Regulatory Impact Analysis (RIA) for Residential Wood Heaters NSPS Revision

Final Report

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SECTION 1
EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) is promulgating revisions to new source performance standards (NSPS) for residential wood stoves, and promulgating NSPS for other wood heating appliances such as pellet stoves, forced air furnaces, single burn rate stoves, and hydronic heaters. The EPA is submitting this revision under the authority of section 111 of the Clean Air Act (CAA), “Standards of Performance for New Stationary Sources,” under which the EPA establishes federal standards of performance for new sources within source categories which cause or contribute significantly to air pollution, which may reasonably be anticipated to endanger public health or welfare. We are amending 40 CFR part 60, subpart AAA, Standards of Performance for New Residential Wood Heaters. The current regulation (subpart AAA) applies to affected residential wood stoves manufactured since 1988. Except as discussed in this final rule, the current requirements would remain in effect for the heaters/stoves and model lines manufactured before this action. In this final rule, we also are broadening the applicability of the wood heaters regulation beyond adjustable burn rate heaters (i.e., “stoves”, the focus of the original regulation) to specifically include single burn rate heaters, pellet stoves, hydronic heaters, and forced-air furnaces. Heaters/stoves and model lines manufactured after the compliance dates would be required to meet fine particulate matter ($PM_{2.5}$) standards. Compliance upon the effective date of the final rule is the intention in section 111 of the CAA.

Revision of the current residential wood heaters NSPS is necessary to capture the improvements in performance of such units and to include additional wood-burning residential heating devices. The revisions are expected to achieve several objectives, including the application of updated emission limits reflecting the best emission reduction systems; elimination of exemptions over a broad suite of residential wood combustion devices; the strengthening of test methods as appropriate; and the streamlining of the certification process. The EPA proposed NSPS for new residential masonry heaters; however, we are not taking final action on these wood combustion devices at this time in order to allow additional time for the Masonry Heater Association (MHA) to finish their efforts to develop revised test methods and alternative compliance calculation procedures. This final rule does not include any requirements for heaters solely fired by gas, oil or coal. In addition, it does not include any requirements associated with wood heaters or other wood-burning appliances that are already in use. The EPA continues to encourage state, local, tribal, and consumer efforts to change out (replace) older heaters with newer, cleaner, more efficient heaters, but that is not part of this Federal rulemaking. These revisions help address the health impacts of particle pollution, of which wood smoke is a contributing factor in many areas. Particulate pollution from wood heaters is a significant national air pollution problem and human health issue. Health benefits associated with these regulations are valued to be much greater than the cost to manufacture cleaner, lower emitting appliances. These regulations would also significantly reduce emissions of many other pollutants from these appliances, including carbon monoxide, volatile organic compounds, hazardous air pollutants and black carbon. Emissions from wood stoves occur near ground level in residential communities across the country, and setting these new requirements for cleaner stoves into the future will result in substantial reductions in exposure and improved public health.

Wood smoke contains a mixture of fine particles and toxic air pollutants (e.g., benzene and formaldehyde) 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, 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. Each year smoke from wood heaters and fireplaces contributes hundreds of thousands of tons of fine particles throughout the country—mostly during the winter months. For more information on the health impacts from exposure to fine particles, please refer to Section 7 of this RIA. Nationally, residential wood combustion accounts for 44 percent of total stationary and mobile polycyclic organic matter (POM) emissions, which accounts for nearly 25 percent of all area source air toxics cancer risks and 15 percent of noncancer respiratory effects. Residential wood smoke causes many counties in the U.S. to either exceed the EPA's health-based national ambient air quality standards (NAAQS) for fine particles or places them on the cusp of exceeding those standards. For example, in places such as Keene, New Hampshire; Sacramento, California; Tacoma, Washington; and Fairbanks, Alaska; wood combustion can contribute over 50 percent of daily wintertime fine particle emissions. The concerns are heightened because wood stoves, hydronic heaters, and other heaters are often used around the clock in many residential areas. To the degree that older, dirtier, less efficient wood heaters are replaced by newer heaters that meet or exceed the requirements of this rule, the emissions would be reduced, and thus exposure as well, and fewer health impacts should occur.

This is an economically significant rule as defined by Executive Order 12866 and Executive Order 13563. Therefore, EPA is required to develop a regulatory impact analysis (RIA) as part of the regulatory process. The RIA includes an economic impact analysis (EIA), a small entity impacts analysis, an engineering cost analysis, and a benefits analysis along with documentation for the methods and results.

We present annualized average cost and benefit results for the time frame from 2015 to 2020; the cost analysis is analyzed over 10 years and emission reductions are analyzed to 2048. The final rule is described in detail in the preamble and in Section 2 of this RIA, and the emission limitation requirements in the final rule are summarized in Section 4. The respective dates of implementation for all affected appliance categories are captured by the range of dates included in the analyses. We estimate the impacts for this RIA for the time frame from 2015 to 2020 in order to provide an average of annualized results from the time of rule promulgation in 2015 to the time of full implementation of the final rule, which occurs by 2020. Because the potential environmental impacts can occur for 20 years or more, which is the typical useful life for wood heater appliances, the impacts for 20 years are also shown in the appendix within Section 9 of this RIA. The variability of annual impacts provides an appropriate rationale for presenting impacts averaged over this time frame. All results in this RIA are presented in 2013 dollars. Estimates of benefits and costs are discounted to the analysis year using both a 7% and 3% discount rates following Circular A-4, "Regulatory Analysis," which provides guidance to Federal agencies on the development of regulatory analyses required by Executive Order 12866.[1]

In addition, this final rule cannot be certified as not having a significant economic impact on a substantial number of small entities (SISNOSE) according to the provisions of the Small Business Regulatory Enforcement Fairness Act (SBREFA). Therefore, small entity impacts analysis presented in Section 6 constitutes a Final Regulatory Flexibility Analysis (FRFA). Section 6 also contains a summary of the proceedings and conclusions of a panel called to find ways to mitigate small entity impacts associated with this rule under the authority of the SBREFA.

1.1 Analysis Summary

The key results of the RIA are as follows:

- **Engineering Cost Analysis:** EPA estimates the revised NSPS's total annualized cost to affected manufacturers on average in the 2015–2020 time frame will be $45.7 million ($2013), with the total annualized cost estimate at a 7% discount rate. At a 3% discount rate, the total annualized cost will be $40.2 million.

- **Economic Impact Analysis:** The metric for economic impacts for industries affected by this NSPS are industry-level average annualized compliance costs to receipts (or

[1] Circular A-4 is available at: http://www.whitehouse.gov/omb/circulars_a004_a-4

sales) ratios. This metric is calculated as an average in the 2015–2020 time frame that is referred to above, and the estimates ranged from 1.1% for industries that produce pellet stoves to as much as 17.1% for industries that produce hydronic heaters. These results approximate the maximum price increase needed for a producer to fully recover the annual compliance costs and, therefore, do not presume any pass through of impacts to consumers. With pass through to consumers, these cost to sales impact estimates will decline proportionately to the degree of pass through assuming no change in consumer demand.

- **Social Cost Analysis:** For this RIA, the Agency assumes that the social cost is equal to the annualized cost to manufacturers. Therefore, the estimated average annual social costs of the final rule in the 2015-2020 timeframe are expected to be $45.7 million when discounted at 7%, and $40.2 million when discounted at 3%. See Section 5 of this RIA for more detail on the estimated social cost.

- **Small Entity Analyses:** EPA performed a screening analysis for impacts on small entities by comparing compliance costs to sales/revenues (e.g., sales and revenue tests). EPA's analysis showed the tests were higher than 1% for small entities included in the screening analysis; the 1% test estimate is often an indicator for significant impacts to small firms. For these industries, almost all (more than 90%) affected entities are small firms. We concluded that we could not certify that there would not be a significant economic impact on a substantial number of small entities (SISNOSE) for this final rule. Pursuant to section 603 of the RFA, EPA prepared a final regulatory flexibility analysis (FRFA) for the final rule and included a summary of the report from the Small Business Advocacy Review Panel convened to obtain advice and recommendations of representatives of the regulated small entities. A detailed discussion of the Panel's advice and recommendations is found in the final Panel Report (Docket ID No. EPA-HQ-OAR-2009-0734-0335. A summary of the Panel's recommendations is also presented in the preamble. In the final rule, EPA included provisions consistent with several of the Panel's recommendations.

- **Benefits Analysis**:

  - Monetized benefits in this RIA include those from reducing particulate matter (PM). These benefits reflect reductions of nearly 8,300 tons annually of fine particulate matter ($PM_{2.5}$) on average during the 2015–2020 time frame. All monetized benefits are annual estimates for each year during the 2015-2020 time frame that are then averaged to a single estimate and then presented in this RIA. All monetized benefits reported reflect improvements in ambient $PM_{2.5}$ concentrations due to emission reductions of direct $PM_{2.5}$. As a result, the monetized benefits likely underestimate the total benefits, however, the extent of the underestimate is unclear. Monetized benefits reflect those associated with reductions in premature mortality due to lower ambient $PM_{2.5}$ concentrations resulting from implementation of the NSPS. Other benefits categories from $PM_{2.5}$ reductions, such as changes in visibility, are assessed qualitatively in this analysis.
  - Using a 3% discount rate, we estimated the total annual monetized benefits of the NSPS to be $3.4 billion to $7.6 billion based on estimates in studies performed by

Krewski and Lepeule, in the 2015–2020 time frame. Using a 7% discount rate, we estimate the total annual monetized benefits of the NSPS to be $3.1 billion to $6.9 billion in the 2015–2020 time frame. Using alternative relationships between $PM_{2.5}$ and premature mortality supplied by experts, higher and lower benefits estimates are plausible, but most of the expert-based estimates fall between these estimates.

– The benefits from reducing some air pollutants have not been monetized in this analysis due to data and resource constraints, including reducing 46,000 tons of carbon monoxide (CO), 9,300 tons of volatile organic compounds (VOCs), and undetermined amounts of black carbon and HAP. Data, resources, and methodological limitations prevented EPA from monetizing the benefits from these important benefit categories. We assessed the benefits of these emission reductions qualitatively in this RIA.

– Due to analytical limitations, it was not possible to conduct air quality modeling for this rule. Instead, we used a "benefit-per-ton"(BPT) approach to estimate the benefits resulting from this rulemaking. EPA has applied this approach in several previous RIAs, in particular the Particulate Matter Regulatory Impact Analysis, (PM-RIA). These BPT estimates provide the total monetized human health benefits (the sum of premature mortality and premature morbidity) of reducing one ton of $PM_{2.5}$ (or $PM_{2.5}$ precursor such as NO_x or sulfur dioxide (SO_2)) from a specified source. The national-average benefit-per-ton estimates used here reflect the geographic distribution of the modeled emissions, which may not exactly match the emission reductions in this rulemaking, and they may not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other related factors for any specific location. The photochemical modeled residential wood combustion-attributable $PM_{2.5}$ concentrations used to derive the BPT values may not match well the change in air quality resulting from the emissions controls described in Section 4 of this RIA. For this reason, the health benefits reported here may be larger, or smaller, than those realized by this rule.

- **Net Benefits:** For the residential wood heater NSPS, the net annual benefits (benefits minus the costs) are $3.4 billion to $7.6 billion ($2013) at a 3% discount rate and $3.1 billion to $6.9 billion ($2013) at a 7% discount rate in the 2015–2020 time frame. All net benefits are in 2013 dollars.

1.2 Organization of this Report

The remainder of this report supports and details the methodology and the results of the RIA:

- Section 2 describes the final regulation.
- Section 3 presents the profile of the affected industries.

- Section 4 describes the baseline emissions and emission reductions for the alternatives analyzed for this rule.
- Section 5 describes the engineering costs, economic impacts, analyses to comply with Executive Orders, and employment impacts.
- Section 6 describes the small entity impact analyses and the Final Regulatory Flexibility Analysis (FRFA) prepared by EPA.
- Section 7 presents the benefits estimates and supporting methodology for the analysis.
- Section 8 presents the net benefits (benefits minus costs) for this final rule.
- Section 9 presents references for the RIA and documentation on the cost analysis and estimates of costs and emission reductions for the final rule beyond 2020.

Table 1-1. Summary of the Monetized Benefits, Social Costs, and Net Benefits for the Residential Wood Heaters NSPS in the 2015–2020 Time Frame ($2013 millions)[a]

	3% Discount Rate			7% Discount Rate		
Final Rule						
Total Monetized Benefits[b]	$3,400	To	$7,600	$3,100	to	$6,900
Total Social Costs[c]		$40			$46	
Net Benefits	$3,400	To	$7,600	$3,100	To	$6,900
Nonmonetized Benefits	46,100 tons of CO					
	9,300 tons of VOC					
	Reduced exposure to HAPs, including formaldehyde, benzene, and polycyclic organic matter					
	Reduced Climate effects due to reduced black carbon emissions					
	Ecosystem effects					
	Reduced visibility impairment					

[a] All estimates reflect average annual estimates for the time frame from 2015 to 2020 inclusive, and are rounded to two significant figures. These results include appliances anticipated to come online and the lowest cost disposal assumption. Total annualized costs are estimated at a 7% and at a 3% interest rate to be consistent with OMB guidance.

[b] The total monetized benefits reflect the human health benefits associated with reducing exposure to $PM_{2.5}$ through reductions of directly emitted $PM_{2.5}$. It is important to note that the monetized benefits include many but not all health effects associated with $PM_{2.5}$ exposure. Benefits are shown as a range from Krewski et al. (2009) to Lepeule et al. (2012). These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. Because these estimates were generated using benefit-per-ton estimates, we do not break down the total monetized benefits into specific components here. See Figure 7-1 of this RIA for an illustration of the breakdown, or the RIA for the final Cross-States Air Pollution Rule (EPA, 2011) for more information.

[c] The annualized social costs are $40.2 million for the final NSPS at a 3% discount rate and $45.7 million when calculated at a 7% interest rate.

SECTION 2
INTRODUCTION

2.1 Background for Rule

EPA is amending the New Source Performance Standard (NSPS) for new residential wood heaters. EPA promulgated the original NSPS for new residential wood heaters including wood stoves in 1988. Based on a review of the NSPS that began in 2009, EPA noted significant technological improvements that allow emissions from these sources to be better controlled than the current standard. Residential Wood Combustion remains one of the five largest categories of PM emissions according to the 2008 National Emissions Inventory.[2] Thus, EPA is revising the current NSPS standards to improve regulation of wood heaters and broaden the new regulation to include other residential heating devices. Specifically, EPA is amending subpart AAA, Standards of Performance for New Residential Wood Heaters. We are also issuing a new subpart to address additional types of wood heating appliances—subpart QQQQ, Standards of Performance for New Residential Hydronic Heaters and Forced-Air Furnaces. [Note the rule uses the terms stoves and heaters interchangeably. Also, the rule uses the terms heaters and furnaces interchangeably.]

The 1988 NSPS developed a stepped compliance approach that provided a reasonable, phased implementation of emission limits for manufacturers. We believe such an approach is prudent also for revised subpart AAA and new subpart QQQQ to allow manufacturers lead time to develop, test, field evaluate and certify current technologies across their consumer product lines and in most cases for retailers to sell-through inventory. In 1988, there were concerns about the capacity of accredited laboratories to conduct certifications tests and time for the EPA to review the tests and adequately assure compliance if all the NSPS requirements were to be immediate. Similar concerns have been expressed in the development of the proposed and final rules. Thus, revised subpart AAA and new subpart QQQQ have stepped requirements beginning upon the effective date of this final rule.

All new residential wood heaters subject to subpart AAA will be required to meet Step 1 PM emission limits on the effective date, i.e., 60 day after publication in the Federal Register. Five years later, subpart AAA will require new heaters to meet Step 2 PM emision limits. Subpart AAA allows a retail sell-through until December 31, 2015, to allow retailers to sell their inventory for the heating season. Also, the final rule includes automatic certification for many

[2] U.S. EPA, 2008 National Emissions Inventory. Accessed on Sept. 11, 2012.

Step 1 models and temporary conditional approval of some models for up to 1 year to minimize potential certification delays.

All new residential hydronic heaters subject to subpart QQQQ will be required to meet Step 1 PM emission limits on the effective date. Five years later, subpart QQQQ will require new hydronic heaters to meet Step 2 PM emision limits. Subpart QQQQ allows a retail sell-through for hydronic heaters until December 31, 2015, to allow retailers to sell their inventory for the heating season. Also, the final rule includes automatic certification for many Step 1 models and temporary conditional approval of some models for up to 1 year to minimize potential certification delays.

All new forced-air furnaces subject to subpart QQQQ will be required to meet work practice/operational standards on the effective date. Small furnaces will be required to meet Step 1 PM emission limits, 1 year after the effective date. Larger furnaces will be required to meet Step 1 PM emission limits, 2 years after the effective date. Subpart QQQQ will require new hydronic heaters to meet Step 2 PM emision limits 5 years after the effective date. Subpart QQQQ does not allow a retail sell-through for forced-air furnaces because the work practice/operational standards can be promptly met without the concerns of potential certification delays discussed above for other heaters. Also, the final rule includes automatic certification for some Step 1 models and temporary conditional approval of some models for up to 1 year to further minimize potential certification delays.

The following sections describe the major provisions of this subpart. Full details of the provisions in this subpart can be found in the preamble for this final rule.

2.2 Room Heaters

The 1988 promulgated subpart AAA (53 FR 5860, February 26, 1988), *i.e*., the 1988 NSPS, applies to affected appliances manufactured since 1988. The emission limits will remain in effect for those heaters and model lines manufactured before the effective date of this final rule. After the effective date, new heaters will be required to meet the updated emission standards. We are broadening the applicability beyond adjustable burn rate wood heaters (the focus of the original regulation) but also to single burn rate wood heaters/stoves, pellet heaters/stoves, and any other affected appliance as defined in revised subpart AAA as a “room heater.” Subpart AAA, as amended, does not apply to new residential hydronic heaters or new residential forced-air furnaces because they are subject to their own subpart. Like the 1988 NSPS, the revised subpart AAA does not apply to fireplaces because they typically are not effective heaters. This final rule tightens the definition for “cook stoves” and adds definitions for "camp stoves" and "traditional Native American bake ovens" to clarify that they are not subject to the standard other than appropriate labeling for cook stoves and camp stoves and no requirements for traditional Native American bake ovens. Finally, the revised subpart AAA clarifies that the emission limits apply only to wood-burning devices (*i.e.*, not to devices that only burn fuels other than wood, *e.g.*, gas, oil or coal).

NSPS determinations of the best system of emission reductions (BSER), formerly referred to as best demonstrated technology (BDT), must consider costs (see section II of the preamble for more detail). The fact that this rule applies to consumer products manufactured for sale results in cost considerations that are fundamentally different from most NSPS. Specifically, the cost of potential lost revenues if production and sales were to be suspended while designing, testing, field evaluating and certifying cleaner models would be significant and necessitates reasonable lead times for compliance with emissions limitations. This was a concern in 1988, and is still true today. Thus, we are giving automatic approval to heaters/stoves with EPA certification currently in effect that can meet the Step 1 PM emission levels until the Step 2 PM emission limit compliance e date. Note that over 85 percent of all heaters/stoves (except single burn rate stoves) being sold today already meet the Step 1 PM emission limit. While our top priorities are to ensure that emission reductions occur in a timely manner and that there is no backsliding from the improvements that many manufacturers have already made, it is also important to avoid unreasonable economic impacts on those manufacturers (mostly small businesses) who need additional time to develop a full range of cleaner models. This should also help avoid potential delays" at laboratories conducting certification testing. Also, the final rule includes temporary conditional approval of some models for up to 1 year to further minimize potential certification delays.

As indicated above, we are promulgating a phased implementation approach that will apply to all new adjustable burn rate wood heaters, single burn rate wood heaters and pellet heaters/stoves required to comply with the stepped PM emission limits specified in the final rule. Under this approach, the Step 1 PM emission limits will apply to each heater (1) manufactured on or after the effective date of the final rule or (2) sold at retail on or after December 31, 2015 (approximately 8 months after the expected effective date of the final rule). Step 2 PM emission limits will apply to each adjustable rate wood heater, single burn rate wood heater and pellet heater/stove manufactured or sold 5 years after the effective date of the final rule.

Table 2-1 summarizes the compliance dates and PM emissions standards that will apply to each wood heater appliance. Note that the emissions standards are "as measured" by the test methods specified in the rule and labeled as PM although the PM is essentially all direct $PM_{2.5}$.

Table 2-1. Subpart AAA Compliance Dates and PM Emissions Standards

Appliance	Compliance Date	PM Emissions Limit
Adjustable Rate Wood Heaters, Single Burn Rate Wood Heaters or Pellet Stoves,	Step 1: upon effective date of final rule	4.5 g/hr
	Step 2: 5 years after effective date of final rule	2.0 g/hr
	Step 2: cordwood alternative compliance option	2.5 g/hr

We are allowing an alternative compliance option for manufacturers who choose to certify using cord wood (rather than crib wood) to meet the Step 2 PM emission limits. Special permanent (required) and temporary (voluntary hangtags) labels for room heater models (wood/pellet stoves) certified with cord wood would specify that they meet a PM emissions limit of 2.5 g/hr. As discussed in the preamble to the final rule, the cord wood option (voluntary) of 2.5 g/hr for wood stoves is based on (1) the cord wood test data submitted to the EPA for three catalytic or hybrid wood stoves and that are included in the Notice of Data Availability (NODA) for this rule (79 FR 37259, July 1, 2014), (2) the 1995 Washington State catalytic stove emission standard of 2.5 g/hr (using cribs) and (3) the fact that this value is 25 percent higher than the 2.0 g/hr regulatory requirement for cribs (allowing some cushion for measurement imprecision versus the several stoves that have been shown to achieve PM emissions as low as 1.3 g/hr or better). Several models of catalytic wood stoves can meet this cord wood limit already. We believe this value is a good balance that recognizes the industry leaders and encourages others to follow quickly.

Although the 1988 NSPS included an additional 1-year compliance extension for low-volume manufacturers, *i.e.*, companies that manufacture (or export to the U.S.) fewer than 2,000 heaters per year, this revised subpart AAA does not include a similar compliance extension. We are not allowing a delay for manufacture of adjustable burn rate heaters (i.e., all types of wood stoves listed except the single burn rate stoves) because over 85 percent of these appliances already comply with Step 1 emission levels.

In this final rule, we have a single determination of BSER for both catalytic and noncatalytic heater systems, and hybrid heater systems so as not to restrict open market competition. As in the 1988 NSPS, we are requiring manufacturers to provide warranties on the catalysts and prohibit the operation of catalytic stoves without a catalyst and require operation according to the owner's manual. In addition, we are requiring manufacturers to provide warranties for noncatalytic and hybrid/heater stoves and require operation according to the owner's manual.

We are not requiring efficiency standards at this time, however, we are requiring testing and reporting of these data to the EPA. We will include this information on the EPA website. This will help inform consumers now to enable them to choose heaters that use less fuel and thus are cheaper to operate and emit less PM and also provide data for us to consider for a future rulemaking.

We are requiring emission testing, reporting, and certification based on crib wood to demonstrate compliance with Step 1 and Step 2 PM standards. As discussed above, although the standard and test method are based on crib wood test fuel, manufacturers may choose an alternative compliance option (voluntary) instead to test with cord wood fuel to certify compliance. As discussed in the preamble to the proposed rule, "crib wood" is a specified configuration and quality of dimensional lumber and spacers that improves the repeatability of the test method. "Cord wood" is a different specified configuration and quality of wood that is intended today to more closely resemble what a typical homeowner would use. As discussed in section III.A of the preamble, we are allowing compliance option for manufacturers who choose to certify compliance based on cord wood testing. We hope that many manufacturers will choose this option so that consumers will have additional marketplace choices of stoves that are tuned for the real world cord wood that they will be using rather than being tuned for laboratory crib wood tests. Stakeholders agree that tuning for the laboratory crib wood tests often results in poorer performance in homes. Additionally, we hope that within the next few years we will receive considerable cord wood test data that would allow us to establish a cord wood test-based regulatory requirement for the next NSPS revisions.

At this time, we lack sufficient data to require a separate CO emissions standard in this final rule. However, we are taking final action to require manufacturers to determine CO emissions during the compliance tests, report those results to the EPA and include those results on the manufacturer's website, so that data will be available to consumers, and to the EPA and states for possible future rulemaking. We will also post context and consumer-friendly summaries of the date on the EPA Burn Wise website.

Like the 1988 subpart AAA, the EPA is using its authority under Section 114 of the CAA to require each manufacturer to submit applications for certifications of compliance with this final rule for all new models. We are revising the certification process to include third-party certifiers in order to reduce the potential for certification delays that could result from insufficient capacity. Also, based on concerns expressed by commenters that there may not be sufficient third-party certifier capacity and review and approval capacity by EPA, especially in the first year, EPA has added an automatic, conditional, temporary approval by EPA based on the manufacturer's submittal of a complete certification application. The application must include the full test report by an EPA-accredited laboratory and all required compliance statements by the manufacturer. The conditional approval would allow manufacture and sales for 1 year or until EPA review of the application, whichever is earlier. Within that year, the manufacturer must submit a certificate of conformity by a third-party certifier.

We are revising the definition of "Accredited Test Laboratory," from only EPA-accredited laboratories to include laboratories accredited by a nationally recognized accrediting body/entity to perform testing for each of the test methods specified in this NSPS under ISO-IEC[3] Standard 17025. Laboratories must be approved by the EPA before beginning certification testing. Current EPA-accredited laboratories may retain their accreditation until 3 years after the effective date of this final rule. Laboratories that are not currently EPA-accredited must achieve ISO-accreditation and register with the EPA within 6 months of the effective date of this rule. Laboratories must report any changes in their accreditation and any deficiencies found under ISO 17025 to the EPA, and the EPA may revoke the approval if warranted.

The EPA is requiring a "Certifying-Body-Based Certification Process" " (tempered with the automatic, conditional temporary approval up to 1 year discussed above) beginning 6 months after the effective date of this final rule for all heaters/stoves except hydronic heaters. For hydronic heaters the "Certifying-Body-Based Certification Process" is required upon the effective date of this final rule because this certification process has already been successfully used under EPA's hydronic heater Partnership Program since October 2008 and over 50 hydronic heater models already have Phase 2 qualifications using this process. Under this process for all heaters/stoves subject to subparts AAA and QQQQ, after testing is complete, a certification of conformity with the PM emissions standards must be issued by a certifying body with whom the manufacturer has entered into contract for certification services. The certification body must be accredited under ISO-IEC Standard 17065 and register their credentials with the EPA and receive EPA approval to conduct any certifications or related work used as a basis for compliance with this rule and report any changes in their accreditation and any deficiencies

[3] The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) prepare and publish international standards.

found under ISO 17065. Any certifying body that is approved by the EPA and is ISO-accredited is required to act in such a way that will not create a conflict of interest and work with integrity and honesty. The EPA will oversee the certification body's work and retain the right to revoke the approval if appropriate. Upon review of the test report and quality control plan submitted by the manufacturer, the certifying body may certify conformity with the NSPS requirements initial compliance requirements and submit the required documentation to the EPA's Office of Enforcement and Compliance Assurance for review, approval and listing of the certified appliance.

In addition to the PM emissions standards, we require the owner or operator of a wood heating appliance to operate the heater consistent with the owner's manual and not burn improper fuel, as did the 1988 rule. Owners and operators must operate pellet fuel appliances with the grades of pellet fuels that are included in the owner's manual. Manufacturers are required to void their warranties in cases of improper operation. Numerous states expressed their support for the continuation of these requirements. Some states and local jurisdictions have enforced similar requirements, and this final rule will allow potential delegation of enforcement authority of these NSPS requirements.

The rule is revised to clarify that this rule includes requirements similar to the 1988 NSPS requirements to operate according to the owner's manual, including a list of prohibited fuel types that create poor or even hazardous combustion conditions and including operation of pellet fuel appliances only with the grades of pellet fuels that are included in the certification tests, or better. We proposed that pellets for the certification tests be only those that have been produced under a licensing agreement with the Pellet Fuels Institute (PFI), or equivalent (after request and subsequent approval by the EPA), to meet certain minimum requirements and procedures for a quality assurance process. Commenters indicated that additional organizations are currently available and others are planned, for example, ENplus and CANplus. Thus, the final rule require that pellets for the certification tests be only those that have been graded under a licensing agreement with a third-party organization and meet the minimum quality specifications in § 60.532. Details of the PFI program are available at http://pelletheat.org/pfi-standards/pfi-standards-program/ . Details of the ENplus program are at http://www.enplus-pellets.eu/wp-content/uploads/2012/01/ENplus-Handbook-2.0.pdf . Details of the CANplus program are at http://controlunion.ca/fileupload/CA/Certifications/ENplusCANplus/CANplus_handbook_v2-0.pdf. Manufacturers' data show that pellet fuel quality assurance is necessary to ensure that the appliances operate properly such that emissions are reduced as intended.

The rule continues to contain the crucial quality assurance provisions in the 1988 NSPS. For example, manufactures must request EPA approval of model line recertifications or new certifications whenever any change is made in the original design that could potentially affect the emissions rate for that model line or when any of several specified tolerances of key components are changed. The 1988 requirements for manufacturer quality assurance programs are strengthened in the revised rule by requiring the manufacturer to contract for a certifying-body to begin conducting quality assurance audits within 12 months. As required by ISO 17065, the certifying body will conduct regular, unannounced audits to ensure that the manufacturer's quality control plan is implemented properly.

The EPA audit testing programs of the 1988 NSPS under the authority of CAA Section 114 are streamlined and simplified to better ensure compliance and to clarify that audits can be based on any information the EPA has available and that audits do not need to be statistically random. Also, the rule clarifies the existing practice of allowing EPA and states to be present during the audits and that states (and any other entities, including the public) may provide the EPA with information that may ultimately be used in any EPA enforcement and compliance assurance efforts.

2.3 Central Heaters: Hydronic Heaters and Forced-Air Furnaces

The new subpart QQQQ will apply to new wood-fired residential hydronic heaters and forced-air furnaces and any other affected appliance defined in subpart QQQQ as a "central heater." These appliances are described in more detail in Section 3 of this RIA. This new "central heater" categorization better ensures that all appliances potentially affected under subpart QQQQ are included in this final action. Adding subpart QQQQ addresses heater appliance types in the 1987 residential wood heater source category listing that were not regulated by the 1988 NSPS. This new subpart is designed using principles similar to those in subpart AAA, *i.e.*, certification testing of a representative unit in a model line, label requirements, associated quality assurance requirements and stepped (phased) implementation.

In this final rule we make clear that those hydronic heaters with valid EPA Phase 2 qualifications under the EPA Hydronic Heater Partnership Agreement of October 12, 2011, or hydronic heaters or forced-air furnaces approvals by the New York State Department of Environmental Conservation (NYSDEC) that show compliance with the Step 1 PM emission, will be automatically deemed as certified to meet the Step 1 PM emission limits under this final rule until the Step 2 PM emission level compliance date. Also, residential pellet hydronic heaters/boilers that have been qualified under the Renewable Heat New York (RHNY) program will be automatically deemed certified to meet the Step 1 PM emission limits. No separate certification will be required for those models. Similarly, forced-air furnaces certified under Canadian Standards Association (CSA) B415.1-10 that show compliance with the Step 1 PM emission limits will be automatically deemed as certified to meet the Step 1 PM emission limits under this final rule until the Step 2 PM emission limit compliance date. This automatic certification will avoid unnecessary economic impacts on those manufacturers (over 90 percent are small businesses) who can then focus their efforts on developing a full range of cleaner models that meet Step 2 emission levels. This measure should also help reduce potential delays at laboratories conducting certification testing for heaters newly subject to the NSPS.

The provisions of subpart QQQQ apply to each affected unit that is manufactured or sold on or after the effective date of the final rule**.** Table 2-2 summarizes the compliance dates and PM emissions standards for new residential hydronic heaters and forced-air furnaces that will apply at each step. Note that the emissions standards are "as measured" by the test methods specified in the rule and labeled as PM although the PM is essentially all direct $PM_{2.5}$. The Step 1 emission limit for new residential hydronic heaters and forced air furnaces will apply upon the effective date of the final rule. The final Step 2 PM emission limit for residential hydronic heaters and forced-air furnaces will apply 5 years after the effective date of the final rule.

We are allowing an alternative compliance option for hydronic heater manufacturers who choose to certify using cord wood (rather than crib wood) to meet the Step 2 PM emission limits. The proposal would have required cord wood for all Step 2 PM emission limit compliance certifications. Cord wood testing is a better measure of how heaters actually perform in home use; however, we are concerned that many manufacturers do not yet have experience with designing their heaters to perform well with cord wood testing. Numerous manufacturers may not be ready by the Step 2 PM emission limit compliance date and that could result in unreasonable economic impacts. Allowing this option acknowledges the efforts of the industry leaders and encourages others to follow their example. Special permanent (required) and temporary (voluntary hangtags) labels for heaters certified with cord wood would specify that they meet a PM emissions limit of 0.15 lb/MMBtu heat output.

Table 2-2. Subpart QQQQ Compliance Dates and PM Emissions Standards

Appliance	Compliance Date	Particulate Matter Emissions Limit
Residential Hydronic Heater	Step 1:Upon effective date of final rule	0.32 lb/MMBtu heat output (weighted average) and a cap of 18.0 g/hr for each individual test run
	Step 2: 5 years after effective date of final rule	0.10 lb/MMBtu heat output for each individual burn rate
	Step 2: cordwood alternative compliance option	0.15 lb/MMBtu heat output for each individual burn rate
Forced-Air Furnace	Work practice/operational standards: Upon effective date of final rule	No specified PM emission value
	Step 1 PM emission limit for small furnaces (<65,000 BTU/hr output): 1 year after effective date	0.93 lb/MMBtu heat output (weighted average) and a cap of 18.0 g/hr for each individual test run
	Step 1 PM emission limit for larger furnaces: 2 years after effective date	0.93 lb/MMBtu heat output (weighted average) and a cap of 18.0 g/har for each individual test run
	Step 2 PM emission limit: 5 years after effective date of final rule rule [Note: The CSA B415.1-10 test method already specifies cord wood.]	0.15 lb/MMBtu heat output for each individual test run

We are not making separate determinations of BSER for catalytic, noncatalytic, and hybrid appliances in order to not restrict open market competition. As in 1988, we are requiring manufacturers to provide warranties on the catalysts, prohibit the operation of catalytic appliances without a catalyst and require operation according to the owner's manual. In addition, we are requiring manufacturers to provide warranties for noncatalytic and hybrid appliances and require users to operate according to the owner's manual.

As discussed at proposal, we considered requiring efficiency standards (heat output divided by fuel input) to ensure that heaters are efficient and burn no more wood than necessary for the heat demand so that the consumers can save money on fuel and so that the emissions are lower. We did not propose an efficiency standard because we concluded we do not yet have sufficient data, but we are using our authority under Section 114 to require efficiency testing and reporting to the EPA. We will include this information on the EPA Burn Wise website. This will help .

At this time, we lack sufficient data to issue a CO emissions limit in today's final rule. However, we are using our authority under Section 114 to require manufacturers to determine CO emissions during the compliance tests (as typically conducted), report those results to the EPA and include those results on the manufacturer's website, so that data will be available to consumers, and to the EPA and states for possible future rulemaking. We also plan to post context and consumer-friendly summaries of the submitted data on the EPA Burn Wise website.

In this final rule, we are not setting limits on visible emissions, and we are not prohibiting use in non-heating seasons. However, operators should note that some state, local and tribal jurisdictions have specific limits, prohibitions and other requirements that must be followed.

Like the subpart AAA requirements, the subpart QQQQ requirements provide a retail sell-through for hydronic heaters until December 31, 2015 so that retailers can sell their inventory for the heating season of units manufactured before the compliance date. For forced-air furnaces, the work practice/operational standards required on the effective date can be promptly met so there is no need for a retail sell-through for those models

As in subpart AAA, subpart QQQQ includes a list of prohibited fuels because their use would cause poor combustion or even hazardous conditions. Also, as in subpart AAA, subpart QQQQ requires that the user must operate the hydronic heater or forced-air furnace in a manner that is consistent with the owner's manual. For pellet-fueled appliances, operation according to the owner's manual includes operation only with pellet fuels that are specified in the owner's manual or better. As in subpart AAA, manufacturers must only specify graded and licensed pellets that meet certain minimum requirements or better. Data show that pellet quality is important to ensure that the appliances operate properly such that emissions are within the appliance certification limits.

The permanent labeling requirements and owner's manual requirements in subpart QQQQ are similar to the guidelines in the EPA's current voluntary hydronic heater program with some improvements. Like in subpart AAA, the temporary labels (voluntary hangtags) are only for models that meet Step 2 levels before the compliance date and these voluntary hangtags end upon the Step 2 compliance date. Subpart QQQQ also has a cord wood alternative compliance option with a special permanent label and temporary label (voluntary hangtag) for models that meet Step 2 using cord wood. The structure of the rest of subpart QQQQ is similar to the subpart AAA certification and quality assurance process.

The final rule requires that before manufacture all affected hydronic heaters and forced-air furnaces subject to new subpart QQQQ PM emission limits must conduct certification compliance testing, submit a certificate of compliance and receive EPA approval for the PM emission limits by the deadlines shown in Table 2-2.

