposes was highest in the Midwest (31 percent of all wood consumed, or 6.6 million cords of wood), closely followed by the South (28 percent or 5.9 million cords of wood) (see figure 16).

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[91] Bureau of the Census, 2005 -2007. House heating fuel. See: http://factfinder.census.gov/servlet/DTTable?_bm=y&-geo_id=01000US&-ds_name=ACS_2007_3YR_G00_&-_lang=en&-redoLog=false&-mt_name=ACS_2007_3YR_G2000_C25117&-mt_name=ACS_2007_3YR_G2000_B25040&-CONTEXT=dt

[92] Hearth, Patio & Barbecue Association, 2009, "US Hearth Statistics", http://www.hpba.org/statistics/hpba-us-hearth-statistics.

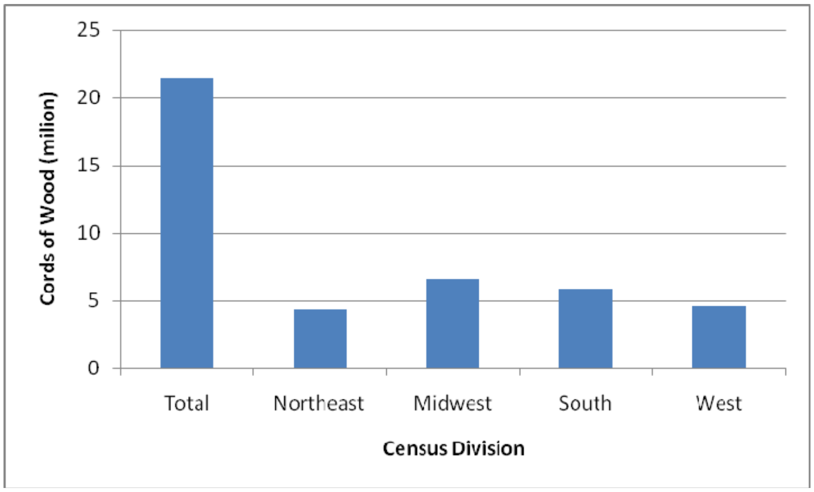

Figure 16. Wood Consumption by U.S. Households in 2005.

3.2.1 Wood Pellet Appliances

There are approximately 800,000 homes in the U.S. using wood pellets for heat, in freestanding stoves, fireplace inserts and even furnaces. Pellet fuel for heating can also be found in such large-scale environments as schools and prisons.[93] The Wood Pellet Association of Canada has been tracking the amount of pellets sold in the USA, divided into the East and the West (see figure 17). The Eastern U.S. has steadily increased its consumption of wood pellets with a drastic jump in 2007.[94] It is expected that this trend will continue in the future, especially as state and federal governments focus more on replacing fossil fuels with renewable energy sources. For example, California has already passed a law that requires the state-owned utilities to obtain 20 percent of their power from renewable sources. The European Union (EU) has also passed a similar law for all member countries, and the Obama administration is encouraging the use of renewable fuels, in particular pellets, as a means to replace fossil fuel use.

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[93] Pellet Fuels Institute, 2009, "What is Pellet Fuel?", http://www.pelletheat.org/3/residential/index.html.

[94] Paksa-Blanchard, M., P. Dolzan, A. Grassi, J. Heinimö, M. Junginger, T. Ranta, A. Walter, 2007, "Global Wood Pellets Markets and Industry: Policy Drivers, Market Status and Raw Material Potential", IEA Bioenergy Task 40, http://www.canbio.ca/documents/publications/ieatask40pelletandrawmaterialstudynov2007final.pdf.

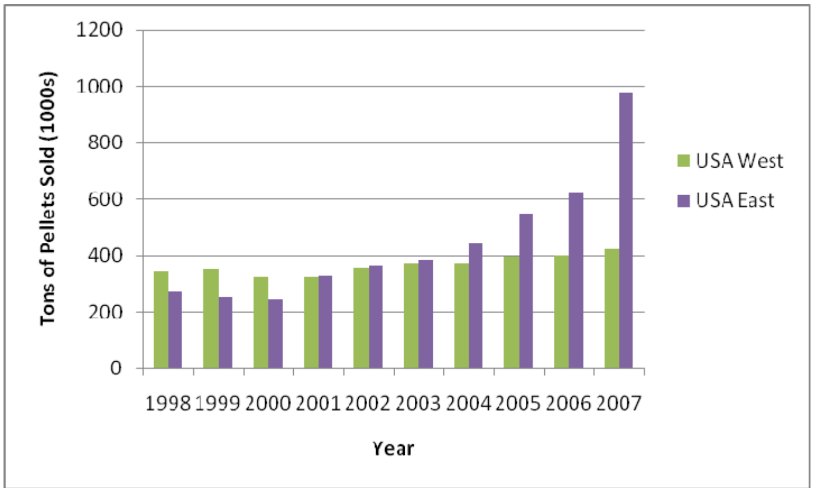

Figure 17. Total Tons of Pellet Fuel Sold in the United States.

3.2.2 Other Wood-Burning Appliances

Other wood-burning appliances available include masonry heaters, pizza ovens, outdoor wood-fired boilers, fireplaces, fireplace inserts, and cook stoves. Masonry heaters and pizza ovens require a certain skill set to build and install correctly. Thus the majority of builders that construct these types of wood-burning appliances also install fireplaces and chimneys due to low demand.[95] Masonry heaters can cost from $10,000 to $20,000 to build and install.[96] The Masonry Heater Caucus estimates that between 600 and 1,100 masonry heaters are installed in North America each year.[97]

Outdoor wood-fired boilers can provide a heat output of 25,000 to 100,000 Btu per hour.[98] These boilers have approximately 30 to 55 percent heat efficiency and can cost anywhere from $5,000 to $10,000 to install.[99,100] In 2006, NESCAUM estimated that over 155,000 outdoor

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[95] Padgitt, Marge, "High-Tech Old-World Technology Latest Trend in Heating", mha-net.org/docs/temp/**Padgitt-masonryheaters**2.pdf.
[96] Woodheat.org, 2009, "Categories of Wood Heating Equipment", http://www.woodheat.org/media/categories.htm.
[97] A Report on the Particulate Emissions Performance of Masonry Heaters – Definitions, Data, Analysis, and Recommendations. Prepared for the Masonry Heater Caucus of the HPBA by Robert Ferguson, Ferguson, Andors and Company. February 13, 2008. P. 3.
[98] Guldberg, Peter, "Outdoor Wood Boilers – New Emissions Test Data and Future Trends", www.epa.gov/ttn/chief/conference/ei16/session5/guldberg.pdf.
[99] "Outdoor Wood-Fire Hydronic Heaters (OWHH) Program Update", 2008, Presentation for HPBA Expo Workshop.

wood boilers had been sold nationwide since 1990. They also reported that national sales had been growing in the past five years at rates of 30 to 128 percent. Given the continued rise in the cost of natural gas and petroleum fuels, it is likely that an increasing sales trend will continue, and by 2010 over 500,000 outdoor wood boilers could be in place.[101]

3.3 International Market Characteristics

All member countries of the EU have regulatory goals in place to achieve 20 percent heat generation in each country and 20 percent of the EU's gross final energy consumption through renewable energy. Pellet stoves and boilers have long been in use in Western Europe, and pellets are beginning to be used increasingly as substitutes for coal in commercial boilers. Denmark, Italy, Belgium and the Netherlands are among the largest pellet importers in the EU, although Sweden, Germany and Austria are the leading pellet consumers. The total annual consumption of pellets in Europe is approximately six million tons, versus 2.3 million tons in the North American market, of which two million tons were consumed in the U.S.[102]

The prices in the pellet market in Europe are very elastic and are extremely vulnerable to weather fluctuations. For example, 2005 had a very cold winter and demand quickly grew for pellet stoves and boilers. Combined with the lowered rate of wood harvesting due to the extremely cold weather, the price of the pellets themselves quickly increased. The winter of 2006, however, proved to be warmer than usual and thus the demand for pellet appliances dropped sharply, causing the price of pellets to drop in both Europe and the United States. Pellet manufacturers and retailers were faced with extra stock of pellet appliances in which they had invested the previous year in anticipation of similar sales. Thus, the market can be quite volatile, although it appears that wood pellets and pellet appliances will remain a mainstay in the European residential heating sector.[103,104] The global pellet production market is expected to

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[100] Lynch, Mike, 2008, "State considers outdoor wood boiler regulations", Adirondack Daily Enterprise, http://www.adirondackdailyenterprise.com/page/content.detail/id/500264.html?nav=5008.