The final rule requires testing of hydronic heaters by one of the following methods: EPA Method 28 WHH, EPA Method 28 WHH- ASTM E2618-13, or EN 303--05 with certain adjustments and conditions specified in the rule. As with all NSPS, affected sources may request EPA approval of alternative test methods on a case-by-case basis as appropriate. See CAA Part 60, Subpart A, General Provisions at 60.8.

In this final rule, the EPA is relying on the cord wood test method that has been developed by the CSA for forced-air furnaces. The current version of CSA B415.1-10 was published in March 2010, and it includes not only the forced-air furnace test method but also Canadian emission performance specifications for indoor and outdoor central heating appliances. (The Step 1 PM emission level of 0.93 lb/MMBtu heat output is identical to the CSA B415.1-10 standard that was issued in 2010.) Also, in this final rule we are relying on efficiency test methods that have been developed by the CSA.

2.4 Summary of Significant Changes to the Rule Following Proposal

2.4.1. Particulate Emission Standards

2.4.1.1. Room Heaters

The EPA is changing the proposed Step 2 PM emissions limit for new residential room heaters, including catalytic and noncatalytic adjustable rate wood heaters, single burn rate wood heaters or pellet heaters/stoves from 1.3 g/hr to 2.0 g/hr using crib wood. (Note that the emissions standards are "as measured" by the test methods specified in the rule and labeled as PM although the PM is essentially all direct $PM_{2.5}$.) Compliance for room heaters will be determined using the weighted average of burn rates rather than requiring each individual burn rate to meet the limit. To reduce potential certification delays and unnecessary costs for small businesses, we are adding automatic deeming of Step 1 certification for models with valid EPA certifications under the 1988 NSPS that show that that the models achieve the Step 1 PM emission levels. Manufacturers may choose to test using either crib wood or cord wood. Testing with cord wood is not required for new residential room heaters under this final rule. If the manufacturers voluntarily choose the cord wood alternative compliance option, the PM emission limit for cord wood is 2.5 g/hr. Although the number is higher, the cord wood test method is more reflective of fuel that is used in homes and the data available to the EPA indicate that this emission level is at least as stringent as the 2.0 g/hr primary crib wood testing emission limit.

If the wood heater/stove manufacturer chooses to perform certification testing using cord wood, the manufacturer may use a special EPA label for these certified models which recognizes that cord wood testing more closely reflects actual in-home use.

The retail sell-through period has been extended from 6 months after the effective date to December 31, 2015, to better cover the heating sales season.

2.4.1.2. Central Heaters: Hydronic Heaters and Forced-Air Furnaces

For new residential hydronic heaters and forced-air furnaces, the EPA is increasing the proposed Step 1 emissions cap of 7.5 g/hr for any individual test run to 18.0 g/hr to match the Phase 2 qualification levels in the EPA hydronic heater voluntary program. The final rule deems hydronic heater models automatically certified to the Step 1 PM emission level if they are qualified as meeting the Phase 2 emissions level under the EPA's voluntary program. To reduce potential certification delays and unnecessary costs for small businesses, we are also adding automatic Step 1 certification for new hydronic heater models that have NYSDEC approval of tests that demonstrate that the models achieve the Step 1 levels or are RHNY-qualified pellet hydronic heaters. Similarly, we are adding automatic Step 1 certification for forced-air furnaces that are certified under CSA B415.1-10 to meet the Step 1 PM emissions level.

We are changing the proposed hydronic heater Step 2 PM emissions limit of 0.06 lb/million BTU heat output for each burn rate to a final emissions limit of 0.10 lb/million BTU heat output for each burn rate, tested on crib wood. Manufacturers may choose to test using either crib wood or cord wood. If the manufacturer chooses the cord wood alternative compliance option, the Step 2 PM emission limit for cord wood is 0.15 pounds per million BTU heat output using cord wood. Although the number is higher, the cord wood test method is more reflective of the fuel that is used in homes and the limited cord wood data available to the EPA indicate that this emission level is at least as stringent as the 0.10 lb/million BTU heat output crib wood testing emission limit. There is no crib wood Step 2 PM emission level for forced-air furnaces because CSA B415.1-10 already specifies the use of cord wood test fuel.

If hydronic heater manufacturers and forced-air furnace manufacturers choose to test with cord wood, they are allowed to use special permanent EPA labels and temporary EPA labels (voluntary hangtags) for these certified models, which recognized that cord wood testing more closely reflects actual operation under in-home-use conditions.

2.4.1.3. Masonry Heaters

As stated in section III of the preamble, the EPA is not taking final action on new residential masonry heaters at this time. Comments indicated that the Masonry Heater Association (MHA) needs more time to finish their efforts to develop revised test methods, alternative compliance calculation procedures and dimensioning procedures. The MHA comments stated that the cost of testing is high and impractical because almost all are custom-built onsite. After we receive additional information from MHA and others, we will consider taking final action for new residential masonry heaters in a future rulemaking.

The potential emission impact of this delay is small. Fewer than 1,000 masonry heaters are built each year. Most manufacturers build fewer than 15 heaters per year. The total nationwide annual emissions are estimated to be less than 10 tons of $PM_{2.5}$.

2.4.2. Appliance Certification and Accreditation of Laboratories and Certifying Entities

In section III.D of the preamble to the proposed rule, we described the proposed approach for a third-party certification program by an International Organization for Standardization (ISO)-accredited certifying body and testing by ISO-accredited testing laboratories. This approach requires manufacturers to use third-party, independent ISO-accredited and EPA-approved test labs and certifying entities to demonstrate compliance with a representative appliance for a model line.

Under the Administrator Approval Process (see section 60.533(c) of the proposed rule), we proposed a transition period of 1 year from the effective date of the final rule for test labs to receive ISO accreditation through an EPA-recognized accreditation body. In this final rule for room heaters and central heaters, we are increasing the transition period for test laboratories that are currently EPA-accredited from 1 year to 3 years from the effective date of this final rule. This additional time for test laboratory accreditation will reduce concerns about costs for small labs and potential testing delays.

We proposed that certifying entities be required to receive ISO accreditation upon the effective date of the final rule; however, commenters stated that ISO accreditations can take 6 months. Requiring use of ISO-accredited certifying bodies/entities on the effective date of the final rule can be difficult for small manufacturers of wood stoves/heaters and forced-air furnaces, which previously have not been required to obtain certifications from ISO-accredited certifying bodies/entities; therefore, we are allowing a 6-month transition for models other than hydronic heaters. The 6-month transition period does not apply to hydronic heaters because they already use ISO-accredited certifying bodies/entities for the EPA's Voluntary Partnership Program.

SECTION 3
INDUSTRY PROFILE

The revisions to the NSPS for residential wood heaters would cover a number of devices that include wood stoves/heaters, pellet stoves/heaters; indoor and outdoor hydronic heaters and forced-air furnaces. (This RIA and the final rule use the terms stove, heater, and stove/heater interchangeably.) EPA has developed this industry profile to provide the reader with a general understanding of the technical and economic aspects of the industries that would be directly affected by potential revisions to the NSPS regulation for new residential wood heaters and to offer information relevant to preparing an economic impact analysis (EIA) for this revision to the NSPS. We begin by outlining the supply side by discussing the production process for wood heaters and the associated costs and follow this with an overview of the demand side of the market for residential wood heaters as a primary or secondary home heating system. We then address the characteristics that define the residential wood heating market and profile the companies that produce wood heating systems. Although the wood heating equipment industry includes multiple product markets, there is little published information about the intricacies of each individual market. For this profile, we analyzed the wood heating market primarily on an aggregated level and provide detailed information for specific product markets when such information is available.

3.1 Supply Side

Wood heating devices embody a variety of products that provide heat for residential consumers by burning wood or other solid biomass fuel. Indoor wood-burning devices can provide space heating for a single room or can be central heaters for a residential home. Indoor heating devices include freestanding wood stoves, pellet stoves, fireplace inserts, and forced-air furnaces. Outdoor wood heating devices, also known as outdoor wood boilers, or water stoves, are typically located adjacent to the home they heat in small sheds with short smoke stacks. Other products considered in the development of revisions of this NSPS (but not included in this rulemaking) include low-mass fireplaces, open masonry fireplaces, fireplaces, fire pits, chimineas, cook stoves, masonry heaters, and pizza ovens Masonry heaters were included in the proposed NSPS, but are not included in the final NSPS. The basis for the removal of masonry heaters from this rule can be found in Section 2 of this RIA or the preamble to the final rule.

This section provides a general description of the residential wood heater manufacturing processes. We then provide more detailed definitions of the indoor and outdoor wood heater products considered and the wood fuels used in their operation.

3.1.1 Production Process

The manufacturing process for residential wood heaters varies depending on the product type being produced. Generally, the manufacturing process entails the assembly of several prefabricated metal components. Major inputs include cast iron, metal products, heat-proof glass, fireproof fabric insulation, refractory brick, and heat-tolerant enamels or coatings.

Wood heating devices are typically categorized by emissions and efficiency ratings. The emissions ratings typically use EPA, ASTM, CSA, or EN (European Union) test methods. The efficiency ratings are based on tests that measure the amount of heating value transferred from a full load of wood or other biomass fuel (fuel type varies based on the product being tested) to the living space. Efficiency tests evaluate two performance metrics that include combustion and heat transfer efficiency. Combustion efficiency determines how effective the fire box design is at burning the fuel and extracting its heating value. Heat transfer efficiency tests are potentially conducted in calorimeter rooms equipped with temperature sensors to measure the degree changes in the heated living space and the flue exhaust to determine how much heat from the fire is delivered to the living space compared with the heat lost up the flue (EPA, 2009c).

Thermal output, typically expressed in British thermal units per hour (BTU/hr) in the United States, is the heat output measure that tells the amount of heat produced each hour. A higher BTU/hr rate suggests that a stove will produce more heat per hour than a stove with a lower rating. Depending on design and size characteristics, a space heating device heat output rating ranges between 8,000 and 90,000 BTU/hr. Larger heating systems designed to provide whole home heating have heat output ratings that range from 100,000 to greater than one million BTU/hr.

3.1.2 Product Types

3.1.2.1 Wood and Coal Stoves

EPA-certified wood stoves typically are enclosed combustion devices that provide direct space heating for a specific room or area of a home.[4] Catalytic and noncatalytic wood stoves are two general types of wood stoves available in the United States. (Some models are hybrids.) This designation refers to the design of the combustion system. Noncatalytic combustion systems rely on high temperatures (>1,000°F) within the fire box to fully combust the chemical compounds (combustible gases and particles) in the wood smoke. In catalytic combustion systems, the presence of the catalytic element lowers the temperature at which wood smoke chemical

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[4] EPA-certified wood stoves are those wood stoves that meet the requirements under the current residential wood heater NSPS.

compounds combust. Catalytic elements or combustion system designs in noncatalytic combustion systems are used in existing stoves to meet EPA emission standards.

Coal stoves are similar in structure and appearance to wood stoves. Most coal stoves are designed to burn hard anthracite coal instead of soft bituminous coal (Houck, 2009), but different varieties of coal have been used in coal stoves over time. Stoves that solely burn coal are not affected by the revisions to the NSPS.

3.1.2.2 Wood Pellet Stoves and Biomass Stoves

Wood pellet and other biomass stoves are similar in application to wood stoves but generate heat through pellet combustion. Wood pellet stoves use tightly compacted pellets of wood as fuel, whereas other biomass stoves can use a variety of pellet types, including corn, fruit pits, and cotton seed (EPA, 2009c). A load of pellets is poured into the stove's hopper; then the user sets a thermostat that controls a feed device within the stove. The feed device regulates the amount of fuel that is released from the hopper into the heating chamber, which is where the combustion takes place (EPA, 2009c). Pellet stoves are typically more efficient in terms of combustion and heating than standard wood stoves but require electricity to operate the fans, controls, and pellet feeders (EPA, 2009c). Stoves that solely burn non-wood biomass are not affected by the revisions to the NSPS.

3.1.2.3 Masonry Heaters

A masonry heater is a solid-fueled heating device that is pre-manufactured or constructed on site using mainly masonry or ceramic materials (Masonry Heater Association of North America, 1998). Though masonry heaters and traditional fireplaces are similar in appearance, masonry heaters are used primarily to generate heat, whereas fireplaces typically serve a more aesthetic purpose. The heater itself is made up of an interior construction unit consisting of a firebox and a set of heat exchange channels (Chernov, 2008). The hot gas produced during rapid combustion of fuel within the firebox passes through the heat exchange channels, which run throughout the structure and saturate the masonry mass with heat (Chernov, 2008). Most masonry heaters weigh over 800 kg. After the masonry walls are saturated, the masonry heater radiates the heat into the area for 12 to 15 hours (Chernov, 2008). Masonry heaters can heat a home all day without having to burn continuously and are often used in areas where other fuel sources are unavailable (Chernov, 2008). However, there is a significant lag time between the initial burn and the time that the masonry structure releases sufficient heat to warm a living space (U.S. Department of Energy [DOE], 2010). Masonry heaters were included in the proposal, but are not affected by the final revisions to the NSPS. The rationale for the removal of masonry heaters from the final rule can be found in Section 2 of the RIA and the preamble to the final rule.

3.1.2.4 Fireplace Inserts

A fireplace insert is a type of heater/stove that is designed to fit inside the firebox of an existing wood-burning fireplace (Wood Heat Organization, 2010). EPA-certified fireplace inserts are essentially wood heaters/stoves without legs or pedestals. An insert is made of steel or cast iron and is typically installed in masonry fireplaces or traditional fireplaces in order to provide effective heating (Hearth, Patio, and Barbeque Association [HPBA], 2010b). As an insulated closed-door system, a fireplace insert improves combustion by slowing down the fire, decreasing the excess air, and increasing the fire’s temperature (HPBA, 2010b). In addition to wood-fueled fireplace inserts, other inserts can be fueled with natural gas, propane, pellets, or coal (HPBA, 2010b).

Fireplace inserts are not covered under this NSPS.

3.1.2.5 Forced Air Furnaces

A forced-air furnace is a type of central heating system that typically burns cordwood or pellets. A forced-air furnace is typically located inside a house and provides controlled heat throughout a home using a network of air ducts (EPA, 2009c). This is a primary heating system that requires electricity to operate and is much more common currently in the U.S. compared to hydronic heaters.

3.1.2.6 Outdoor Wood Heaters

An outdoor wood heater, also often called a wood-fired boiler, is a type of hydronic heater that is designed to be the home’s primary heating system. Wood boilers are typically located outdoors and have the appearance of a small shed with a smokestack (EPA, 2009c). Hydronic heaters burn wood to heat a working liquid contained in a closed-loop system. The heated liquid is then circulated to the house to provide heat and hot water (EPA, 2009). Hydronic heaters are typically sold in areas with cold climates where wood may be the most readily available fuel source (EPA, 2009c). In addition to outdoor hydronic heaters, there is an emerging market for indoor hydronic heaters. Currently, the indoor hydronic heater market is approximately 10% of the hydronic heater market.

3.1.2.7 Indoor and Outdoor Fireplaces

Fireplaces are typically not effective heating sources and are typically considered more of an aesthetic feature than a functional device. The common low-mass fireplace is pre-fabricated of steel in a factory and shipped to the home builder. A low-mass fireplace and its attached chimney are light enough to be weighed on a platform scale (EPA, 2009c). Although low-mass fireplace installations in homes often surrounded by natural or synthetic facades of masonry–like materials, they should not be confused with masonry fireplaces or masonry heaters that are primarily constructed if brick, stone, or other masonry materials. Masonry fireplaces are traditional, aesthetic fireplaces that do not have the extensive heat channels that define masonry heaters (Fireplaces & Woodstoves, 2010).

Fireplaces are also often used to enhance the outdoor area of a house. A portable grated cylinder style has a bottom basin surrounded by open grating for a fire, a cooking grate, and a lid (EPA, 2009c). A permanent outdoor fireplace is similar to one that would be found indoors. They can be freestanding or attached to the outside of the house (EPA, 2009c).

Indoor and outdoor fireplaces are not covered by or affected by the revisions to the NSPS.

3.1.2.8 Fire Pits, Chimineas, Cook Stoves, and Pizza Ovens

Several outdoor appliances involve using wood fuel for cooking or heating. A fire pit is a round outdoor hearth appliance that is designed to replicate the ambiance of a campfire by radiating heat in 360 degrees around the pit (HPBA, 2010c). A chiminea is typically constructed out of cast iron, terra cotta, or clay and burns firewood inside the internal oven. As the fire burns, the walls of the oven absorb heat. After the dome chamber reaches the desired temperature, the fire can be allowed to die down (EPA, 2009c). Wood cook stoves are made of cast iron to withstand the high temperatures produced by the fire (EPA, 2009c). They are similar in appearance to a conventional stove, complete with an oven and cooking ranges, but are larger in order to accommodate the wood fuel (EPA, 2009c). North American traditional cook stoves have defined dimensions and cooking performance characteristics. Native American bake ovens have defined cultural and cooking functions. Pizza ovens are made out of a masonry material, such as clay adobe or refractory bricks, which can endure high temperatures for an extended period of time (EPA, 2009c).

These appliances are not covered or affected by the revisions to the NSPS.

3.1.3 Costs of Production

Because of the variety of products covered under the wood heat source category, different manufacturers use a wide range of materials and have varying labor requirements. Since there is significant diversity in output between the producers in this category, as well as the broader industries in which they may be classified for data purposes, this section highlights the production costs associated with several of the North American Industry Classification System (NAICS) codes under which a significant number of the wood heating equipment manufacturing facilities in our database are included.

Table 3-1 displays costs for the heating equipment and hardware manufacturing industries. The production of devices like wood stoves, hydronic heaters, and fireplace inserts is included under the heating equipment category (NAICS 333414). In 2011, the total cost of materials used for production represented roughly 48% of the industry's total value of shipments,

Table 3-1. Costs for Labor and Materials for U.S. Heating Equipment and Hardware Manufacturing: 2011

NAICS-Based Code	Meaning of NAICS-Based Code	Year	Number of Employees	Annual Payroll ($1,000)	Production Workers Average per Year	Total Cost of Materials ($1,000)	Materials, Parts, Containers, Packaging, etc., Used ($1,000)	Cost of Purchased Fuels ($1,000)	Cost of Purchased Electricity ($1,000)	Total Value of Shipments ($1,000)
333414	Heating Equipment (except warm air furnace)	2011	15,911	805,803	9,466	1,980,145	1,649,941	10,896	42,255	4,165,203
332510	Hardware Manufacturing	2011	24,062	1,158,084	16,715	3,356,842	2,660,573	21,548	52,477	6,771,825

Source: U.S. Census Bureau. 2013a. American Fact Finder2011Annual Survey of Manufactures REFRESH: General Statistics: Statistics for Industry Groups and Industries: 2011. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ASM_2011_31GS201&prodType=table. Data made available on December 17, 2013. Accessed on August 13, 2014.

while labor costs (represented as annual payroll estimates) only represented 19%. The hardware manufacturing industry (NAICS 332510) had fairly similar statistics: materials used and annual payroll accounted for 50% and 17% of the total value of shipments, respectively.

The 2007 production costs for plumbing and heating equipment wholesalers (NAICS 423720), which are the most recent available from the Census Bureau, are outlined in Table 3-3. This category includes the merchant wholesale production of cooking and heating stoves and hydronic heaters. Table 3-4 displays the costs for certain home furnishing stores, including those that sell wood stoves at retail prices. The costs for these industries may be more indicative of the wholesale and retail exchanges of wood-heating equipment rather than the actual production process.

3.2 Demand Side

The subject wood-fired heaters are sold explicitly for residential use. These devices can be included in the original construction of a new home or installed later in the life of the home. Demand for residential wood heating devices is driven by several key factors that include size, price, efficiency, aesthetics, and fuel type (e.g., cord wood, pellet wood, or other biomass fuels). However, consumer demand for any one product discussed in Section 3.1 is driven primarily by the intended end-use heating application. This section defines the three major consumer segments that drive demand based on the end-use application. Following this discussion, we present some national statistics on the variation in residential wood heat consumers in the United States. We conclude our discussion of the demand side by characterizing some of the substitutes for residential wood-burning devices.

Table 3-2. Costs for U.S. Single-Family Home Contractors: 2007

NAICS-Based Code	Meaning of NAICS-Based Code	Year	Number of Employees	Total Payroll ($1,000)	Cost of Materials, Components, and Supplies ($1,000)	Total Value of Construction Work ($1,000)
236115	New single-family general contractors	2007	259,905	10,834,064	37,676,878	89,282,708

Source: U.S. Census Bureau. 2010b. American Fact Finder. Sector 23: EC0723SG01: Construction: Summary Series: General Summary: Detailed Statistics for Establishments: 2007. Released May 18, 2010. http://factfinder.census.gov.

Table 3-3. Costs for U.S. Plumbing and Heating Equipment Supplies Wholesalers: 2007

NAICS-Based Code	Meaning of NAICS-Based Code	Year	Number of Employees	Annual Payroll ($1,000)
423720	Plumbing and heating equipment supplies (hydronics) merchant wholesalers	2012	68,534	3,988,326

Source: U.S. Census Bureau, 2014c. American Fact Finder. 2012 County Business Patterns. Released June 26, 2014. Accessed on August 13, 2014. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=BP_2012_00A2&prodType=table

Table 3-4. Costs for U.S. Specialized Home Furnishing Stores: 2007

NAICS-Based Code	Meaning of NAICS-Based Code	Year	Number of Employees	Annual Payroll ($1,000)
442299	All other home furnishing stores	2012	14,731	2,780,875

Source: U.S. Census Bureau, 2014d. *American Fact Finder.* Sector 44: EC0744A1: Retail Trade: Geographic Area Series: Summary Statistics for the United States, States, Metro Areas, Counties, and Places: 2012. Released on June 26, 2014. Accessed on August 13, 2014. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=BP_2012_00A1&prodType=table.

3.2.1 End-Use Consumer Segments

The intended end-use heating application is a primary driver of demand for residential heating devices. The U.S. Annual Housing Survey (HUD, 2008) provides a starting point for classifying the various types of residential consumer of heating equipment. For the purposes of this profile we grouped consumers into three major segments based on their desired heating needs: whole-house heating, secondary or zone heating, and recreational outdoor heating applications.

The primary, or whole-house heating segment, includes homes with no other central heating system that can provide heating service in or outside the house. In smaller homes, a large stove or masonry heater may be sufficient to provide heat to the entire house. However, larger homes typically require, either individually or in some combination thereof, an outdoor wood boiler, a hydronic heater, or a pellet-burning forced-air furnace, to meet the consumers' heating needs.

The secondary, or zone heating segment, includes consumers that desire supplemental heat from a wood-burning device in homes with an existing central heating system that serves as the home's primary heat source. Cordwood and wood pellet-burning stoves are ideal for heating a single room or zone within a home. Smaller masonry heaters are also well suited for zone heating needs.

Finally, a third component of demand is represented by consumers who desire a wood-burning device for recreational aesthetic applications. Outdoor fireplaces, chimineas, outdoor ovens, and pizza stoves are some examples of the wood-burning devices designed for recreational applications. The products that address the needs of this consumer segment are primarily intended to enhance the aesthetics or landscape outside the home. Indoor fireplaces typically serve aesthetic or recreational purposes rather than providing effective room heat. Only about 9% of wood fireplaces are used for heat generation (HPBA, 2010a).

3.2.2 Regional Variation in Residential Demand

In 2010, 2.1% of total occupied homes in the United States relied on wood heat as the primary fuel source for home heating. The demand for wood heat is concentrated in the Northeast, the Northwest, and the northern Midwest regions of the United States. Table 3-5

Table 3-5. Wood as Primary Fuel Source for Home Heating in the United States: 2006–2008

State	Percentage of State Owner-Occupied Houses	Percentage of National Owner-Occupied Houses	Count
California	2%	9%	165,440
New York	3%	6%	103,740
Pennsylvania	3%	6%	100,355
Washington	6%	5%	92,664
Michigan	3%	5%	85,712
Wisconsin	5%	5%	83,040
Oregon	8%	4%	79,637
Ohio	2%	4%	67,665
Virginia	3%	3%	60,579
North Carolina	2%	3%	58,397
Minnesota	3%	2%	43,234
Maine	10%	2%	41,509
Indiana	2%	2%	38,550
West Virginia	7%	2%	38,142
Idaho	8%	2%	32,817
Colorado	2%	2%	28,668
Vermont	15%	1%	26,601
Massachusetts	2%	1%	25,870
Montana	9%	1%	24,355
New Hampshire	7%	1%	24,071
Top 20 total		68%	1,221,046
National total		100%	1,792,741

Source: U.S. Census Bureau. 2009. *American Community Survey: 2006–2008.* Available at: http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=ACS&_submenuId=&_lang=en&_ts=.

illustrates this regional concentration by listing the 20 states that represent the highest percentage of households that use wood heat based on Census data from 2006–2008. The second column shows the number of wood-heat users as a percentage of the total homes in the state, while the third column shows the number of wood-heated homes as a percentage of the total users in the United States. These 20 states account for over two-thirds of the total primary U.S. residential wood heat demand.

About 10–12% of American households use wood when secondary wood heat demand is counted, according to the Census and the Energy Information Administration (EIA). Table 3-6 illustrates the regional breakdown of secondary wood heat demand by U.S. Census divisions in 2009, which is the most recent year for which these data are available. Roughly 8% of the American households use wood as a secondary heat source.

Table 3-6. Wood as Secondary Heat Source by Census Division, 2009 (millions of households)

Census Division	Number of Households	Percentage of U.S. Households using Wood as Secondary Heat Source	Percentage of Total U.S. Households
Northeast	1.7	19%	2%
Midwest	1.9	22%	2%
South	2.6	30%	2%
West	2.5	28%	2%
Grand total	8.8		8%
Total U.S. households	113.6		

Source: U.S. Energy Information Administration, 2013. *Residential Energy Consumption Survey: 2009.* Available at. http://www.eia.gov/consumption/residential/data/2009/index.cfm#undefined. Released (final) April 2013.

Figure 3-1 shows which states fall into which Census divisions. More households rely on wood fuel as a supplemental heat source rather than as a primary source. Roughly 8% of American households used wood fuel for a secondary heat source in 2009, whereas 3% of households relied on wood for their primary heat source in the same year. The proportion of the population using primary wood heat was relatively consistent between 2005 data presented in Table 3-6 and the 2006 to 2008 period, as shown in Table 3-5.[4] One interesting note about

[4] Although the total occupied households between the Department of Energy's *Residential Energy Consumption Survey* [RECS] and the Census Bureau's *American Community Survey* [ACS] differ, the proportion of total occupied households using wood fuel as their primary home heating fuel is consistent. The survey data sources used in Table 3-6 assumes 111 million occupied homes in 2009 while Figure 2-2 assumes 109 million for the same year.

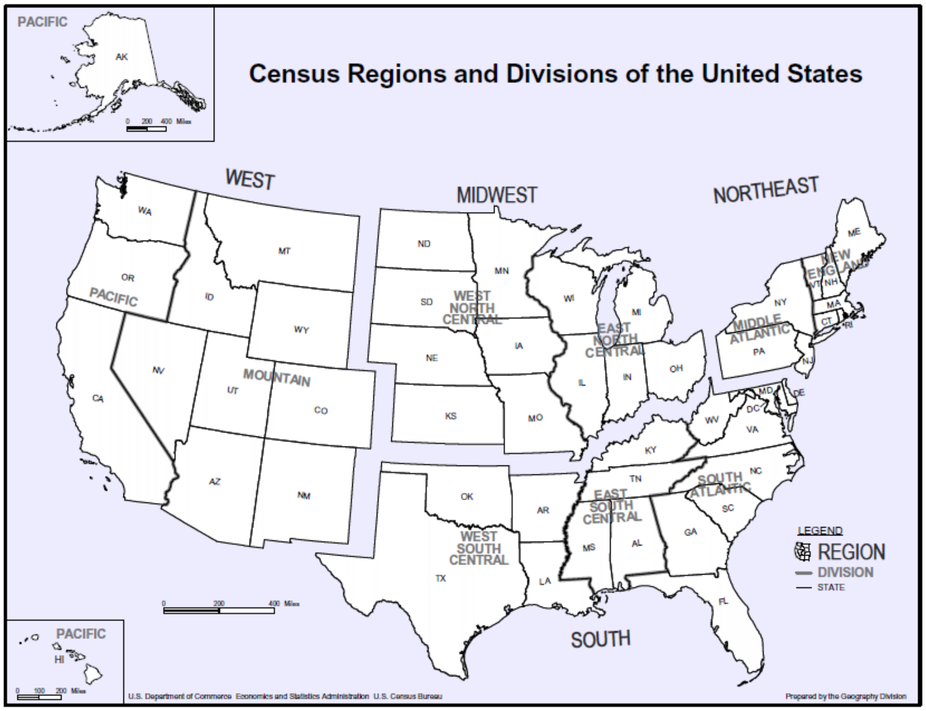

Figure 3-1. Census Regions and Divisions of the United States

Source: U.S. Census Bureau, 2014e. *Census Regions and Divisions of the United States.* Available at https://www.census.gov/geo/maps-data/maps/pdfs/reference/us_regdiv.pdf.

secondary wood fuel use is that it does not appear prevalent in the Middle Atlantic or New England states, which account for only 19% of the total secondary use. This fact is in contrast to the primary use data in Table 3-5, which shows households in Vermont, New Hampshire, Maine, Pennsylvania, Massachusetts, and New York accounting for 17% of the total national primary demand.

Within the wood heat demand constituency, there is also regional demand variation for different wood-fueled appliances. For example, the demand for wood-fired forced-air furnaces is concentrated primarily in the Great Lakes region of the country and, to a lesser extent, the Midwest (HPBA, 2010a). These two regions account for 82% of the 30,000 to 35,000 furnaces sold annually in the United States (HPBA, 2010a). Demand for wood-fueled cook stoves is concentrated in the Amish and Mennonite communities in the Midwest (HPBA, 2010a).

3.2.3 National Home Heating Trends

Residential demand for wood fuel has been declining steadily throughout the United States over a fairly long period of time. Figure 3-2 illustrates the number of households from 1989 to 2005 that reported using wood fuel for heating, cooking, or heating water. In 1989,

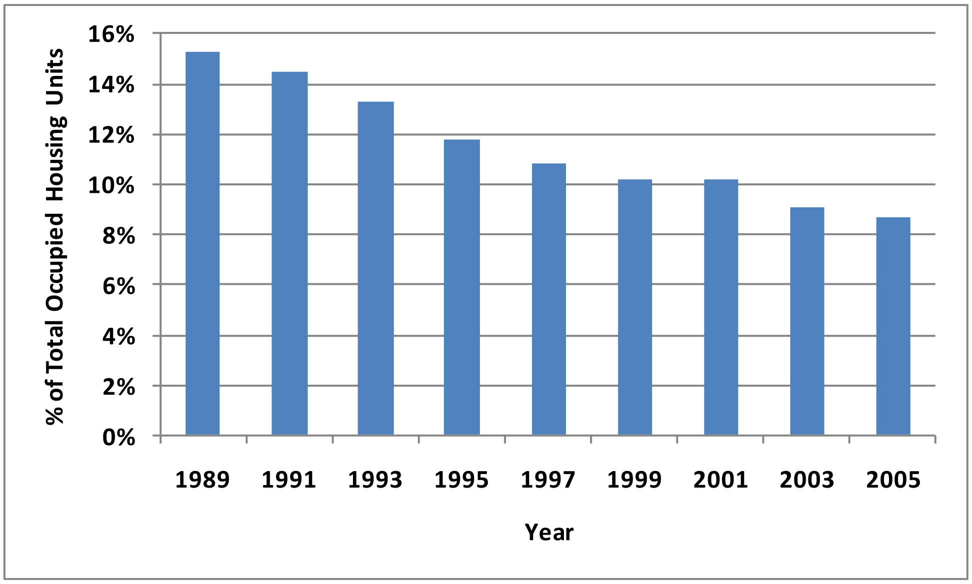

Figure 3-2. Declining Trend in U.S. Housing Units Using Wood Fuel: 1989–2005

Source: U.S. Housing and Urban Development [HUD]. 2008. *American Housing Survey for the United States.* Multiple Years. Table 3-5. Available at http://www.census.gov/hhes/www/housing/ahs/nationaldata.html.

roughly 15% of all occupied housing units used wood fuel. The proportion of wood-fuel users has declined relatively steadily throughout the past 20 years. By 2005, fewer than 9% of the total 109 million occupied households in the United States used wood fuel for heating, cooking, or heating water.

The indoor fireplace market illustrates the continuing decline in wood fuel use over the past decade (HPBA, 2010a). As discussed in the next section, consumers are trending toward gas fireplaces instead of wood-fueled fireplaces. Fireplace manufacturers report that shipments of wood-fired factory-built fireplaces have been declining over the past decade as a result of the weakening new home construction market and the shift in consumer preferences toward gas fireplaces in the new homes that are being built (HPBA, 2010a). Of new home fireplaces, only 35% burn wood, whereas 65% are fueled by gas (HPBA, 2010a).

It should be noted, however, that this trend has been arrested to some degree in recent times as the cost of wood fuel for heater/stove/furnace heating has come in line with the cost of oil and gas stove/heater/furnace heating, and trends show an increase in wood heating in households as shown in the unit cost memo prepared for this rule.[5] In fact, nine states in New England and the mid-Atlantic saw at least a 50% jump from 2005 to 2012 in the number of

[5] U.S. EPA. Memorandum. Unit Cost Estimates of Residential Wood Heating Appliances. August 13, 2014. Prepared by EC/R, Inc.

households that rely on wood as the main heating source. As the use of fuel oil and kerosene in this region has declined in recent years, many households have turned to lower-cost alternatives, including wood. In total, about 2.5 million households (2.1%) across the country use wood as the main fuel for home heating, up from 1.9 million households (1.7%) in 2005.[6]

3.2.4 Substitution Possibilities

The availability of close substitutes for wood heating equipment is largely contingent on two key factors: (1) the consumer's heating needs and preferences and (2) the price and availability of an alternative heating source. As discussed in Section 3.2.1, consumers tend to fall into one of three demand segments depending on their desired end use for their heating device. Each consumer group displays varying degrees of substitutability. The relative price of alternatives is also an important aspect of product substitution, which includes the cost of the heating equipment itself and the price and availability of the fuel it requires.

For most consumers looking for whole-house heat or single-room heat, gas or electric heat provides a common substitute for wood fuel. Electricity can power central heating systems for whole-house heat and smaller space heaters for single rooms. Since the majority of American households have easy access to electric power, these home heating options are often a convenient and low-cost alternative to wood heat. Gas-powered central furnaces and room heaters and oil-powered central heating systems are also on the market for residential use (DOE, 2009). Although most consumers have homes equipped for gas or electric power, more rural areas of the country have limited access to reliable utilities. In these regions, electric or gas heat may not be an available or cost-efficient choice relative to wood heat.

Recreational or aesthetic wood-fired appliances have fewer direct substitutes. Traditional indoor fireplaces and masonry fireplaces can be outfitted for burning natural gas rather than wood. Consumers may have a personal preference for one over the other. Wood fuel can be messy and somewhat difficult to store, whereas natural gas can be more convenient and easier to use, and gas furnaces can be much more efficient. Outdoor recreational appliances may be difficult to substitute directly because many consumers desire the aesthetic effect created by a wood-burning fire pit or chiminea. Outdoor charcoal or gas grills provide an alternative for outdoor wood-fired cooking appliances, but consumers may not consider these a direct

[6] U.S. Energy Information Administration. "Increase in wood as main source of house heating most notable in the Northeast." Released on March 17, 2014. Available at http://www.eia.gov/todayinenergy/detail.cfm?id=15431.

substitute. It should be noted that outdoor recreational wood-burning appliances such as fire pits, chiminea, and grills are not covered in this final rule.

3.2.5 Price Elasticity of Demand

Price elasticity of demand is a concept in economic theory. It is a numeric measure of the sensitivity of quantity demanded following an increase or decrease in the product's price. The level of sensitivity is determined by a number of factors that include the availability and price of substitutes (e.g., other types of heating equipment, gas or electric space heaters and furnaces) and the price of complements (wood fuels). A study done on residential wood energy consumption from 1967 to 2009 showed that a composite of non-wood energy prices was positively associated with U.S. residential wood energy consumption in the long-run with elasticity of 1.82. This can be interpreted as a 1% increase in non-wood energy prices leading to a 1.82% increase in U.S. residential wood energy consumption.[7]

In preparing this profile, we searched for, but were unable to identify, any empirical estimates of the price elasticity of demand for residential wood heating equipment in recent times. An estimate, which is now dated, of −1.6 was derived for use in the RIA for the 1988 Residential Wood Combustion NSPS (EPA, 1986). A commenter on the proposed NSPS estimated a price elasticity of demand for hydronic heaters of -1.0 based on data taken from sales trends in states with hydronic heater standards.[8] We do not have elasticities for the other appliances covered in this final rule. Although numerous articles estimate the elasticity of demand for residential energy and heating fuels, these estimates focus almost exclusively on electricity, natural gas, and fuel oil. These estimates find that residential energy and heating fuel demand is relatively inelastic (i.e., there are only very small changes in demand in response to an increase in energy or fuel prices). A recent RAND report suggests that in the short term, demand for electricity and natural gas in residential markets is relatively inelastic (Bernstein and Griffin, 2005). However, the authors of the report also note that sustained higher energy prices in the long term may result in demand for energy becoming more elastic as consumers have time to identify more energy-efficient options.

With limited empirical estimates, we offer a qualitative discussion of the key determinants of the price elasticity of demand to provide a general sense of whether consumer

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[7] Song. N. Aguilar, F.X., Shiftley. S.R., and Goerndt, M. Analysis of U.S. Residential Wood Energy Consumption: 1967-2009. Energy Economics, 34(6). November 2012. Pp. 2116-2124.

[8] NERA. Cost-Effectiveness Analysis of Alternative Hydronic Heater New Source Performance Standards. May 2014. Prepared for the Hearth, Patio, and Barbecue Association.

demand is elastic or inelastic. As mentioned earlier, the determinants of elasticity include the degree of substitutability, product necessity, and duration of the price increase.

There are a number of close substitutes for residential wood heating devices that include electric and gas furnaces and space heaters. The extent to which consumers are able to substitute between these options is likely to vary depending on geographic location. Overall, the presence of good substitutes will increase the elasticity of demand for wood heating equipment. In contrast, if locally-available alternative heating fuels (i.e., electricity, and fuel oil) are relatively higher priced, it may make switching away from wood heating equipment less likely and, ultimately, make demand for wood heating equipment inelastic. Also, the elasticity may depend on whether the fuel in question is a secondary source of fuel instead of a primary fuel source.

Finally, the magnitude of the cost for residential wood heating equipment may also increase the elasticity of demand. Consumer demand tends to be more elastic when the price of the good represents a large proportion of consumer income (Bernstein and Griffin, 2005). In other words, consumers become more sensitive to small price changes when considering the purchase of a large household appliance (e.g., refrigerator, oven range, or heating system).

3.3 Industry Organization

A review and description of market characteristics (i.e., geography, product differentiation, product transportation, entry barriers, and degree of concentration) can enhance our understanding of the mechanisms underlying the wood heating equipment industry. These characteristics provide indicators of a firm's ability to influence market prices by varying the quantity of product it sells. For example, in markets with large numbers of sellers and identical products, firms are unlikely to be able to influence market prices via their production decisions (i.e., they are "price takers" and operate in highly competitive markets). However, in markets with few firms, significant barriers to entry (e.g., licenses, legal restrictions, or high fixed costs), or products that are similar but can be differentiated, a firm may have some degree of market power (i.e., to set or significantly influence market prices). In addition, if a product is difficult to transport over long distance (due to weight or hazardous nature), then the market size may be more restricted than one might expect, all other things being equal.

3.3.1 Market Structure

Market structure characterizes the level of competition and determines the extent to which producers and sellers can influence market prices. Economic market structure typically focuses on the number of producers and consumers, the barriers to market entry, and product substitutability.

The residential wood heater market contains a number of large producers selling a number of differentiated products along with a large number of small producers. These characteristics suggest a quasi-monopolistic competitive market (i.e., somewhere between highly competitive and less competitive) for large producers who will have some influence over market prices. For small producers, the market will be highly competitive in nature. In addition, existing regulatory requirements for product testing and certifications represent a barrier to market entry for new producers of wood heating devices. Competition in this market may be further constrained by transportation costs due to the weight of these products. A similar assessment was determined in the 1986 study by the American Enterprise Institute (AEI) and Brookings Institution Joint Center for Regulatory Studies.

The AEI-Brookings report also identified several key factors that influence manufacturers' pricing decisions. These factors included production costs, prices of similar products sold by competitors, transportation costs, combustion technology and efficiency, and consumers' ability to differentiate products based on brand name and efficiency.

Price elasticity of supply is a numeric measure of the industry's response to a small percentage increase in the product price (Landsburg, 2005). The law of supply suggests producers supply greater quantities at higher prices as a result of increasing marginal returns for each additional unit produced as the average cost per unit of output declines. As a result, the elasticity of supply for most industries is positive. Determinants of supply elasticity are flexibility of sellers to adjust production and the time period being considered in estimating the elasticity. Most manufactured goods have an elastic supply, meaning that sellers can adjust production quickly in response to a change in prices (Mankiw, 1998). Industries with excess plant capacity are likely to have elastic supply as sellers can ramp up production in a relatively short time frame.

Based on 2006 plant capacity utilization data as shown in Figure 3-3, the heating equipment manufacturing industry averaged 60% utilization, growing from 59% in 2002 to a maximum utilization of 65% in 2005 and then falling to 54% in 2006 (U.S. Census Bureau, 2007). Similar statistics are not available for more recent years because this survey was discontinued after 2006. The available data suggest that there is ample existing capacity to increase production in the short and long terms, assuming an increase in price of residential wood-burning heating equipment.

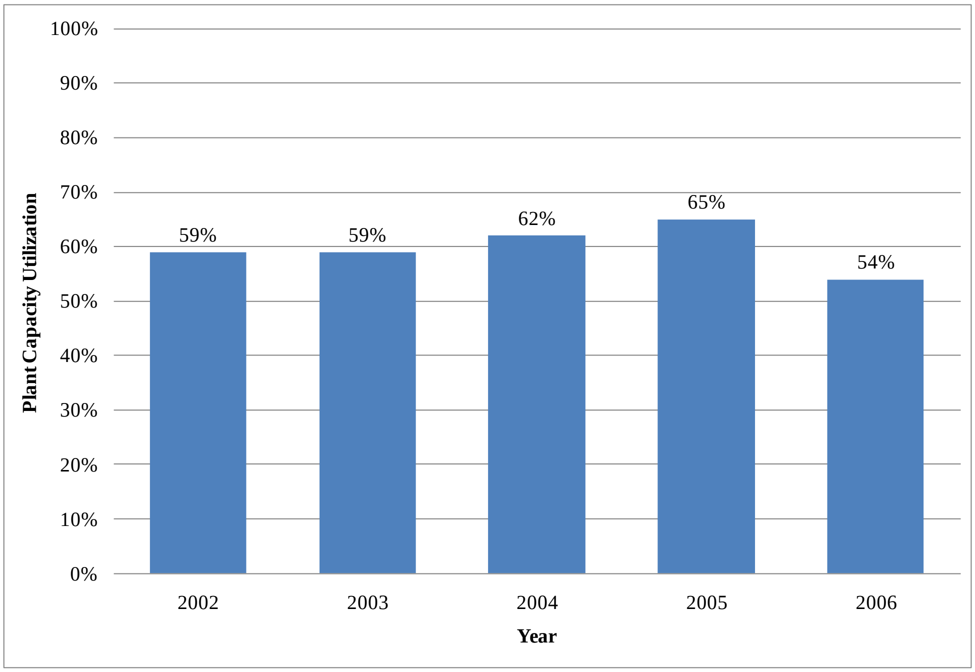

Figure 3-3. Annual Plant Capacity Utilization for Heating Equipment Manufacturers (NAICS 333414): 2002–2006

Source: U.S. Census Bureau. 2007. *Survey of Plant Capacity: 2006.* "Table 1a. Full Capacity Utilization Rates by Industry Fourth Quarter 2002–2006." Census Bureau, Washington DC. Report No. MQ-C1(06).

3.3.2 Manufacturing Plants

Since 1988, the change in the number of residential wood-fired heater producers is unclear. The U.S. Economic Census reports that between 1992 and 2007 the number of establishments (places of business) in the industry has remained unchanged. Alternatively, the industry association (HPBA) has suggested that the number of manufacturers of wood-fired heaters fell by 80% following the 1988 NSPS, down from approximately 500 to roughly 120 manufacturers today (Houck and Tiegs, 2009). The difference between the 2 estimates is thought to be due to the large number of "backyard welders" in 1988 who built handmade stoves in their backyard as a sideline rather than their main source of income and chose not to attempt to develop competitive designs for the marketplace after the 1988 NSPS was promulgated.

For this analysis, we were able to identify 611 firms in the residential wood heating equipment industry in the United States. RTI developed this estimate leveraging a number of different sources that included EPA's official list of certified wood heater manufacturers, Dun & Bradstreet's online company database, and a number of industry association membership lists. The estimate includes the manufacturers listed on EPA's official certification lists (~120 manufacturers). We then expanded this list to include manufacturers of outdoor wood boilers and manufacturers of non-heating devices, such as cook stoves, outdoor fireplaces, and bake ovens. Table 3-7 reports the count of U.S.-based companies in the industry by major business type.

Table 3-7. Number of U.S. Companies by Business Type

Business Type	Number of Companies	Reported Sales 2008 ($1,000s)	U.S. Market Share (% of Net Sales)
Manufacturers	577	$1,285,800	97.00%
Wholesalers, distributors	19	$34,200	2.58%
Residential construction	10	$3,200	0.24%
Retailers	5	$600	0.04%
U.S. Totals	**611**	**$1,324,000**	**100%**

Sources: Dun & Bradstreet *Marketplace*, a company database. RTI International calculations.

Residential wood heater manufacturers account for over 90% of the firms in the industry and span 14 different NAICS codes, of which 560 are categorized as NAICS 333414, as establishments primarily engaged in manufacturing heating equipment (except electric and warm air furnaces), such as heating boilers, heating stoves, floor and wall furnaces, and wall and baseboard heating units (Census Bureau, 2010f). An average manufacturer may produce anywhere from one to five technically different products (HPBA, 2010a). Manufacturers dominate the market, accounting for over 97% of sales for the industry in 2008.

3.3.3 Location

The industry is, for the most part, co-located in areas of the country with the largest demand for winter heating. Over 50% of U.S.-owned companies are located in 10 states in the northern half of the country. The largest number of companies is located in California, with additional concentrations in the Northwest, Northeast, the upper Midwest, and Central Plains. Table 3-8 reports the number of U.S. companies for the top 10 states. Additionally, approximately 104 foreign-based companies operate in the United States, two-thirds of which are Canadian-based companies.

Table 3-8. U.S. Wood Heat Equipment Industry by Geographic Location

Location	Business Count	% of Total U.S. Industry
California	63	10%
Pennsylvania	36	6%
Minnesota	35	6%
New York	33	5%
Washington	31	5%
Ohio	29	5%
Texas	29	5%
Wisconsin	26	4%
Michigan	25	4%
Illinois	21	3%
U.S. Total	**635**	**86%**
Canada	67	9%
Other foreign	37	5%
Industry Total	**739**	**100%**

Sources: Dun & Bradstreet *Marketplace*, a company database. RTI International calculations.

3.3.4 Company Sales and Employment

Overall sales for the residential wood heating industry totaled more than $1.3 billion in 2008. Based on company data obtained for this profile, the industry employs approximately 17,000 workers annually. Previous analysis suggests that the industry relies on seasonal labor, ramping up production in months leading up to winter and reducing employment and production during the warmer parts of the year (AEI, 1986). Table 3-9 presents median sales and employment for the industry by business type.

Table 3-9. U.S. Sales and Employment Statistics by Business Type

Business Type	Number of Companies	Median Sales 2013 ($1,000s)	Median Employment per Company
Manufacturers	577	$219	4
Wholesalers, distributors	19	$548	5
Residential construction	10	$110	2
Retailers	5	$110	2
U.S. Totals	611	$247	4

Sources: Dun & Bradstreet *Marketplace*, a company database. RTI International calculations. Median sales estimates are escalated to 2013 from 2008 using the GDP implicit price deflator. The resulting escalation ratio for these years is 1.075. Annual values of the GDP implicit price deflator are available at http://research.stlouisfed.org/fred2/series/GDPDEF/downloaddata.

Firms manufacturing heating equipment (except electric and warm air furnaces), such as heating boilers, heating stoves, floor and wall furnaces, and wall and baseboard heating units (NAICS 333414), are classified as small businesses by the Small Business Administration (SBA, 2014) if they have fewer than 500 employees. Looking across the manufacturing-related NAICS codes in our analysis, we find that approximately 90% of manufacturers are considered small businesses based on their reported employment compared with the SBA threshold. SBA classifies wholesalers and distributors as small if their employment is fewer than 100 workers. Approximately 68% of the industry's wholesalers and distributors are considered small based on the employment data obtained for this analysis.

SBA thresholds for construction, and retail firms are based on annual sales. SBA standards for NAICS codes under these business types range between $20.5 and $33 million in annual revenue. As reported in Table 3-9, median sales in these business categories are far below the range of SBA standards. As one would expect, our analysis finds that all 39 firms are considered small based on their reported annual sales compared with the SBA standards for their respective NAICS code classifications.

3.3.4.1 Profits of Affected Entities

Table 3-10 reports profit margins for manufacturers, and wholesalers and distributors. The profit margin represents an average of reported profit per unit sales across the industry classified by the 6-digit NAICS code.

Table 3-10. Profit Margins for NAICS 333414 and 423720: 2008

NAICS Code	NAICS Description	Profit Margin	Industry Sales ($$10^6$)
333414	Heating Equipment Manufacturers	4.3%	$70,965
423720	Plumbing and Heating Equipment Supplies (Hydronics) Merchant Wholesalers	3.4%	$58,907

Source: The Risk Management Association. 2008. *Annual Statement Studies, Financial Ratio Benchmarks 2008–2009.* Risk Management Association, Philadelphia: 2008.

3.4 Residential Wood Heater Market

Residential wood heating device shipments in the United States were relatively consistent from year to year between 1998 and 2005, according to the HPBA's reported hearth industry shipment data (2009). Since 2005, total industry shipments on average have declined annually by 24%. Industry experts attribute this decline in large part to the broader economic downturn and poor housing market. Renewable energy tax rebates offered in 2008 provided some relief for pellet-fueled devices, resulting in a 1-year increase in shipments of 161%, only to steeply decline again in 2009. This reflects the impact that the renewable energy tax rebates can have on wood burning appliances depending on the size and duration of the rebates. Table 3-11 presents shipment volumes by product type in 2008.

Outdoor wood boilers (or hydronic heaters) are a relatively new product in the market since 1990. Previous studies have reported annual growth in sales of between 30 and 128%, with over 155,000 outdoor wood boilers in use in the United States in 2006 (NESCAUM, 2006). Sales have been regionally focused in the Northeast (especially the Great Lakes region) and Midwestern states. The NESCAUM report predicted that over 500,000 outdoor wood boilers will be in use before the end of 2010 if trends in annual sales continue to follow growth rates observed between 1990 and 2006.

Market data for coal-burning stoves are very limited. However, anecdotal evidence suggests that coal stove use is limited to major coal states, including Pennsylvania, West Virginia, and Indiana, where coal is abundant and cheap relative to other heating fuels (Dagan,

Table 3-11. Unit Shipments and Percentage of Total Units by Product Type: 2008

Product Type	Units	% of Total Units
Wood stove	166,527	33%
Pellet stove	130,381	26%
Biomass stove	6,819	1%
Wood fireplaces[a]	180,966	36%
Outdoor fireplaces	6,302	1%
Hydronic central heating systems	13,385	3%
Total	**504,380**	**100%**

[a] Wood fireplaces in this table include both factory-built and site-built models.

Source: Frost & Sullivan. 2010. *Market Research Report on North American Residential Wood Heaters, Fireplaces, and Hearth Heating Products Markets.* Prepared for EC/R Inc.

2005). Most of the major stove manufacturers feature at least one coal-burning stove model. However, at the time of writing this profile, we were unable to locate any reliable estimate of shipments in the United States for coal stoves.

3.4.1 Market Prices

Residential wood combustion device prices range from $200 to $50,000 depending on the product type and characteristics.[9] Consumers who purchase these products must also consider the costs of installation, which average between $300 and $6,000.[10] Tables 3-12 and 3-13 report the average cost of installation and purchase price for residential wood combustion devices.

[9] Frost & Sullivan. 2010. *Market Research Report on North American Residential Wood Heaters, Fireplaces, and Hearth Heating Products Markets.* Prepared for EC/R Inc.

[10] Frost & Sullivan. 2010. *Market Research Report on North American Residential Wood Heaters, Fireplaces, and Hearth Heating Products Markets.* Prepared for EC/R Inc.

Table 3-12. Installation Costs for Average System by Product Type (North America): 2008

Product Type	Installation Cost
Wood stove	$500
Pellet stove	$300
Biomass stove	$300
Wood fireplaces	$600
Outdoor fireplaces	$350
Hydronic central heating systems	$2,000

Source: Frost & Sullivan. 2010. *Market Research Report on North American Residential Wood Heaters, Fireplaces, and Hearth Heating Products Markets.* Prepared for EC/R Inc.

Table 3-13. Manufacturers' Price by Product Type (North America): 2008

Product Type	Average Price	Price Range
Wood stove	$848	$200 to $2,800
Pellet stove	$1,279	$300 to $3,500
Biomass stove	$1,403	$350 to $4,000
Wood fireplaces	$450	$150 to $5,000
Outdoor fireplaces	$755	$250 to $6,000
Hydronic central heating systems	$7,433	$5,000 to $35,000

Source: Frost & Sullivan. 2010. *Market Research Report on North American Residential Wood Heaters, Fireplaces, and Hearth Heating Products Markets,* Figure 2.6. Prepared for EC/R Inc.

Hydronic heaters are the most expensive product in Table 3-13 partly because of the additional material requirements. The price of freestanding stoves and fireplace inserts varies depending on the fuel it burns. Biomass stoves are almost twice as expensive as cord wood-burning stoves because biomass stoves are more similar in construction to pellet stoves. Although no price data exist on coal-burning stoves, costs are comparable to traditional cord wood stoves. Coal stove prices for 2010 collected for this profile averaged $1,338 and ranged between $500 and $3,000 depending on the size and manufacturer.

3.4.2 International Competition

The U.S. market for wood-fueled heating products has been concentrated on the local scale in recent years. Manufacturers concentrate production where wood heat is in demand, which is in the Northeast and Northwest. Some regions of the country have specific emissions requirements on wood burning, so consumers may be restricted to buying stoves and heaters that can cater to local regulations (Frost & Sullivan, 2010). Domestic producers have traditionally faced some competition from European manufacturers in certain wood heat markets, but Asian manufacturers have been gaining market share, especially in the EPA-certified wood stove and currently exempt single-burn-rate stove markets (Frost & Sullivan, 2010).

Asian-based companies, especially those in China, have the advantage of relatively low overhead and labor costs compared with other companies worldwide (Frost & Sullivan, 2010). Although the products coming from these producers are lower in price, they are also lower in quality (Frost & Sullivan, 2010). However, money-conscious consumers have been willing to settle for lower quality stoves as the economy remains uncertain (Frost & Sullivan, 2010). Companies from all over the world have been moving some manufacturing operations to China in an attempt to compete with Asian producers through low-cost production (Frost & Sullivan, 2010). Still, U.S. manufacturers are likely to see increased competition from Asia in the future.

3.4.3 Future Market Trends

While there has been a steady decline in the residential markets for wood heaters, fireplaces, and hearth products, increases in oil and gas prices have led to substitution back to wood as a source of heat in 2007, in which a growth rate of 16.4% between 2007 and 2008 took place in these markets. However, demand for these products fell victim to the recession in 2009 (Frost & Sullivan, 2010). A weak residential construction market coupled with a tight credit market decreased overall demand in the market for wood heating products, which led analysts to project a 2009 growth rate of −36.1% (Frost & Sullivan, 2010). The growth forecast for 2010 improved relative to 2009 to a rate of −4.1%, due in part to the residual effects of the severe 2009 winter temperatures and the financial incentive provided by the federal energy efficient tax credit (Frost & Sullivan, 2010).

As the economy continues to recover beyond 2010, demand should trend upward as consumers look to cut heating costs with wood and biomass (Frost & Sullivan, 2010). New home construction and increased credit availability will further foster demand, which is expected to grow at a compound annual rate of 4.1% from 2009 to 2015 (Frost & Sullivan, 2010). The current regional demand patterns are expected to continue, with the Northeast and Northwest regions of the country driving wood fuel combustion demand, but analysts anticipate that the wood heat product market will be embraced in other areas of the country in which wood and biomass are viable and inexpensive fuel sources (Frost & Sullivan, 2010).

Although the overall residential wood heat market is expected to grow, there may be variation in demand between individual product segments. Pellet and biomass stoves are expected to lead the way in demand as consumers look for options with sustainable fuel sources and cleaner-burning technologies (Frost & Sullivan, 2010). Outdoor wood boilers (hydronic heaters) saw a surge in demand throughout the 1990s and mid-2000s, a trend that is projected to continue (Northeast States for Coordinated Air Use Management, 2006). Future demand for primary and secondary wood-burning heating devices will be somewhat dependent on the price of wood fuel relative to electric and gas heat, as well as consumer preferences. Since fireplaces and masonry fireplaces typically are not effective heaters and purchases are based on the aesthetic value rather than function, future demand will likely stay in line with consumer preferences.

SECTION 4
BASELINE EMISSIONS AND EMISSION REDUCTIONS

4.1 Introduction

This section presents the baseline emissions for the pollutants emitted by affected units and also the resulting emissions after imposition of the NSPS. We present the baseline emissions and emission reductions for $PM_{2.5}$ and also for other pollutants from affected units such as volatile organic compounds (VOCs) and carbon monoxide (CO). Baseline emissions were calculated using a 2008 base inventory and were then projected to future years beyond the promulgation of the rule in 2015 to 2020 and beyond, using emissions factors specific to the category of the affected unit (e.g., certified wood stove, pellet stove). These emissions factors are listed in the emissions memorandum for this final rule (EC/R, Inc., January 2015). Emission reductions were calculated from the baseline emissions based on the considered emissions limits for each appliance type affected, and the emission reductions were used as inputs to the benefits analysis presented in Section 7.

4.2 Background to Emissions Estimates

We used the EPA Residential Wood Combustion (RWC) emission estimation tool,[12] which is an Access™ database that compiles nationwide RWC emissions using county level, process specific data and calculations. We summed the nationwide number of appliances and total tons of wood burned for each of the relevant product categories (Table 4-1 below) in the inventory.

Table 4-1. RWC Emission Inventory Categories Used

Woodstove: fireplace inserts; EPA certified; non-catalytic
Woodstove: fireplace inserts; EPA certified; catalytic
Woodstove: freestanding, EPA certified, non-catalytic
Woodstove: freestanding, EPA certified, catalytic
Woodstove: pellet-fired, general
Woodstove: freestanding, non-EPA certified
Hydronic heater: outdoor
Furnaces: indoor, cordwood

[12] rwc_2008_tToolv4.1_feb09_2010.zip.

We then made some adjustments/assumptions to the baseline RWC inventory. First, we deleted data in the RWC database for non-certified stoves and inserts, as these cannot be sold. With the exception of wood stoves, we applied the $PM_{2.5}$ emission factors for each class to the total tons of wood burned and calculated an average emission rate/appliance/category. In the case of wood stoves, the RWC database used an average of all PM_{10} AP-42 emission factors for wood stoves.[13] The RWC database assumes that PM_{10} and $PM_{2.5}$ factors are identical. At a minimum, we estimate that all new wood stoves meet the AP-42 PM_{10} emission factors for "Phase II" stoves (the current NSPS promulgated in 1988) and therefore started with the lower AP-42 Phase II emissions factors for catalytic and non-catalytic stoves at baseline, rather than the higher average of all AP-42 emission factors used in the RWC database. Furthermore, to avoid any potential for overstating baseline emissions, we went a step further and assumed that all new shipments will meet the current Washington State limits, which are approximately 40% less than the 1988 NSPS Phase II limits. We therefore used baseline emission factors which are 60 percent of the AP-42 Phase II emission factors – less than half the value used in the RWC to represent the average of all AP-42 emission factors – in order to ensure a forward-looking and understated baseline.

Second, we assumed that outdoor hydronic heaters and indoor hydronic heaters have the same emission profile.

It should be noted that the $PM_{2.5}$ emissions factors for hydronic heaters and cord wood furnaces (i.e., forced air furnaces) increased to 64.0 lb/ton from the estimate of 27.6 lb/ton of wood burned used for the proposal. The increase is a result of updates taken from a peer-reviewed 2012 report[14] that were applied in the RWC database These updates result from testing of hydronic heater models that showed that $PM_{2.5}$ emissions from these sources had been underestimated at proposal. In addition, industry estimates of hydronic heater shipments were higher than EPA's estimates at proposal for particular years, and EPA has incorporated these industry estimates into the shipment estimates used for emissions estimation in the final rule. The $PM_{2.5}$ emissions factors for the other appliance categories remain unchanged from the proposal.

[13] AP-42, Chapter 1.10, Residential Wood Stoves, Table 1.10-1. See: http://www.epa.gov/ttnchie1/ap42/ch01/final/c01s10.pdf.

[14] Emission factors for the final rule estimates are based on EPA's Residential Wood Combustion Tool version 4.1 with updates from the 2012 EPA report (Gullett et al., Environmental, Energy Market, and Health Characterization of Wood-Fired Hydronic Heater, Final Report, June 2012).

Single burn rate stoves are not included in the RWC database as separate identifiable units. We assumed that they would have the same baseline emission factor as freestanding non-certified woodstoves, i.e., 30.6 lb/ton of wood burned. We used the average tons burned per appliance factor as representative of these stoves as well.

We used this subset of the RWC database to calculate a baseline average emission rate/appliance/category, including an adjustment of the RWC emission factor to the current Washington State limits where warranted. We multiplied the total tons of wood burned for the appliance by the RWC emission factor (adjusted as appropriate) to calculate the total tons of $PM_{2.5}$ emissions. We divided this value by the number of appliances in the category to calculate the baseline average $PM_{2.5}$ emissions per individual appliance, and these results are shown in Table 4-2.

Table 4-2. $PM_{2.5}$ Tons per Appliance Estimate (Baseline)

Emission Inventory Category	Pollutant	Baseline Emission factor (lb/ton)	Emissions (tons)	Tons per appliance /yr
Woodstove: fireplace inserts; EPA certified; non-catalytic	Primary $PM_{2.5}$	8.76	5,371	0.0041
Woodstove: fireplace inserts; EPA certified; catalytic	Primary $PM_{2.5}$	9.72	2,023	0.0047
Woodstove: freestanding, EPA certified, non-catalytic	Primary $PM_{2.5}$	8.76	6,745	0.0077
Woodstove: freestanding, EPA certified, catalytic	Primary $PM_{2.5}$	9.72	3,769	0.0101
Woodstove: pellet-fired, general	Primary $PM_{2.5}$	3.06	1,798	0.0021
Hydronic heater: outdoor/indoor	Primary $PM_{2.5}$	64.0	116,933	0.3208
Furnace: indoor, cordwood	Primary $PM_{2.5}$	64.0	83,972	0.2392
Single burn rate stoves[a]	Primary $PM_{2.5}$	30.6	71,424	0.0324

[a] Non-EPA certified wood stove emission factor and tons/appliance were used to represent single burn rate stoves.

4.2.1 Emissions Factors

The next step in this analysis was to develop emission factors representing the impacts on emissions from the final NSPS. The following is a summary of the NSPS for each appliance type that is examined in detail in Section 2. The NSPS are based on phased-in compliance dates, or “steps,” for subcategories of appliances. Subpart AAA will regulate “room heaters” and includes adjustable burn rate stoves, single burn rate stoves, and pellet stoves. Subpart QQQQ will regulate “central heaters” and includes outdoor and indoor hydronic heaters and forced air furnaces. Following is a summary of the current NSPS implementation assumptions for appliances within the regulated subcategories. As mentioned in Section 2, the final rule is a 2-step standard with compliance dates of the effective date and 5 years after the effective date for different appliances. The final NSPS is a phased standard with compliance dates of 2015 and 2020 for all appliances. In addition, forced-air furnaces will have a Step 1 PM emission limit for small forced-air furnaces in 2016 and for large forced-air furnaces in 2017, as discussed below. The Step 2 PM emission limit compliance date is 2020 for all appliances.

The emission limits for room heaters and central heaters were made less stringent for the final rule as compared to the proposal. The rationale for this change is in Section 2 of this RIA and the preamble to the final rule.

Subpart AAA ("room heaters"):

- These are adjustable burn rate, single burn rate, and pellet stoves: Step 1 PM emissions limit of 4.5 g/hr upon promulgation in 2015; and Step 2 PM emissions limit of 2.0 g/hr five years after promulgation in 2020. **Note**: The Step 1 limit is the 1995 Washington State standard for non-catalytic stoves; the Step 2 limit is the 1995 Washington State standard for catalytic stoves; and the Step 2 limit is already met by the top performing catalytic, non-catalytic and pellet stove models, according to industry data.[15] Specifically, this industry data from 2010 indicate that 90% (130 out of 145 catalytic, non-catalytic and pellet stoves combined) already meet the Step 1 limit. We expect that manufacturers will focus on existing models that meet the Washington State limits in order to comply with the Step 1 standard. Furthermore, certification data[16] indicate that 26% of non-catalytic and catalytic stoves combined and 70% of pellet stoves already meet the Step 2 standard. Although previously unregulated and a less developed technology than adjustable burn rate stoves, single burn rate stove designs have been undergoing R&D in anticipation of the NSPS and cleaner designs are nearly market-ready.[17]

Subpart QQQQ ("central heaters"):

- Hydronic heaters (both outdoor and indoor): Step 1 PM emission limit of 0.32 lb/MM BTU heat output (weighted average and an 18.0 g/hr cap for each test run) upon promulgation in 2015; and Step 2 PM emission limit of 0.10 lb/MM BTU heat output (at each burn rate) five years after promulgation in 2020. **Note**: The Step 1 limit is identical to the EPA "Phase 2 "voluntary program limit and is therefore already met by all 50 of the 50 currently Phase 2 qualified hydronic heater models built by U.S. manufacturers participating in the voluntary program. In addition, there are 19 qualification tests that have been recently submitted to EPA and, if valid, are all expected to be added to the Phase 2 qualification list very soon. The Step 2 limit is already met by 9 hydronic heater models of the 50 (or 18%) built by U.S. manufacturers participating in the voluntary program; as well as over 100 European manufacturers per test method EN 303-05.[18] It should be noted that to-date cleaner models continue to become Phase 2 qualified and additional manufacturers not participating in the voluntary program may also have models meeting Step 1 and Step 2.

  Based on the EPA's experience with the hydronic heater market through the voluntary program, we understand that it is dominated by a few manufacturers in

[15] Final HPBA Heater Database version 2/25/10, EC/R received from Bob Ferguson for HPBA on 4/26/10.

[16] Memo to David Cole, Gil Wood and Amanda Aldridge, US EPA, from Jill Mozier, EC/R, Inc. Derivation of wood heater model percentages meeting Step 2 standards. November 10, 2014.

[17] 2/8/13 telephone discussion between Gil Wood, USEPA, and a manufacturer of single burn rate stoves.

[18] European Wood-Heating Technology Survey: An Overview of Combustion Principles and the Energy and Emissions Performance Characteristics of Commercially Available Systems in Austria, Germany, Denmark, Norway, and Sweden; Final Report; Prepared for the New York State Energy Research and Development Authority; NYSERDA Report 10–01; April 2010.

terms of the bulk of sales, and these manufacturers have qualifying units at one or both of the stepped emission limits, as noted above. Therefore, on a sales-weighted basis, only a percentage of the hydronic heater models currently sold in the United States would be required to undertake R&D to meet Step 1, with higher percentages needing R&D to meet the Step 2 limit. We assume that 18% of existing hydronic heaters can meet the Step 2 limit without intensive R&D efforts, so that 82% of models would begin R&D to meet the Step 2 limit.[19] <u>Forced-Air Furnaces:</u> Work practice/operational standards will be required of all forced-air furnaces upon the rule's 2015 effective date. A Step 1 PM emission limit of 0.93 lb/mm BTU heat output will be required by 2016 (1 year after the 2015 effective date) for small forced-air furnaces (<65,000 BTU/hr models, representing approximately 25% of current sales) and this same limit of 0.93 lb/mm BTU will be required by 2017 (2 years after the 2015 effective date) for large forced-air furnaces (>=65,000 BTU/hr models, representing approximately 75% of current sales). A Step 2 PM emission limit of 0.15 lb/mm BTU heat output will be required for all forced-air furnace models five years after promulgation in 2020. **Note**: The phased timelines are based on the technological and economic limitations of testing and certifying approximately 50 previously untested forced–air furnaces in the 60 days between signature and the effective date and also on industry comments on the proposed rule, explaining the design challenges for small and large forced-air furnaces, respectively. The Step 1 PM emission limits and the Step 2 PM emission limits are based on test data from development of Canadian standard B415.1-10[20] conversations with industry regarding cleaner forced air furnace models currently being tested in R&D[21] and comments on the proposed rule. Forced air furnace designs able to meet the Step 2 PM emission limit are expected to be based on technology transferred from hydronic heater designs and/or wood stove designs.

We developed adjusted emission factors to reflect the NSPS discussed above, which were then used to calculate new average tons of emissions per appliance for each RWC appliance type. Adjustments were assumed for NSPS emission factors (as noted below) in order to not overstate emission reductions under the NSPS; actual emission reductions may be somewhat greater than reductions resulting from our emission factor adjustments for the purpose of this analysis. Following is a description of how the RWC factors were adjusted for each appliance type:

- <u>Woodstove: all EPA certified</u>. As noted above, we determined the ratio of emissions between the existing 1988 NSPS limits compared to the Washington State standards. For both catalytic and non-catalytic devices, the Washington standard is 60% of the

[19] Memo to David Cole, Gil Wood and Amanda Aldridge, US EPA, from Jill Mozier, EC/R, Inc. Derivation of wood heater model percentages meeting Step 2 standards. November 10, 2014.

[20] CSA B415.1-10, Performance Testing of Solid-Fuel-Burning Heating Appliances. Appendix D. March 2010.

[21] 2/8/13 telephone discussion between Gil Wood, USEPA, and a manufacturer of forced air furnaces.

1988 NSPS. We assumed this same ratio would apply to the emissions factors and multiplied the RWC emission factor (for Phase II certified models) by 60%. We used these adjusted RWC emission factors (shown in Table 4-2) as both baseline and Step 1 PM emission factors for catalytic and non-catalytic stoves. We made the assumption that the Step 1 PM emission factor was the same as the baseline emission factor, because, as noted above, approximately 90% of current wood stove models already meet the Step 1 PM limit according to industry data.[22] For the Step 2 PM emission factor for non-catalytic models, we scaled the Step 1 PM emission factor by the ratio of the Step 2 PM limit to the Step 1 PM limit (or 2.0/4.5 = 0.44). Again, in order to not overstate emissions, for catalytic models, we scaled the Step 1 PM emission factor by the ratio of the Step 2 PM emission limit to the Washington State standard for catalytic stoves (2.0/2.5 = 0.8). For consistency with our shipment data (mentioned later in this RIA) and because the RWC database provides four separate emission factors for catalytic and non-catalytic, freestanding models and fireplace inserts, we used the weighted average value for all four wood stove types to represent the total population of adjustable burn rate woodstoves. Finally, we multiplied the resulting emission factors by the total tons burned for the appliance type (provided by the RWC database) and then divided that by the appliance population (also provided by the RWC database) to derive the tons/appliance of $PM_{2.5}$ emissions. The emission factors and tons/appliance are shown in the green rows in Table 4-3.

- Woodstove: pellet fired, general. We used the RWC emission factor shown in Table 4-2 as both the baseline and Step 1 PM emission factor for pellet stoves because nearly all current pellet stove models already meet the Step 1 PM standard according to industry data.[23] For the Step 2 PM emission factor, we scaled the Step 1 PM emission factor by the ratio of the Step 2 PM limit to the Step 1 PM limit (2.0/4.5 = 0.44). We multiplied the resulting emission factors by the total tons burned for pellet stoves and then divided that by the pellet stove appliance population to derive the tons/appliance of $PM_{2.5}$ emissions. The emission factors and tons/appliance are shown in the orange row in Table 4-3.

- Woodstove: freestanding, non-EPA certified (single burn rate stoves). As described above, we assumed that the freestanding non-EPA certified woodstove emission inventory category includes the population of single burn rate stoves. We therefore used the RWC emission factor for freestanding non-EPA certified woodstoves (30.6 lb/ton) as the baseline emission factor for single burn rate stoves. For the Step 1 PM emission factor, we used the same emission factor as a certified non-catalytic stove meeting the Washington state standards (i.e., 8.76 lb/ton) because the same standard is being proposed for single burn rate stoves as for adjustable burn rate stoves. Likewise, we used the same emission factor used for non-catalytic stoves for the Step 2 PM emission factor. We multiplied the resulting emission factors by the total tons burned for this appliance category and then divided that by the appliance population

[22] Final HPBA Heater Database version 2/25/10, EC/R received from Bob Ferguson for HPBA on 4/26/10.
[23] Final HPBA Heater Database version 2/25/10, EC/R received from Bob Ferguson for HPBA on 4/26/10.

to derive the tons/appliance of $PM_{2.5}$ emissions. The emission factors and tons/appliance are shown in the gray row in Table 4-3.

4.2.1.1 Hydronic Heater: Outdoor/Indoor.

As noted above, we assumed that indoor hydronic heaters (a minority of the hydronic heater population) have the same emission profile as the outdoor hydronic heater appliance category provided in the RWC database. According to the EPA voluntary hydronic heater program, the "Phase 2" heaters that are presumed to represent the NSPS are 90% cleaner than older unqualified units, as determined in laboratory tests on crib wood[24]. We estimate as described in our emissions memorandum that the majority of the existing inventory is represented by these unqualified units, and applied a 90% reduction to the RWC baseline emission factor shown in Table 4-2 (64.0 lb/ton) to derive the Step 1 PM emission factor (6.40 lb/ton). For the Step 2 PM emission factor, we scaled the Step 1 PM emission factor by the ratio of the Step 2 PM limit to the Step 1 PM limit (or 0.10/0.32 = 0.31). We multiplied the resulting emission factors by the total tons burned for the hydronic heater RWC appliance category and then divided that by the hydronic heater appliance population to derive the tons/appliance of $PM_{2.5}$ emissions. The emission factors and tons/appliance are shown in the blue row in Table 4-3.