[101] Assessment of Outdoor Wood-fired Boilers. Prepared by NESCAUM. March 2006 (revised June 2006). pp. 3-2 to 3-3.

[102] Egger, C. and Oehlinger, C., 2009, "Burning Issues: An Update on the Wood Pellet Market", Renewable Energy World Magazine, http://www.renewableenergyworld.com/rea/news/article/2009/04/burning-issues-an-update-on-the-wood-pellet-market.

[103] Rakos, Christian, 2009, "The Development of International Wood Pellet Markets", proPellets Austria, http://www.propellets.at/cms/cms.php?pageName=14&newsId=170.

[104] See footnote 102.

grow from 9 million tons currently to 15 million tons by 2010, with EU's demand to grow to 150 million tons by 2020.[105]

3.4 Market Drivers of the Wood Fuel Sector

Rising energy costs and growing concern about energy security and greenhouse gas emissions in the United States have compelled a push towards increasing the use of renewable energy, particularly to power the residential sector. The major sources of renewable energy include solar, wind, and biomass. From the regulatory point of view, the renewable fuel standard in the Energy Independence and Security Act of 2007 (which includes various appliance efficiency standards) and renewable portfolio standard (RPS) programs at the state levels (which require electricity generation by renewable energy) have been factors in the increasing growth rate in consumption of renewable energy. The federal government has provided tax incentives to encourage the general public to turn towards renewable energy. For example, in 2009 and 2010, a 30 percent consumer tax credit is available to consumers to use towards the purchase and installation of a 75 percent efficient biomass-burning stove (IRS Notice 2009-53).

Moreover, the ordinances and regulations passed in Europe to require 20 percent of energy generation to come from renewable energy has spurred the growth of pellet production plants in the United States.[106]

3.5 Costs and Efficiencies of Wood-burning Fuel

Table 3 shows the range of costs for different fuels used in the residential sector for hearth appliances.[107]

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[105] See footnote 103.
[106] Kesller, Richard, 2009, "New England to meet rising wood pellet demand with new plant", RECharge, http://www.rechargenews.com/regions/north_america/article185408.ece
[107] Hearth, Patio & Barbecue Association, 2009, "Hearth Product Fuels Factsheet". http://www.hpba.org/media/hearth-industry-prs/product-information/product-factsheets.

Table 3. Cost Effectiveness of Various Fuels Used in Hearth Appliances.

Fuel	Price Per Unit	Price per BTU
Firewood	$90-$350/cord	$5.77-$13.46MM BTU
Electricity	$.08-$.26/kWh	$23.45-$75.68/MM BTU
Fuel Oil	$.75-$2.75/gallon	$5.35-$19.64/MM BTU
Natural Gas	$.60-$2.25/therm	$5.00-$22.50/MM BTU
Pellets	$150-$250/ton	$8.33-$13.89/MM BTU
Propane	$1-$33.25/therm	$10.80-$34.95/MM BTU

MM BTU is million British Thermal Units

Coal and corn (which have similar heating properties as wood) range from $225-$250 per ton with a 70 percent heating efficiency, similar characteristics to wood pellets.[108] From a cost-effectiveness point of view, natural gas and fuel oil still provide the most efficient appliances on the low end of the range. However, the average cost effectiveness show pellets and firewood as the most cost effective ($11.11/MM BTU and $9.62/MMBTU, respectively).

Information from EPA's emissions inventory program highlights the amount of fuel consumed by conventional (non-EPA certified) wood stoves compared to certified stoves:
Wood stoves, conventional, for main heating = 3.45 cords per year.
Wood stoves, conventional, for secondary heating = 1.80 cords per year
Wood stoves, conventional, for pleasure heating = 0.60 cords per year
vs.
Wood stoves, EPA certified, for main heating = 2.74 cords/year
Wood stoves, EPA certified, for secondary heating = 1.43 cords/year
Wood stoves, EPA certified, for pleasure heating = 0.474 cords/year.

[108] Ontario Ministry of Agriculture, Food & Rural Affairs, 2009, "Fact sheet: Burning Shelled Corn as a Heating Fuel", http://www.omafra.gov.on.ca/english/engineer/facts/93-023.htm.

4.0 EXISTING STATE AND FOREIGN REGULATIONS AND INTERNATIONAL STANDARDS

The purpose of this chapter is to summarize the existing wood heating regulations in the United States and foreign countries.

4.1 Wood Heater Regulations in the United States

4.1.1 Emission Standards

Most of the United States, including the northeast states of Maine, Connecticut, Vermont and New York, incorporate subpart AAA into their air program. As leaders for wood burning regulations, Washington, Oregon, and Colorado have adopted their own regulations that are consistent with or surpass subpart AAA. The current NSPS phase II emissions standard mandates that all new stoves (subject to the NSPS) presently sold in the U.S equipped with a catalytic combustor cannot emit more than a weighted average of 4.1 g/hr of PM, and units that are not equipped with a catalytic combustor cannot emit more than a weighted average of 7.5 g/hr of PM. The state of Washington, since 1995, has adopted more stringent standards than the NSPS of 2.5 g/hr of PM for catalytic stoves and 4.5 g/hr of PM for all other solid fuel burning devices.

For test methods and procedures, the NSPS specifies EPA Method 28 for fuel and appliance operation with methods 5G and 5H defining the emissions sampling procedures. Method 28 requires the use of air-dried Douglas fir 2x4 and 4x4- inch timber (16–20 percent moisture wet weight) constructed into cribs. Emissions concentrations may be sampled using a dilution tunnel (Method 5G) or directly from the stack (Method 5H). Testing is conducted at four burn rates. A few local agencies in California (Bay Area Air Quality Management District (AQMD), Yolo-Solano AQMD, and San Joaquin Valley) also specify ASTM-D 4442-92 for use in determining moisture content.

In addition to PM, some agencies restrict carbon monoxide (CO) emissions. For example, Maricopa County, AZ, restricts the maximum allowable 8-hour concentration of CO to 9 ppmv.

To also help control smoke from chimneys or flues and to encourage cleaner burning techniques, several states and local agencies have adopted rules that require no “visible emissions" or that limit the "opacity" of emissions as another form of mandatory curtailment. Prohibiting "visible emissions" means no smoke should be seen coming out of a chimney for a given amount of time and if there is, it could be considered a violation. Opacity limits are restrictions on the percentage of light that may be prevented from passing through the smoke plume and require a qualified opacity reader to determine compliance. See EPA Test Method 22 for details on determination of visible emissions and EPA Test Method 9 for details on determination of opacity. Table 4 shows examples of visible emission standards of some states and local agencies.

Table 4. Visible Emissions/Opacity Standards as of 2009.

State/Local Agency	Visible Emissions/Opacity
Washington	20% for a period or periods aggregating more than 6 minutes in any 1 hour period.
Utah	20% as measured by EPA Method 9.
Alaska	50% for a period or periods aggregating more than 15 minutes in any 1 hour period.
Spokane County, WA	20% for a period or periods aggregating more than 6 minutes in any 1 hour period.
Maricopa County, AZ	No visible emissions during the curtailment period.
Missoula County, MT	Within the Air Stagnation Zone, no greater than 40%
Washoe County, NV	No. 2 on the Ringelmann Chart for a period or periods aggregating more than 3 minutes in any 1 hour period.
Bay Area Air Quality Management District, CA	No. 1 on the Ringelmann Chart or 20% for a period or periods aggregating more than 6 minutes in any 1 hour period.

See section 4.1.5 for a discussion of outdoor hydronic heater regulations.

4.1.2 Curtailment Periods

Cold weather often leads to unhealthy levels of air pollution because of a combination of air inversions and an increase in wood burning to keep homes warm. As a result, some states and local agencies developed mandatory curtailment programs to reduce wintertime wood smoke. Some communities implement both a voluntary and mandatory curtailment program depending on the severity of their problem. Curtailment programs often have two stages with Stage I allowing EPA-certified wood stoves to operate and Stage II banning all wood burning appliances, unless it is the homeowner's only source of heat. Alaska, Colorado, Oregon, Texas, and Washington as well as Libby, MT; Maricopa County, AZ; Washoe, NV; and several districts in California have curtailment programs.