4.2.1.2 Furnace: Indoor, Cordwood

At baseline, we estimated that forced-air furnaces have the same updated emission factor as hydronic heaters (64 lb/ton), consistent with the fact that hydronic heaters and forced-air furnaces have the same emission factor in version 4.1 of EPA's RWC tool.[25] We therefore used the RWC PM emission factor shown in Table 4-2 (64.0 lb/ton) as the baseline emission factor. For the Step 1 PM emission factor, we scaled the baseline emission factor by 75% (to 16.0 lb/ton) because background material provided in the Canadian standards review process stated that the emission limit associated with this method would result in an approximately 75% reduction in emissions compared to a non-qualifying furnace.[26] The Step 2 PM emission limit of 0.15 lb/mm BTU for indoor cordwood furnaces (based on cord wood, consistent with the test method) is roughly equivalent to the hydronic heater (crib wood-based) limit of 0.10 lb/mm BTU. We estimate that the baseline PM emission factor for each appliance category is also the same. Therefore, we used the same Step 2 PM emission factor used for hydronic heaters (2.00

[24] See the EPA Burnwise Website: http://www.epa.gov/burnwise/participation.html.

[25] Emission factors are based on EPA's Residential Wood Combustion Tool version 4.1 with updates from the 2012 EPA report (Gullett et al. Environmental, Energy Market, and Health Characterization of Wood-Fired Hydronic Heater, Final Report, June 2012).

[26] Review draft of CSA B415.1-10, Performance Testing of Solid-Fuel-Burning Heating Appliances. Appendix C. March 2010.

lb/ton). We multiplied the emission factors by the total tons burned for the cordwood furnace RWC appliance category and then divided that by the furnace appliance population to derive the tons/appliance of $PM_{2.5}$ emissions. The emission factors and tons/appliance are shown in the lavender row in Table 4-3. See Table 4-3 for a summary of all of the PM emission factors and resulting tons/appliance values for the baseline and NSPS. Table 4-3 presents the baseline, Step 1, and Step 2 PM emission factors for each appliance type resulting from our assumptions and adjustments described above. We used the appropriate tons/appliance with annual shipment data to estimate annual $PM_{2.5}$ emissions based on the phased emission reduction dates.

Table 4-3. NSPS Adjusted Factors for $PM_{2.5}$ – Baseline, Step 1, and Step 2*

Emission Inventory Category	Baseline Emission Factor (lb/ton)	Baseline Emissions/ Appliance (tons)	Tons/ Appl/ yr	Step 1 Emission Factor	Step 1 Emissions (Tons)	Step 1 Tons/ Appl/yr	Step 2 Emission Factor lb/ton	Step 2 Emissions (tons)	Step 2 Tons/appl
Woodstove: fireplace inserts; EPA certified; non-catalytic	8.76	5,371	0.0041	8.76	5,371	0.0041	3.89	2,387	0.0018
Woodstove: fireplace inserts; EPA certified; catalytic	9.72	2,023	0.0047	9.72	2,023	0.0047	7.79	1,618	0.0038
Woodstove: freestanding, EPA certified, noncatalytic	8.76	6,745	0.0077	8.76	6,745	0.0077	3.89	2,998	0.0034
Woodstove: freestanding, EPA certified, catalytic	9.72	3,769	0.0101	9.72	3,769	0.0101	7.78	3,016	0.0081
Woodstove: pellet-fired, general	3.06	1,798	0.0021	3.06	1,798	0.0021	1.36	799	0.0009
Hydronic heater: outdoor	64.0	116,933	0.3208	6.4	11,693	0.0321	2.00	3,654	0.0100
Furnace: indoor, cordwood (all)	64.0	83,972	0.2392	16.0	20,993	0.0598	2.00	2,624	0.0075
Furnace: indoor, cordwood (small)	64.0	20,993	0.2392	16.0	5,248	0.0598	2.00	656	0.0075
Furnace: indoor, cordwood (large)	64.0	62,979	0.2392	16.0	15,745	0.0598	2.00	1,968	0.0075
Single Burn Rate Stoves (freestanding, non-EPA certified)	30.6	71,424	0.0324	8.76	20,447	0.0093	3.89	9,088	0.0041

* Step 1 standards becomes effective in 2015 for all appliances, except forced-air furnaces, for which the compliance dates are 2015 for work practice/operational standards, 2016 for the Step 1 PM emission limit for small furnaces and 2017 for the Step 1 PM emission limits for large furnaces. Step 2 standards becomes effective in 2020 for all appliances.

4.2.2 Voluntary Programs

Within these emissions projections are the effects not only of rules but also of various voluntary programs managed by EPA and states. Studies have shown that fine particle ($PM_{2.5}$) concentrations in proximity to a typical outdoor wood boiler are likely to exceed the 24-hour National Ambient Air Quality Standards (NAAQS).[18] Thus, the EPA developed the voluntary Hydronic Heater Program to encourage manufacturers to reduce impacts on air quality through developing and distributing cleaner, more efficient hydronic heaters. We developed the voluntary program because it could bring cleaner models to market faster than the traditional federal regulatory process. Phase 1[19] emission level (0.60 pounds per million British Thermal Unit (lb/MMBTU) heat input) qualifying[20] units are approximately 70% cleaner than typical unqualified units. After March 31, 2010, units that only meet the Phase 1 emission level are no longer considered "qualified models" under the voluntary program. Phase 2 emission level (0.32 lb/MMBTU heat output) qualifying units are approximately 90% 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 improved heat exchangers.

In addition to the voluntary program, the 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 regulate residential wood hydronic heaters. The model rule is a starting point for local regulatory authorities to consider, and they may need to also adopt additional actions due to site-specific concerns, e.g., local terrain, meteorology, proximity of neighbors and other exposed individuals. Thus, some regulatory authorities have instituted additional requirements, including bans on hydronic heaters in some areas.

The EPA also developed a similar voluntary partnership program for low-mass fireplaces (engineered, pre-fabricated fireplaces) and site-built masonry fireplaces. The original partnership agreements were dated February 19, 2009, and pertained to low-mass fireplaces. On July 4, 2009, the program was expanded to other fireplaces, e.g., masonry fireplaces. Under this

[18] For more information on wood smoke health effects, See: "Smoke Gets in Your Lungs: Outdoor Wood Boilers in New York State," prepared by Judith Schrieber, Ph.D., et al., for the Office of the Attorney General of New York. August 2005. See also: "Assessment of Outdoor Wood-fired Boilers," prepared by NESCAUM, March 2006 (revised June 2006).

[19] Phase 1" and "Phase 2" emission levels refer to levels established in EPA voluntary programs. The earlier use of the term "Phase II" (with a Roman numeral) standard refers to standards established in the current subpart AAA for residential wood heaters.

[20] The terms "qualified" and "unqualified," or other similar terms, refer to models that meet the voluntary program performance levels. Later use of the terms "certified" and "uncertified," or other similar terms, refers to models that are deemed to be in compliance with the NSPS emission limits.

program, cleaner burning fireplaces are ones that qualify for the Phase 1 emissions level of 7.3 g of particles emitted per kg of fuel burned (approximately 57% cleaner than unqualified models) or the Phase 2 emissions level of 5.1 g/kg (approximately 70% cleaner than unqualified models). So far, 11 models have qualified under this voluntary program at the Phase 2 level. Typically, qualified models have improved insulation and added secondary combustion and/or a catalyst to reduce emissions. Some manufacturers have added closed doors to reduce the excess air and thus improve combustion. Some state and local agencies have needed to reduce emissions further and thus some have no-burn days and some have adopted bans of new fireplaces in some areas in order to attain the $PM_{2.5}$ NAAQS.

4.2.3 Shipment Data Used to Estimate Baseline Emissions

We used data in the Frost & Sullivan Market (F&S) report[21] on 2008 shipments by product category, and F&S revenue forecasts which incorporated the weak economy in years 2009 and 2010, to calculate the reduced number of shipments in years 2009 and 2010. Forced air furnaces were outside the scope of the F&S report. Instead, we used manufacturer estimates of total industry sales in 2008[22] and applied the F&S market factors to estimate shipments through 2010. The F&S wood stove numbers included both certified and non-certified stoves, so we estimated numbers of non-certified stove shipments out of the total reported wood stove category. [23] These shipments were deleted from the total wood stove category shipments. We expanded the 2008 single burn rate estimate using the F&S factors. Our estimates of annual shipments, truncated to 2020, are shown in Table 4-4. The full set of annual shipments data can be found in the emissions memo for this final rule.

For years 2011 through 2029 (for the NSPS) estimated shipments are based on a forecasted revenue growth rate of 2.0%, in keeping with the average annual growth in real U.S. GDP predicted by the Conference Board.[24] We use the average annual growth rate forecast from the Conference Board as a basis for estimating future growth in shipments when specific projections are not available. We do this since there are manufacturing industries in multiple NAICS that are impacted by this final rule as noted in Section 3 of this RIA, and the economic activity in these industries is typically reflective of changes in real GDP in the U.S. There is not a perfect correlation between shipments and revenue (for example, because of their higher unit

[21] Market Research and Report on North American Residential Wood Heaters, Fireplaces, and Hearth Heating Products Market. Prepared by Frost & Sullivan. April 26, 2010. pp. 31-32.
[22] NSPS Review and Comments. Confidential Business Information submitted by manufacturer. September 2010.
[23] Memo to Gil Wood, USEPA, from EC/R, Inc. Estimated Emissions from Wood Heaters. January 30, 2015.
[24] 2014 Global Outlook projections prepared by the Conference Board in November 2013; http://www.conference-board.org/data/globaloutlook.cfm

cost, pellet stoves generate more absolute revenue than wood stoves), but as stated in our emissions memorandum, we think the overall trend in the projection is reasonable in the absence of specific shipment projections. The only exceptions to the use of a 2.0% GDP-based growth rate are for years 2012 and 2018, in which we used industry estimates for hydronic heater and wood stove shipments, respectively. In addition, for year 2012, an HPBA consultant estimated there were 13,100 baseline hydronic heater sales.[26] For year 2018, the same HPBA consultant projected there to be 100,000 wood stove sales.[27] We adjusted our estimated shipment data accordingly. The shipment data in Table 4-4 below includes presentation by indoor cordwood furnace (forced air furnace) size categories as well for that entire appliance category.[28]

Table 4-4. Estimated Annual Shipments by Category, 2008-2020

	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Wood stoves	126,527	80,851	77,617	79,169	80,752	82,367	84,015	85,695	87,409	89,157	100,000	102,000	104,040
Single burn rate stoves	40,000	25,560	24,538	25,028	25,529	26,039	26,560	27,091	27,633	28,186	28,750	29,325	29,911
Pellet stoves	130,381	83,313	79,981	81,581	83,212	84,876	86,574	88,305	90,072	91,873	93,710	95,585	97,496
Furnace: indoor, cordwood (all)	41,000	26,199	25,151	25,654	26,167	26,690	27,224	27,769	28,324	28,891	29,468	30,058	30,659
Furnace: indoor, cordwood (small)	10,250	6,550	6,288	6,414	6,542	6,673	6,806	6,942	7,081	7,223	7,367	7,514	7,665
Furnace: indoor, cordwood (large)	30,250	19,649	18,863	19,241	19,625	20,018	20,418	20,827	21,243	21,668	22,101	22,543	22,994
Hydronic heating systems	13,385	8,553	8,211	8,375	13,100	13362	13,629	13,902	14,180	14,463	14,753	15,048	15,349

[26] Cost-Effectiveness Analysis of Alternative Hydronic Heater New Source Performance Standards, prepared for the Hearth, Patio, and Barbecue Association by NERA Economic Consulting, May 2014.

[27] Cost-Effectiveness Analysis of Alternative Woodstove New Source Performance Standards, prepared for the Hearth, Patio, and Barbecue Association by NERA Economic Consulting, May 2014.

[28] Memorandum to Docket ID Number EPA-HQ-2009-0734 from EC/R, Inc. to U.S. EPA. Baseline and NSPS emissions from small and large forced-air furnaces. February 2015.

Our cost effectiveness analysis (CE)[29] assumes a 10-year model design lifespan as well as a 20-year use/emitting appliance lifespan. These assumptions were made to best characterize the actual model design and use lifespans. For proposal, we used a 20-year model design lifespan, reasoning that many models developed for the 1988 NSPS are still being sold (after 25 years), with many "new" models retaining the same internal working parts with merely exterior cosmetic changes. Respectful of comments on the proposed rule[30], however, in which some industry representatives commented that a shorter model lifespan is more accurate, we reduced our assumed model design lifespan to 10 years for this analysis. Regarding the emitting lifespan of the appliance, most wood heaters in consumer homes emit for at least 20 years and often much longer. Therefore our CE analysis tracks shipments through year 2029 (assuming a 10-year design life for a model meeting the Step 2 limit in year 2020) and emissions through year 2048 (assuming a 20-year emitting life for an appliance shipped in year 2029). Table 4-4 is a truncated summary of our actual shipment data which extended through years 2029. See the CE analysis spreadsheets[31] for the complete shipment data.

4.3 Estimated $PM_{2.5}$ Emissions from Shipments of New Appliances

As described above, we calculated the average emissions per appliance type using the emission factor for each category multiplied by the inventory value of total tons of wood burned divided by the number of appliances in the inventory population. This value was then multiplied by the number of shipments to calculate total emissions from each category per year under baseline conditions (i.e., in the absence of an NSPS). Furthermore, in order not to overstate emission reductions caused by the NSPS, baseline emissions were discounted by the percentage of appliances already meeting the Step 2 PM emission limit (i.e., 26% of wood stoves, 70% of pellet stoves, and 18% of hydronic heaters are estimated to already meet the Step 2 PM emission limit). More information on these calculations is available in the emissions memorandum in the docket for this rulemaking.[26]

Table 4-5 on the next page shows a truncated summary of the estimated $PM_{2.5}$ emissions (in tons) under baseline conditions through year 2020. We then estimated emissions under the

[29] Memorandum to USEPA from EC/R, Inc. Residential Wood Heater Cost Effectiveness Analysis. January 30, 2015.

[30] Comments on the proposed NSPS are available electronically through http://www.regulations.gov by searching Docket IDs EPA-HQ-OAR-2009-0734.

[31] *See* January 2015 cost effectiveness (CE) spreadsheets including for $PM_{2.5}$ the *Revised Final Wood Heater NSPS PM CE 7%* for the CE analysis supporting the NSPS. All of these spreadsheets are found in the public docket for this rulemaking.

[26] Memo to Gil Wood, USEPA, from EC/R, Inc. Estimated Emissions from Wood Heaters. January 30, 2015.

NSPS (Table 4-6) based on the respective assumptions and phase-in timelines. Under the NSPS, the Step 1 limit becomes effective in 2015 and the Step 2 limit in 2020. The emission estimates assume that the total number of shipped units meet the standard in the year the standard is implemented. As noted above, we discounted NSPS emissions by the percentage of appliances already meeting the Step 2 limit.

Tables 4-5, 4-6, and 4-7 show the $PM_{2.5}$ emission estimates in the baseline, with the final NSPS, and difference between the two out to year 2020 for comparison. These are truncated summaries. These summaries include emission estimates by forced air furnace size category as well as for that entire appliance category. Our CE analysis tracks emission reductions out through 2048, for the NSPS assuming a 10 year design life for a model meeting each phased-in limit, and assuming that stoves shipped in the 10th year will be emitting in homes for another 20 years. See the cost-effectiveness analysis spreadsheets[27] for all years of emission data, both baseline and under each NSPS option considered. As evident in our spreadsheets, our CE analysis incorporates "trailing emissions" as part of our 20-year emitting lifespan assumption, in order to not overstate emission reductions. For example, our analysis assumes that a stove shipped in 2015 will emit in homes for 20 years – or until 2034 (inclusive of both 2015 and 2034). We therefore drop emissions from this stove in our analysis in year 2035. Likewise, we drop emissions for a stove shipped in 2016 in year 2036, and so on. These spreadsheets are available in the public docket for this rulemaking.

The CE analysis spreadsheets[18] show all years of emission data, under both baseline and NSPS scenarios, as well as cumulative $PM_{2.5}$ emission reductions through year 2048. Spreadsheets are provided for appliances regulated under subpart AAA "Room Heaters" (i.e., wood stoves, pellet stoves, and single burn rate stoves), as well as for appliances under subpart QQQQ "Central Heaters" (i.e., forced air furnaces and hydronic heaters). The CE analysis also includes a spreadsheet showing cumulative emissions and emission reductions for subparts AAA and QQQQ combined.

[27] See cost effective (CE) spreadsheets including for $PM_{2.5}$ the *2020 Step 2 Wood Heater NSPS PM25 CE 7% 1-30-4-2015.xls* for the CE analysis of the NSPS.

Table 4-5. Estimated $PM_{2.5}$ Emissions (Tons): Baseline*

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Wood stoves	563	360	345	352	359	367	374	381	389	397	445	454	463
Single burn rate stoves	1,295	827	794	810	826	843	860	877	895	912	931	949	968
Pellet stoves	83	53	51	52	53	54	55	56	57	59	60	61	62
Furnace: indoor, cordwood (all)	9,808	6,267	6,017	6,137	6,260	6,385	6,513	6,643	6,776	6,911	7,049	7,190	7,334
Furnace: indoor, cordwood (small)	2,452	1,567	1,504	1,534	1,565	1,596	1,628	1,661	1,694	1,728	1,762	1,798	1,834
Furnace: indoor, cordwood (large)	7,356	4,700	4,512	4,603	4,695	4,789	4,884	4,982	5,082	5,183	5,287	5,393	5,501
Hydronic heating systems	3,520	2,250	2,160	2,203	3,446	3,514	3,585	3,656	3,730	3,804	3,880	3,958	4,037
Total	**15,269**	**9.757**	**9,367**	**9,554**	**10,944**	**11,163**	**11,386**	**11,614**	**11,846**	**12,083**	**12,365**	**12,612**	**12,865**

*Estimates are reduced for the percentage of appliances assumed to already meet the Step 2 PM emission limit (26% of wood stoves, 70% of pellet stoves and 18% of hydronic heaters), in order to not overstate emission reductions attributable to this NSPS.

Table 4-6. Estimated $PM_{2.5}$ Emissions (Tons): NSPS**

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Wood stoves	563	360	345	352	359	367	374	381	389	397	445	454	259
Single burn rate stoves	1,295	827	794	810	826	843	860	251	256	261	266	272	123
Pellet stoves	83	53	51	52	53	54	55	56	57	59	60	61	28
Furnace: indoor, cordwood (all)	9,808	6,267	6,017	6,137	6,260	6,385	6,513	6,643	5,505	1,728	1,762	1,798	229

Furnace: indoor, cordwood (small)	2,452	1,567	1,504	1,534	1,565	1,596	1,628	1,661	423	432	441	449	57
Furnace: indoor, cordwood (large)	7,356	4,700	4,512	4,603	4.695	4,789	4,884	4,982	5,082	1,296	1,322	1,348	172
Hydronic heating systems	3,520	2,250	2,160	2,203	3,446	3,514	3,585	366	373	380	388	396	126
Total	**15,269**	**9,757**	**9,367**	**9,554**	**10,944**	**11,163**	**11,386**	**7,697**	**6,581**	**2,825**	**2,922**	**2,980**	**765**

**Step 1 PM emission limit in 2015 and Step 2 PM emission limit in 2020 for all appliances, except forced-air furnaces have work practice/operational standards in 2015, Step 1 PM emission limits for small furnaces in 2016, Step 1 PM emission limits for large furnaces in 2017 and Step 2 PM emission limits for all furnaces in 2020. In order to not overstate emission reductions attributable to this NSPS, estimates are reduced for the percentage of appliances estimated to already meet the Step 2 PM emission limits (26% of wood stoves, 70% of pellet stoves and 18% of hydronic heaters). In this analysis, emission reductions for forced-air furnaces are not quantified for the work practice/operational standard required in 2015, although stakeholders agree that work practice/operational standards will reduce emissions.

Table 4-7. Estimated $PM_{2.5}$ Emission Reductions from the NSPS (Tons):

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Wood stoves	0	0	0	0	0	0	0	0	0	0	0	0	204
Single burn rate stoves	0	0	0	0	0	0	0	626	639	651	665	677	845
Pellet stoves	0	0	0	0	0	0	0	0	0	0	0	0	34
Furnace: indoor, cordwood (all)	0	0	0	0	0	0	0	0	1,271	5,183	5,287	5,392	7,105
Furnace: indoor, cordwood (small)	0	0	0	0	0	0	0	0	1,271	1,296	1,321	1,349	1,777
Furnace: indoor, cordwood (large)	0	0	0	0	0	0	0	0	0	3,887	3,965	4,043	5,328
Hydronic heating systems	0	0	0	0	0	0	0	3,290	3,357	3,424	3,492	3,562	3,911
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3,917**	**5,265**	**9,258**	**9,443**	**9,632**	**12,099**

From the tables above, we can show that the average of the annual $PM_{2.5}$ emission reductions between the year of rule promulgation, 2015, and the year that the final rule is fully implemented (2020) is 8,269 tons, or nearly 8,300 tons, for the final rule. Most of these reductions occur from the indoor cordwood furnace and hydronic heater categories.

4.4 Methodology for Estimating VOC Emissions from New Units

We used the same methodology described in Section 4.3 to develop emission estimates for VOC emissions. Using the RWC database, we developed an estimate of VOC emissions per appliance using baseline emission factors. Then, using the same NSPS phase-in assumptions and anticipated emission reductions (i.e., that VOC reductions are comparable to $PM_{2.5}$ reductions), we developed emission factors to be used in analyzing the NSPS. Table 4-8 provides the VOC emission factors by compliance step and appliance category.

Table 4-8. NSPS VOC Emission Factors – Baseline, Step 1, and Step 2*

Emission Inventory Category	Baseline Emission Factor (lb/ton)	Emissions (tons)	Tons/ Appl/Yr	Step 1 Emission Factor (lb/ton)	Step 1 Emissions (tons)	Step 1 Tons/ Appl/Yr	Step 2 Emission Factor (lb/ton)	Step 2 Emissions (tons)	Alt. Step 2 Tons/ Appl/Yr
Woodstove: fireplace inserts; EPA certified; non-catalytic	12.00	7,357	0.0056	12.00	7,357	0.0056	5.33	3,270	0.0025
Woodstove: fireplace inserts; EPA certified; catalytic	15.00	3,121	0.0073	15.00	3,121	0.0073	12.00	2,497	0.0058
Woodstove: freestanding, EPA certified, non-catalytic	12.00	9,240	0.0106	12.00	9,240	0.0106	5.33	4,107	0.0047
Woodstove: freestanding, EPA certified, catalytic	15.00	5,817	0.0155	15.00	5,817	0.0155	12.00	4,654	0.0124
Woodstove: pellet-fired, general	0.041	24	0.0000	0.041	24	0.0000	0.02	11	0.0000
Hydronic heater: outdoor	67.4	123,145	0.3378	6.74	12,314	0.0338	2.11	3,848	0.0106
Furnace: indoor, cordwood (all)	67.4	88,433	0.2519	16.85	22,108	0.0630	2.11	2,764	0.0079
Furnace: indoor, cordwood (small)	67.4	22,108	0.2519	16.85	5,527	0.0630	2.11	691	0.0079
Furnace: indoor, cordwood (large)	67.4	66,325	0.2519	16.85	16,581	0.0630	2.11	2,073	0.0079
Single burn rate stoves (freestanding, non-EPA certified)	53.00	123,709	0.0561	12.00	28,010	0.0127	5.33	12,449	0.0056

* Step 1 PM standard becomes effective in 2015 for all appliances, except forced-air furnaces, for which the compliance dates are 2015 for work practice/operational standards, 2016 for the Step 1 PM emission limit for small furnaces and 2017 for the Step 1 PM emission limit for large furnaces. Step 2 standards become effective in 2020 for all appliances.

Using the same assumptions as we used for $PM_{2.5}$, we calculated VOC emissions at baseline and under each NSPS option based on a 10-year model design lifespan for appliance shipments as well as a 20-year appliance life. Tables 4-9 through 4-11 provide the time series of VOC annual emissions estimates between 2008 and 2020 for the baseline, with the NSPS, and the difference between the two. Although VOC emissions are not being regulated under this NSPS, estimated VOC emissions and emission reductions are provided separately in our CE analysis spreadsheets.[32]

[32] See cost effective (CE) spreadsheets for VOC entitled *2020 Step 2 Wood Heater NSPS VOC CE 7% 1-30-15.xls*

Table 4-9. Estimated VOC Emissions (Tons): Baseline*

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Wood stoves	803	513	493	502	512	523	533	544	555	566	635	647	660
Single burn rate stoves	2,243	1,433	1,376	1,403	1,431	1,460	1,489	1,519	1,549	1,580	1,612	1,644	1,677
Pellet stoves	1	1	1	1	1	1	1	1	1	1	1	1	1
Furnace: indoor, cordwood (all)	10,329	6,600	6,336	6,463	6,592	6,724	6,859	6,996	7,136	7,278	7,424	7,572	7,724
Furnace: indoor, cordwood (small)	2,582	1,650	1,584	1,616	1,648	1,681	1,715	1,749	1,784	1,820	1,856	1,893	1,931
Furnace: indoor, cordwood (large)	7,747	4,950	4,752	4,847	4,944	5,043	5,144	5,247	5,352	5,459	5,568	5,679	5,793
Hydronic heating systems	3,707	2,369	2,274	2,320	3,629	3,701	3,775	3,851	3,928	4,006	4,086	4,168	4,251
Total	**17,083**	**10,916**	**10,480**	**10,689**	**12,165**	**12,409**	**12,657**	**12,910**	**13,168**	**13,431**	**13,758**	**14,033**	**14,313**

Table 4-10. Estimated VOC Emissions (Tons): NSPS*

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Wood stoves	803	513	493	502	512	523	533	544	555	566	635	647	376
Single burn rate stoves	2,243	1,433	1,376	1,403	1,431	1,460	1,489	344	351	358	365	372	169
Pellet stoves	1	1	1	1	1	1	1	1	1	1	1	1	0
Furnace: indoor, cordwood (all)	10,329	6,600	6,336	6,463	6,592	6,724	6,859	6,996	5,798	1,820	1,856	1,893	241
Furnace: indoor, cordwood (small)	2,582	1,650	1,584	1,616	1,648	1,681	1,715	1,749	446	455	464	473	60
Furnace: indoor, cordwood (large)	7,747	4,950	4,752	4,847	4,944	5,043	5,144	5,247	5,352	1,365	1,392	1,420	181
Hydronic heating systems	3,707	2,369	2,274	2,320	3,629	3,701	3,775	385	393	401	409	417	133
Total	**17,083**	**10,916**	**10,480**	**10,689**	**12,165**	**12,409**	**12,657**	**8,269**	**7,097**	**3,145**	**3,265**	**3,330**	**919**

* Step 1 PM emission limit in 2015 and Step 2 PM emission limit in 2020 for all appliances, except forced-air furnaces have work practice/operational standards in 2015, Step 1 PM emission limits for small furnaces in 2016, Step 1 PM emission limits for large furnaces in 2017 and Step 2 PM emission limits for all furnaces in 2020. In order to not overstate emission reductions attributable to this NSPS, estimates are reduced for the percentage of appliances estimated to already meet the Step 2 PM emission limits (26% of wood stoves, 70% of pellet stoves and 18% of hydronic heaters). In this analysis, emission reductions for forced-air furnaces are not quantified for the work practice/operational standard required in 2015, although stakeholders agree that work practice/operational standards will reduce emissions.

Table 4-11. Estimated VOC Emission Reductions from the NSPS (Tons):

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Wood stoves	0	0	0	0	0	0	0	0	0	0	0	0	284
Single burn rate stoves	0	0	0	0	0	0	0	1,175	1,198	1,222	1,247	1,272	1,508
Pellet stoves	0	0	0	0	0	0	0	0	0	0	0	0	0
Furnace: indoor, cordwood (all)	0	0	0	0	0	0	0	0	1,338	5,458	5,568	5,679	7,483
Furnace: indoor, cordwood (small)	0	0	0	0	0	0	0	0	1,338	1,365	1,392	1,420	1,871
Furnace: indoor, cordwood (large)	0	0	0	0	0	0	0	0	0	4,094	4,176	4,259	5,612
Hydronic heating systems	0	0	0	0	0	0	0	3,466	3,535	3,606	3,678	3,751	4,119
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4,641**	**6,071**	**10,287**	**10,493**	**10,702**	**13,394**

From the tables above, we can show that the average of the annual emission reductions between the year of rule promulgation, 2015, and the year that the NSPS is fully implemented (2020) is 9,265 tons, or nearly 9,300 tons, for the final rule.

4.5 Methodology for Estimating CO Emissions from New Units

We used the same methodology described in Section 4.3 to develop estimates for CO emissions. Using the RWC database, we developed an estimate of CO emissions per appliance using baseline emission factors. Then, using the same NSPS phase-in assumptions and anticipated emission reductions (i.e., that CO reductions are comparable to $PM_{2.5}$ reductions), we developed emission factors to be used in analyzing the changes in emissions from applying the NSPS. Table 4-12 presents the CO emission factors by compliance step and appliance category.

Table 4-12. NSPS CO Emission Factors-Baseline, Step 1, and Step 2*

Emission Inventory Category	Baseline Emission Factor (lb/ton)	Baseline Emissions (tons)	Tons/ Appl/Yr	Step 1 Emission Factor (lb/ton)	Step 1 Emissions (tons)	Step 1 Tons/ Appl/Yr	Step 2 Emission Factor (lb/ton)	Step 2 Emissions (tons)	Step 2 Tons/ Appl./Year
Woodstove: fireplace inserts; EPA certified; non-catalytic	140.8	86,323	0.0662	140.8	86,323	0.0662	62.6	38,366	0.0294
Woodstove: fireplace inserts; EPA certified; catalytic	104.4	21,725	0.0509	104.4	21,725	0.0509	83.5	17,380	0.0407
Woodstove: freestanding, EPA certified, non-catalytic	140.8	108,418	0.1241	140.8	108,418	0.1241	62.6	48,186	0.0552
Woodstove: freestanding, EPA certified, catalytic	104.4	40,486	0.1082	104.4	40.486	0.1082	83.5	32,389	0.0866
Woodstove: pellet-fired, general	15.9	9,344	0.0110	15.9	9,344	0.0110	7.1	4,153	0.0049
Single burn rate stoves (freestanding, non-EPA-certified)	230.8	538,716	0.2442	140.8	328,645	0.1489	62.6	146,064	0.0662
Hydronic heater: outdoor	360	657,748	1.8042	36	65,775	0.1804	11.3	20,555	0.0564
Furnace: indoor, cordwood (all)	360	472,341	1.3456	90	118,085	0.3364	11.3	14,761	0.0421
Furnace: indoor, cordwood (small)	360	118,085	1.3456	90	29,521	0.3364	11.3	3,690	0.0421
Furnace: indoor, cordwood (large)	360	354,256	1.3456	90	88,564	0.3364	11.3	11,071	0.0421

* Step 1 PM standard becomes effective in 2015 for all appliances, except forced-air furnaces, for which the compliance dates are 2015 for work practice/operational standards, 2016 for Step 1 PM emissions limit for small furnaces and 2017 for the Step 1 PM emission limits for large furnaces. Step 2 standards becomes effective in 2020 for all appliances.

Using the same assumptions as we used for $PM_{2.5}$, we calculated CO emissions at baseline and for the NSPS. Table 4-13 shows the annual baseline emissions for CO for 2008 to 2020, and Tables 4-14 and 4-15 show the CO emissions with the NSPS and difference between the two. Although CO emissions are not being regulated under this NSPS, estimated CO emissions and emission reductions are provided separately in our CE analysis spreadsheets.[33]

[33] See cost effective (CE) spreadsheets for CO entitled *2020 Step 2 Wood Heater NSPS CO CE 7%1-30-15.xls.*

Table 4-13. Estimated CO Emissions (Tons): Baseline*

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Wood stoves	8,079	5,163	4,956	5,055	5,156	5,259	5,365	5,472	5,581	5,693	6,385	6,513	6,643
Single burn rate stoves	9,766	6,241	5,991	6,111	6,233	6,358	6,485	6,614	6,747	6,882	7,019	7,160	7,303
Pellet stoves	432	276	265	270	275	281	287	292	298	304	310	316	323
Furnace: indoor, cordwood (all)	55,170	35,254	33,844	34520	35,211	35,915	36,633	37,366	38,113	38,876	39,653	40,446	41,255
Furnace: indoor, cordwood (small)	13,793	8,813	8,461	8,630	8,803	8,979	9,158	9,342	9,528	9,719	9,913	10,112	10,314
Furnace: indoor, cordwood (large)	41,378	26,440	25,383	25,890	26,408	26,936	27,545	28,025	28,585	29,157	29,740	30,335	30,941
Hydronic heating systems	19,803	12,654	12,148	12,391	19,381	19,769	20,164	20,567	20,979	21,398	21,826	22,263	22,708
Total	**93,249**	**59,586**	**57,203**	**58,347**	**66,256**	**67,582**	**68,933**	**70,312**	**71,718**	**73,152**	**75,194**	**76,698**	**78,232**

Table 4-14. Estimated CO Emissions (Tons): NSPS*

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Wood stoves	8,079	5,163	4,956	5,055	5,156	5,259	5,365	5,472	5,581	5,693	6,385	6,513	3,524
Single burn rate stoves	9,766	6,241	5,991	6,111	6,233	6,358	6,485	4,035	4,116	4,198	4,282	4,368	1,980
Pellet stoves	432	276	265	270	275	281	287	292	298	304	310	316	143
Furnace: indoor, cordwood (all)	55,170	35,254	33,844	34,520	35,211	35,915	36,633	37,366	2,383	9,719	9,913	10,112	1,289
Furnace: indoor, cordwood (small)	13,793	8,813	8,461	8,630	8,803	8,979	9,158	9,342	2,382	2,430	2,478	2,528	322
Furnace: indoor, cordwood (large)	41,378	26,440	25,383	25,890	26,408	26,936	27,475	28,025	28,585	7,289	7,435	7,584	967
Hydronic heating systems	19,803	12,654	12,198	12,391	19,381	19,769	20,164	2,057	2,098	2,140	2,183,	2,226	710
Total	**93,249**	**59,586**	**57,203**	**58,347**	**66,256**	**67,582**	**68,933**	**49,222**	**43,060**	**22,054**	**23,073**	**23,535**	**7,647**

* Step 1 PM emission limit in 2015 and Step 2 PM emission limit in 2020 for all appliances, except forced-air furnaces have work practice/operational standards in 2015, Step 1 PM emission limits for small furnaces in 2016, Step 1 PM emission limits for large furnaces in 2017 and Step 2 PM emission limits for all furnaces in 2020. In order to not overstate emission reductions attributable to this NSPS, estimates are reduced for the percentage of appliances estimated to already meet the Step 2 PM emission limits (26% of wood stoves, 70% of pellet stoves and 18% of hydronic heaters). In this analysis, emission reductions for forced-air furnaces are not quantified for the work practice/operational standard required in 2015, although stakeholders agree that work practice/operational standards will reduce emissions.

Table 4-15. Estimated CO Emission Reductions (Tons)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Wood stoves	0	0	0	0	0	0	0	0	0	0	0	0	3,119
Single burn rate stoves	0	0	0	0	0	0	0	2,579	2,631	2,684	2,737	2,792	5,323
Pellet stoves	0	0	0	0	0	0	0	0	0	0	0	0	180
Furnace: indoor, cordwood (all)	0	0	0	0	0	0	0	0	35,730	29,157	29,740	30,335	39,966
Furnace: indoor, cordwood (small)	0	0	0	0	0	0	0	0	7,146	7,289	7,435	7,584	9,992
Furnace: indoor, cordwood (large)	0	0	0	0	0	0	0	0	0	21,868	22,305	22,751	29,974
Hydronic heating systems	0	0	0	0	0	0	0	18,511	18,881	19,258	19,644	20,036	21,998
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**21,090**	**28,658**	**51,099**	**52,121**	**53,163**	**70,585**

From the tables above, we can show that the average of the annual CO emission reductions between the year of rule promulgation, 2015, and the year that the NSPS is fully implemented (2020) is 46,119 tons, or just over 46,000 tons.

Sensitivity analyses of these emission estimates were prepared for GDP growth rates of 2.1%, 2.5%, and 3.0%. These analyses can be found in Appendix A of the cost-effectiveness memorandum for the final rule.[34]

[34] Memo to Gil Wood and David Cole, US EPA from EC/R, Inc. Residential Wood Heater Cost Effectiveness Analysis. January 30, 2015. Appendix A.

SECTION 5
COST ANALYSIS, ENERGY IMPACTS, AND EXECUTIVE ORDER ANALYSES

In this section, we provide the estimates of total compliance costs and background behind their estimation. The estimates of compliance costs use the control cost methodology employed in the EPA Air Pollution Control Cost Manual to estimate capital and annual costs,[46] and incorporate some of the data provided by commenters on the proposal as explained in the section. In addition, we provide a qualitative economic impact analysis of the proposed rule's impact on consumer and producer decisions, a qualitative discussion on unfunded mandates that may occur as a result of this final rule, and a partial analysis of the impacts of this rule on employment. We used the direct annual compliance costs as an approximate measure of total social costs.

Given these constraints, several economic frameworks can be used to estimate the economic impacts and social costs of regulations; however, OAQPS has traditionally relied on partial equilibrium market models. Previous NSPS economic impact analyses for the residential wood stove market were prepared reflecting such a model standpoint. However, the current data do not provide sufficient details to develop a market model; the data that are available have little or no sector/firm detail and are reported at the national level. In addition, some sectors have unique market characteristics that make developing partial equilibrium models difficult. Therefore, we have prepared the economic impact analysis including a qualitative partial equilibrium framework.

The costs for the final rule are higher than those for the proposal rule. Changes to the cost analyses from the proposal to the final rule are included in the presentation of the cost analyses below.

5.1 Background for Compliance Costs

5.1.1 Estimated Research and Development (R&D) Costs

5.1.1.1 Model Development Costs – Room Heaters

Prior to proposal of the NSPS, EPA received various estimates of the costs to bring a wood heater from concept to completion, from $200,000 for a single model to $1,360,000 for a 4-firebox model line. For example, a recent *Hearth and Home* article [47]estimated the total cost to

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[46] EPA Air Pollution Control Cost Manual. 2002. Sixth Edition. Available on the Internet at http://epa.gov/ttn/catc/products.html#cccinfo.

[47] James E. Houck and Paul Tiegs. *There's a Freight Train Comin'*. *Hearth and Home*. December 2009.

bring a model from conception to market as $645,000 to $750,000 for steel stoves and over $1 million for cast-iron, enameled wood stoves. The authors indicated that costs would decrease for separate models in the same line by up to 25%. Based on this information, we estimate that a 4-model steel line would cost up to $328,000 per model to develop. These costs include marketing, design, developing first generation, second generation and prototype units; NSPS and safety testing, equipment tooling, etc. The manufacturer supplying these figures for the article estimated that the NSPS and safety testing component of these costs would constitute $40,000 per model. Two other manufacturers also provided estimated development costs for a 4-box model line, and based on that information we estimated average costs to develop a new model line, including testing with both crib and cord wood and reporting and recordkeeping, of $356,000 for certified wood stoves and pellet stoves. We also assumed $356,000 for single burn rate stoves, which may be somewhat high if they are as clean as the manufacturers claim. We likewise assumed a development cost of $356,000 for forced air furnaces and hydronic heaters.

Comments received on the proposed rule included information and opinions regarding these wood heater cost estimates.[48] Comments ranged from criticism that the EPA overestimated costs to criticism that the EPA underestimated costs. For example, one commenter stated that the proposal cost estimates were overly generous and did not address input from Woodstock Soapstone Stoves, winner of the 2013 Wood Stove Decathlon, which estimates that the cost of new product development is approximately $200,000, and furthermore that the proposal cost estimates did not address the economies manufacturers realize when they develop functionally identical models from the originally certified model.[49] Other commenters generally stated that the breakdown of cost estimates faced by manufacturers is inaccurately low.

One commenter, in particular, provided detailed estimates of adjustable burn rate wood stoves and hydronic heater model development costs. According to this commenter, the proposal cost estimates are deficient because they do not reflect specific emission rates or emission performances. The commenter provided cost estimates for categories not covered specifically in EPA’s cost analysis for the proposal nor by the NSPS. The detailed wood stove cost estimates are located in Attachment 2 of the Hearth, Patio and Barbeque Association (HPBA) comments and were prepared by NERA Economic Consulting (May 2014).[50] Appendix A of the document,

[48] Comments on the proposed NSPS are available electronically through http://www.regulations.gov by searching Docket ID EPA-HQ-OAR-2009-0734.

[49] Comment on the proposed rule to Docket EPA-HQ-OAR-2009-0734 from the Washington State Department of Ecology; available at http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2009-0734-1397

[50] Comment on the proposed rule to Docket EPA-HQ-OAR-2009-0734 from the Hearth, Patio and Barbeque Association available at http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2009-0734-1643

Woodstove Cost Modeling (prepared by Ferguson, Andors & Company) contains the detailed cost estimates we reviewed and adapted for this analysis. According to Appendix A, "…*a 'bottom-up' approach was used to identify the relevant components of compliance costs and to develop a range of cost estimates for each cost component based on [their] extensive experience in woodstove development, testing and manufacturing. The cost estimates were focused on mid-sized non-catalytic stove models since those models currently represent the biggest segment of the market. In developing the cost estimates, [they] incorporated detailed comments from a review panel consisting of ten industry experts. The range of cost estimates resulting from this process are representative of typical manufacturers and typical woodstove models, but actual costs for particular manufacturers could lie outside the range. NERA used the mid-points (averages) of the cost ranges for the cost-effectiveness analysis*."[51]

The Ferguson analysis provides cost estimates for four categories of emission reductions based on the proposed emission levels, consisting of modifying 7.5 g/hr stoves to comply with a new 4.5 g/hr standard, modifying the 4.5 g/hr stoves to comply with new standards of 2.5 g/hr or 1.3 g/hr stoves, and modifying a 2.5 g/hr stove to a new standard of 1.3 g/hr. The resulting cost components consisted of *capital costs per model* (R&D, engineering labor, tooling, equipment integration, preliminary testing, and other costs to design and manufacture the modified wood stove model) and *other fixed costs per model* (certification testing and safety testing, roll-out of the modified products including store display models and burn programs, brochures, user manuals, training and product discounts). The mid-point capital costs presented by Ferguson range from $281,725 to $532,050 depending on the emission reduction range.[52]

Unlike the proposed rule, the final rule only contains a Step 1 PM emission limit of 4.5 g/hr and a Step 2 PM emission limit of 2.0 g/hr, with no alternative, three-step limits. We maintain that the Step 1 cost for 7.5 to 4.5 g/hr is a reasonable representation of model development costs for all models subject to subpart AAA, with some exceptions, described below. The Ferguson analysis shows that several of the cost components are identical across scenarios. The analysis claims, however, that other cost components vary according to the specified emission reduction scenario. We found these differences to be unsupported. For

[51] Ferguson, Robert (Ferguson, Andors & Company), prepared for the Hearth, Patio & Barbecue Association. Proposed Wood Heater NSPS Incremental Cost Effectiveness Analyses, Appendix A: Woodstove Cost Modeling. May 2014. p. 1.
[52] Ferguson, Robert (Ferguson, Andors & Company), prepared for the Hearth, Patio & Barbecue Association. Proposed Wood Heater NSPS Incremental Cost Effectiveness Analyses, Appendix A: Woodstove Cost Modeling. May 2014. pp. 4 – 5.

purposes of this analysis, we used the 7.5 to 4.5 g/hr scenario as a baseline case and modified it to reflect the deletion of cost categories that we deemed inappropriately attributed to the NSPS.

We did accept the assumptions and logic related to evaluating the tooling cost differences between steel stoves and cast iron stoves, as both are commonly manufactured. Like Ferguson, we used an average of their tooling costs to reflect product differences, even though we believe this may overestimate the number of cast iron stoves in the market place. While we recognize the range in capital cost estimates provided both prior to and after proposal of the draft standards leave room for additional cost scenarios, especially the much lower cost scenario for Woodstock Soapstone Stoves, we concluded that the Ferguson costs represent the best documented cost ranges and cost categories available at this time. Table 5-1, below, is a summary of the estimated wood stove capital costs used in our analyses.

For the final cost analysis, we used the mean wood stove costs estimated in Table 5-1. We have assumed that these model development costs represent feasible costs for adjustable burn rate stoves and pellet stoves. For single burn rate stoves, we believe, as we did at proposal, that additional R&D may be required to bring these stoves to qualifying levels. In addition, testing with cordwood is not required for all of these appliances as mentioned in Section 2 of this RIA and the preamble, so the costs presented here accordingly reflect that. Therefore, we estimated that the R&D/Engineering cost portion of the total costs would require double the investment in the first 2 years, with “normal” model development proceeding thereafter.

Table 5-1. Estimated Wood Stove Capital Costs

Capital Costs	Appliance Costs			Notes
	High	Low	Mean	2013 dollars; All costs based on HPBA estimates under 7.5 to 4.5 g/hr scenario, with modifications
R&D/Engineering Costs				
Market research, aesthetic design, initial prototype design/construction/testing, formulate design changes, modify/test prototype	$45,500	$19,000	$32,250	
Adjust design/test until emission target is met	$47,500	$30,000	$38,750	
Construct final prototypes, safety test check, eng. drawings/specs, patent application	$27,000	$17,000	$22,000	
Confirm final prototype performance	$0	$0	$0	
R&D/Engineering Total costs	**$120,000**	**$66,000**	**$93,000**	
Tooling				
Steel Stove	$31,200	$9,700	$20,450	
Cast Iron Stove	$62,000	$31,000	$46,500	
Average tooling cost	**$46,600**	**$20,350**	**$33,475**	
				HPBA costs for equipment and integration not included because these are considered duplicative of R&D costs, above
Other Capital Cost components	**$14,000**	**$6,000**	**$10,000**	
Total Capital Cost per model	***$180,600***	***$92,350***	***$136,475***	
Fixed Costs per model				HBPA costs for personnel at lab and travel expenses not accepted as independent third party testing costs
Certification				
EPA testing, Confirmation safety testing or full safety testing, shipping of prototype	$19,000	$14,500	$16,750	
Owner's manual, labeling	$3,500	$1,800	$2,650	
Roll-out	**$0**	**$0**	**$0**	Roll-out considered normal business operation and not due to NSPS
Total Fixed Capital Cost per model	***$22,500***	***$16,300***	***$19,400***	
Total Costs per Model	**$203,100**	**$108,650**	**$155,875**	

Annualized capital cost per model	$42,610	$22,794	$32,702	Annualized over 6 years at 7%
Annualized capital cost for development of 4 models	$170,438	$91,177	$130,808	

5.1.2 Model Development Costs – Central Heaters

At proposal, we assumed that hydronic heaters and forced air furnaces would face the same model development costs as room heaters. Some commenters objected to this characterization, particularly based on the detailed hydronic heater cost estimates located in Attachment 3 of the HPBA comments as prepared by NERA Economic Consulting (May 2014).[53] Appendix A of that document, Hydronic Heater Cost Modeling (prepared by Ferguson, Andors & Company) contains the detailed cost estimates we reviewed and adapted for this analysis.

These costs were prepared with the same methodology and overall assumptions as were used in development of the wood heater costs. The Ferguson analysis provides cost estimates for four categories of hydronic heater emission reductions, based on the proposed emission levels consisting of modifying uncontrolled heaters to comply with a new 0.32 lb/MMBtu standard, modifying the 0.32 lb/MMBtu heaters to comply with new standards of 0.15 or 0.06 lb/MMBtu, and modifying a 0.15 lb/MMBtu heater to a new standard of 0.06 lb/MMBtu. The resulting cost components consisted of *capital costs per model* (R&D, engineering labor, tooling, equipment integration, preliminary testing, and other costs to design and manufacture the modified wood stove model) and *other fixed costs per model* (certification testing and safety testing, roll-out of the modified products including store display models and burn programs, brochures, user manuals, training and product discounts). The mid-point capital costs presented by Ferguson range from $1,743,750 to $2,162,300 depending on the emission reduction range.[54]

Unlike the proposed rule, the final rule only contains a Step 1 PM emission limit of 0.32 lb/MMBtu and a Step 2 PM emission limit of 0.1 lb/MMBtu, with no alternative three-step limits. We estimate that the Step 1 PM emission limit cost for uncontrolled to 0.32 lb/MMBtu is a reasonable representation of model development costs for all models subject to subpart QQQQ, with some exceptions, described below. The Ferguson analysis shows that several of the cost components are identical across scenarios. The analysis claims, however, that other cost components vary according to the specified emission reduction scenario. We found these differences to be unsupported. For purposes of this analysis, we used the uncontrolled to 0.32

[53] Comment on the proposed rule to Docket EPA-HQ-OAR-2009-0734 from the Hearth, Patio and Barbeque Association available at http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2009-0734-1643

[54] Ferguson, Robert (Ferguson, Andors & Company), prepared for the Hearth, Patio & Barbecue Association. Proposed Wood Heater NSPS Incremental Cost Effectiveness Analyses, Appendix A: Hydronic Heater Cost Modeling. May 2014. p. 4.

lb/MMBtu as a baseline case and modified it to reflect the deletion of cost categories that we deemed inappropriately attributed to the NSPS.

For the final cost analysis, we used the mean hydronic heater costs estimated in Table 5-2 below. We have assumed that these model development costs represent feasible costs for hydronic heaters. For forced air furnaces, we estimate, as we did at proposal, that additional R&D may be required to bring these heaters to qualifying levels. Rather than doubling total model development costs during the first 2 years as we did at proposal, we assumed that the R&D/Engineering cost portion of the total costs would require double the investment in the first 2 years, with "normal" model development proceeding thereafter. This revised assumption is consistent with information provided in public comments. In addition, testing with cordwood is not required for these appliances as mentioned in Section 2 of this RIA and the preamble (though the test method is based on cord wood), so the costs presented here accordingly reflect.

Table 5-2. Estimated Hydronic Heater Capital Costs

Capital Costs	Appliance Costs			Notes
	High	**Low**	**Mean**	2013 dollars; All costs based on HPBA estimates under uncontrolled to 0.32 lb/mmBTU scenario, with modifications
R&D Engineering Costs				
Market research, aesthetic design, initial prototype design/construction/testing, formulate design changes, modify/test prototype	$180,000	$115,000	$147,500	
Formulate design changes	$4,500	$2,500	$3,500	
Modify prototype	$16,000	$9,000	$12,500	
Test/Retest	$615,000	$410,000	$512,500	App. A (NERA) concludes erroneously $887,000 for high cost and $581,000 for low cost
Construct final prototype, confirm testing, safety testing	$133,500	$88,500	$111,000	
Document final changes	$8,000	$6,000	$7,000	
R&D/Engineering Total costs	**$957,000**	**$631,000**	**$794,000**	
Manufacturing/Engineering				
Programming and Tooling - Steel parts	$22,000	$13,000	$17,500	
Tooling – Refractory	$45,000	$28,000	$36,500	
Electronic Control System	$10,000	$5,000	$7,500	
Final Production samples/Confirm product. Fit-up	$25,000	$15,000	$20,000	
Create QA/QC specs	$4,000	$2,000	$3,000	
Manufacturing/Engineering total costs	**$106,000**	**$63,000**	**$84,500**	
Other Capital Cost components				HPBA costs for equipment and integration not included because these are considered duplicative of R&D costs, above
Purchased parts sourcing	$41,000	$23,500	$32,250	
Test first production heaters	$200,000	$150,000	$175,000	
Equipment and facilities	$75,000	$25,000	$50,000	
Other Capital Cost components total costs	**$316,000**	**$198,500**	**$257,250**	
Total Capital Cost per model	***$1,379,000***	***$892,500***	***$1,135,750***	
Fixed Costs per model				HBPA costs for personnel at lab and travel expenses not accepted as independent
Certification				
EPA testing, Confirmation safety testing or full safety testing, shipping of prototype	$72,500	$36,000	$54,250	

				third party testing costs
Owner's manual, labeling	$6,500	$3,500	$5,000	
Certification Total Costs	$79,000	$39,500	$59,250	
Roll-out	**$0**	**$0**	**$0**	Roll-out considered normal business operation and not due to NSPS
Total Fixed Capital Cost per model	***$79,000***	***$39,500***	***$59,250***	
Total Costs per Model	**$1,458,000**	**$932,000**	**$1,195,000**	
Annualized capital cost per model	**$305,882**	**$195,530**	**$250,706**	Annualized over 6 years at 7%
Annualized capital cost for development of 4 models	**$1,223,529**	**$782,119**	**$1,002,824**	

5.1.3 General Approach and Assumptions for Costs to Manufacturers

Manufacturers have told us that it takes several years to develop new models, and this is documented in the manufacturer's cost memo.[55] One manufacturer said that development time is 12 to 14 months for non-catalytic heaters and 10 to 12 months for catalytic heaters.[56] Another manufacturer estimated costs over an 8- to 12-month schedule for a relatively uncomplicated product, but added that costs will increase for products that have more sophisticated controls.[57] Two other manufacturers suggested a 14- to 18-month timeframe is required to develop a new firebox, but added that it will take from 5 to 6 years of intensive engineering and R&D efforts to have a model line consisting of 4 boxes ready-for-manufacture, agreeing that knowledge of the process obtained during each firebox development will shorten (somewhat) the time necessary, but not enough to consider within a guiding framework.[58] Given this information and in an effort to not underestimate the time needed for R&D, we amortized R&D costs (shown in Tables 5-1 and 5-2 above) over 6 years.

[55] Memo to Gil Wood, USEPA, from Jill Mozier, EC/R, Inc. Estimated Wood Heater Manufacturer Cost Impacts. January 30, 2015.

[56]James E. Houck and Paul Tiegs. *There's a Freight Train Comin'*. Hearth and Home. December 2009.

[57] Comments from United States Stove Company, Small Entity Representative. July 13, 2010.

[58] NSPS Review/Revision, and Impact on Our Companies: A Manufacturer's Position Statement. Prepared by Stove Builder International and United States Stove Company. June 2010

We have assume that many manufacturers have already begun R&D efforts in anticipation of the rule whose initial development was publicly announced by EPA in November 2009. However, for purposes of our cost estimate, we amortized the model development costs (shown in Tables 5-1 and 5-2) over the 6 year period beginning in 2015 and ending in 2020 (inclusive). We prepared estimates using both a 7% interest rate and a 3% interest rate during the amortization period.[59]

We estimated both the average annual cost to manufacturers of each appliance type and then extended those costs to nationwide total annual costs. The basic components to each manufacturer's estimated annual cost are:

- Annualized R&D cost;
- Ongoing annual Certification cost; and
- Ongoing annual Reporting and Record Keeping cost.

The Annualized R&D costs (shown in Tables 5-1 and 5-2) are by far the largest cost component and we have applied these costs to most models in each appliance category – especially to models in previously unregulated appliance categories and for appliances without a voluntary program — in order to present an estimate of what might happen and avoid underestimating cost impacts. For these appliances (i.e., single burn rate stoves and forced-air furnaces), we estimated that 100% of the existing models will undergo R&D beginning in 2015 to meet the final limits. In cases where we assumed less than 100% of the models would require R&D (e.g., adjustable burn rate stoves, pellet stoves and hydronic heaters), this was based on the percentage of models estimated to already meet the 2020 Step 2 limit, as explained above.

However, it is important to note that manufacturers will likely consolidate their model lines, focusing on models able to achieve the limit, rather than incur R&D costs for every currently non-compliant model line. Therefore fewer models than we used in our cost estimates will likely undergo R&D, which will decrease cost impacts, potentially significantly. But since we do not have data to suggest the degree of consolidation which may occur, we assumed all non-compliant models would remain in existence and incur R&D costs, in order to avoid underestimating costs.

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[59] *See* January 2015 cost effectiveness (CE) spreadsheets including for PM2.5 the *Revised Final Wood Heater NSPS PM CE 7%* and the *Revised Final Wood Heater NSPS PM CE 3%* for the CE analysis supporting the NSPS. All of these spreadsheets are found in the public docket for this rulemaking.

Furthermore, for appliances like single burn rate stoves and forced air furnaces, which were previously unregulated (and also were not pushed technologically by a voluntary program, as hydronic heaters were), we have doubled the R&D/Engineering cost portion of the total costs in the first 2 years (2014 and 2015). This doubling of the R&D/Engineering costs represents an intensification of the R&D efforts to meet the Step 1 limit and begin development of models to meet the Step 2 limit – R&D efforts which industry has indicated are already ongoing.[60]

All manufacturers, except for wood stoves that are subject to the existing 1988 NSPS (and therefore already incur certification costs), will face ongoing certification costs above baseline conditions. In the 2015 to 2020 time frame, we have incorporated these costs as part of the overall R&D expenditures. For the purposes of our analysis, which estimates initial R&D costs from 2015 to 2020 and ongoing costs for bringing a model to market after 2020, the ongoing certification and reporting and recordkeeping costs faced by manufacturers are estimated over the 10-year model lifespan.[61,62]

Regarding ongoing certification costs (after initial certification which is estimated in the R&D costs itemized above in Tables 5-1 and 5-2), we estimated a continuing cost of $10,000 per model for pellet stoves and single burn rate stoves and a continuing cost of $20,000 per model for hydronic heaters and forced air furnaces.[63] We distributed these ongoing costs out over the 5 year certification life, assuming annual certification costs for one-fifth of the models. For example, compliant (but as yet uncertified) pellet stoves will incur certification costs in 2015. As explained in the manufacturer's cost memo,[64] approximately 70% of existing pellet stove models are expected to comply with the Step 2 PM standard without requiring intensive R&D. However, in order to be sold, these stove models would now be required to demonstrate compliance with an emissions limit, incurring an upfront cost of $10,000 per model to become certified. We have estimated that one fifth of the pellet stove models will certify in any given year.

We based reporting and recordkeeping (R&R) costs on the annual average costs derived from development of the Information Collection Request (ICR) supporting statements.[65] These

[60] February 8, 2013 telephone discussion between Gil Wood, USEPA, and a manufacturer of forced air furnaces and single burn rate stoves.

[61] Memorandum to USEPA from EC/R, Inc. Estimated Emissions from Wood Heaters. January 2015.

[62] Memorandum to USEPA from EC/R, Inc. Residential Wood Heater Cost Effectiveness Analysis. January 2015.

[63] Conversation with Dennis Brazier, Central Boiler. August 9, 2010.

[64] Memo to Gil Wood, USEPA, from Jill Mozier, EC/R, Inc. Estimated Wood Heater Manufacturer Cost Impacts. January 30, 2015.

[65] Memo to David Cole, Gil Wood and Amanda Aldridge, USEPA, from Joanne O'Loughlin, EC/R, Inc. Estimated Reporting and Recordkeeping Costs Itemized for Cost Effectiveness Analysis. January 30, 2015.

are annual estimates of the ongoing R&R burden to manufacturers associated with final rule compliance. We estimate that R&R costs are incurred beginning in 2015 in our analysis.

As noted above, the certification and reporting and recordkeeping costs were estimated to be incurred by manufacturers for the full 10-year model design lifespan, for models designed to meet each final limit.[66] We therefore estimated costs from 2015 through 2029—that is, 10 years after the 2020 compliance year marking the beginning of the model lifespan designed to meet the Step 2 PM emission limit. We provide these costs in the manufacturer's cost memo.

5.1.4. Estimated Manufacturer Costs – Specific Assumptions & Resulting Costs

Below is a list of approach and assumptions for estimating costs for each category of appliances affected by this final rule, as taken from the manufacturer cost memo.[67] Costs vary by appliance type based on the estimated number of models. Our estimates of the number of models for each appliance type are described in the unit cost memo.[68] For numbers of manufacturers, we started with HPBA data and modified those numbers as needed, based on internet searches of manufacturers of the major appliance types.[69]

1. Nationwide Annual Cost assumes R&D investment is amortized over 6 years (2015 through 2020). Ongoing certification costs are incurred through 2029 (based on a model brought to market in 2020 with a lifespan of 10 years).

2. Since certification is required every 5 years, it is assumed that certification costs will be spread out so that 1/5 of the models certify each year.

3. This analysis considers additional costs resulting from the NSPS. For wood stoves, the analysis assumes that 26% meet Step 2 already so that 74% of the models will undergo re-design to meet the Step 2 limit. The costs modeled for years 2021 through 2029 exclude the ongoing certification costs and ongoing reporting and recordkeeping costs incurred by wood stove manufacturers who already had to certify and report under the existing 1988 NSPS.

4. For pellet stoves, the analysis assumes that 70% meet Step 2 already so that 30% of models undergo R&D re-design to meet Step 2. The R&D budget includes certification costs. The analysis also assumes that the 70% of the pellet stove models

[66] Memo to Gil Wood, USEPA, from Jill Mozier, EC/R, Inc. Unit Cost Estimates of Residential Wood Heating Appliances. January 30, 2015.

[67] Memo to Gil Wood, USEPA, from Jill Mozier, EC/R, Inc. Estimated Wood Heater Manufacturer Cost Impacts. January 30, 2015.

[68] Memorandum to USEPA from EC/R, Inc. Unit Cost Estimates of Residential Wood Heating Appliances. January 30, 2015.

[69] HPBA Solid Fuel Product List. Attachment to E-mail from John Crouch, HBPS, to Gil Wood, EPA. September 24, 2010.

that already meet Step 2 will certify in an ongoing basis starting in 2015. The analysis reflects the certification costs beginning in 2015 for the 70% of models meeting Step 2, and beginning in 2020 for the remaining 30% of models which underwent R&D re-design. The analysis also reflects ongoing reporting and recordkeeping costs for 100% of the models beginning in 2015.

5. Based on conversations with industry, single burn rate stoves and forced air furnaces have been undergoing R&D prior to 2014 to develop cleaner models. Because these devices were previously unregulated and may need to transfer technology from adjustable burn rate stoves and hydronic heaters, respectively, this analysis assumes that these efforts will intensify in 2015 and 2016. Therefore estimated R&D costs are doubled in 2015 and 2016 to reflect model development to meet the more stringent 2020 Step 2 PM emission limit.

6. For single burn rate stoves and forced air furnaces, the analysis assumes that only a small percentage meet Step 2 so that approximately 100% of the models undergo R&D re-design to meet Step 2. The R&D budget includes certification costs. Ongoing certification costs for the re-designed models are reflected in this analysis beginning in 2021. Ongoing reporting & recordkeeping for all models are estimated beginning in 2015.

7. Reporting and recordkeeping costs (R&R) are based on the annual average costs derived from the ICR and are estimates of the ongoing R&R burden to manufacturers associated with the NSPS. The annual average nationwide R&R burden estimated to manufacturers for Subpart AAA is $179,000 for years 2015 through 2017, and $352,000 for years 2018 through 2020. For Subpart QQQQ, the R&R burden to manufacturers is $141,000 for years 2015 through 2017, and $197,000for years 2018 through 2020. Although the 2018 through 2020 costs are carried forward to 2029 for this analysis, actual R&R costs from 2021 through 2029 may vary slightly. These R&R costs do not include the R&R burden to laboratories and certifying entities, which have been calculated separately.

8. For hydronic heaters, the analysis assumes that 18% of models meet Step 2 already so that the remaining 82% must undergo R&D to meet Step 2 in 2020. The R&D budget includes certification costs. Ongoing certification costs for the re-designed models are reflected in this analysis beginning in 2021. Ongoing reporting & recordkeeping for all models are estimated beginning in 2015.

Table 5-3 provides the average annual cost per manufacturer under the final NSPS. The costs in the table vary by appliance type based on the average number of models per manufacturer. The estimate of the number of model types are described in the unit cost memo.[70]

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[70] Memo to Gil Wood and David Cole, US EPA, from Beth Friedman, EC/R, Inc. Unit Cost Estimates of Residential Wood Heating Appliances. January 30, 2015.

For numbers of manufacturers, we started with HPBA data, modified based on internet searches of manufacturers of the major appliance types.[71]

The following example explains how the average annual cost in Table 5-3 is estimated for hydronic heater manufacturers.

1) We derived the annualized capital cost per model for R&D related costs including certification based on industry-supplied cost components as described on pages 5-7 to 5-10 of the RIA. The estimated annualized capital cost to bring a hydronic heater (HH) model through R&D, based on an amortization period of 6 years and an interest rate of 7%, is **$250,706**.

2) To derive the average annual cost to each HH manufacturer, we multiplied the annualized capital cost of **$250,706** by the estimated number of Hydronic Heater models in the nation, **120**, divided by the estimated number of HH manufacturers, **30**. As stated above, the numbers of models and manufacturers were derived from an industry-supplied list of manufacturers by product type with additional refining via internet searches and EPA's experience with the HH voluntary program.

3) To refine the average annual cost further, we estimated the percentage of HH models that already meet the Step 2 PM emission limit – and therefore would not need to incur R&D costs, but only certification and reporting & recordkeeping (R&R) costs. This percentage is based on the qualifying emissions data in the current EPA-HH Voluntary Program database. We estimate that **18%** of current HH models can meet Step 2 without additional R&D. Therefore **82%** of HH models will incur R&D, certification and reporting and recordkeeping costs; while 18% of HH models will incur only certification and reporting and recordkeeping costs.

4) We estimate ongoing HH certification testing (outside the R&D process) to cost **$20,000 per certification**. This $20,000 figure is supplied by industry. Since a certification is good for 5 years, in order to determine an annual certification cost, we assumed that manufacturers will choose to spread out certification costs by certifying **one-fifth** of their models each year. (Note again that the certification cost for models undergoing R&D is included in the $250,706 R&D cost).

5) We estimated ongoing HH (R&R) costs based on Information Collection Request (ICR) assumptions, which were calculated for the first 3 years and then for the 3 years following, respectful of changing R&R costs to meet a 2-Step standard. R&R costs are based on the annual average costs derived from the ICR and are estimates of the ongoing R&R burden to manufacturers associated with the NSPS. The annual average R&R

[71] HPBA Solid Fuel Product List. Attachment to E-mail from John Crouch, HBPA, to Gil Wood, US EPA. September 24, 2010.

burden estimated to HH manufacturers is **$3,300** per HH manufacturer for years 2015 through 2017 and **$4,635** per HH manufacturer for years 2018 through 2020.

Based on the above costs and assumptions, the annual cost to a HH manufacturer in year 2019 is: **(120/30) * [0.82*$250,706 + 0.18*($20,000/5)] + $4,635 = $829,830 per manufacturer.**

6) To derive the total **Nationwide Annual Cost** to all hydronic heater manufacturers in the U.S. market, we multiplied the above average annual cost to each HH manufacturer by the total number of manufacturers (30). Therefore, the estimated **Nationwide Annual Cost** to all HH manufacturers in year 2019 is:

   $829,830/per manufacturer * 30 manufacturers = approximately **$24,895,000.**

   It should be noted that the estimated cost to each hydronic heater manufacturer drops significantly after the investment required during the R&D period. In years 2021 and 2029, we estimate that ongoing certification and R&R will cost approximately $21,000 per manufacturer, or $619,000 nationwide, annually.

Table 5-3. Average Annual Cost per Manufacturer under the Final NSPS

				Average Annual Cost per Manufacturer	
NSPS Subpart	Appliance Type	# Manufac-turers	# Models	(Step 1 compliance) 2015	2016
	Wood Stoves (R&D)[3]	34	125	$88,968	$88,968
AAA: Room Heaters	Pellet Stoves (R&D, R&R, cert)[4,7]	29	125	$51,179	$51,179

	Single Burn Rate Stoves (R&D, R&R, cert.)[5, 6, 7]	3	20	$352,506	$352,506	$
QQQQ: Central Heaters	Forced Air Furnaces (R&D, R&R, cert.)[5, 6, 7]	7	50	$2,986,523	$2,986,523	$1,
	Hydronic Heaters (R&D, R&R, cert.)[7,8]	30	120	$828,513	$828,513	$

5.1.5 Labor Requirements for Monitoring, Recordkeeping and Reporting

The focus of this part of the analysis is on labor requirements related to the compliance actions of the affected entities within the affected sector. This analysis estimates the labor requirements associated with new reporting and recordkeeping requirements.

The labor changes may either be required as part of an initial effort to comply with the new regulation or required as a continuous or annual effort to maintain compliance. We estimate up-front and continual, annual labor requirements by estimating hours of labor required for the monitoring, recordkeeping, and reporting efforts to maintain compliance. All of these estimates are included in the Supporting Statement for each subpart for the final rule.[72]

The estimated burden for subpart AAA (room heaters – wood stoves, pellet stoves, and single burn rate stoves) is based on an estimated 72 respondents (66 manufacturers and 6 testing laboratories) that would be subject to the rule. The annual burden for this information collection averaged over the first 3 years of this ICR is estimated to be a total of 2,947 labor hours per year at a total labor cost of $250,551 per year. Of the total labor cost estimated per year, approximately $179,000 is incurred by manufacturers, $16,000 is incurred by third-party certifiers, and $55,000 is incurred by test manufacturers. The ICR estimates that capital and the associated operation and maintenance (O&M) costs for these systems would be $1,466,438 per year. The average annual labor burden per response is 12 hours.

The estimated burden for subpart QQQQ (central heaters – hydronic heaters and forced air furnaces) is based on an estimated 41 respondents (37 manufacturers and 4 testing laboratories) that would be subject to the rule. The number of total annual responses for subpart QQQQ is estimated at 199.The annual burden for this information collection averaged

[72] Supporting Statements for Subpart AAA and Subpart QQQQ, NSPS for New Residential Wood Heaters. Prepared by EC/R, Inc. for U.S. EPA. January 30, 2015.

over the first 3 years of this ICR is estimated to be a total of 2,337 labor hours per year at a total labor cost of $191,904 per year. Of the total labor cost estimated per year, approximately $140,000 is incurred by manufacturers, $15,000 is incurred by third-party certifiers, and $36,000 is incurred by test manufacturers. The ICR estimates that capital and operation and maintenance (O&M) costs would be $3,191,188 per year. The average annual labor burden per response is 12 hours.

We note that certification testing (once every 5 years unless a waiver is granted) costs of approximately $10,000 ($20,000 for hydronic heaters and forced air furnaces) per model line in 2021 result in labor hours spent at the test lab, which are not included in this labor rate analysis. In addition, each model that is developed (i.e., number of affected units) will face an annual estimated cost of $160,000 for the salaries of two full-time experimental employees for 5 years. This estimate should be regarded as a partial labor estimate, with other possible labor associated with new model development (such as re-tooling) left as unquantified and described qualitatively in the manufacturer cost and unit cost impact memos.

Ongoing monitoring, recordkeeping, and reporting labor requirements for the final rule are estimated at about 5,300 hours per year.[73] These ongoing labor requirements can be viewed as average sustained labor requirements required for affected entities to continuously comply with the new regulations in 2020 and beyond.

5.2 Compliance Costs of the Rule as Presented in the RIA

EPA's engineering cost analysis estimates that the total annualized cost, which includes all compliance costs associated with the regulation, to manufacturers as presented in this RIA is $45.7 million, calculated as an average of the annualized costs incurred from 2015 to 2020 (all costs are reported in 2013 dollars) (EC/R, August 2014). Annualized costs are estimated at a 7% interest rate.[74] We calculate the costs in this way in order to provide an average of annualized costs from the time of rule promulgation in 2015 to the time of full implementation which occurs in 2020. Having an average annualized calculation for the costs allows for a reasonable measure of the costs to be incurred by manufacturers given the changes in costs year by year between

[73] Memo to Gil Wood, USEPA, from EC/R, Inc. Residential Wood Heating ICR Analysis. January 30, 2015.

[74] EC/R, Inc. to U.S. EPA, Memorandum. Estimated Residential Wood Heater Manufacturer Cost Impacts. January 30, 2015.

2015 and 2020 as shown in the manufacturer's cost memo for this final rule. The total annualized costs for each year and for each option are in Table 5-4.

With total annualized costs estimated at a 3% interest rate, the total annualized cost of the rule is $40.2 million in 2013 dollars. More detailed information on the costs at a 3% interest rate can be found in the cost memoranda for this final rule.

Under the NSPS, the costs in the 2015-2020 time frame fall most heavily on manufacturers of hydronic heating systems (54%), followed by forced air furnaces (34%), then by wood stoves (7%). The remaining 5% of the costs are distributed to pellet stove manufacturers (3%), and manufacturers of single burn rate stoves (2%).

Table 5-4. Summary of Average Annualized Nationwide Costs for the 2015–2020 Time Frame Under the Final NSPS

Appliance Type	Final NSPS
Wood Heaters	$3,020,000
Single Burn Rate Heaters	$870,000
Pellet Stoves	$1,520,000
Forced-Air Furnaces	$15,360,000
Hydronic Heating Systems	$24,880,000
Total Average Annual Cost for 2015–2020 Time Frame	$45,660,000

The final rule, will affect an estimated 2.7 million new residential wood heating devices between 2015 and 2020 assuming an average of ~296,000 new shipments annually as presented in the emissions memo for the final rule.[75] As shown previously in Table 4-4 in Section 4, annual shipments are forecasted to increase for all product types over the same time period.

To assess the size of the compliance costs relative to the value of shipments to end-use consumers, we compared industry-level compliance costs relative to projected sales over the timeframe from 2015 to 2020. In this case, cost-to-receipts ratios approximate the maximum price increase needed for a producer to fully recover the annual compliance costs associated with a regulation. These industry-level cost-to-receipts ratios can be interpreted as an average impact on potentially affected firms in these industries all other things equal, and where ratios less than

[75] U.S. EPA. Memorandum. Estimated Emissions from Wood Heaters. January 30, 2015. Prepared by EC/R, Inc.

1% suggest the rule will not have a significant impact using EPA's SBREFA guidance as a basis. Results for affected industries for the 2015–2020 time frame can be found in Table 5-5.Under the NSPS, none of the six affected product types will have an annualized cost-to-receipts ratio of less than 1%. In the 2015-2020 time frame for this option, cost-to-receipts ratios range from 1.1% for pellet stoves to 17.1% for hydronic heaters. These estimates reflect the distribution of impacts to products affected by this final rule, but are not themselves estimates of social costs.