Curtailment periods vary from state to state. Some states use set periods during the year, while others have mandatory curtailment during periods of high pollution. For example, the Bay Area AQMD and South Coast AQMD have curtailment periods from the months of November through February. Oregon, however, has mandatory curtailment a) during any designated Stage I advisory, when the PM_{10} standard is being approached, b) during any designated Stage II advisory, when an exceedance of the PM_{10} standard is forecasted to be imminent, c) during any designated PM_{10} Alert, when PM_{10} alert levels have been reached and are forecasted to continue, and d) during any designated PM_{10} Warning, when PM_{10} warning levels have been reached and are forecasted to continue.

4.1.3 Fuel Restrictions

Several states and local agencies also restrict the type of fuels that may be burned in a wood-burning device. These restrictions are intended to avoid dangerous combustion products (e.g., dioxins) and conditions that are not optimal for combustion. Table 5 below shows examples of the state and local agencies that place these restrictions and the type of fuels that are restricted.

Table 5. Restriction on Fuel Types.

<table>
<tr><th>State/Local Agency</th><th>Examples of Restricted Materials</th></tr>
<tr><td>Washington</td><td rowspan="8">Garbage; Treated Wood; Plastic or Plastic Products; Rubber or Rubber Products; Animal Carcasses; Products that Contain Asphalt; Waste Petroleum Products; Paint; Chemicals; Paper or Paper Products, Except for Paper Used to Kindle a Fire; Coal; Animal Droppings; Insulated Wire; Poultry Litter</td></tr>
<tr><td>Montana</td></tr>
<tr><td>Oregon</td></tr>
<tr><td>Bay Area Air Quality Management District, CA</td></tr>
<tr><td>Maricopa County, AZ</td></tr>
<tr><td>Washoe County, NV</td></tr>
<tr><td>San Joaquin Valley, CA</td></tr>
<tr><td>Yolo-Solano, CA</td></tr>
</table>

Some local agencies also restrict sale and/or use of wood above a specified moisture content. As discussed earlier, a higher moisture content will cause firewood to burn less efficiently and release more harmful pollutants. To increase the likelihood that stove owners will burn seasoned wood, some air pollution control agencies have passed regulations making it illegal for the homeowner to burn wood with a moisture content of 20 percent or more. For example, some California air agencies, such as the Bay Area and Sacramento AQMDs' regulations, require the wood moisture content not exceed 20 percent. Homeowners may purchase a basic wood moisture meter at woodworking specialty shops or online. Other areas have made it illegal to sell, advertise or supply wood unless the wood moisture content is 20 percent or less.

4.1.4. Building Code Restrictions on Installation or Sale of Property

Some areas impose restrictions on ability to install and/or sell houses with wood heating devices. This is because old wood stoves are usually made of metal, weigh 250 to 500 pounds, last for decades and can continue to pollute as long as they are operated. Many homeowners are less likely to replace old stoves with a new, cleaner-burning technology or remove the old stove especially if they are not using it. To help get these old stoves "off-line," some local communities have required the removal and destruction of old (non-certified) wood stoves upon the resale of a home. For example, the Oregon Department of Environmental Quality established a law in 1991 stipulating that uncertified stoves, i.e., those made prior to 1991, cannot be resold or reinstalled in homes or outbuildings, and only EPA-certified wood burning appliances may be installed. In Oregon, wood stoves manufactured prior to 1990 are allowed as long as they have not been moved from their original location. Though this measure may be difficult to enforce, if implemented over a long period, it may result in significant emissions reductions. To help address the enforcement challenges, some areas have their building department inspectors enforce this rule.

The Bay Area AQMD in California allows for the installation of natural gas fireplaces, EPA-certified wood heaters, pellet-fueled wood heaters, and EPA-certified fireplaces that do not produce emissions greater than those from an EPA-certified wood heater. Enforcement of these ordinances can be carried out through the permit process by local building departments.

Other areas choose instead to ban the use of non-EPA certified wood stoves. Lincoln County, Montana, first provided incentives for households to change out their old stoves. Then, in 2006, the county passed a regulation that banned the use of old wood stoves that were not EPA-certified. Each home using a "Solid Fuel Burning Device" (e.g., wood stove or fireplace) must have an operating permit. To enforce their regulation, Lincoln County air program personnel periodically "drive by" homes and look for visible emissions coming from chimneys. If there are visible emissions and the homeowner does not have an operating permit on record with the Lincoln County Health Department, the County may issue a notice of violation (NOV) for failure to have a permit.

In another variation, Washoe County Rule 040.051 (Wood Stove/Fireplace Insert Emissions) limits the number of certified wood stoves or fireplaces to no more than one per acre in new construction and prohibits installation of additional solid fuel burning devices in existing developments. The requirements are not applicable to low-emitting devices which include: gaseous-fueled appliances, pellet stoves, masonry heaters, and other appliances that meet a certified emission rate of 1 g/hr or less. Other areas such as the South Coast AQMD completely ban the installation of wood-burning devices in some areas.

4.1.5 Hydronic Heaters

Many states and local governments have tried to use nuisance or opacity regulations to regulate hydronic heaters. Many states have opacity regulations that could apply to hydronic heaters. Four states, including Massachusetts, Maine, New Hampshire, and Vermont, have new emissions standards specific to hydronic heater use. Washington applies its wood stove regulation (4.5 g/hr) to hydronic heaters. Other states, such as Indiana, New York, Ohio, and Pennsylvania, are in the process of developing standards. NESCAUM, with financial and technical assistance from EPA and several states, released a model regulation in 2007 for outdoor hydronic heaters for states to follow. Several states also limit fuels that can be burned, require notifications to buyers of their obligations, and establish setback and stack height standards for hydronic heaters. Many state and local governments have considered and/or enacted outright bans on the use of hydronic heaters. Some bans only apply to new uses or consist of seasonal restrictions, but others apply to any use of outdoor wood boilers. Table 6 below shows several of the hydronic heater regulations adopted, including their emissions standards, test method, and opacity standards.

Table 6. State-Level Outdoor Hydronic Heater Regulations, 2009.

State/Local Agency	Emissions Standards	Test Method	Opacity
Maine	a) Phase I: 0.60 lb/MM BTU of heat input b) Phase II: 0.32 lb/MM BTU of heat output	a) EPA Outdoor Wood-Fired Hydronic Heater Phase I Program until replaced with the Environmental Technology Verification Program. b) Alternative methods approved by the Department.	30% for a period or periods aggregating more than 6 minutes in any 1 hour period.
Massachusetts	0.32 lb/MM BTU of heat output	a) Method 28 OWHH b) Method 9	20% for two minutes in any 1 hour period; 40% for the first 6 minutes during the startup period of a new fire
New Hampshire	a) Phase I: 0.60 lb/MM BTU of heat input b) Phase II: 0.32 lb/MM BTU of heat output	None specifically established	N/A
Vermont	0.44 lb/MM BTU of heat input (plan to propose a Phase II limit)	a) EPA Method 28 OWHH, or b) 40 CFR Part 60, Appendix A, Test Methods 1 through 5, and 40 CFR Part 51, Appendix M, Test Method 202, or c) Alternative methods approved by the Department.	N/A
NESCAUM (Model Regulation)	a) Phase I: 0.44 lb/MM BTU of heat input b) Phase II: 0.32 lb/MM BTU of heat output; in addition, no individual test run shall exceed 18 g/hr	a) EPA Method 28 OWHH, or b) Alternative methods approved by the air pollution control office.	20% for a period or periods aggregating more than 6 minutes in any 1 hour period. Exception: 40% for 20 consecutive minutes during the startup period of a new fire.

4.2 Other Countries

It is important to recognize that wood-heater emission limits are based on specific standard-measuring procedures designed to allow comparison of different heater designs and to ensure that emissions from new appliances meet a minimum level of performance. Standardized tests are designed to minimize sources of variation external to heater design, including fuel type (hardwood, softwood), moisture, density, fuel loading, etc. In addition, national emission standards can have strong regional characteristics and are potentially less applicable outside the regions for which they were designed. Given this evolution of different national standards, one important issue to be considered is the relevance of tests tailored for Northern vs. Southern hemisphere conditions and types of heaters and fuels specific to the geographic region. Test specifications which vary widely between different standards include:

- Fuel types (cord vs. crib, moisture content, and softwood vs. hardwood) and burning regimes (for example, whether to include start-up emissions and whether measurements are undertaken directly on the chimney flue or through a dilution chamber)
- The species used to assess emission performance, e.g. PM, CO and VOC
- Physical parameters measured (e.g. heating efficiency and whether both filterable and condensable particulates are collected)
- The number of duplications.