Table 5-5. Industry Level-Annualized Compliance Costs (2013 dollars) as a Fraction of Total Industry Revenue by Product Type in the 2015–2020 Time Frame—NSPS

Product Type	Total Annualized Costs ($ millions)	Average Annual Product Sales in 2015-2020 timeframe ($ millions)[a]	Cost-to-Receipts Ratio
Wood stoves	$3.0	$123.1	2.4%
Single burn rate stoves	$0.9	$11.6	7.8%
Pellet stoves	$1.5	$132.2	1.1%
Forced-air furnaces	$15.4	$91.8	16.8%
Hydronic heating systems	$24.9	$145.7	17.1%

[a] Sales based on projected product shipments shown in Section 4 of this RIA and average unit cost estimates from Table 2 of the unit cost memo. We estimate annual sales using the average of annual shipments and unit cost estimates over the 2015-2020 timeframe. Total annualized costs are the average of annual costs for each product type from 2015 to 2020. Total annualized costs in this table are estimated at a 7% interest rate.

Sources:

Unit Costs and Shipment Projections from *Unit Cost Memo.* Received by EPA on January 30, 2015.

Industry Compliance Costs from *Wood Stove NSPS Annual Costs.* Received by EPA on January 30, 2015.

5.3 How Might People and Firms Respond? A Qualitative Partial Equilibrium Analysis

Markets are composed of people as consumers and producers acting as economic agents to maximize utility or profits, respectively. One way economists illustrate behavioral responses to pollution control costs is by using market supply and demand diagrams. The market supply curve describes how much of a good or service firms are willing and able to sell to people at a particular price; we often draw this curve as upward sloping because some production resources are fixed. As a result, the cost of producing an additional unit typically rises as more units are made. The market demand curve describes how much of a good or service consumers are willing and able to buy at some price. Holding other factors constant, the quantity demanded is assumed to fall when prices rise. In a perfectly competitive market, equilibrium price (P_0) and quantity (Q_0) are determined by the intersection of the supply and demand curves (see Figure 5-2).

5.3.1 Changes in Market Prices and Quantities

To qualitatively assess how the regulation may influence the equilibrium price and quantity in the affected markets, we assumed the market supply function shifts up by the additional cost of producing the good or service; the unit cost increase is typically calculated by dividing the annual compliance cost estimate by the baseline quantity (Q_0) (see Figure 5-2). As shown, this model makes two predictions: the price of the affected goods and services are likely to rise and the consumption/production levels are likely to fall.

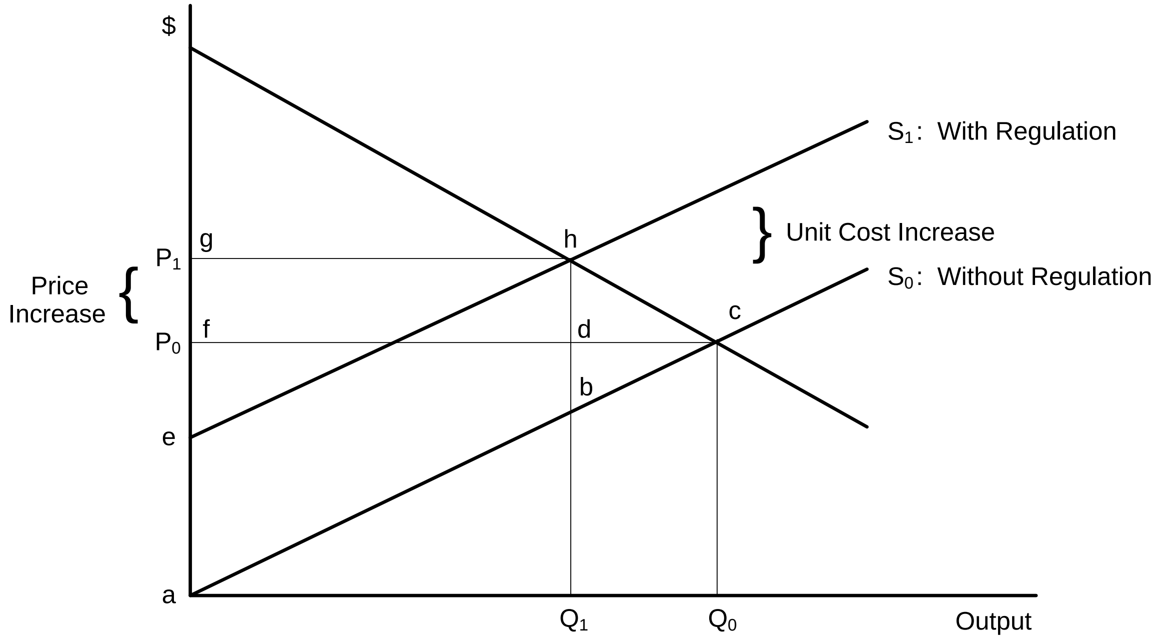
The size of these changes depends on two factors: the size of the unit cost increase (supply shift) and differences in how each side of the market (supply and demand) responds to changes in price. Economists measure responses using the concept of price elasticity, which represents the percentage change in quantity divided by the percentage change in price. This dependence has been expressed in the following formula:[76]

$$\textit{Share of per-unit}\ \text{cost} = \frac{\textit{Price Elasticity of Supply}}{\left(\textit{Price Elasticity of Supply - Price Elasticity of Demand)}\right)}$$

As a general rule, a higher share of the per-unit cost increases will be passed on to consumers in markets where

- goods and services are necessities and people do not have good substitutes that they can switch to easily (demand is inelastic) and
- suppliers have excess capacity and can easily adjust production levels at minimal costs, or the time period of analysis is long enough that suppliers can change their fixed resources; supply is more elastic over longer periods.

[76] For examples of similar mathematical models in the public finance literature, see Nicholson (1998), pages 444–447, or Fullerton and Metcalf (2002).



consumer surplus = –[fghd + dhc]

producer surplus = [fghd − aehb] − bdc

total surplus = consumer surplus + producer surplus = −[aehb + dhc + bdc]

Figure 5-2. Market Demand and Supply Model: With and Without Regulation

Short-run demand elasticities for energy goods (electricity and natural gas), agricultural products, and construction are often inelastic. Specific estimates of short-run demand elasticities for these products can be obtained from existing literature. For the short-run demand of energy products, the National Energy Modeling System (NEMS) buildings module uses values between 0.1 and 0.3; a 1% increase in price leads to a 0.1 to 0.3% decrease in energy demand (Wade, 2003). For the short-run demand of agriculture and construction, EPA has estimated elasticities to be 0.2 for agriculture and approximately 1 for construction (EPA, 2004). As a result, a 1% increase in the prices of agriculture products would lead to a 0.2% decrease in demand for those products, while a 1% increase in construction prices would lead to approximately a 1% decrease in demand for construction. Given these demand elasticity scenarios (shaded in gray), approximately a 1% increase in unit costs would result in a price increase of 0.1 to 1% (Table 5-6). As a result, 10 to 100% of the unit cost increase could be passed on to consumers in the form of higher goods/services prices. This price increase would correspond to a 0.1 to 0.8% decline in consumption in these markets (Table 5-7).

For this final rule, a commenter on the proposed rule provided an estimate of -0.97 for the price elasticity of demand for hydronic heaters. [77] The commenter also provided estimates of changes in price and output for hydronic heater as part of their report. However, the commenter's analysis presumed an inelastic (or flat) supply curve, which presumes no responsiveness of producers to a change in product price. EPA does not have estimates of the price elasticity of supply, an essential value in order to accurately estimate impacts of appliance supply and demand. In addition, the price elasticity of demand provided by the commenter is specific to data for this appliance category and not other appliance categories covered by this final rule. Thus, EPA does not estimate price and output changes using partial equilibrium techniques for wood-burning appliance producers and consumers affected by this final rule. While we are unable to estimate price and output changes, we note that the high increases in unit costs for some affected appliances could lead to potential nontrivial increases in market price to wood-burning appliance consumers and potential decreases in output for such appliances if supply elasticities are determined to be low. This could be true for hydronic heaters and forced air furnaces, but is unlikely for wood stoves and pellet stoves.

As for using other economic impact modeling approaches such as computable general equilibrium (CGE) modeling, which was used in the Transport Rule proposed in the summer of 2010 and in other rulemakings over the last several years, EPA used the Economic Model for Policy Analysis (EMPAX) to estimate the effect of impacts on markets outside of the regulated sector. EMPAX is a dynamic computable general equilibrium model (CGE) which forecasts a new equilibrium for the entire economy after a policy intervention. However, since the Transport Rule was proposed, an updated version of EMPAX was used to estimate the social cost of the Clean Air Act in an EPA report entitled "The Benefits and Costs of the Clean Air Act from 1990 to 2020." This report is available at http://www.epa.gov/air/sect812/feb11/fullreport.pdf. This updated version of EMPAX added in the benefit-side effects (incorporating labor-force and health care expenditures) which significantly changed the social cost estimate from the previous edition. In December 2010, EPA's Science Advisory Board (SAB)'s external Council on Clean Air Compliance Analysis (hereafter "Council") peer review of this EPA report stated found that inclusion of benefit-side effects, specifically adapted for use in that study, "represent[ed] a significant step forward in benefit-cost analysis," While the Council has made this finding, EPA recognizes that serious technical challenges remain when attempting to evaluate the benefits and costs of potential regulatory actions using economy-wide models. Consistent with the Council's advice regarding

[77] NERA. Cost-Effectiveness Analysis of Alternative Hydronic Heater New Source Performance Standards. May 2014. Prepared for the Hearth, Barbecue, and Patio Association.

the importance of including benefit-side effects as demonstrated by the EPA report mentioned above, and the lack of available multi-year air quality projections needed to include these benefit-side effects, among other reasons, EPA did not conduct CGE modeling for this rule.

In recognition of the serious technical challenges to evaluate the benefits and costs of potential regulatory actions using economy-wide models, EPA is establishing a new Science Advisory Board (SAB) panel on economy-wide modeling to consider the technical merits and challenges of using this analytical tool to evaluate costs, benefits, and economic impacts in regulatory development. The EPA will use the recommendations and advice of this panel as an input into its process for improving benefit-cost and economic impact analyses that are used to inform decision-making at the Agency. The panel will also be asked to identify potential paths forward for improvements that could address the challenges posed when economy-wide models are used to evaluate the effects of regulations. The advice from this panel will not be available in time for use in this final rule.

Table 5-6. Hypothetical Price Increases for a 1% Increase in Unit Costs

Market Demand Elasticity	Market Supply Elasticity						
	0.1	**0.3**	**0.5**	**0.7**	**1**	**1.5**	**3**
−0.1	**0.5%**	0.8%	0.8%	0.9%	0.9%	0.9%	1.0%
−0.3	0.3%	**0.5%**	0.6%	0.7%	0.8%	0.8%	0.9%
−0.5	0.2%	0.4%	**0.5%**	0.6%	0.7%	0.8%	0.9%
−0.7	0.1%	0.3%	0.4%	**0.5%**	0.6%	0.7%	0.8%
−1.0	0.1%	0.2%	0.3%	0.4%	**0.5%**	0.6%	0.8%
−1.5	0.1%	0.2%	0.3%	0.3%	0.4%	**0.5%**	0.7%
−3.0	0.0%	0.1%	0.1%	0.2%	0.3%	0.3%	**0.5%**

Table 5-7. Hypothetical Consumption Decreases for a 1% Increase in Unit Costs

Market Demand Elasticity	Market Supply Elasticity						
	0.1	**0.3**	**0.5**	**0.7**	**1**	**1.5**	**3**
−0.1	**−0.1%**	−0.1%	−0.1%	−0.1%	−0.1%	−0.1%	−0.1%
−0.3	−0.1%	**−0.2%**	−0.2%	−0.2%	−0.2%	−0.3%	−0.3%
−0.5	−0.1%	−0.2%	**−0.3%**	−0.3%	−0.3%	−0.4%	−0.4%
−0.7	−0.1%	−0.2%	−0.3%	**−0.4%**	−0.4%	−0.5%	−0.6%
−1.0	−0.1%	−0.2%	−0.3%	−0.4%	**−0.5%**	−0.6%	−0.8%
−1.5	−0.1%	−0.3%	−0.4%	−0.5%	−0.6%	**−0.8%**	−1.0%
−3.0	−0.1%	−0.3%	−0.4%	−0.6%	−0.8%	−1.0%	**−1.5%**

5.3.2 Partial Equilibrium Measures of Social Cost: Changes in Consumer and Producer Surplus

In partial equilibrium analysis, the social costs are estimated by measuring the changes in consumer and producer surplus, and these values can be determined using the market supply and demand model (as shown in Figure 5-2). Assuming linear market supply and demand curves as shown in Figure 5-2, the change in consumer surplus (CS) is measured as follows:

$$\Delta CS = -\,[\Delta Q_1 \times \Delta p] + [0.5 \times \Delta Q \times \Delta p]. \tag{5.1}$$

where a coefficient of 0.5 is multiplied to the change in Q and P resulting from the shock to the markets based on the assumption of linear demand and supply curves in the diagram above and applying principles of basic geometry. Higher market prices and lower quantities lead to consumer welfare losses. Similarly, the change in producer surplus (PS) is measured as follows for affected supply:

$$\Delta PS = [\Delta Q_1 \times \Delta p] - [\Delta Q_1 \times \mathrm{t}] - [0.5 \times \Delta Q \times (\Delta p - t)]. \tag{5.2}$$

Where t = per unit cost increase. Higher unit costs and lower production levels reduce producer surplus because the net price change ($\Delta p - t$) is negative. However, these losses are mitigated because market prices tend to rise. In contrast, for unaffected supply, the change in producer surplus is:

$$\Delta PS = [Q_0 \times \Delta p] + [0.5 \times \Delta Q \times \Delta p]. \tag{5.3}$$

Higher prices increase producer surplus for unaffected producers in the U.S. and other countries.

5.4 Social Cost Estimate

As shown in Table 5-6, the social cost as approximated by the annual compliance costs as a percent of sales represent a fraction of the affected product value that is greater than 1% for each of the product categories; this suggests that the shift of the supply curve may be relatively large for some product types and result in larger changes in market prices and consumption. However, lacking information on the shift of affected supply curves and related price elasticities of supply, EPA believes the national annualized compliance cost estimates provide a reasonable approximation of the social cost of this rule. EPA believes this approximation is better for industries whose markets are well characterized as perfectly competitive. However, given the data limitations noted earlier, EPA believes the accounting for annual compliance costs is a reasonable approximation to inform policy discussion in this rulemaking. We were not able to prepare a full economic analysis of the impacts of this proposal on supply and demand, or the effects of such impacts on emissions (e.g. feedback effect on emissions). Most of the affected industries can be characterized as having a high degree of competitive market behavior as described in Section 3 of this RIA. To shed more light on the level of market behavior, EPA ran hypothetical economic impact analyses and the results are in Tables 5-6 and 5-7.

5.5 Energy Impacts

Executive Order 13211 (66 FR 28355, May 22, 2001) provides that agencies will prepare and submit to the Administrator of the Office of Information and Regulatory Affairs, Office of Management and Budget, a Statement of Energy Effects for certain actions identified as "significant energy actions." Section 4(b) of Executive Order 13211 defines "significant energy actions" as any action by an agency (normally published in the *Federal Register*) that promulgates or is expected to lead to the promulgation of a final rule or regulation, including notices of inquiry, advance notices of proposed rulemaking, and notices of proposed rulemaking: (1) (i) that is a significant regulatory action under Executive Order 12866 or any successor order, and (ii) is likely to have a significant adverse effect on the supply, distribution, or use of energy; or (2) that is designated by the Administrator of the Office of Information and Regulatory Affairs as a significant energy action.

This final rule is not a "significant energy action" as defined in Executive Order 13211 (66 FR 28355, May 22, 2001), because it is not likely to have a significant adverse effect on the supply, distribution, or use of energy. Further, we have concluded that this rule is not likely to have any significant adverse energy effects. In general, we expect the NSPS to improve technology, including energy efficiency. Reducing emissions and increasing efficiency might increase the use of wood fuel, which would relieve pressure on traditional coal or petroleum based energy sources. However, as described in section VI.E of the preamble, it is difficult to determine the precise energy impacts that might result from this rule. This is because wood-fueled appliances compete with other biomass forms as well as more traditional oil, electricity and natural gas. Robust data are not available to determine the potential conversion to other types of fuels and their associated appliances if the consumer costs of wood-fueled appliances increase and at what level that increase would drive consumer choice.

5.6 Unfunded Mandates Reform Act (UMRA)

5.6.1 Future and Disproportionate Costs

The UMRA requires that we estimate, where accurate estimation is reasonably feasible, future compliance costs imposed by the rule and any disproportionate budgetary effects. Our estimates of the future compliance costs of the rule are discussed previously in this RIA. The nationwide annualized average compliance cost of this rule for directly affected appliances is $45.7 million in the 2015-2020 time frame (2013 dollars). Therefore, this rule is not subject to the requirements of Sections 202 or 205 of the UMRA.

This rule is not subject to the requirements of Section 203 of UMRA because it contains no regulatory requirements that might significantly or uniquely affect small governments. The rule would not apply to such governments and would impose no obligations upon them.

5.6.2 Effects on the National Economy

The UMRA requires that we estimate the effect of the rule on the national economy. To the extent feasible, we must estimate the effect on productivity, economic growth, full employment, creation of productive jobs, and international competitiveness of U.S. goods and services if we determine that accurate estimates are reasonably feasible and that such effect is relevant and material. The nationwide economic impact of the rule is presented earlier in this RIA chapter. This analysis provides estimates of the effect of the rule on most of the categories mentioned above, and these estimates are presented earlier in this RIA chapter. The nature of this rule is such that it is not practical for us to use existing approaches, such as the Morgenstern et al. approach,[78] to estimate the impact on employment to the regulated entities and others from this rule. We explain why this is true, and provide impacts associated with the monitoring, recordkeeping, and reporting requirements to provide some understanding of what impacts this will have on employment for affected firms in section 5.7 below.

5.6.3 Executive Order 13045: Protection of Children from Environmental Health Risks and Safety Risks

Executive Order 13045, "Protection of Children from Environmental Health Risks and Safety Risks" (62 FR 19885, April 23, 1997), applies to any rule that: (1) is determined to be "economically significant," as defined under Executive Order 12866, and (2) concerns an environmental health or safety risk that EPA has reason to believe may have a disproportionate effect on children. If the regulatory action meets both criteria, EPA must evaluate the environmental health or safety effects of the planned rule on children and explain why the planned regulation is preferable to other potentially effective and reasonably feasible alternatives considered by the Agency.

This rule is not subject to Executive Order 13045 (62 FR 19885, April 23, 1997) because the Agency does not believe the environmental health risks or safety risks addressed by this action present a disproportionate risk to children. The report, "Analysis of Exposure to Residential Wood Combustion Emissions for Different Socio-Economic Groups," [79]shows that on a nationwide basis, cancer risks due to residential wood smoke emissions among disadvantaged population groups generally are lower than the risks for the general population due to residential wood smoke emissions**.** One of the demographic variables examined for this report was that of children 18 years and younger.

This final rule is expected to reduce environmental impacts for everyone, including children. This action promulgates emissions limits at the levels based on the best system of emissions reduction (BSER), as required by the Clean Air Act. Based on our analysis, we believe that this rule would not have a disproportionate impact on children, and, in fact, will result in improvements to children's health. These emissions happen in neighborhoods and affect people in their homes. To the extent that children are particularly sensitive to asthma, this rule will help.

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[78] Morgenstern, R. D., W. A. Pizer, and J. S. Shih. 2002. "Jobs versus the Environment: An Industry-Level Perspective." *Journal of Environmental Economics and Management* 43(3):412-436.

[79] "Analysis of Exposure to Residential Wood Combustion Emissions for Different Socio-Economic Groups, Revised Draft Report." Prepared for Gil Wood, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC. Prepared by EC/R Inc., EPA Contract No. EP-D-05-085, Work Assignment No. 4-3. April 22, 2010.

5.6.4 Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations

Executive Order 12898 (59 FR 7629 (Feb. 16, 1994)) establishes federal executive policy on environmental justice. Its main provision directs federal agencies, to the greatest extent practicable and permitted by law, to make environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations and low-income populations in the United States. The EPA defines "Environmental Justice" to include meaning involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations, and polices.

As discussed in the proposal preamble, the report, "Analysis of Exposure to Residential Wood Combustion Emissions for Different Socio-Economic Groups," [80]shows that on a nationwide basis, cancer risks due to residential wood smoke emissions among disadvantaged population groups generally are lower than the risks for the general population due to residential wood smoke emissions. Thus, we have determined that this rule will not have disproportionately high and adverse human health or environmental effects on minority, low-income or indigenous populations because it increases the level of environmental protection for all affected populations without having any disproportionately high and adverse human health or environmental effects on any population, including any minority low-income or indigenous population.[81] This rule establishes national standards that will reduce primarily PM emissions from new residential wood heaters and is expected to decrease the amount of these emissions to which all affected populations are exposed. These emissions happen in minority and low-income neighborhoods and affect people in their homes. To the extent that minority populations and low-income populations are more vulnerable, this rule will help.

Although Executive Order 12898 focuses on human health and environmental impacts, commenters on the proposed rule noted that wood heaters are purchased less frequently by low-income groups than other income groups.

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[80] "Analysis of Exposure to Residential Wood Combustion Emissions for Different Socio-Economic Groups, Revised Draft Report." Prepared for Gil Wood, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC. Prepared by EC/R Inc., EPA Contract No. EP-D-05-085, Work Assignment No. 4-3. April 22, 2010.

[81] "Analysis of Exposure to Residential Wood Combustion Emissions for Different Socio-Economic Groups, Revised Draft Report." Prepared for Gil Wood, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC. Prepared by EC/R Inc., EPA Contract No. EP-D-05-085, Work Assignment No. 4-3. April 22, 2010.

5.7 Employment Impacts

In addition to addressing the costs and benefits of the final rule, EPA has analyzed the impacts of this rulemaking on employment, which are presented in this section. While a standalone analysis of employment impacts is not included in a standard cost-benefit analysis, such an analysis is of particular concern in the current economic climate given continued interest in the employment impact of regulations such as this final rule. . Executive Order 13563, states, "Our regulatory system must protect public health, welfare, safety, and our environment while promoting economic growth, innovation, competitiveness, and job creation" (emphasis added). A discussion of labor requirements associated with the installation, operation, and maintenance of control requirements, as well as reporting and recordkeeping requirements is included in Section 5.1.4, on compliance costs, of this RIA. However, due to data and methodology limitations, we have not quantified the rule's effects on labor, or the effects induced by changes in workers' incomes. What follows is an overview of the various ways that environmental regulation can affect employment. EPA continues to explore the relevant theoretical and empirical literature and to seek public comments in order to ensure that the way EPA characterizes the employment effects of its regulations is valid and informative.

This regulation is expected to affect employment in the United States through the regulated sector – residential wood heater manufacturers – and related sectors, specifically, wholesalers and distributors, and retailers (e.g. home furnishing stores that sell wood heaters), and suppliers of substitutes for residential wood-burning heaters (e.g. electric or natural gas heaters). The production of devices like wood stoves, hydronic heaters, and fireplace inserts is included under the heating equipment category (NAICS 333414). The U.S. Census Bureau reports that, in 2011, the industry employed 15,911 workers (see Table 3-1 in Section 3.1.3 of this RIA). Based on company data obtained for this profile, the residential wood heaters industry has a large number of producers, and we were able to identify 611 firms, employing approximately 15,000 workers annually. Previous analysis suggests that the industry relies on seasonal labor, ramping up production in months leading up to winter and reducing employment and production during the warmer parts of the year (AEI, 1986).

As described in Section 3.2.3 of this RIA, demand for residential wood heaters has been declining steadily, as shown from 1989 to 2005, but has increased more recently. More households rely on wood fuel as a supplemental heat source rather than as a primary source. In 2010, 2.1% of total occupied homes in the United States relied on wood heat as the primary fuel source for home heating. About 10–12% of American households rely on wood when secondary wood heat demand is counted, according to the U.S. Census Bureau and the Energy Information Administration (EIA). Demand varies regionally, in part, due to availability of energy sources. Current regional demand patterns are expected to continue, with the Northeast and Northwest regions of the country driving wood fuel combustion demand, but analysts anticipate that the wood heat product market will be embraced in other areas of the country in which wood and biomass are viable and inexpensive fuel sources (Frost & Sullivan, 2010).

The extent to which an increase in the price of residential wood heaters due to this rule would reduce the sales depends on the elasticity of demand for residential wood heaters. However, as mentioned in Section 3 of this RIA, there are no recent empirical estimates of the price elasticity of demand for residential wood heaters. An estimate of −1.6 was derived for use in the RIA for the current Residential Wood Combustion NSPS (EPA, 1986). Information provided by NERA in a public comment on the proposal included a price elasticity of demand of -0.97 for hydronic heaters in ten states that regulate such devices (NERA, 2014a). Available estimates for residential energy and heating fuel demand generally are relatively inelastic (i.e., there are only very small changes in demand in response to an increase in energy or fuel prices). A recent RAND report suggests that in the short term, demand for electricity and natural gas in residential markets is relatively inelastic (Bernstein and Griffin, 2005). There are a number of close substitutes for residential wood heating devices that include electric and gas furnaces and space heaters. The extent to which consumers are able to substitute between these options is likely to vary depending on geographic location. Overall, the presence of good substitutes will increase the elasticity of demand for wood heating equipment. In contrast, if locally-available alternative heating fuels (e.g. electricity, fuel oil) are relatively higher-priced, it may make switching away from wood heating equipment less likely and, ultimately, make demand for wood heating equipment inelastic. Also, the elasticity may depend on whether the fuel in question is a secondary source of fuel instead of a primary fuel source. Based on the available information, including the RAND report, we do not expect sales of residential wood to fall substantially due to this rule, particularly in the near-term.

From an economic perspective labor is an input into producing goods and services; if a regulation requires that more labor be used to produce a given amount of output, that additional labor is reflected in an increase in the cost of production. Moreover, when the economy is at full employment, we would not expect an environmental regulation to have an impact on overall employment because labor is being shifted from one sector to another. On the other hand, in periods of high unemployment, employment effects (both positive and negative) are possible.

For example, an increase in labor demand due to regulation may result in a short-term net increase in overall employment as workers are hired by the regulated sector to help meet new requirements (e.g., to install new equipment) or by the environmental protection sector to produce new abatement capital resulting in hiring previously unemployed workers . When significant numbers of workers are unemployed, the opportunity costs associated with displacing jobs in other sectors are likely to be smaller. And, in general, if a regulation imposes high costs and does not increase the demand for labor, it may lead to a decrease in employment. The responsiveness of industry labor demand depends on how these forces all interact. Economic theory indicates that the responsiveness of industry labor demand depends on a number of factors: price elasticity of demand for the product, substitutability of other factors of production, elasticity of supply of other factors of production, and labor's share of total production costs. Berman and Bui (2001) put this theory in the context of environmental regulation, and suggest that, for example, if all firms in the industry are faced with the same compliance costs of regulation and product demand is inelastic, then industry output may not change much at all.

Regulations set in motion new orders for pollution control equipment and services. New categories of employment have been created in the process of implementing environmental regulations. When a regulation is promulgated, one typical response of industry is to order pollution control equipment and services in order to comply with the regulation when it becomes effective. On the other hand, the closure of plants that choose not to comply – and any changes in production levels at plants choosing to comply and remain in operation - occur after the compliance date, or earlier in anticipation of the compliance obligation. Environmental regulation may increase revenue and employment in the environmental technology industry. While these increases represent gains for that industry, they translate into costs to the regulated industries required to install the equipment.

Environmental regulations support employment in many basic industries. Regulated firms either hire workers to design and build pollution controls directly or purchase pollution control devices from a third party for installation. Once the equipment is installed, regulated firms hire workers to operate and maintain the pollution control equipment—much like they hire workers to produce more output. In addition to the increase in employment in the environmental protection industry (via increased orders for pollution control equipment), environmental regulations also support employment in industries that provide intermediate goods to the environmental protection industry. The equipment manufacturers, in turn, order steel, tanks, vessels, blowers, pumps, and chemicals to manufacture and install the equipment. Currently in most cases there is no scientifically defensible way to generate sufficiently reliable estimates of the employment impacts in these intermediate goods sectors.

5.7.1 Employment Impacts within the Regulated Industry

It is sometimes claimed that new or more stringent environmental regulations raise production costs thereby reducing production which in turn must lead to lower employment. However, the peer-reviewed literature indicates that determining the direction of net employment effects in a regulated industry is challenging due to competing effects. Environmental regulations are assumed to raise production costs and thereby the cost of output, so we expect the "output" effect of environmental regulation to be negative (higher prices lead to lower sales). On the other hand, complying with the new or more stringent regulation requires additional inputs, including labor, and may alter the relative proportions of labor and capital used by regulated firms in their production processes. Two sets of researchers discussed here, Berman and Bui (2001) and Morgenstern, Pizer, and Shih (2002),[82] demonstrate using standard neoclassical microeconomics that environmental regulations have an ambiguous effect on employment in the regulated sector.[59] These theoretical results imply that the effect of environmental regulation on employment in the regulated sector is an empirical question and both sets of authors tested their models empirically using different methodologies. Both Berman and Bui and Morgenstern et al. examine the effect of environmental regulations on employment and both find that overall they had no significant net impact on employment in the sectors they examined.

Berman and Bui (2001) developed an innovative approach to examine how an increase in local air quality regulation that reduces nitrogen oxides (NOx) emissions affects manufacturing employment in the South Coast Air Quality Management District (SCAQMD), which incorporates Los Angeles and its suburbs. During the time frame of their study, 1979 to 1992, the SCAQMD enacted some of the country's most stringent air quality regulations. Using SCAQMD's local air quality regulations, Berman and Bui identify the effect of environmental regulations on net employment in the regulated industries.[83,84] The authors find that "while regulations do impose large costs, they have a limited effect on employment" (Berman and Bui,

[82] Berman, E. and L. T. M. Bui (2001). "Environmental Regulation and Labor Demand: Evidence from the South Coast Air Basin." Journal of Public Economics 79(2): 265-295. Morgenstern, R. D., W. A. Pizer, and J. S. Shih. 2002. Jobs versus the Environment: An Industry-Level Perspective.‖ Journal of Environmental Economics and Management 43(3):412-436.

[83] Note, like Morgenstern, Pizer, and Shih (2002), this study does not estimate the number of jobs created in the environmental protection sector.

[84] Berman and Bui include over 40 4-digit SIC industries in their sample.

2001, p. 269). Their conclusion is that local air quality regulation "probably increased labor demand slightly" but that "the employment effects of both compliance and increased stringency are *fairly precisely estimated zeros* [emphasis added], even when exit and dissuaded entry effects are included" (Berman and Bui, 2001, p. 269).[85]

Morgenstern et al. (2002) estimated the effects of pollution abatement expenditures from 1979 to 1991 at the plant level on net employment in four highly regulated sectors (pulp and paper, plastics, steel, and petroleum refining). Thus, in contrast to Berman and Bui (2001), this study identifies employment effects by examining differences in abatement expenditures rather than geographical differences in stringency. They conclude that increased abatement expenditures generally have *not* caused a significant change in net employment in those sectors. While the specific sectors Morgenstern et al. examined are different than the sectors considered here, the methodology that Morgenstern et al. developed is still an informative way to qualitatively, if not quantitatively,assess the effects of this rulemaking on employment in the regulated sector.

While there is an extensive empirical, peer-reviewed literature analyzing the effect of environmental regulations on various economic outcomes including productivity, investment, competitiveness as well as environmental performance, there are only a few papers that examine the impact of environmental regulation on employment, but this area of the literature has been growing. As stated previously in this RIA section, empirical results from Berman and Bui (2001) and Morgenstern et al (2002) suggest that new or more stringent environmental regulations do not have a substantial impact on net employment (either negative or positive) in the regulated sector. Nevertheless, other empirical research suggests that more highly regulated counties may generate fewer jobs than less regulated ones (Greenstone 2002, Walker 2011). However, the methodology used in these two studies cannot estimate whether aggregate employment is lower or higher due to more stringent environmental regulation, it can only imply that relative employment growth in some sectors differs between more and less regulated areas. List et al. (2003) find some evidence that this type of geographic relocation, from more regulated areas to less regulated areas may be occurring. Overall, the peer-reviewed literature does not contain evidence that environmental regulation has a large impact on net employment (either negative or positive) in the long run across the whole economy.

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[85] Including the employment effect of exiting plants and plants dissuaded from opening will increase the estimated impact of regulation on employment.

While the theoretical framework laid out by Berman and Bui (2001) and Morgenstern et al. (2002) still holds for the industries affected under this NSPS, important differences in the markets and regulatory settings analyzed in their study and the setting presented here lead us to conclude that it is inappropriate to utilize their quantitative estimates to estimate the employment impacts from this proposed regulation. In particular, the industries used in these two studies as well as the timeframe (late 1970's to early 1990's) are quite different than those in this proposed rule. Furthermore, the control strategies analyzed for this RIA mostly include process and design changes to reduce emissions during the production of affected heaters, and not after these heaters are in operation.[86] For instance, use of a catalyst combustor is common in wood stoves in order to reduce emissions and also improve heat efficiency. Retrofits are highly uncommon because replacing the wood stove is often a more economical alternative. On the other hand, the pollution control strategies examined by Berman and Bui and Morgenstern et al. are primarily add-on or end-of-line pollution controls. For these reasons we conclude there are too many uncertainties as to the transferability of the quantitative estimates in these two studies to apply their estimates to quantify the employment impacts within the regulated sectors for this regulation, though these studies have usefulness for qualitative assessment of employment impacts.

The preceding sections have outlined the challenges associated with estimating net employment effects in the regulated sector and in the environmental protection sector and labor supply impacts. These challenges make it very difficult to accurately produce net employment estimates for the whole economy that would appropriately capture the way in which costs, compliance spending, and environmental benefits propagate through the macro-economy. Quantitative estimates are further complicated by the fact that macroeconomic models often have very little sectoral detail and usually assume that the economy is at full employment. EPA's Science Advisory Board (SAB) is currently in the process of seeking input from an independent expert panel on modeling economy-wide impacts, including employment effects.

5.7.2. Conclusion

Economic theory predicts that the total effect of an environmental regulation on labor demand in regulated sectors is not necessarily positive or negative. Peer-reviewed econometric studies that use a structural approach, applicable to in the regulated sectors, converge on the finding that such effects, whether positive or negative, have been small.

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[86] More detail on how emission reductions expected from compliance with this rule can be obtained can be found in Section 4 of this RIA.

References for Employment Impacts Analysis

Greenstone, M. (2002). “The Impacts of Environmental Regulations on Industrial Activity: Evidence from the 1970 and 1977 Clean Air Act Amendments and the Census of Manufactures.” *Journal of Political Economy* 110(6): 1175-1219.

List, J. A., D. L. Millimet, P. G. Fredriksson, and W. W. McHone (2003). “Effects of Environmental Regulations on Manufacturing Plant Births: Evidence from a Propensity Score Matching Estimator.” *The Review of Economics and Statistics 85*(4): 944-952.

Walker, Reed. (2011).“Environmental Regulation and Labor Reallocation." American Economic Review: Papers and Proceedings, 101(2).

SECTION 6
SMALL ENTITY SCREENING ANALYSIS

The Regulatory Flexibility Act as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) generally requires an agency to prepare a regulatory flexibility analysis of any rule subject to notice and comment rulemaking requirements under the Administrative Procedure Act or any other statute, unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. Small entities include small businesses, small governmental jurisdictions, and small not-for-profit enterprises.

After considering the economic impact of the rule on small entities, the screening analysis indicates that we cannot conclude that this rule may not have a significant economic impact on a substantial number of small entities (or "SISNOSE") for certain residential wood heating products covered under the revised NSPS. For this analysis EPA considered sales and revenue tests for establishments owned by representative small entities that manufacture or construct residential wood heating devices.

6.1 Small Entity Data Set

The industry sectors covered by the rule were identified during the development of the cost analysis (see Sections 3 and 5). The Statistics of U.S. Businesses (SUSB) provides national information on the distribution of economic variables by industry and enterprise size (U.S. Census, 2008a, 2008b). The Census Bureau and the Office of Advocacy of the Small Business Administration (SBA) supported and developed these files for use in a broad range of economic analyses.[87] Statistics include the total number of establishments and receipts for all entities in an industry; however, many of these entities may not necessarily be covered by the final rule. SUSB also provides statistics by enterprise employment and receipt size.

The Census Bureau's definitions used in the SUSB are as follows:

- *Establishment*: An establishment is a single physical location where business is conducted or where services or industrial operations are performed.
- *Receipts*: Receipts (net of taxes) are defined as the revenue for goods produced, distributed, or services provided, including revenue earned from premiums, commissions and fees, rents, interest, dividends, and royalties. Receipts exclude all revenue collected for local, state, and federal taxes.

[87] See http://www.census.gov/csd/susb/ and http://www.sba.gov/advo/research/data.html for additional details.

- *Enterprise*: An enterprise is a business organization consisting of one or more domestic establishments that were specified under common ownership or control. The enterprise and the establishment are the same for single-establishment firms. Each multi-establishment company forms one enterprise—the enterprise employment and annual payroll are summed from the associated establishments. Enterprise size designations are determined by the summed employment of all associated establishments.