All of these approaches have associated benefits and limitations.[109]

4.2.1 Canada

In 2000, Environment Canada (EC), along with other federal, provincial and territorial jurisdictions across Canada, signed the Canada Wide Standard (CWS) for particulate matter and ozone, which recognizes that $PM_{2.5}$ and ozone negatively affect human health and the environment. The agreement also describes the need for nationally coordinated long-term management aimed at minimizing the risk from these pollutants. EC and the other governments committed to undertake a number of Joint Initial Actions toward meeting the CWSs, which are to

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[109] Australian Government report (Emissions from domestic solid fuel burning appliances (wood-heaters, open fireplaces)). See: http://www.environment.gov.au/atmosphere/airquality/publications/report5/chapter9.html.

be completed by 2005. Under the Joint Initial Actions, the governments committed to participate in new initiatives to reduce emissions from residential wood burning appliances, including:

- An update of the CSA standards for new wood burning appliances
- The development of a national regulation for new, clean burning residential wood heating appliances
- National public educational programs
- The assessment of the option to create a national wood stove upgrade or change-out program.[110]

To date, British Columbia is the only Canadian province to regulate wood stoves with a requirement that the stoves must meet the Canadian Standard B415.1 or the U.S. NSPS. CSA B415.1 is undergoing revision and includes the following proposed particulate emissions rate for any test run that is required to be used in determining the average emissions for an appliance not equipped with a catalytic combustor:

- 15 g/hr for burn rates ≤ 1.5 kg/hr;
- 18 g/hr for burn rates > 1.5 kg/hr but ≤ 8.3 kg/hr; or
- 0.20 g/MJ (output) for burn rates > 8.3 kg/hr; or for an appliance equipped with a catalytic combustor:
- 3.55•BR + 4.98 g/hr for burn rates ≤ 2.82 kg/hr;
- 15 g/hr for burn rates > 2.82 kg/hr but ≤ 8.3 kg/hr; or
- 0.20 g/MJ (output) for burn rates > 8.3 kg/hr

where BR = the dry fuel burn rate, kg/hr.

The standard also requires calculation of heat output and establishes the following particulate matter limits for an appliance not equipped with a catalytic combustor

- ≤ 4.5 g/hr or 0.137 g/MJ (output); or

for an appliance equipped with a catalytic combustor

- ≤ 2.5 g/hr or 0.137 g/MJ (output).

For indoor central heating appliances, PM shall not exceed 0.4 g/MJ (output) and for outdoor central heating appliances, emissions shall not exceed 0.137 g/MJ (output). As described in

[110] Environment Canada (government actions). See: http://www.ec.gc.ca/cleanair-airpur/Government_Actions_on_Residential_Wood_Burning-WS95958979-1_En.htm

section 5.3.3.2, EPA has approved the use of the efficiency test methods contained in this standard, but not the particulate emissions limits because of significant differences in the test methods.

4.2.2 New Zealand and Australia

In 1999, a stricter joint New Zealand and Australian Standard (AS/NZS 4013) was introduced, mandating maximum emissions allowed from new wood heaters of 4.0 g/kg of PM. Initially a voluntary emissions limit, it has since been adopted as a mandatory standard in most states and territories of Australia. The Australian regulations are currently under review and may result in more stringent emission limits and the addition of an efficiency standard (e.g., 60 percent). In New Zealand, the regulations require that, beginning September 2005, all new wood burners installed on properties with less than two hectares must have a maximum particle emission of 1.5g/kg and a minimum thermal efficiency of 65 percent when tested in accordance with AS/NZS 4012/4013. AS4013 is a dilution tunnel method that uses dry hardwood of specified density and size and incorporates measurements at three different airflow settings (low, medium, and high) with specified repetitions and conditioning burns. Emissions are determined as particle mass. Once again, test methods are not directly comparable to U.S. methods and the format of the standards differs as well.

4.2.3 European Standards

There are European (EN) Standards for residential solid fuel appliances and for independent boilers with nominal heat output of up to 300 kW. The Standards include minimum requirements for efficiency, construction and safety of appliances. No EN Standards include NO_x emission performance criteria, and only EN 303 Pt 5, the independent boiler Standard, includes PM emissions criteria. EN Standards for residential appliances are mandatory across the EU. Many of the heating appliances covered by the EN Standards for residential appliances can also include boilers in addition to the primary heating (or cooling) function. EN 12809 includes boilers that also provide a space-heating function. Boilers that do not provide a space heating function are covered by EN 303 pt 5 which applies to solid fuel boilers up to 300 kW output. This Standard defines an efficiency testing procedure and also assigns performance classes based on efficiency and emissions of PM, CO and 'OGC' (organic gaseous carbon). [111]

Following is a list of the existing European Standards that apply to the residential solid fuel burning appliance sector.

Table 7. List of European Standards.

Standard reference	**Title**
CEN/TS 15883:2009	Residential solid fuel burning appliances - Emission test methods
EN 12809:2001	Residential independent boilers fired by solid fuel - Nominal heat output up to 50 kW - Requirements and test methods
EN 12809:2001/A1:2004	Residential independent boilers fired by solid fuel - Nominal heat output up to 50 kW - Requirements and test methods
EN 12809:2001/A1:2004/AC:2007	Residential independent boilers fired by solid fuel - Nominal heat output up to 50 kW - Requirements and test methods
EN 12809:2001/AC:2006	Residential independent boilers fired by solid fuel - Nominal heat output up to 50 kW - Requirements and test methods
EN 12815:2001	Residential cookers fired by solid fuel - Requirements and test methods
EN 12815:2001/A1:2004	Residential cookers fired by solid fuel - Requirements and test methods
EN 12815:2001/A1:2004/AC:2007	Residential cookers fired by solid fuel - Requirements and test methods
EN 12815:2001/AC:2006	Residential cookers fired by solid fuel - Requirements and test methods
EN 13229:2001	Inset appliances including open fires fired by solid fuels - Requirements and test methods
EN 13229:2001/A1:2003	Inset appliances including open fires fired by solid fuels - Requirements and test methods
EN 13229:2001/A2:2004	Inset appliances including open fires fired by solid fuels -Requirements and test methods
EN 13229:2001/A2:2004/AC:2007	Inset appliances including open fires fired by solid fuels - Requirements and test methods
EN 13229:2001/AC:2006	Inset appliances including open fires fired by solid fuels - Requirements and test methods
EN 13240:2001	Room heaters fired by solid fuel - Requirements and test methods
EN 13240:2001/A2:2004	Roomheaters fired by solid fuel - Requirements and test methods
EN 13240:2001/A2:2004/AC:2007	Roomheaters fired by solid fuel - Requirements and test methods
EN 13240:2001/AC:2006	Roomheaters fired by solid fuel - Requirements and test methods
EN 14785:2006	Residential space heating appliances fired by wood pellets - Requirements and test methods
EN 15250:2007	Slow heat release appliances fired by solid fuel - Requirements and test methods
EN 15544:2009	One off Kachelgrundöfen/Putzgrundöfen (tiled/mortared stoves) - Dimensioning

[111] Biomass and Air Quality Guidance for Local Authorities (England and Wales). Draft Guidance Document for Consultation. April 2009. Prepared by Environment Protection UK and LACORS. (Chapter 2).

A number of ecolabel and biomass grant schemes in Europe specify performance criteria which are typically higher than the minimum efficiency requirements of the EN product Standards and national regulations. Some of these ecolabel schemes recognize the importance of PM emissions and include criteria for assessment. See Table 8 for a summary of the existing ecolabel programs.[112]

Table 8. Ecolabeling Criteria for Biomass Combustion

Ecolabel	Country	NOx?	PM?	Comment
Blue Angel	Germany	X	X	Includes efficiency and limit values for wood pellet stoves and wood pellet boilers
Nordic Swan	Sweden, Norway, Denmark, Finland	X	X	Includes efficiency, PM and VOC limit values for various residential room heater types and NOx, PM, and VOC limits for boilers <300kW
EFA	European Association of Fireplace Manufacturers		X	Higher efficiencies than product standards and also PM emission limits for various residential room heaters
Umweltz Eichen37	Austria	X	X	Higher efficiency and more stringent emission criteria than legislative limits for boilers and room heaters
Flamme Verte	France		X	Differs from other ecolabeling schemes in that criteria show an annual improvement. Efficiency criteria set for room heaters, additional PM and VOC emission limits for boilers
DINplus	Germany	X	X	VOC limit also set and also covers certification of pellet fuels
Housing Grants	Denmark		X	Efficiency and PM emission limits for biomass boilers
P Marking	Sweden		X	Efficiency and PM emission limits for pellet boilers, pellet stoves and wood-fired room heaters

[112] **Biomass and Air Quality Guidance for Local Authorities (England and Wales).** Draft Guidance Document for Consultation. April 2009. Prepared by Environment Protection UK and LACORS. (Chapter 2).

5.0 NSPS IMPLEMENTATION ISSUES

This chapter describes issues related to the implementation experience of the existing wood heater NSPS and suggestions presented to EPA to improve implementation of a revised NSPS. A model line[113] certification process is the heart of the NSPS implementation process. As an alternative to testing every individual unit, the NSPS requires manufacturers of wood stoves to certify that each model line of wood stoves offered for sale in the United States complies with the subpart AAA particulate emissions standards. As part of the certification process, each wood stove model line is required to undergo emissions testing in accordance with EPA Reference Method 28 and sampling methods 5G or 5H by an EPA-accredited laboratory. Only after successfully passing these tests can a non-exempt wood stove be offered for sale in the United States.

The wood heater NSPS is implemented under the federal Wood Heater Program (WHP) managed by the Compliance Assessment and Media Programs Division of EPA. Its purpose is to promote compliance with the requirements of the wood heater regulation. The WHP consists of a wide range of activities including:

- Certification of new residential wood heaters
- Approval of design change requests
- Interpretation of rule language
- Conducting facility inspections
- Provision of public access to compliance information
- Direct monitoring of compliance by accredited laboratories, manufacturers, retailers and homeowners
- Response to complaints regarding violations of the rule

See the WHP website for more information: http://www.epa.gov/oecaerth/monitoring/programs/caa/woodheaters.html.

There are four major components to NSPS implementation. The first is the model line certification process, which is presented in section 5.1. The second is the laboratory

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[113] A "model line" means all wood heaters offered for sale by a single manufacturer that are similar in all material respects.

accreditation process, which is presented in section 5.2. Section 5.3 presents the third component, which are the test procedures required to demonstrate compliance with the emissions limits. Section 5.4 presents the fourth component, which are the audit and quality assurance procedures.

5.1 Model Line Certification

5.1.1 What is the current NSPS certification process?

Under subpart AAA, the issuance of a certificate of compliance is based upon whether a representative wood heater meets the applicable emission limits as determined by a validly conducted test. The certification based upon this test would apply to the wood heater model line, provided that the units are similar in all material respects to the tested model. An application for certification must also include several other items, such as detailed engineering drawings and affirmations by the manufacturer regarding compliance with other provisions, such as the in-house quality assurance program.

A certificate for a wood heater meeting the 1990 emission limits is valid for 5 years. A model line can be recertified without testing, at EPA's discretion, if the model line continues to meet the requirements for certification. Once every 2 years, manufacturers of certified models are also required to report to EPA that no changes that would require recertification have been made in the model line.

The issue of whether an individual unit selected for testing is representative of the entire model line was given a lot of attention in developing the NSPS. The key concept is that the unit does not have to be identical, but is instead "similar in all material respects" relevant to emissions. For example, the color of a unit or the size of the door handle is not "material" to emissions.[114] The regulation specifies eight components that are presumed to affect emissions, such as firebox volume and dimensions, criteria related to restrictive air inlets and baffles, and door and catalyst bypass gasket dimensions and fit. Changes to any of these components, or other components EPA deems likely to increase emissions, would require a new certification test.

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[114] 52 FR 5009. February 18, 1987.

The representativeness concept also includes provisions for variances in components within specified tolerances. Manufacturing tolerances may be submitted by the manufacturer, or default tolerances established by the rule must be followed. To avoid unnecessary testing and to prevent a barrier to improvements in wood heater design, EPA can waive the recertification requirement for changes that exceed the specified tolerances if the manufacturer demonstrates that the change would not reasonably be anticipated to cause emissions to exceed the standard. For example, if a manufacturer wants to substitute a new type of refractory material which has been shown to reduce emissions in other models, EPA can grant a waiver from recertification testing. This demonstration could be made with any relevant data, including test data from the manufacturer's research and development laboratory.

5.1.2 What issues have been raised regarding the certification process?

It currently takes EPA from 30 to 60 days to process a complete certification application. Additional delays can occur if materials are missing in the application, such as the certification signature or blueprints or drawings. Under the current NSPS, EPA is processing approximately 30 new certification requests per year and 50 renewals (testing has not typically been required to obtain a renewal.) EPA also processes approximately 25 requests for design changes per year.[115] Industry members have raised concerns that the length of time required to obtain certifications or to make changes to certifications hinders their ability to make quick design changes as products mature, including changes that could improve the heating efficiency of the unit and/or reduce PM emissions from the unit. They said that this concern contributes to a decision not to submit some units for certification (e.g., certain pellet stoves) under the current program.[116]

One option that might be considered is to add some flexibility to the design change process. Subpart AAA at 40 CFR 60.533(k) (the "K" list) contains a list of design factors that are presumed to affect emissions if they are changed. EPA might consider adding provisions to allow a streamlined testing process (for example, testing at a nonaccredited laboratory, testing for only the worst case burn rate, etc.) Another option is to review the K list to ensure that it still reflects modern manufacturing procedures and is relevant.

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[115] Summary of Discussion and Action Items from 8/20/09 EPA Wood Stove NSPS-OECA Meeting. Prepared by EC/R, Inc. August 20, 2009.

[116] Summary of Discussion and Action Items from 6/16/09 HPBA-EPA Wood Stove NSPS Review Meeting. Prepared by EC/R, Inc. July 7, 2009.

There also is interest in taking steps to streamline the certification process, such as developing an electronic system for submittals and approvals. Electronic reporting would provide several benefits and has received preliminary support from the accredited laboratories. First, it would ensure that test results and certification applications are readily available for review, research, and potential enforcement concerns. It would streamline the administrative parts of the application and allow manufacturers to more easily make administrative changes, such as names of model lines and companies. The use of a standardized format would allow for quicker review and could also contain some built-in quality assurance features.

One option is to adapt EPA's current electronic reporting tool to accommodate the wood heater test methods. The Electronic Reporting Tool (ERT), a Microsoft Access desktop application, is an electronic alternative for paper reports documenting 19 of EPA's emissions measurement methods for stationary sources. The ERT replaces the time-intensive manual preparation and transcription of stationary source emissions test plans and reports currently performed by contractors for emissions sources, as well as the time-intensive manual quality assurance evaluations and documentation performed by State agencies. The ERT provides a format that:

- Highlights the need to document the key information and procedures required by the existing EPA Federal Test Methods;
- Facilitates coordination among the source, the test contractor, and the regulatory agency in planning and preparing for the emissions test;
- Provides for consistent criteria to quantitatively characterize the quality of the data collected during the emissions test;
- Standardizes the reports; and
- Provides for future capabilities to electronically exchange information in the reports with facility, state or federal data systems.

See EPA's website for more information on the ERT (http://www.epa.gov/ttnchie1/ert/ert_tool.html).

Some stakeholders have indicated a need to make the results of the certification process more consumer-friendly. For example, it might be helpful to make results available in a spreadsheet format containing a list of current certifications ranked by emissions, tested efficiency, and output.

Additional guidelines might be needed to enhance implementation of the NSPS. For example, manufacturers often license their designs to other companies. A revised NSPS might provide specific guidelines regarding how and when a certified wood stove design can be licensed to another manufacturer. The guidelines could address who, how, and when design change requests and recertification requests should be submitted and requirements related to internal QA procedures and sealed test stove requirements. Other guidelines related to company name changes and model line name changes could clarify the process by which a manufacturer notifies EPA when a wood stove manufacturer is purchased, sold or merged with another wood stove manufacturer. Additionally, all wood stove model line name changes should be reported to EPA before the unit can be sold or offered for sale as an EPA-certified wood heating appliance. EPA might provide an electronic template for reporting such information.