Because the SBA's business size definitions (SBA, 2014) apply to an establishment's "ultimate parent company," we assumed in this analysis that the "enterprise" definition above is consistent with the concept of ultimate parent company that is typically used for SBREFA screening analyses and the terms are used interchangeably.

6.2 Small Entity Economic Impact Measures

The analysis generated a set of establishment sales tests (represented as cost-to-receipt ratios) for NAICS codes associated with sectors listed in Table 6-1. It should be noted that the cost-to-receipt ratios presented in Table 5-5 of this RIA are estimated at the product level and are not calculated to inform the small entity analysis, while the small entity impact estimates will be estimated at the establishment (place of business) level. Although the appropriate SBA size definition should be applied at the parent company (enterprise) level, we can only compute and compare ratios for a model establishment owned by an enterprise within an SUSB size range (employment or receipts). Using the SUSB size range helps us account for receipt differences between establishments owned by large and small enterprises and also allows us to consider the variation in small business definitions across affected industries. Using establishment receipts is also a somewhat conservative approach, because an establishment's parent company (the "enterprise") may have other economic resources that could be used to cover the costs of the final rule. It should be noted that these impacts are for the 2015–2020 time frame; as mentioned earlier in this RIA, the annualized costs considered in this analysis reflect an average of the rule's compliance costs incurred by affected sources each year from promulgation through 2020.

6.2.1 Establishment Employment and Receipts

The sales test compares a representative establishment's total annual compliance costs to the average establishment receipts for enterprises in several size categories.[88] For industries with SBA employment size standards, we calculated average establishment receipts for each enterprise employment range (Table 6-2). For industries with SBA receipt size standards, we calculated average establishment receipts for each enterprise receipt range (Table 6-3). The

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[88] For the 1 to 20 employee category, we excluded SUSB data for enterprises with zero employees. These enterprises did not operate the entire year.

analysis assumes that the majority of affected entities are covered under hardware manufacturing (NAICS 332510) and heating equipment manufacturing (NAICS 333414). We use establishment data from the 2007 Economic Census because that data is the most recent release of public establishment-level information for the industries impacted by this proposal.

Table 6-1. Revised NSPS for Residential Wood Heating Devices: Affected Sectors and SBA Small Business Size Standards

Industry Description	Corresponding NAICS	SBA Size Standard for Businesses (July 14, 2014)	Type of Small Entity
Hardware manufacturing	332510	500 employees	All product types
Heating equipment (except warm air) manufacturing	333414	500 employees	All product types
Plumbing and heating equipment and supplies (hydronics) merchant wholesalers	423720	100 employees	All product types
All other home furnishing stores	442299	$20.5 million in annual receipts	Business

However, the revised NSPS has the potential to affect small entities classified as new home construction. In addition, wholesalers of imported residential heating devices may also be affected if these establishments are required to certify imported products.

6.2.2 Establishment Compliance Cost

Annual entity compliance costs vary depending on the product type manufactured and the number of product models they would need to redesign under the revised NSPS as mentioned in Section 5 of this RIA. For this analysis compliance costs were estimated based on the average development costs defined in the engineering cost analysis, presented in Section 5-1. The analysis assumes that manufacturers have between two and seven model fireboxes that would be subject to the new NSPS. There is limited information on the actual number of model fireboxes associated with small businesses. Hence, for purposes of the small entity screening analysis, we assumed that smaller companies maintain fewer than three firebox models that would be subject to the revised NSPS. In the absence of better data, EPA believes that between one and three firebox models is a reasonable assumption for our analysis of impacts to potentially affected small businesses.

Table 6-2. Average Receipts for Affected Industry by Enterprise Employment Size: 2007 ($2013 million/establishment)

NAICS	NAICS Description	SBA Size Standard for Businesses (effective July 14, 2014)	Owned by Enterprises with Employment Ranges: All Enterprises	Fewer than 20 Employees	22 to 99 Employees	100 to 499 Employees	500 to 749 Employees	750 to 999 Employees	1,000 to 1,500 Employees	1,500+ Employees
332510	Hardware manufacturing	500 employees	$15.26	$1.53	$8.87	$30.20	$83.75	$71.51	$43.59	$71.61
333414	Heating equipment manufacturing	500 employees	$13.85	$1.46	$12.85	$45.78	NA	NA	NA	$0.16
423720	Plumbing and heating equipment wholesalers	100 employees	$8.61	$2.97	$11.13	$12.41	$11.29	NA	NA	$9.30
442299	All other home furnishing stores	$20.5 million in annual receipts	$3.08	$0.06	$0.32	$0.90	$2.29	NA	NA	$461.41

NA = Not available. SUSB did not report this data due to concern with disclosure of confidential information or other reasons. Escalation of average receipts from 2007 to 2013 is accomplished by use of the annual GDP implicit price deflator (available at http://research.stlouisfed.org/fred2/series/GDPDEF/downloaddata?cid=21). The escalation ratio between 2007 and 2013 is 1.097.

Then, we computed per-entity compliance costs for representative establishments and for manufacturing each product type (see Table 6-3). For this analysis, the annualized costs as presented in Table 6-3 assumed the total model development costs for four model fireboxes spread over a 6-year model development time frame and scaled to a single model. Table 6-3 shows the estimated average annualized cost of $85,400 per model and its use in deriving the national total compliance costs for the NSPS. Lower compliance cost for pellet stoves was due to the fact that most existing models already comply with the regulation.

Table 6-3. Per-Entity Annualized Compliance Costs by Product Type— with NSPS ($2013 millions)

Product Type	No. Establishments	Assumed Affected Models per Establishment[a]	Annual Compliance Cost per Model Firebox ($ millions)	Total Industry Costs—NSPS ($ millions)
Wood stoves	42	3	$0.02	$3.02
Single burn rate stoves	3	7	$0.04	$0.87
Pellet stoves	31	4	$0.01	$1.52
Forced-air furnaces	7	7	$0.31	$15.36
Hydronic heating systems	30	4	$0.21	$24.88
National Annualized Compliance Cost				**$45.7**

[a] Table totals may differ because of rounding. Number of models is based on estimates in the Unit Cost memo, EC/R, January 30, 2015.

For each case in this analysis, the number of models each representative establishment must redesign to comply with the NSPS emission limits analyzed in this RIA varies by product type. The total annualized compliance cost per establishment (TAC/establishment) is calculated by multiplying the number of firebox models requiring redesign by the average annualized cost per model across product types and weighting by the number of models for each product type. Thus, product types with a larger number of affected establishments and assumed models per establishment will have a larger effect on the estimate of TAC/establishment when not considering the costs for product types. This information is summarized above in Table 6-3 and is provided in more detail in the unit cost memo. The greater the number of models, the greater the effect on the total annualized compliance cost. Using this approach, the TAC/establishment is $103,700. Table 6-3 presents the assumed number of models per establishment by product type.

Table 6-4. Representative Establishment Costs Used for Small Entity Analysis ($2013)

	Best Estimate
Number of models requiring redesign	2
Annual cost per model	$103,700
Average annual cost per establishment	$207,400

For the sales test, we divided the representative establishment compliance costs reported in Table 6-4 by the representative establishment receipts reported in Tables 6-2 and 6-3. This is known as the cost-to-receipt (i.e., sales) ratio, or the "sales test." The "sales test" is the impact methodology EPA employs in analyzing small entity impacts as opposed to a "profits test," in which annualized compliance costs are calculated as a share of profits.

Information on annual revenues or sales is more commonly available data for entities normally affected by EPA regulations, and profits data normally made available are often not the true profit earned by firms because of accounting and tax considerations. Revenues as typically published are usually correct figures and are more reliably reported when compared with profit data. The use of a "sales test" for estimating small business impacts for a rulemaking such as this one is consistent with guidance offered by EPA on compliance with SBREFA[89] and is consistent with guidance published by the SBA's Office of Advocacy that suggests that cost as a percentage of total revenues is a metric for evaluating cost increases on small entities in relation to increases on large entities (SBA, 2003).[90] The annualized cost per sales for a company represents the maximum price increase in affected product needed for the company to completely recover the annualized costs imposed by the regulation.

For purposes of this analysis, EPA assumes most small entities in the residential wood heating industry are likely to manufacture fewer than three distinctive firebox models and in many cases they would support only one model. We assume for this analysis that most small entities in this industry will manufacture an average of two distinctive firebox models. Hence, EPA believes that the estimate in Table 6-4 above is the most representative establishment costs to assess impacts on small businesses. If the cost-to-receipt ratio is less than 1%, then we consider the rule to not have a significant impact on the establishment (and, company) in question. Table 6-5 presents the cost-to-receipt ratios for each category of establishments (establishments with ratios that exceed 1% under each case are highlighted) for the final NSPS.

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[89] The SBREFA compliance guidance to EPA rule writers (EPA, 2006a) regarding the types of small business analysis that should be considered can be found at http://www.epa.gov/sbrefa/documents/rfaguidance11-00-06.pdf, pp. 24-25.

[90] This compliance guide produced by SBA can be found at http://www.sba.gov/sites/default/files/rfaguide_0512_0.pdf.

Table 6-5. Cost-to-Receipt Ratio Results for the NSPS by NAICS Code[a]

NAICS	Description	All Establishments	Fewer than 20 Employees	22 to 99 Employees	100 to 499 Employees
332510	Hardware manufacturing	5.09%	32.22%	5.53%	1.61%
333414	Heating equipment manufacturing	3.08%	33.82%	3.82%	1.14%
423720	Plumbing and heating equipment wholesalers	5.70%	16.55%	4.41%	3.96%
442299	All other home furnishing stores	12.77%	366.95%	75.07%	12.19%

[a] All the cost to receipts results incorporate costs that are primarily R&D activities that firms will engage in to build appliance models that comply with the options analyzed in this RIA. The R&D cycle is estimated at 6 years, while the appliance life for all affected categories is 10 years.

6.3 Analysis Results

In our small entity analysis for the final rule, using an annual compliance cost of $207,800 as the estimated cost borne by an affected small entity, establishments in NAICS 332510, 333414, and 423720 with fewer than 500 employees have cost-to-receipt ratios higher than 1% as shown in Table 6-5. Establishments in NAICS 442299 with receipts less than $10 million have cost-to-receipt ratios considerably higher than 1%.

After considering the economic impacts of this rule on small entities, we cannot certify that this action will not have a significant economic impact on a substantial number of small entities. This certification is based on the economic impact of this action to all affected small entities across all industries affected. Using the estimate of impacts presented earlier in this chapter, we estimate that all small entities will have annualized costs of greater than 1% of their sales in all industries with establishments of fewer than 100 employees and NAICS 236115, 238140, and 442299 with receipts less than $20 million. Those establishments in NAICS 332510, 333414, and 423720 with cost-to-receipt ratios higher than 1% account for more than 85% of small entities. Establishments in NAICS 442299 with cost-to-receipt ratios higher than 1% account for more than 99% of small entities. We thus conclude that we cannot certify that there is not a significant economic impact on a substantial number of small entities (SISNOSE) for this rule.

It should be noted that the cost to receipts analysis included in this RIA reflect the large majority of annualized costs that are composed of research and development (R&D) activities (nearly 90%, based on the manufacturers' cost memorandum) that have a shorter life than the total life of affected appliances—six years for an R&D cycle as mentioned in section 5 of this RIA compared to 10 years for the life of affected appliances. The impacts on small entities should be understood in the context that a large share of the estimated annualized costs reflect expenses in the early years of the appliance life, and only a small share recurs each year over the entire appliance life of 10 years. In addition, the application of these costs for the options analyzed in this RIA will lead to a somewhat conservative (or, over-stated) cost estimate as stated previously in section 5.1.3. One example of this is that all hydronic heaters will undergo R&D beginning in 2015 to comply with the final NSPS; there is a small percentage of hydronic heaters that already meet the emission limits under each option as mentioned in Section 4 in the RIA. Similar assumptions are also made in the cost estimates for single burn rate stoves and forced air furnaces. Given these two considerations, the costs that are included in the cost to sales analyses presented in this RIA could be somewhat overstated in nature, and the cost to receipts impacts shown above should be understood in that context.

A sensitivity analysis showing the effect of the R&D cycle lifespan on the cost to sales estimates for each option is below. Table 6-6 shows how the model firebox costs that are input to the cost to sales (and small business) analyses will change with changes to the R&D cycle lifespan.

Table 6-6. Total Annual Cost (TAC) per Appliance Model Firebox– for Varying Annualized R&D Cycle Lifespans

Annualized R&D Cycle Lifespan (Years)	TAC/Appliance Model Firebox (2013$)	TAC per Establishment
4	$146,000	292,000
6*	103,700	$ 207,400
10	70,540	141,080
20	46,760	93,520

*As mentioned in Section 5 of this RIA, six years represents the annualized R&D cycle lifespan incorporated in the cost estimates for the RWH NSPS rule. In addition, each affected firm or establishment is estimated to have two affected models on average. The interest rate for estimating TAC per appliance model firebox in this table is 7%.

The total annual cost per appliance model is the value of costs included in the cost to sales estimates to calculate these values. Each small entity is expected to modify 2 appliance models on average in order to comply with the rule, an assumption we established earlier in this section of the RIA. We assume each small entity owns only one establishment (or place of business). Hence, the total annual cost to each small entity is twice the annual cost per appliance model. The annual cost to sales in the RIA will change proportionately to a change in the TAC since the sales estimates are presumed to remain constant for purposes of this analysis.

As shown in Table 6-6, with an increase in the R&D cycle lifespan from 6 to 10 years, the TAC/appliance model estimate falls to $70,540 from $103,700. The new TAC/appliance model estimate is 32% less than before. Thus, the cost to sales estimates will fall by 32% from the previous values. If the R&D cycle lifespan increases from 6 to 20 years, the TAC/appliance model estimate falls to $46,760 from $103,700. Thus, the cost to sales estimate will fall by 55% from the previous values. Finally, if the R&D cycle lifespan is reduced to 4 years, the TAC/appliance model estimate increases to $146,000 from $103,700. The new TAC/appliance model estimate is now 41% higher than before. Thus, the cost to sales estimates will increase by 41% from the values that use an R&D cycle lifespan of 6 years.

Table 6-7 contains estimates of the changes in the cost to sales estimates for the NSPS with an increase in the R&D cycle lifespan to 10 and 20 years from 6 years. The estimates with the change in R&D cycle lifespan to 10 and 20 years are in parentheses; the other values are those for the NSPS.

Table 6-7. Cost-to-Sales Ratio Sensitivity Analysis Results Reflecting Different R&D Cycle Lifespans for the NSPS by NAICS Code*

NAICS	Industry Description	All Establishments	Establishments with Fewer than 20 Employees (%)	Establishments with Between 20 and 99 Employees (%)	Establishments with Between 100 and 499 Employees (%)
332510	Hardware manufacturing	5.90 (3.47, 2.30)	32.22 (21.90, 14.48)	5.54 (3.77, 2.49)	1.61 (1.09, 0.72)
333414	Heating equipment manufacturing	3.08 (2.08, 1.37)	33.82(23.03, 15.22)	3.81(2.59, 1.71)	1.14 (0.77, 0.51)
423720	Plumbing and heating equipment wholesalers	5.70 (3.87, 2.55)	16.54 (11.24, 7.43)	4.44(3.00, 1.98)	3.97 (2.69, 1.78)

* The first value in parentheses is the cost to sales estimate for a 10 year R&D cycle lifespan; the second value is the cost to sales estimates for a 20 year R&D cycle lifespan. The values that are not in the parentheses are the cost to sales estimates for a 6 year R&D cycle lifespan, the value used in the estimates of costs for the NSPS.

6.4 Final Regulatory Flexibility Analysis (FRFA)

An FRFA illustrates how EPA considers the rule’s small entity effects for a final rule and provides information about how the objectives of the rule were achieved while minimizing significant economic impacts on small entities. We provide a summary of FRFA elements; the preamble to this final rule provides additional details.

6.4.1 Reasons Why Action Is Being Considered

This rule was developed following a Clean Air Act (CAA) section 111(b)(1)(B) periodic review of the existing residential wood heater new source performance standards (NSPS) and because emissions from residential wood heaters can be a significant source of air pollution, and thus adverse health effects, in some areas.

6.4.2 Statement of Objectives and Legal Basis of Proposed Rule

The EPA is amending Standards of Performance for New Residential Wood Heaters, and is adding one new subpart: Standards of Performance for New Residential Hydronic Heaters and Forced-Air Furnaces. This final rule achieves several objectives, including applying updated emission limits that reflect BSER; improving coverage of the broad suite of residential wood heaters; improving the test methods; and streamlining the certification process. This final rule does not include any requirements on heaters solely fired by coal, gas or oil. This final rule does not establish new emissions limits for existing heaters. This rule was developed under the authority of CAA section 111.

6.4.3 Response to Any Comments to the Proposed Rule Filed by the Chief Counsel for Advocacy of the SBA

The SBA's Chief Counsel for Advocacy did not file any comments in response to the proposed rule.

6.4.4 Description and Estimate of the Number of Small Entities

Small entities that EPA anticipates being affected by the standards would include almost all manufacturers of wood heaters listed earlier this document. EPA estimates that roughly 250–300 U.S. companies manufacture residential wood heaters. EPA believes that approximately 90% of these manufacturers meet the SBA small-entity definition of having fewer than 500 employees.

6.4.5 Description of Impact Methodology and Compliance Costs

A discussion of the methodology used to estimate cost impacts is presented in Section 5 of this RIA.

6.4.5 Panel Recommendations for Small Business Flexibilities

As required by section 609(b) of the RFA, as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA), the EPA also convened a Small Business Advocacy Review Panel (Panel) to obtain advice and recommendations of representatives of the small entities that potentially would be subject to the rule's requirements. The following paragraphs describe the process, the type of small entity representatives, the outreach efforts and the Panel members.

Well before beginning the formal SBREFA process, the EPA actively engaged in outreach with HPBA, MHA and PFI and many of their member companies to discuss the rule under development and to provide these contacts with an early opportunity to ask questions and discuss their concerns.[91] The EPA provided each small business with general information on the SBREFA process and background information on the NSPS rulemaking process and current schedule.

Based on consultations with the Small Business Administration, and resulting from solicited self-nominations, we prepared a list of 30 potential Small Entity Representatives (SERs), from residential wood heating appliance manufacturers (wood heaters, pellet heaters/stoves, hydronic heaters, forced-air furnaces and masonry heaters), other wood-burning appliance manufacturers (fireplaces, cook stoves), equipment suppliers, chimney sweeps, test laboratories, masons and trade associations. Once the official pre-Panel process began and potential SERs were identified, the EPA held an outreach meeting with the potential SERs and invited representatives from the Office of Advocacy of the Small Business Administration (OA/SBA) and the Office of Information and Regulatory Affairs within the Office of Management and Budget (OIRA/OMB) on June 29, 2010, to solicit their feedback on the upcoming proposed rulemaking. Representatives from 26 of the 30 companies and organizations that we selected as potential SERs for this SBREFA process participated in the meeting (in person and by phone). At that meeting, the EPA solicited written comments from the potential SERs, which were later summarized and shared with the Panel as part of the convening document.

The SBAR Panel convened on August 4, 2010. The Panel consisted of representatives of the EPA, OA/SBA and OIRA/OMB. The Panel held a formal outreach meeting/teleconference with the SERs on August 25, 2010. To help the SERs prepare for this meeting, on August 11, 2010, the Panel sent a list of questions, preliminary cost information and other materials to each of the SERs via email. Additional materials were emailed to the SERs on August 19, 2010. The Panel provided the opportunity for questions and comment during the meeting on various aspects of the proposal being developed, including the expanded scope of the rule, changes to the current requirements under consideration, preliminary cost information and follow up from the June 29, 2010, meeting on the SERs' ideas for regulatory flexibility. During the August 25 meeting, SERs voiced general support for the planned proposed rule and shared specific concerns with the Panel

[91] Also, as noted in the proposal preamble in the discussion of development of the proposed hydronic heater emission limits, the EPA worked with the hydronic heater industry in 2006 to develop a voluntary partnership program to encourage manufacture of cleaner models, www.epa.gov/burnwise/participation.

members. As a result of this meeting, the EPA received many useful verbal comments, and the EPA received many helpful written comments by September 10, 2010.

Consistent with the RFA/SBREFA requirements, the Panel evaluated the assembled materials and small-entity comments on issues related to elements of the Interim Regulatory Flexibility Analysis. A copy of the Panel final full report is included in the docket for this rule. We have attempted to follow the Panel's recommendations to the degree we can while also ensuring that the options are practicable, enforceable, environmentally sound and consistent with the CAA. For those recommendations not adopted by the EPA, we included an explanation at proposal for why we rejected them.

In addition, the EPA is preparing a Small Entity Compliance Guide to help small entities comply with this rule. Small entities can obtain of a copy of this guide at http://www.epa.gov/rfa/compliance-guides.html or http://www2.epa.gov/residential-wood-heaters. We expect the Small Entity Compliance Guide to be available by April 2015.

SECTION 7

HUMAN HEALTH BENEFITS OF EMISSIONS REDUCTIONS

7.1 Synopsis

Implementation of emissions limits required by the residential wood heaters NSPS is expected to reduce direct emissions of $PM_{2.5}$. These reductions result from the imposition of tightened and new PM emissions limits for a number of emissions categories as described in Section 2 of this RIA. In this section, we quantify the monetized benefits for this rule associated with reduced exposure to ambient fine particulate matter ($PM_{2.5}$) resulting from the reduction of direct emissions of $PM_{2.5}$. The total $PM_{2.5}$ reductions are the consequence of the expected design changes to the affected appliances needed in order to meet the emissions limits analyzed in this RIA. We estimate the total monetized benefits for the NSPS to be $3.4 billion to $7.6 billion at a 3% discount rate and $3.1 billion to $6.9 billion at a 7% discount rate on a yearly average between 2015 and 2020. All estimates are in 2013$ as they are summarized in Table 7-2. These estimates reflect the monetized human health benefits of reducing cases of morbidity and premature mortality among populations exposed to $PM_{2.5}$ reduced by this rule.

Data, resources, and methodological limitations prevented EPA from monetizing the benefits from several important benefit categories. Included among the nonmonetized benefits are those associated with reduced exposure to about 9,300 tons of VOCs. VOCs are also precursors to ozone formation and therefore reducing health impact due to ozone exposure. Further, this rule would reduce each year 46,100 tons of CO, black carbon emissions, and several HAP emissions such as benzene, formaldehyde, and dioxin. This rule will also reduce ecosystem effects, and visibility impairment due to PM emissions.

7.2 $PM_{2.5}$-Related Human Health Benefits

This rule is expected to reduce direct emissions of PM and emissions of VOCs, which are precursors to formation of ambient $PM_{2.5}$. Therefore, reducing these emissions would also reduce human exposure to ambient $PM_{2.5}$ and the incidence of $PM_{2.5}$-related health effects. In this section, we provide an overview of the $PM_{2.5}$-related benefits. A full description of the underlying data, studies, and assumptions is provided in the PM NAAQS RIA (U.S. EPA, 2012a).

In implementing this rule, emission controls may lead to reductions in ambient $PM_{2.5}$ concentrations below the National Ambient Air Quality Standards (NAAQS) for PM in some areas and assist other areas with attaining the PM NAAQS. Because the PM NAAQS RIA (U.S.

EPA, 2012a) also calculated PM benefits, there are important differences worth noting in the design and analytical objectives of each RIA. The NAAQS RIAs illustrate the potential costs and benefits of attaining a revised air quality standard nationwide based on an array of emission reduction strategies for different sources including known and unknown controls, incremental to implementation of existing regulations and controls needed to attain the current standards. In short, NAAQS RIAs hypothesize, but do not predict, the reduction strategies that States may choose to enact when implementing a revised NAAQS. The setting of a NAAQS does not directly result in costs or benefits, and as such, the NAAQS RIAs are merely illustrative and the estimated costs and benefits are not intended to be added to the costs and benefits of other regulations that result in specific costs of control and emission reductions. However, it is possible that some costs and benefits associated with the required emission controls estimated in this RIA may account for the same air quality improvements as estimated in the illustrative PM NAAQS RIA.

By contrast, the emission reductions for implementation rules such as this rulemaking are generally for specific, well-characterized sources. In general, EPA is more confident in the magnitude and location of the emission reductions for implementation rules. As such, emission reductions achieved under these and other promulgated implementation rules will ultimately be reflected in the baseline of future NAAQS analyses, which would reduce the incremental costs and benefits associated with attaining revised future NAAQS. EPA remains forward looking towards the next iteration of the 5-year review cycle for the NAAQS. As a result, EPA does not re-issue NAAQS RIAs that retroactively update the baseline to account for implementation rules promulgated after a NAAQS RIA outside of the NAAQS review process. For more information on the relationship between the NAAQS and rules that are not ambient standards, such as analyzed here, please see Section 1.3 of the PM NAAQS RIA (U.S. EPA, 2012a).

7.2.1 Health Impact Assessment

The *Integrated Science Assessment for Particulate Matter* (PM ISA) (U.S. EPA, 2009) identified the human health effects associated with ambient $PM_{2.5}$, which include premature mortality and a variety of morbidity effects associated with acute and chronic exposures. Table 7-1 provides the quantified and unquantified benefits captured in EPA's benefits estimates for reduced exposure to ambient $PM_{2.5}$. Although the table below does not include entries for the unquantified health effects such as exposure to ozone and NO_2 nor welfare effects such as ecosystem effects and visibility impairment, these effects are itemized in Chapters 5 and 6 of the

Table 7-1. Human Health Effects of Ambient $PM_{2.5}$

Category	Specific Effect	Effect Has Been Quantified	Effect Has Been Monetized	More Information in PM NAAQS RIA
Improved Human Health				
Reduced incidence of premature mortality from exposure to $PM_{2.5}$	Adult premature mortality based on cohort study estimates and expert elicitation estimates (age >25 or age >30)	✓	✓	Section 5.6
	Infant mortality (age <1)	✓	✓	Section 5.6
Reduced incidence of morbidity from exposure to $PM_{2.5}$	Non-fatal heart attacks (age > 18)	✓	✓	Section 5.6
	Hospital admissions—respiratory (all ages)	✓	✓	Section 5.6
	Hospital admissions—cardiovascular (age >20)	✓	✓	Section 5.6
	Emergency room visits for asthma (all ages)	✓	✓	Section 5.6
	Acute bronchitis (age 8–12)	✓	✓	Section 5.6
	Lower respiratory symptoms (age 7–14)	✓	✓	Section 5.6
	Upper respiratory symptoms (asthmatics age 9–11)	✓	✓	Section 5.6
	Asthma exacerbation (asthmatics age 6–18)	✓	✓	Section 5.6
	Lost work days (age 18–65)	✓	✓	Section 5.6
	Minor restricted-activity days (age 18–65)	✓	✓	Section 5.6
	Chronic Bronchitis (age >26)	—[a]	—[a]	Section 5.6
	Emergency room visits for cardiovascular effects (all ages)	—[a]	—[a]	Section 5.6
	Strokes and cerebrovascular disease (age 50–79)	—[a]	—[a]	Section 5.6
	Other cardiovascular effects (e.g., other ages)	—	—	PM ISA[b]
	Other respiratory effects (e.g., pulmonary function, non-asthma ER visits, non-bronchitis chronic diseases, other ages and populations)	—	—	PM ISA[b]
	Reproductive and developmental effects (e.g., low birth weight, pre-term births, etc.)	—	—	PM ISA[b,c]
	Cancer, mutagenicity, and genotoxicity effects	—	—	PM ISA[b,c]

[a] We assess these benefits qualitatively due to time and resource limitations for this analysis. In the PM NAAQS RIA, these benefits were quantified in a sensitivity analysis, but not in the core analysis.

[b] We assess these benefits qualitatively because we do not have sufficient confidence in available data or methods.

[c] We assess these benefits qualitatively because current evidence is only suggestive of causality or there are other significant concerns over the strength of the association.

PM NAAQS RIA (U.S. EPA, 2012a). It is important to emphasize that the list of unquantified benefit categories is not exhaustive, nor is quantification of each effect complete.

We follow a "damage-function" approach in calculating benefits, which estimates changes in individual health endpoints (specific effects that can be associated with changes in air quality) and assigns values to those changes assuming independence of the values for those individual endpoints. Because EPA rarely has the time or resources to perform new research to measure directly either the health outcomes or their values for regulatory analyses, our estimates are based on the best available methods of benefits transfer, which is the science and art of adapting primary research from similar contexts to estimate benefits for the environmental quality change under analysis.

The health impact assessment (HIA) quantifies the changes in the incidence of adverse health impacts resulting from changes in human exposure to $PM_{2.5}$ or other air pollutants. We use the environmental ***Ben***efits ***M***apping and ***A***nalysis ***P***rogram (BenMAP) to systematize health impact analyses by applying a database of key input parameters, including population projections, health impact functions, and valuation functions (Abt Associates, 2012). For this assessment, the HIA is limited to those health effects that are directly linked to ambient $PM_{2.5}$ concentrations. Epidemiological studies generally provide estimates of the relative risks of a particular health effect for a given increment of air pollution (often per 10 $\mu g/m^3$ for $PM_{2.5}$). These relative risks can be used to develop risk coefficients that relate a unit reduction in $PM_{2.5}$ to changes in the incidence of a health effect. We refer the reader to section 5.6 of the PM NAAQS RIA for more information regarding the epidemiology studies and risk coefficients applied in this analysis (U.S. EPA, 2012a), and we briefly elaborate on adult premature mortality below. The size of the mortality effect estimates from epidemiological studies, the serious nature of the effect itself, and the high monetary value ascribed to prolonging life make mortality risk reduction the most significant health endpoint quantified in this analysis.

Considering a substantial body of published scientific literature, reflecting thousands of epidemiology, toxicology, and clinical studies, the PM ISA documents the association between elevated $PM_{2.5}$ concentrations and adverse health effects, including increased premature mortality (U.S. EPA, 2009). The PM ISA, which was twice reviewed by the Clean Air Scientific Advisory Committee of EPA's Science Advisory Board (SAB-CASAC) (U.S. EPA-SAB, 2009b, 2009c), concluded that there is a causal relationship between mortality and both long-term and short-term exposure to $PM_{2.5}$ based on the entire body of scientific evidence. The PM ISA also concluded that the scientific literature consistently finds that a no-threshold log-linear model (i.e. referring to the Lowest-Measured-Level, LML analysis presented in this section) most adequately portrays the PM-mortality concentration-response relationship while recognizing potential uncertainty about the exact shape of the concentration-response function.

For mortality, we use the effect coefficients from the most recent epidemiology studies examining two large population cohorts: the American Cancer Society (ACS) cohort (Krewski et al., 2009) and the Harvard Six Cities cohort (Lepeule et al., 2012). The PM ISA (U.S. EPA, 2009) concluded that the ACS and Six Cities cohorts provide the strongest evidence of the association between long-term $PM_{2.5}$ exposure and premature mortality with support from a number of additional cohort studies. The SAB's Health Effects Subcommittee (SAB-HES) also supported using these two cohorts for analyses of the benefits of PM reductions (U.S. EPA-SAB, 2010a). As both the ACS and Six Cities cohort studies have inherent strengths and weaknesses, we present benefits estimates using relative risk estimates from both these cohorts (Krewski et al., 2009; Lepeule et al., 2012).

As a characterization of uncertainty regarding the $PM_{2.5}$ -mortality relationship, EPA graphically presents benefits derived from EPA's expert elicitation study (Roman et al., 2008; IEc, 2006). The primary goal of the 2006 study was to elicit from a sample of health experts probabilistic distributions describing uncertainty in estimates of the reduction in mortality among the adult U.S. population resulting from reductions in ambient annual average $PM_{2.5}$ levels. In that study, twelve experts provided independent opinions of the $PM_{2.5}$ -mortality concentration-response function. Because the experts relied upon the ACS and Six Cities cohort studies to inform their concentration-response functions, the benefits estimates derived from the expert responses generally fall between results derived from the these studies (see Figure 7-1). We do not combine the expert results in order to preserve the breadth and diversity of opinion on the expert panel. This presentation of the expert-derived results is generally consistent with SAB advice (U.S. EPA-SAB, 2008), which recommended that the EPA emphasize that "scientific differences existed only with respect to the magnitude of the effect of $PM_{2.5}$ on mortality, not whether such an effect existed" and that the expert elicitation "supports the conclusion that the benefits of $PM_{2.5}$ control are very likely to be substantial." Although it is possible that newer scientific literature could revise the experts' quantitative responses if elicited again, we believe that these general conclusions are unlikely to change.

7.2.2 Economic Valuation

After quantifying the change in adverse health impacts, we estimate the economic value of these avoided impacts. Reductions in ambient concentrations of air pollution generally lower the risk of future adverse health effects by a small amount for a large population. Therefore, the appropriate economic measure is willingness to pay (WTP) for changes in risk of a health effect. For some health effects, such as hospital admissions, WTP estimates are generally not available, so we use the cost of treating or mitigating the effect. These cost-of-illness (COI) estimates generally (although not necessarily in every case) understate the true value of reductions in risk of a health effect. They tend to reflect the direct expenditures related to treatment but not the value of avoided pain and suffering from the health effect. The unit values applied in this analysis are provided in Table 5-9 of the PM NAAQS RIA for each health endpoint (U.S. EPA, 2012a).

Avoided premature deaths account for 98% of monetized PM-related benefits. The economics literature concerning the appropriate method for valuing reductions in premature mortality risk is still developing. The adoption of a value for the projected reduction in the risk of premature mortality is the subject of continuing discussion within the economics and public policy analysis community. Following the advice of the SAB's Environmental Economics Advisory Committee (SAB-EEAC), the EPA currently uses the value of statistical life (VSL) approach in calculating estimates of mortality benefits, because we believe this calculation provides the most reasonable single estimate of an individual's willingness to trade off money for reductions in mortality risk (U.S. EPA-SAB, 2000). The VSL approach is a summary measure for the value of small changes in mortality risk experienced by a large number of people.

EPA continues work to update its guidance on valuing mortality risk reductions, and the Agency consulted several times with the SAB-EEAC on the issue. Until updated guidance is available, the Agency determined that a single, peer-reviewed estimate applied consistently best reflects the SAB-EEAC advice it has received. Therefore, EPA has decided to apply the VSL that was vetted and endorsed by the SAB in the *Guidelines for Preparing Economic Analyses* (U.S. EPA, 2000)[92] while the Agency continues its efforts to update its guidance on this issue. This approach calculates a mean value across VSL estimates derived from 26 labor market and

[92] In the updated *Guidelines for Preparing Economic Analyses* (U.S. EPA, 2010e), EPA retained the VSL endorsed by the SAB with the understanding that further updates to the mortality risk valuation guidance would be forthcoming in the near future.

contingent valuation studies published between 1974 and 1991. The mean VSL across these studies is $6.3 million (2000$).[93]

We then adjust this VSL to account for the currency year used in this RIA and to account for income growth from 1990 to the analysis year. The adjusted value for VSL is $8.5 million ($2013).). Further details on the methodology are available in section 5.6.8 of the PM RIA (U.S.EPA, 2012a).

The Agency is committed to using scientifically sound, appropriately reviewed evidence in valuing mortality risk reductions and has made significant progress in responding to the SAB-EEAC's specific recommendations. In the process, the Agency has identified a number of important issues to be considered in updating its mortality risk valuation estimates. These are detailed in a white paper on "Valuing Mortality Risk Reductions in Environmental Policy," (U.S. EPA, 2010c) which recently underwent review by the SAB-EEAC. A meeting with the SAB on this paper was held on March 14, 2011 and formal recommendations were transmitted on July 29, 2011 (U.S. EPA-SAB, 2011). EPA is taking SAB's recommendations under advisement.

In valuing premature mortality, we discount the value of premature mortality occurring in future years using rates of 3% and 7% (OMB, 2003). We assume that there is a "cessation" lag between changes in PM exposures and the total realization of changes in health effects. The distributed lag accounts for the expected distribution of avoided deaths according to the cause of death. The lag assumes that the initial proportion of deaths is due to cardiovascular outcomes, while the latter proportion is due to lung cancer. Although the structure of the lag is uncertain, the EPA follows the advice of the SAB-HES to assume a segmented lag structure characterized by 30% of mortality reductions in the first year, 50% over years 2 to 5, and 20% over the years 6 to 20 after the reduction in $PM_{2.5}$ (U.S. EPA-SAB, 2004c). Changes in the cessation lag assumptions do not change the total number of estimated deaths but rather the timing of those deaths.

7.2.3 Benefit-per-ton Estimates

Due to analytical limitations, it was not possible to conduct air quality modeling for this rule. Instead, we used a "benefit-per-ton" approach to estimate the benefits of this rulemaking. EPA has applied this approach in several previous RIAs (e.g., U.S. EPA, 2011b, 2011d, 2012b). These benefit-per-ton estimates provide the total monetized human health benefits (the sum of

[93] In 1990$, this VSL is $4.8 million.

premature mortality and premature morbidity) of reducing one ton of $PM_{2.5}$ (or $PM_{2.5}$ precursor such as NO_x or sulfur dioxide (SO_2)) from a specified source. Specifically, in this analysis, we multiplied the estimates from the "Residential Wood Heaters" sector[94,95] by the corresponding emission reductions. The method used to derive these estimates is described in the Technical Support Document (TSD) on estimating the benefits-per-ton of reducing $PM_{2.5}$ and its precursors from 17 sectors (U.S. EPA, 2013). One limitation of using the benefit-per-ton approach is an inability to provide estimates of the health benefits associated with exposure to HAP, CO, NO_2 or ozone.