On rare occasions, problems have developed and/or been identified with certified wood stoves. Providing a recall provision in the NSPS might be a mechanism to ensure that stoves that do not meet the regulatory requirements are repaired, retrofitted, or replaced. Related recordkeeping provisions might be needed to facilitate a recall, such as requirements to keep production records, serial numbers, destination information, and sales. A number of stakeholders have expressed concern that the certification process does not consider the degradation of performance over the long lifetime of wood stoves. Interest has been expressed in the need for durability testing, e.g., similar to the 50,000-mile tests required for motor vehicle engine certification.

5.2 Laboratory Accreditation

5.2.1 What is the current NSPS accreditation process?

Under the current NSPS, certification testing must be conducted by EPA-accredited laboratories. EPA grants accreditation to laboratories based upon their demonstrated proficiency and upon the criteria specified in 40 CFR 60.535 of subpart AAA. EPA developed these procedures in recognition of the difficulty (relative to traditional stack testing) of performing the wood heater emissions tests. In order for a test laboratory to qualify for accreditation, it must submit its written application providing information related to laboratory equipment and management and technical experience of laboratory personnel, have no conflict of interest and receive no financial benefit from the outcome of certification testing, agree to enter into a contract with each wood heater manufacturer for whom a certification test has been performed, and demonstrate proficiency to achieve reproducible results with at least one test method and procedure required by subpart AAA. In addition, the laboratory must agree to participate in the proficiency testing program conducted by EPA (see more discussion in section 5.4), as well as other quality assurance and reporting and recordkeeping steps. The accreditation is valid for 5 years from the date of issuance.

Currently, there are four accredited testing laboratories in the United States and one in Canada:

- OMNI Environmental Services, Inc., Beaverton, Oregon
- Intertek Testing Services, Inc. (ITS, Wisconsin), Middleton, WI
- Myren Consulting, Inc., Colville, WA
- Lokee Testing Laboratory, Sumner, WA
- Intertek Testing Services, Inc. (ITS, Quebec), Lachene, Quebec.

5.2.2 What issues have been raised regarding the accreditation process?

The HPBA has suggested that EPA allow the use of third-party certification.[117] HPBA listed important elements that make third-party certifications, such as safety ratings, trustworthy:

- Periodic unannounced inspections
- Verification that products being "marked' as certified comply with design, process and QA requirements
- Documentation of results and reporting of any deficiencies or deviations
- No product modifications allowed without review and verification of compliance with certification requirements
- Certification Body must investigate and determine scope/severity of non-compliance
- Determine appropriate remedial actions
- If warranted, suspension or revocation of authorization to apply certification mark.

The HPBA recommended that EPA allow the use of nationally accredited third-party product certification agencies/bodies such as the ISO. However, some states have voiced concerns about any system that appears to rely on third-party enforcement of environmental standards. In

[117]See footnote 116.

addition, EPA would still need to be the final authority for approvals and would still need manufacturers to certify that they are in compliance with all aspects of the NSPS, i.e., the manufacturers would still be liable for enforcement actions and not be able to transfer enforcement liability to the third party.

EPA has allowed third-party certification of the models in the current fireplace voluntary program. However, some states have raised concerns about this program, pointing to errors made by some of the third-party ISO-accredited labs. An enforcement-related concern with using third-party laboratories is that some manufacturers might try to avoid taking responsibility for the performance of their units without some sort of required written acceptance of that responsibility. The EPA Fireplace Partnership Program uses a combination of ISO-accredited labs, or EPA-accredited labs, and ISO-accredited certifying bodies plus oversight by EPA and issuance of qualification letters by EPA. This process, combined with the manufacturer's certification that the manufacturer and the subject model meet all the requirements of the NSPS and that the manufacturer is ultimately responsible for compliance, regardless of any errors from the test lab or certifying body, might be an alternative accreditation process too.

EPA has also already explored using the existing Environmental Technology Verification (ETV) program as an alternative to an EPA accreditation process in the voluntary outdoor wood heater program. An option for the NSPS might be to expand the use of the ETV process as an alternative to the current accredited laboratory process. However, EPA would still need to be the final authority for approvals, and the manufacturer would need to certify compliance.

EPA established the ETV in 1995, and its mission is to accelerate entrance of innovative technologies designed to reduce risks to human health and the environment into the domestic and international marketplace. ETV centers operate independently as stakeholder-driven third parties; and EPA provides oversight, review, and approval of center documents. A specific ETV program is developed using the following steps:

1. The vendor submits an application.
2. The ETV Center, potential testing organization(s), and the applicant discuss the intent and scope of the test.
3. The ETV Center develops and the applicant signs a contract.
4. The ETV and the potential testing organization(s) sign a contract.

5. The ETV Center and the testing organization(s) (with input from the applicant) prepare a test/quality assurance plan for Center and EPA approval.
6. The testing organization conducts the test and drafts a report.
7. The ETV Center reviews the draft test report, and if satisfactory, submits the draft verification report and verification statement for review by EPA and the applicant.
8. EPA approves and signs the verification report and statement.
9. The ETV Center distributes the verification report and statement to the applicant, and EPA posts them on the ETV Center web sites so they are available to the general public.

Note: In the case of the hydronic heater voluntary program, there is an additional step in which the EPA lead for the hydronic heater voluntary program issues a qualification letter to the applicant.

The ETV Center for Air Pollution Control Technologies has developed a "Generic Verification Protocol for Determination of Emissions from Outdoor Wood-Fired Hydronic Heaters."[118] This protocol has been established in the Hydronic Heater (HH) Partnership Program as the means for partners to certify their units. EPA's goal for the HH agreement is to use ETV to reduce the resource burden on EPA. The next step is for the ETV Center and prospective testing organization(s) to develop a Quality Assurance Project Plan (QAPP). After that, the ETV Center will announce that the testing organization(s) has been approved.

5.3 Test Procedures

5.3.1 What test procedures are currently required by subpart AAA?

Subpart AAA includes procedures for loading the test fuel, for setting up the wood heater, for operating the wood heater, and for conducting the emissions tests. Two different methods for measuring PM are permitted in the regulation, with a correction factor to allow comparison of the results. Efficiency testing is optional. However, although not yet processed through a formal test method review in the *Federal Register*, EPA has approved the use of CSA B415.1. Nevertheless, most manufacturers continue to use the default values.

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[118] Generic Verification Protocol for Determination of Emissions from Outdoor Wood-Fired Hydronic Heaters. Prepared by: RTI International, Research Triangle Park, NC under a Cooperative Agreement with: U. S. Environmental Protection Agency. June 2008

5.3.1.1 EPA Method 28

EPA Method 28[119], Certification and Auditing of Wood Heaters, establishes standard stove operating procedures that are used to measure PM emissions from a wood heater burning a prepared test fuel crib in a test facility maintained at a set of prescribed conditions. Procedures for determining burn rates and particulate emission rates and for reducing data are provided. The method requires at least four test runs that meet the burn rate specifications in Table 9.

Table 9. Burn Rate Categories (Average kg/hr (lb/hr), dry basis).

Category 1	Category 2	Category 3	Category 4
< 0.80 (< 1.76)	0.80 to 1.25 (1.76 to 2.76)	1.25 to 1.90 (2.76 to 4.19)	Maximum burn rate

For stoves that cannot operate in the Category 1 range, two runs in the Category 2 range may be substituted. For stoves that cannot operate in the Category 2 range, the flue shall be dampered or the air supply otherwise controlled in order to achieve two test runs within Category 2.

The method specifies the test fuel type, untreated, air-dried, Douglas fir lumber, and moisture content range of the wood, between 16 to 20 percent on a wet basis (19 to 25 percent dry basis). The method also specifies the size of the wood, depending on firebox volume, how it is to be loaded, and fuel ignition procedures. There are slight variations for catalyst-equipped heaters.

ASTM is considering making changes to Method 28, including changing the number of required burn rates.

5.3.1.2 EPA Method 5G

EPA Method 5G, Determination of Particulate Matter Emissions from Wood Heaters (Dilution Tunnel Sampling Location), is used to determine PM emissions concentrations. In this method, the exhaust from a wood heater is collected with a total collection hood and is combined with ambient dilution air to mimic the expected atmospheric cooling and condensation. Particulate matter is withdrawn proportionally from a single point in a sampling tunnel and is collected on two glass fiber filters in series. The filters are maintained at a temperature of no

[119]The methods described in this section are located in 40 CFR part 60, Appendix A.

greater than 32 °C (90 °F). The particulate mass is determined gravimetrically after the removal of uncombined water.

5.2.1.3 EPA Method 5H

EPA Method 5H, Determination of Particulate Matter Emissions from Wood Heaters from a Stack Location, is an alternative method used to determine PM emissions concentrations. In this method, PM is withdrawn proportionally from the wood heater exhaust and is collected on two glass fiber filters separated by impingers immersed in an ice water bath. The first filter is maintained at a temperature of no greater than 120 °C (248 °F). The second filter and the impinger system are cooled such that the temperature of the gas exiting the second filter is no greater than 20 °C (68 °F) to include condensable particulate. The particulate mass collected in the probe, on the filters, and in the impingers is determined gravimetrically after the removal of uncombined water.

5.3.1.4 EPA Method 28A

EPA Method 28A, Measurement of Air-to-Fuel Ratio and Minimum Achievable Burn Rates for Wood-Fired Appliances, is used to determine that a wood combustion unit qualifies under the current definition of wood heater in 40 CFR 60.531(a). If such a determination is necessary, this test must be conducted by an accredited laboratory. In this method a gas sample is extracted from a location in the stack of a wood-fired appliance while the appliance is operating at a prescribed set of conditions. The gas sample is analyzed for carbon dioxide (CO_2), oxygen (O_2), and carbon monoxide (CO). These stack gas components are measured for determining the dry molecular weight of the exhaust gas. Total moles of exhaust gas are determined stoichiometrically. Air-to-fuel ratio is determined by relating the mass of dry combustion air to the mass of dry fuel consumed.

5.3.2 What additional test procedures might be needed in a revised subpart AAA?

5.3.2.1 Preliminary EPA Method 28 OWHH

EPA has issued a preliminary method [Method 28 OWHH (listed as Other Test Method 15 at http://www.epa.gov/ttn/emc/prelim.html)] for outdoor wood-fired hydronic heaters, in order to implement the voluntary program. Test Method 28 OWHH for Measurement of

Particulate Emissions and Heating Efficiency of Outdoor Wood-Fired Hydronic Heating Appliances is designed to simulate hand loading of seasoned cordwood, and it measures particulate emissions and delivered heating efficiency at specified heat output rates based on the appliance's rated heating capacity. Particulate emissions are measured by the dilution tunnel method as specified in ASTM Standard Test Method for Determination of Particulate Matter Emissions Collected in a Dilution Tunnel (E-2515). Delivered efficiency is measured by determining the heat output through measurement of the flow rate and temperature change of water circulated through a heat exchanger external to the appliance and determining the input from the mass of dry wood fuel and its higher heating value. Delivered efficiency does not attempt to account for pipeline loss.

5.3.2.2 Canadian Standards Association (CSA) Method B415A

CSA Method B415.1, Performance Testing of Solid-Fuel-Burning Heating Appliances, is undergoing revision to issue the third edition of the standard. This standard describes a test procedure for measuring the emissions, heat output, and efficiency of solid-fuel-burning manually and automatically fuelled stoves and fireplace inserts; factory-built fireplaces with a minimum burn rate less than 5 kg/h; and furnaces and hydronic heaters designed to have the useful heat produced by the appliance conveyed to areas remote from the appliance by ducting or plumbing. Site-built masonry fireplaces, site-built masonry heaters; or factory-built fireplaces with a minimum burn rate above 5.0 kg/hr are excluded. The test procedure is based on EPA Method 5G, described above.

In June 2007, EPA approved a request that the CSA B415.1 test protocol be approved as an alternative method for determining thermal energy efficiency ratings for wood stoves affected under subpart AAA.[120] This request was made on behalf of the EPA-accredited laboratories that perform wood stove certification testing and manufacturers of wood stoves affected under the NSPS. The NSPS at 40 CFR 60.534(d)(1) allows affected sources to determine the thermal efficiency rating for a wood stove either by using a default number (63 percent for noncatalytic

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[120]Memorandum: Request to Use the CSA B415.1 Test Protocol as an Alternative Test Method for Determining Thermal Energy Efficiency Ratings for Wood Stoves Affected under the New Source Performance Standard (NSPS) for Residential Wood Heaters at 40 CFR Part 60, Subpart AAA. From Michael S. Alushin, Director, Compliance Assessment and Media Programs, Division Office of Compliance, EPA to Conniesue Oldham, Group Leader Measurement Technology Group Office of Air Quality and Planning Standards, EPA. February 6, 2007.

wood stoves, 72 percent for catalytic wood stoves, and 78 percent for pellet stoves), or by using a measured efficiency protocol. However, because a method for measuring thermal efficiency was never developed by EPA, affected sources were limited to use of the default number option for compliance with the NSPS. In the memorandum requesting approval of use of the method, it was noted that failure to have an approved efficiency measurement method undermines technical innovation in the wood stove industry and, most importantly, has a negative impact on the environment because of the reduced opportunity to encourage consumers to replace older, inefficient, high-polluting wood stoves with more efficient, clean-burning EPA-certified wood stoves. Because the default values used in the NSPS were calculated using an Oregon method that closely resembles the CSA B415.1 method, EPA approved the use of CSA B415.1. However, as of August 2009, no manufacturers have decided to use this option.

Note that this approval does not extend to the emissions estimation procedures, which are different from those in the EPA methods. The B415.1 method has several different assumptions for emissions (crib vs. cord, burn rate requirements) that make it difficult to compare the B415.1 emissions results to results derived using EPA methods. However, the proposed revisions to B415.1 include alternative procedures to match EPA methods.

5.3.2.3 ASTM Standards

A number of potentially relevant ASTM methods are presently available or are currently under development. Following is a list of the potentially applicable ASTM standards.[121] In order to comply with the National Technology Transfer and Advancement Act (NTTAA), EPA will consider any relevant final standards for use as potential alternative standards if a revised NSPS is developed. EPA is participating in a current review process to update some of the ASTM standards and to develop new ones. The development of potential efficiency methods is of key interest to many stakeholders because the Internal Revenue Service (IRS) has allowed manufacturers to self-certify the efficiency of their biomass heaters in order for buyers to potentially qualify for a tax credit. However, the IRS did not specify a test method to satisfy this requirement. Manufacturers also have asked the Energy Star office to develop specifications, and a decision is forthcoming.

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[121] Descriptions and status of methods taken from ASTM website. See: http://www.astm.org/Standard/index.shtml

1. 2515-09 Standard Test Method for Determination of Particulate Matter Emissions Collected by a Dilution Tunnel: This test method is applicable for the determination of particulate matter emissions from solid-fuel-burning appliances, including wood stoves, pellet-burning appliances, factory-built fireplaces, masonry fireplaces, masonry heaters, indoor furnaces, and indoor and outdoor hydronic heaters within a laboratory environment. The ASTM has an active work group considering revisions to this method, labeled WK20442.
2. E2558-08 Standard Test Method for Determining Particulate Matter Emissions from Fires in Low Mass Wood-Burning Fireplaces: This test method is used for determining emission factors and emission rates for low mass wood-burning fireplaces. The emission factor is useful for determining emission performance during product development, and by the air quality regulatory community for determining compliance with emission performance limits. The emission rate may be useful for the air quality regulatory community for determining impacts on air quality from fireplaces, but must be used with caution as use patterns must be factored into any prediction of atmospheric particulate matter impacts from fireplaces based on results from this method. The reporting units are grams of particulate per kilogram of dry fuel and grams of particulate per hour. Appropriate reporting units for comparing emissions from non-heating appliances: g/kg. The ASTM has an active workgroup considering revisions to this method, labeled WK22754.
3. E2618-09 Standard Test Method for Measurement of Particulate Emissions and Heating Efficiency of Outdoor Solid Fuel-Fired Hydronic Heating Appliances: The measurement of particulate matter emission rates is an important test method widely used in the practice of air pollution control. These measurements, when approved by federal or state agencies, are often required for the purpose of determining compliance with regulations and statutes. The measurements made before and after design modifications are necessary to demonstrate the effectiveness of design changes in reducing emissions and make this standard an important tool in manufacturer's research and development programs. Measurement of heating efficiency provides a uniform basis for comparison of product performance that is useful to the consumer. It is also required to relate emissions produced to the useful heat production. This is a laboratory method and is not

intended to be fully representative of all actual field use. It is recognized that users of hand-fired wood burning equipment have a great deal of influence over the performance of any wood-burning appliance. Some compromises in realism have been made in the interest of providing a reliable and repeatable test method. Note that this method currently uses cordwood instead of crib wood for manual heaters. The Method includes procedures for automatic feed heaters and heat storage, but the workgroup is considering adding a crib wood procedure.

5.3.2.4 International Standards

The European standards are a combination of test methods and emission limit(s). See section 4.2.3 for an introduction to these standards.

5.3.3 What issues exist regarding wood heating test procedures?

5.3.3.1 General EPA Test Method Issues

Since before the initial rule was proposed, stakeholders have disagreed with each other on various aspects of Method 28. Frequent comments are that (1) it does not reflect real-world practices of consumers in the field, (2) it does not result in reproducible test results, and (3) it does not allow for innovative and unique designs.[122] The EPA Office of Research and Development commissioned a review of the residential wood combustion (RWC) that was summarized in a 1998 report.[123] That study of the then-current states-of-the-art of RWC addressed test method issues. The key findings of the review related to the EPA test methods included: (1) the NSPS certification procedure only qualitatively predicts the level of emissions from wood heaters under actual use in homes, (2) wood stove durability varies with model, and a method to assess durability is controversial, and (3) the effect of wood moisture and wood type on particulate emissions appears to be real but to be less than an order of magnitude. A more

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[122] 53 FR 5867, February 26, 1988.
[123] Residential Wood Combustion Technology Review Volume 1. Technical Report. James E. Houck and Paul E. Tiegs, OMNI Environmental Services, Inc. EPA-600/R-98-174a. December 1998. Abstract.

recent study points to wood moisture content vs. wood type as the biggest factor in increasing emissions.[124]

One concern is that as emission standards become more stringent, such as levels that are better than the current Washington standards, the current variability in the test method results could challenge the ability to distinguish between units that meet the standards and those that do not.

More recently, HPBA provided specific recommendations to improve the particulate emissions method.[125] They said EPA should:

- Consider adjusting the burn rate categories from fixed kg/hr ranges to percentages of the maximum burn rate
- Adjust the minimum burn rate range upward to help insure more robust performance in the "real world"
- Increase the "5-minute" start-up time in the fueling and operating test method.

HPBA representatives also referenced calculation errors in the burn rate data used by EPA to develop the burn rate weightings. Some state representatives indicated a willingness to eliminate the lowest burn rate requirement for units that are not capable of operating within the lowest range. They also said EPA should consider reducing the number of burn rates from four to three, because this would simplify the test, reduce costs, and it is consistent with the European approach. They said a mixture of conditions reflecting (1) high burn rate, (2) high concentration, and (3) low burn rate would be sufficient.[126] Any changes to the methods would need to be assessed to determine the impact of the changes on the underlying database of wood heater performance.

In contrast, the Catalytic Hearth Coalition (CHC) opposes several of the HPBA recommendations. The CHC maintains that changes to the burn rates that de-emphasize performance at low BTUs do not reflect how consumers really operate their stoves in the most typical overnight or "at work" mode. Such changes mask the superior performance of catalytic

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[124] Evaluation of methods for the physical characterization of the fine particle emissions from two residential wood combustion appliances. By John S. Kinsey (U.S. EPA), Peter H. Kariher (Arcardis) and Yuanji Dong (Arcardis). Atmospheric Environment, Volume 43, Issue 32, October 2009, Pages 4959-4967.
[125] HPBA presentation from June 16, 2008 meeting between HPBA and EPA, RTP, NC.
[126] Summary of Discussion and Action Items from 6/11/09 NESCAUM-EPA Wood Stove NSPS Review Call on Test Methods. Prepared by EC/R, Inc. June 15, 2009.

heaters at these low burn rates. Similarly, they argue that increasing the allowable change in temperature (delta T) at the initial burn rate poses similar problems. EPA has indicated their interest in obtaining data that address these various positions and in correcting any errors.

5.3.3.2 Methods 5G and 5H Issues.

The 1998 RWC review document addressed Method 5G and 5H correlation issues.[127] The document concluded that the "general perception among interviewees was that although the performance of Method 5H generally results in lower measured emissions rates, it is a very complicated and difficult method to perform. Its multi-step and multi-component sample train complexities are compounded by the use of a tracer gas flow measurement procedure making the overall method fraught with many points of potential error, and it is not surprising that the Method-5G-to-Method-5H conversion equation does not reflect industry experience with the two methods. There is no question among most interviewees that Method 5G is more precise than Method 5H and that it probably reflects actual wood stove emissions more consistently than Method 5H."

The document went on to note that several interviewees also stated that "if the EPA ever eliminates Method 5H, the relationship between Methods 5G and 5H should first be established with much greater certainty than is obtained using the Method 5G conversion equation. It was the experience of several interviewees that the present Method 5G to Method 5H conversion equation penalizes the use of Method 5G especially at lower measured emissions rates. All interviewees felt a concern that any change in the Method 5G conversion equation not increase the current stringency of the NSPS. Some concern was also expressed that because the regulators dealing with wood stove emissions control strategies, industry research and sales people, and consumers are now familiar with the current emissions rates, there should be no drastic change from the present use of Method 5H emissions equivalents."

Representatives from the HPBA have stated that HPBA believes that Method 5G is the appropriate method to use and that the data supporting the existing correlation factor is flawed (5H/5G conversion is not linear.)[128]

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[127] Residential Wood Combustion Technology Review Volume 1. Technical Report. James E. Houck and Paul E.Tiegs, OMNI Environmental Services, Inc. EPA-600/R-98-174a. December 1998. p. 27.
[128] See footnote 116.

5.3.3.3 *Use of ASTM or other Alternative Standards*

As described above, ASTM is in the process of revising some potentially relevant wood heater standards. EPA is participating in the workgroup discussions, but it is not known if these revisions will be made final by the time a revised NSPS might be issued. In addition, some stakeholders have expressed concerns about the overall ASTM standards development process. Per state law, some states are not able to comply with the intellectual property requirements imposed by ASTM and thus cannot participate in ASTM standards development/review any longer. They have also expressed concern that the development/review process effectively excludes state agency participation because of their budget constraints. Other stakeholders (Catalytic Hearth Coalition) have expressed concerns that the committee make-up is too biased to certain technologies.

5.3.3.4 *Comparing Methods*

Different methods have taken different approaches to standardizing test conditions. There is an ongoing, robust debate over the use of crib wood vs. cordwood in tests. Other issues include the use of a range of burn rates vs. "sweet spots" and the inclusion of back half condensibles vs. just the front half of the filters and the issues described in section 4.2.3.

5.4 *Audit and Quality Assurance/Quality Control Requirements*

5.4.1 What are the current requirements?

As a means to ensure the continued production of wood heaters that comply with the emission limits and in place of "look back" penalties or recall provisions, the NSPS requires that manufacturers conduct a quality assurance program and that EPA conduct enforcement audits, both consisting of parameter inspections and emission testing.[129] In addition, manufacturers are required to maintain records of certification testing data, QA program results, production volumes, and information needed to support a request for a waiver or exemption. Accredited laboratories must keep testing records and report periodically certain information required under alternative certification provisions.

[129] 52 FR 5009. February 18, 1987.

5.4.2 What issues exist regarding current requirements?

A key element of the current NSPS audit program is the “round robin” test program. In this program, EPA purchases a wood heater and sends it to each of the accredited laboratories to conduct emissions tests (2 runs at each burn rate for a total of 8 runs.) The results are then compared to determine inter-laboratory performance. A question for an expanded NSPS is whether all types of units should be tested and the frequency of testing.

The random compliance certification testing program is considered underutilized by many. The NSPS review will assess the procedures to conduct such audits, including ways to make the test funds more accessible. Some stakeholders have suggested that EPA take the round-robin effort seriously and provide an incentive for labs to conduct the round-robin tests as carefully as they do certification tests. The common belief is that labs sometimes just go through the motions and/or intentionally show variation is possible.

Some stakeholders believe that holding testing laboratories to standard safety certification procedures might be a sufficient replacement of the existing NSPS requirements. Some stakeholders have noted the stringency of the safety programs and that there are many common elements between the NSPS and the safety certification programs. Safety certification audits take place quarterly and include the random inspection of manufactured units for compliance with design and safety factors. The NSPS review will assess the feasibility of substituting such QA audits and the frequency of such audits.