The benefit-per-ton estimates described in the TSD (U.S. EPA, 2013) were derived using the approach published in Fann et al. (2012), but they have since been updated to reflect the studies and population data in the final PM NAAQS RIA (U.S. EPA, 2012a). The approach in Fann et al. (2012) is similar to the work previously published by Fann et al. (2009), but the newer study includes improvements that EPA believes would provide more reliable estimates of $PM_{2.5}$-related health benefits for emissions reductions in specific sectors. Specifically, the air quality modeling data reflect sectors that are more narrowly defined. In addition, the updated air quality modeling data reflect more recent emissions data (2005 rather than 2001) and has higher spatial resolution (12 km rather than 36 km grid cells).

The benefit per ton of reducing directly emitted $PM_{2.5}$ from the residential wood sector is close to the median of the distribution of all 17 BPT values (TSD Table 7). For example, the residential wood sector BPT for directly emitted $PM_{2.5}$ is smaller than the value for the Coke ovens and Iron and Steel sectors, but greater than the value for the Taconite and Electricity Generating Unit sectors. The size of the benefit per-ton estimate is influenced in part by factors including: proximity of sources to population receptors; the baseline health status of the population receptors; and, dispersion characteristics of the emitting source.

As noted below in the characterization of uncertainty, all benefit-per-ton estimates have inherent limitations. Specifically, all national-average benefit-per-ton estimates reflect the geographic distribution of the modeled emissions, which may not exactly match the emission reductions in this rulemaking, and they may not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors for any specific location. The photochemical modeled residential wood combustion-attributable $PM_{2.5}$

[94] As explained in the TSD (U.S. EPA, 2013), we only have benefit-per-ton estimates for certain analysis years (i.e., 2005, 2016, 2020, 2025, and 2030). For this RIA, we selected the benefit-per-ton estimate closest to the analysis years for this RIA.

[95] Data from year 2020 was used as the year closest to the full implementation year for the final NSPS, which is 2020.

concentrations used to derive the BPT values may not match well the change in air quality resulting from the emissions controls described in Section 4. For this reason, the health benefits reported here may be larger, or smaller, than those realized by this rule.

Even though we assume that all fine particles have equivalent health effects, the benefit-per-ton estimates vary between precursors depending on the location and magnitude of their impact on $PM_{2.5}$ levels, which drive population exposure. The sector-specific modeling does not provide estimates of the $PM_{2.5}$-related benefits associated with reducing VOC emissions, but these unquantified benefits are generally small compared to other $PM_{2.5}$ precursors (U.S. EPA, 2012a).

7.2.4 $PM_{2.5}$ Benefits Results

Table 7-2 summarizes the monetized PM-related health benefits by precursor pollutant, including the emission reductions and benefit-per-ton estimates using discount rates of 3% and 7%. Benefits estimates are based on the average of annual emission reductions from proposed rule implementation between 2015 and 2020 (inclusive). Table 7-3 provides a summary of the reductions in health incidences associated with these pollution reductions. Figure 7-1 provides a visual representation of the range of $PM_{2.5}$-related benefits estimates using concentration-response functions from Krewski et al. (2009) and Lepeule et al. (2012) as well as

Table 7-2. Summary of Annual Monetized $PM_{2.5}$-Related Health Benefits Estimates for the Residential Wood Heaters NSPS in the 2015–2020 Time Frame (2013$)[a]

Pollutant	Average Annual Emissions Reductions (tons)	Benefit per ton (Krewski, 3%)	Benefit per ton (Lepeule, 3%)	Benefit per ton (Krewski, 7%)	Benefit per ton (Lepeule, 7%)	Total Monetized Annual Benefits (millions 2013$ at 3%)			Total Monetized Annual Benefits (millions 2013$ at 7%)		
Proposed											
Direct $PM_{2.5}$	8,269	$410,000	$920,000	$370,000	$830,000	$3,400	to	$7,600	$3,100	to	$6,900
$PM_{2.5}$ Precursors											
VOC[b]	9,265	NA	NA	NA	NA	NA	to	NA	NA	to	NA
					Total	**$3,400**	**to**	**$7,600**	**$3,100**	**to**	**$6,900**

[a] All monetized benefits are annual estimates that reflect the average of annual emission reductions expected to occur between 2015 and 2020 (inclusive) resulting from rule implementation. All estimates are rounded to two significant figures so numbers may not sum across columns. It is important to note that the monetized benefits do not include reduced health effects from direct exposure to NO_2, ozone exposure, ecosystem effects, or visibility impairment. All fine particles are assumed to have equivalent health effects, but the benefit per ton estimates vary depending on the location and magnitude of their impact on $PM_{2.5}$ levels, which drive population exposure. The monetized benefits incorporate the conversion from precursor emissions to ambient fine particles. Confidence intervals are unavailable for this analysis because of the benefit-per-ton methodology.

[b] Estimates of VOCs health benefits are currently not monetized and will be addressed only qualitatively.

7-10

Table 7-3. Summary of Reductions in Health Incidences from $PM_{2.5}$-Related Benefits for the Residential Wood Heaters NSPS in the 2015-2020 Time Frame[a]

Health Incidences	RWH NSPS
Avoided Premature Mortality	
Krewski et al. (2009) (adult)	360
Lepeule et al. (2012) (adult)	810
Avoided Morbidity	
Emergency department visits for asthma (all ages)	180
Acute bronchitis (age 8–12)	550
Lower respiratory symptoms (age 7–14)	7,000
Upper respiratory symptoms (asthmatics age 9–11)	10,000
Minor restricted-activity days (age 18–65)	280,000
Lost work days (age 18–65)	48,000
Asthma exacerbation (age 6–18)	25,000
Hospital admissions—respiratory (all ages)	92
Hospital admissions—cardiovascular (age > 18)	110
Non-Fatal Heart Attacks (age >18)	
Peters et al. (2001)	390
Pooled estimate of 4 studies	42

[a] All estimates are rounded to whole numbers with two significant figures. Confidence intervals are unavailable for this analysis because of the benefit-per-ton methodology.

the 12 functions supplied by experts. Figure 7-2 provides a breakdown of monetized benefits by pollutant. In Table 7-4, we provide the benefits using our anchor points of Krewski et al., and Lepeule et al., as well as the results from the 12 experts' elicitation on PM mortality.

7.2.5 Characterization of Uncertainty in the Monetized $PM_{2.5}$ Benefits

In any complex analysis using estimated parameters and inputs from numerous models, there are likely to be many sources of uncertainty. This analysis is no exception. This analysis includes many data sources as inputs, including emission inventories, air quality data from models (with their associated parameters and inputs), population data, population estimates, health effect estimates from epidemiology studies, economic data for monetizing benefits, and assumptions regarding the future state of the world (i.e., regulations, technology, and human behavior). Each of these inputs may be uncertain and would affect the benefits estimate. When the uncertainties from each stage of the analysis are compounded, even small uncertainties can have large effects on the total quantified benefits. Therefore, the estimates of annual benefits

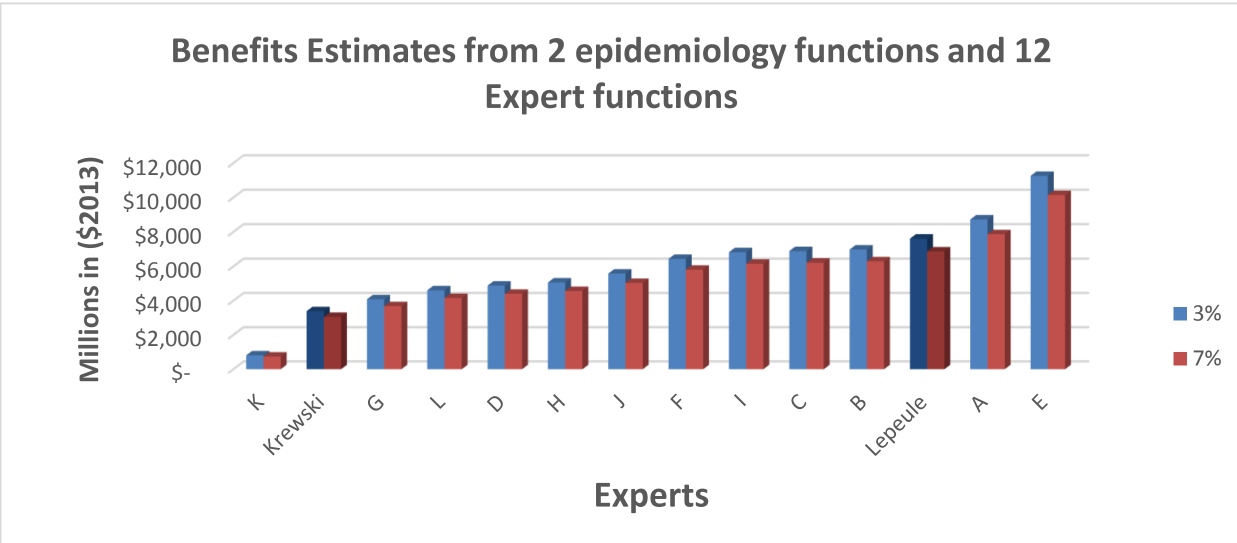


Figure 7-1. Total Monetized $PM_{2.5}$ Benefits of the Residential Wood Heaters NSPS in the 2015–2020 Time Frame[a]

[a] This graph shows the estimated benefits at discount rates of 3% and 7% using effect coefficients derived from the Krewski et al. study and the Lepeule et al. study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response functions provided in those studies.

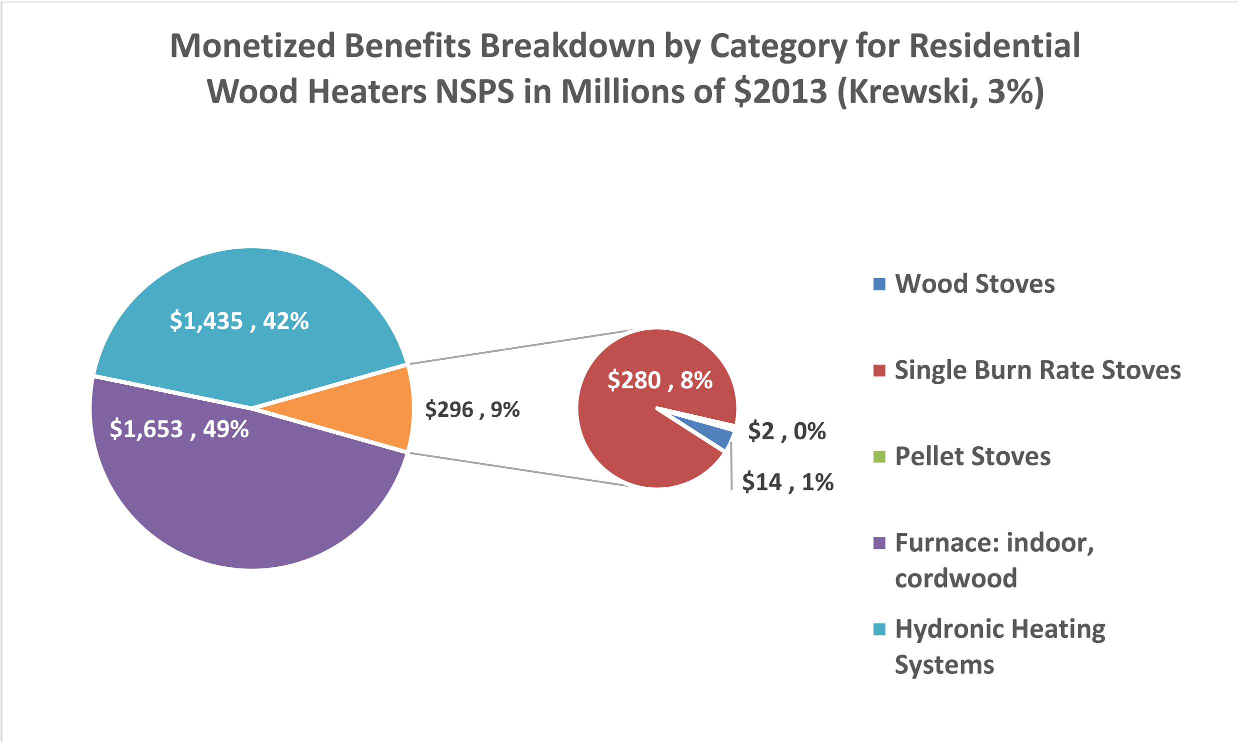


Figure 7-2. Breakdown of Total Monetized $PM_{2.5}$ Benefits of the Residential Wood Heaters NSPS by Category

Table 7-4. All $PM_{2.5}$ Annual Benefits Estimates for the Residential Wood Heaters NSPS at Discount Rates of 3% and 7% for the 2015 to 2020 Time Frame ($2013 millions)[a]

	RWH NSPS	
	3%	7%
Benefit-per-ton Coefficients Derived from Epidemiology Literature		
Krewski et al.	$3,400	$3,100
Lepeule et al.	$7,600	$6,900
Benefit-per-ton Coefficients Derived from Expert Elicitation		
Expert A	$8,700	$7,900
Expert B	$7,000	$6,300
Expert C	$6,900	$6,200
Expert D	$4,900	$4,400
Expert E	$11,000	$10,000
Expert F	$6,400	$5,800
Expert G	$4,100	$3,700
Expert H	$5,000	$4,600
Expert I	$7,200	$6,200
Expert J	$5,600	$5,000
Expert K	$810	$740
Expert L	$4,600	$4,200

[a] All estimates are rounded to two significant figures. All estimates are annual estimates that reflect the average annual estimates of $PM_{2.5}$ emission reductions over the 2015 to 2020 timeframe. Estimates do not include confidence intervals because they were derived through the benefit-per-ton technique described above. The benefits estimates from the expert elicitation are provided as a reasonable characterization of the uncertainty in the mortality estimates associated with the concentration-response function. Confidence intervals are unavailable for this analysis because of the benefit-per-ton methodology.

should be viewed as representative of the magnitude of annual benefits expected, rather than the actual benefits that would occur every year.

This RIA does not include the type of detailed uncertainty assessment found in the PM NAAQS RIA (U.S. EPA, 2012a) because we lack the necessary air quality input and monitoring data to run the benefits model. However, the results of the uncertainty analyses presented in the PM NAAQS RIA can provide some information regarding the uncertainty inherent in the benefits results presented in this analysis. Sensitivity analyses conducted for the PM NAAQS RIA indicate that alternate cessation lag assumptions could change the $PM_{2.5}$-related mortality benefits discounted at 3% by between 10% and –27% and that alternate income growth adjustments could change the $PM_{2.5}$-related mortality benefits by between 33% and −14%.[96]

Unlike the PM NAAQS RIA, we do not have data on the specific location of the air quality changes associated with this rulemaking. As such, it is not feasible to estimate the proportion of benefits occurring in different locations, such as designated nonattainment areas. Instead, we applied benefit-per-ton estimates, which reflect specific geographic patterns of emissions reductions and specific air quality and benefits modeling assumptions for each sector (US EPA, 2013). For example, these estimates do not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors that might lead to an over-estimate or under-estimate of the actual benefits of controlling PM precursors. Use of these $/ton values to estimate benefits may lead to higher or lower benefit estimates than if benefits were calculated based on direct air quality modeling. Great care should be taken in applying these estimates to emission reductions occurring in any specific location, as these reflect national or regional emission changes and therefore represent average benefits-per-ton over the entire United States (EPA, 2013). The benefits-per-ton for emission reductions in specific locations may be very different from the estimates presented here, and the approach above did not yield benefit per-ton estimates at a sub-national level. To the extent that the geographic distributions of the emissions reductions for this rule are different from the modeled emissions, the benefits may be underestimated or overestimated. In general, there is inherently more uncertainty for new sources, which may not be included in the emissions inventory, than existing sources. For more information, see the TSD describing the calculation of these benefit-per-ton estimates (U.S. EPA, 2013).

Our estimate of the total benefits is based on EPA's interpretation of the best available scientific literature and methods and supported by the SAB-HES and the NAS (NRC, 2002). Below are key assumptions underlying the estimates for premature mortality, which accounts for 98% of the total monetized $PM_{2.5}$ benefits:

1. We assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because $PM_{2.5}$ varies considerably in composition across sources, but the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. The PM ISA concluded that "many constituents of $PM_{2.5}$ can be linked with multiple health effects, and the evidence is not yet sufficient to allow differentiation

[96] http://www.epa.gov/ttn/ecas/regdata/RIAs/finalria.pdf (pp 6-16).

of those constituents or sources that are more closely related to specific outcomes" (U.S. EPA, 2009).

2. We assume that the health impact function for fine particles is log-linear without a threshold in this analysis. Thus, the estimates include health benefits from reducing fine particles in areas with varied concentrations of $PM_{2.5}$, including both areas that do not meet the fine particle standard and those areas that are in attainment, down to the lowest modeled concentrations.

3. We assume that there is a "cessation" lag between the change in PM exposures and the total realization of changes in mortality effects. Specifically, we assume that some of the incidences of premature mortality related to $PM_{2.5}$ exposures occur in a distributed fashion over the 20 years following exposure based on the advice of the SAB-HES (U.S. EPA-SAB, 2004c), which affects the valuation of mortality benefits at different discount rates.

In general, we are more confident in the magnitude of the risks we estimate from simulated $PM_{2.5}$ concentrations that coincide with the bulk of the observed PM concentrations in the epidemiological studies that are used to estimate the benefits. Likewise, we are less confident in the risk we estimate from simulated $PM_{2.5}$ concentrations that fall below the bulk of the observed data in these studies. Concentration benchmark analyses (e.g., lowest measured level [LML] or one standard deviation below the mean of the air quality data in the study) allow readers to determine the portion of population exposed to annual mean $PM_{2.5}$ levels at or above different concentrations, which provides some insight into the level of uncertainty in the estimated $PM_{2.5}$ mortality benefits. There are uncertainties inherent in identifying any particular point at which our confidence in reported associations becomes appreciably less, and the scientific evidence provides no clear dividing line. However, the EPA does not view these concentration benchmarks as a concentration threshold below which we would not quantify health benefits of air quality improvements.[97] Rather, the benefits estimates reported in this RIA are the best estimates because they reflect the full range of air quality concentrations associated with the emission reduction strategies and because the current body of scientific literature indicates that a no-threshold model provides the best estimate of PM-related long-term mortality. In other words, although we may have less confidence in the magnitude of the risk at concentrations below these benchmarks, we still have high confidence that $PM_{2.5}$ is causally associated with risk at those lower air quality concentrations.

[97] For a summary of the scientific review statements regarding the lack of a threshold in the $PM_{2.5}$-mortality relationship, see the Technical Support Document (TSD) entitled *Summary of Expert Opinions on the Existence of a Threshold in the Concentration-Response Function for $PM_{2.5}$-related Mortality* (U.S. EPA, 2010b).

For this analysis, policy-specific air quality data is not available due to time or resource limitations. For this rule, we are unable to estimate the percentage of premature mortality associated with this specific rule's emission reductions at each $PM_{2.5}$ level. However, we believe that it is still important to characterize the distribution of exposure to baseline air quality levels. As a surrogate measure of mortality impacts, we provide the percentage of the population exposed at each $PM_{2.5}$ level in the baseline of the source apportionment modeling used to calculate the benefit-per-ton estimates for this sector. It is important to note that baseline exposure is only one parameter in the health impact function, along with baseline incidence rates population, and change in air quality. In other words, the percentage of the population exposed to air pollution below the LML is not the same as the percentage of the population experiencing health impacts as a result of a specific emission reduction policy. The most important aspect, which we are unable to quantify for rules without rule-specific air quality modeling, is the shift in exposure associated with this specific rule. Therefore, caution is warranted when interpreting the LML assessment for this rule because these results are not consistent with results from rules that had air quality modeling.

Table 7-5 provides the percentage of the population exposed above and below two concentration benchmarks (i.e., LML and 1 standard deviation below the mean) in the modeled baseline. Figure 7-3 shows a bar chart of the percentage of the population exposed to various air quality levels in the baseline, and Figure 7-4 shows a cumulative distribution function of the same data. Both figures identify the LML for each of the major cohort studies.

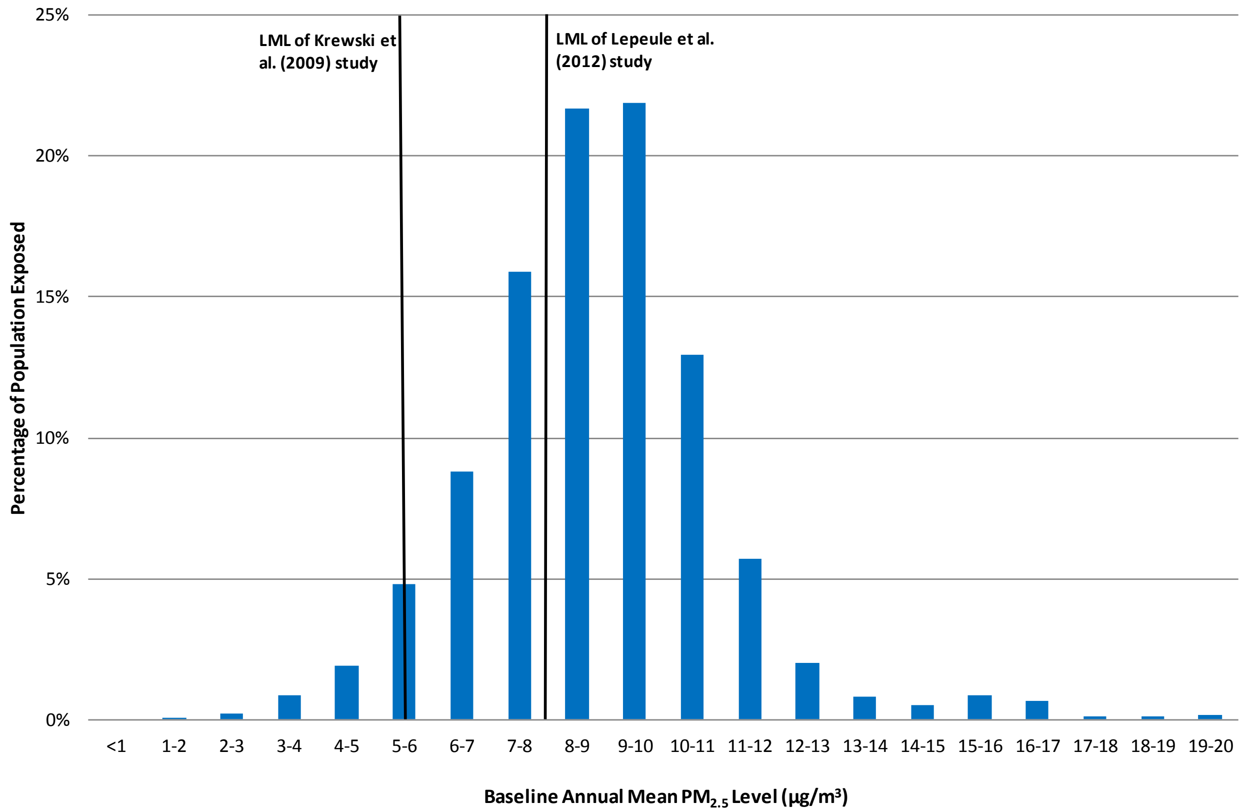
7.3 Unquantified Benefits

The monetized benefits estimated in this RIA only reflect a subset of benefits attributable to the health effect reductions associated with ambient fine particles. Data, time, and resource limitations prevented EPA from quantifying the impacts to, or monetizing the benefits from several important benefit categories, including benefits associated with the potential exposure to ozone formation due to VOC emissions as a precursor, VOC emissions as a $PM_{2.5}$ precursor,

Table 7-5. Population Exposure in the Baseline Above and Below Various Concentration Benchmarks in the Underlying Epidemiology Studies[a]

Epidemiology Study	Below 1 Std. Dev. Below AQ Mean	At or Above 1 Std. Dev. Below AQ Mean	Below LML	At or Above LML
Krewski et al. (2009)	89%	11%	7%	93%
Lepeule et al. (2012)	N/A	N/A	23%	67%

[a] One standard deviation below the mean is equivalent to the middle of the range between the 10th and 25th percentile. For Krewski, the LML is 5.8 µg/m³ and one standard deviation below the mean is 11.0 µg/m³. For Lepeule et al., the LML is 8 µg/m³ and we do not have the data for one standard deviation below the mean. It is important to emphasize that although we have lower levels of confidence in levels below the LML for each study, the scientific evidence does not support the existence of a level below which health effects from exposure to $PM_{2.5}$ do not occur.



Among the populations exposed to $PM_{2.5}$ in the baseline:

93% are exposed to $PM_{2.5}$ levels at or above the LML of the Krewski et al. (2009) study

67% are exposed to $PM_{2.5}$ levels at or above the LML of the Lepeule et al. (2012) study

Figure 7-3. Percentage of Adult Population by Annual Mean $PM_{2.5}$ Exposure in the Baseline

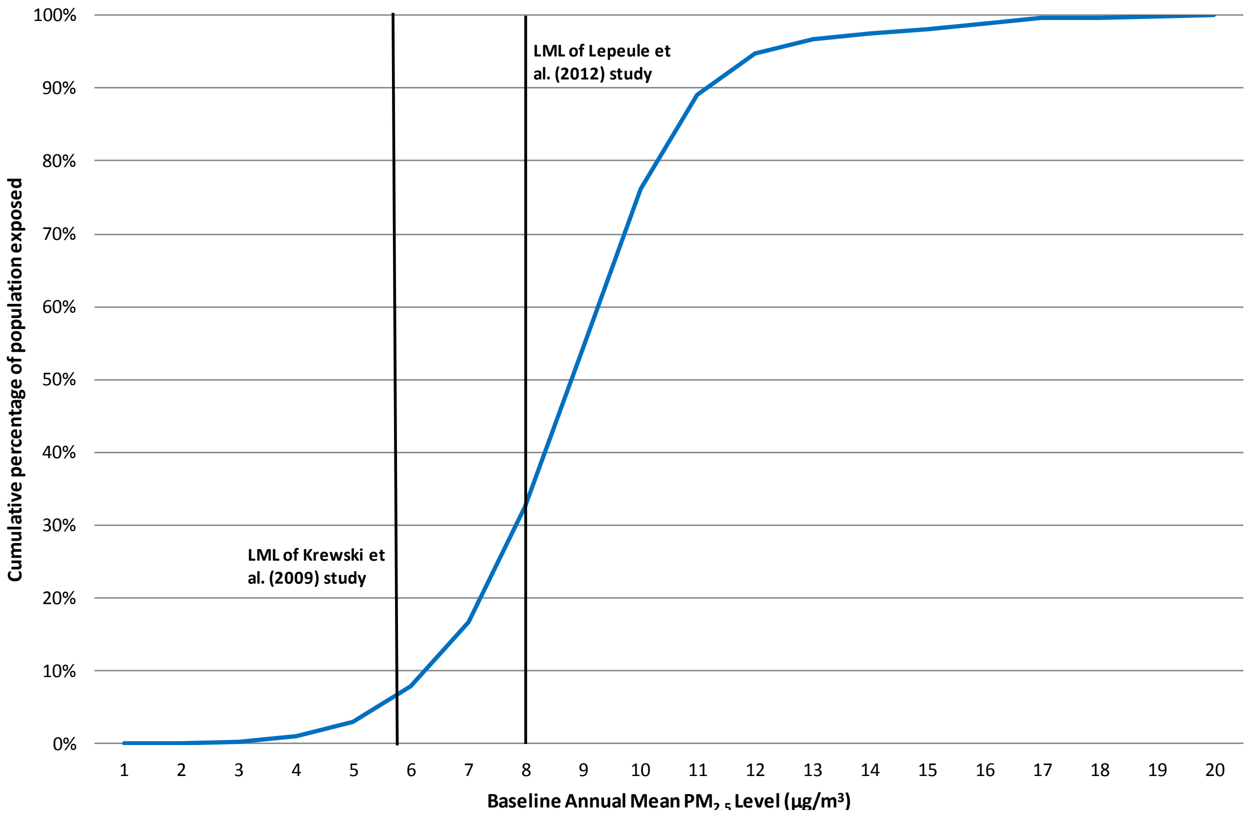
HAP, CO exposure, as well as ecosystem effects, and visibility impairment due to the absence of air quality modeling data for these pollutants in this analysis. This does not imply that there are no benefits associated with these emission reductions. In this section, we provide a qualitative description of these benefits.

7.3.1 HAP Benefits

When looking at exposures from all air toxic sources of outdoor origin across the U.S., we see that emissions have declined by approximately 42% since 1990. However, despite this declines, the 2005 National-Scale Air Toxics Assessment (NATA), which includes emissions from residential wood heater, predicts that many Americans are exposed to ambient concentrations of air toxics at levels that may have the potential to cause adverse health effects (U.S. EPA, 2011c).[98] The levels of air toxics to which people are exposed vary depending on where people live and work and the kinds of activities in which they engage. In order to identify and prioritize air toxics, emission source types and locations that are of greatest potential concern, U.S. EPA conducts the National Air Toxic Analysis (NATA).[99] The most recent NATA was conducted for calendar year 2005 and was released in March 2011. NATA includes four steps:

[98] The 2005 NATA is available on the Internet at http://www.epa.gov/ttn/atw/nata2005/.

[99] The NATA modeling framework has a number of limitations that prevent its use as the sole basis for setting regulatory standards. These limitations and uncertainties are discussed on the 2005 NATA website. Even so, this modeling framework is very useful in identifying air toxic pollutants and sources of greatest concern, setting regulatory priorities, and informing the decision making process. U.S. EPA.(2011). 2005 National-Scale Air Toxics Assessment. http://www.epa.gov/ttn/atw/nata2005/



Among the populations exposed to $PM_{2.5}$ in the baseline:

93% are exposed to $PM_{2.5}$ levels at or above the LML of the Krewski et al. (2009) study

67% are exposed to $PM_{2.5}$ levels at or above the LML of the Lepeule et al. (2012) study

Figure 7-4. Cumulative Distribution of Adult Population by Annual Mean $PM_{2.5}$ Exposure in the Baseline

1. Compiling a national emissions inventory of air toxics emissions from outdoor sources
2. Estimating ambient concentrations of air toxics across the United States
3. Estimating population exposures across the United States utilizing exposure models
4. Characterizing potential public health risk due to inhalation of air toxics including both cancer and noncancer effects

Based on the 2005 NATA, EPA estimates that about 5% of census tracts nationwide have increased cancer risks greater than 100 in a million. The average national cancer risk is about 50 in a million. Nationwide, the key pollutants that contribute most to the overall cancer risks are formaldehyde and benzene.[100] Secondary formation (e.g., formaldehyde forming from other emitted pollutants) was the largest contributor to cancer risks, while stationary, mobile and background sources contribute almost equal portions of the remaining cancer risk.

Noncancer health effects can result from chronic,[101] subchronic,[102] or acute[103] inhalation exposures to air toxics, and include neurological, cardiovascular, liver, kidney, and respiratory effects as well as effects on the immune and reproductive systems. According to the 2005 NATA, about three-fourths of the U.S. population was exposed to an average chronic concentration of air toxics that has the potential for adverse noncancer respiratory health effects. Results from the 2005 NATA indicate that acrolein is the primary driver for noncancer respiratory risk.

Figures 7-5 and 7-6 depict the 2005 NATA estimated census tract-level carcinogenic risk and noncancer respiratory hazard from the assessment. It is important to note that large reductions in HAP emissions may not necessarily translate into significant reductions in health risk because toxicity varies by pollutant, and exposures may or may not exceed levels of concern. For example, acetaldehyde mass emissions are more than double acrolein emissions on a national basis, according to EPA's 2005 National Emissions Inventory (NEI). However, the Integrated Risk Information System (IRIS) reference concentration (RfC) for acrolein is considerably lower

[100] Details about the overall confidence of certainty ranking of the individual pieces of NATA assessments including both quantitative (e.g., model-to-monitor ratios) and qualitative (e.g., quality of data, review of emission inventories) judgments can be found at http://www.epa.gov/ttn/atw/nata/roy/page16.html.

[101] Chronic exposure is defined in the glossary of the Integrated Risk Information (IRIS) database (http://www.epa.gov/iris) as repeated exposure by the oral, dermal, or inhalation route for more than approximately 10% of the life span in humans (more than approximately 90 days to 2 years in typically used laboratory animal species).

[102] Defined in the IRIS database as repeated exposure by the oral, dermal, or inhalation route for more than 30 days, up to approximately 10% of the life span in humans (more than 30 days up to approximately 90 days in typically used laboratory animal species).

[103] Defined in the IRIS database as exposure by the oral, dermal, or inhalation route for 24 hours or less.

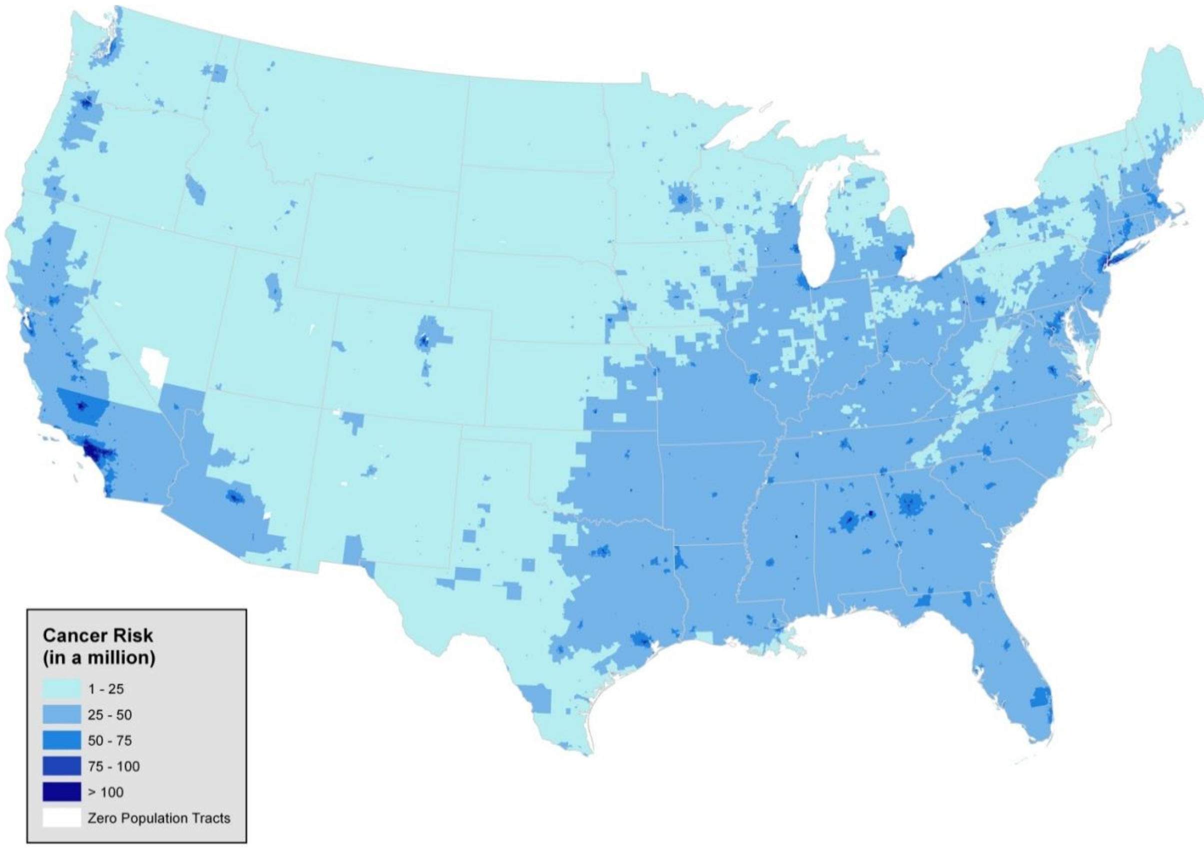


Figure 7-5. 2005 NATA Model Estimated Census Tract Carcinogenic Risk from HAP Exposure from Emissions of All Outdoor Sources (inclusive of Residental Wood Heaters) based on the 2005 National Toxic Inventory

than that for acetaldehyde, suggesting that acrolein could be potentially more toxic than acetaldehyde. Thus, it is important to account for the toxicity and exposure, as well as the mass of the targeted emissions.

Due to methodology limitations, we were unable to estimate the benefits associated with the hazardous air pollutants that would be reduced as a result of this rule. In a few previous analyses of the benefits of reductions in HAP, EPA has quantified the benefits of potential reductions in the incidences of cancer and non-cancer risk (e.g., U.S. EPA, 1995). In those analyses, EPA relied on unit risk factors (URF) and reference concentrations (RfC) developed through risk assessment procedures. The URF is a quantitative estimate of the carcinogenic potency of a pollutant, often expressed as the probability of contracting cancer from a 70-year lifetime continuous exposure to a concentration of one µg/m3 of a pollutant .[104]These URFs are designed to be conservative, and as such, are more likely to

[104] The unit risk factor is a quantitative estimate of the carcinogenic potency of a pollutant, often expressed as the probability of contracting cancer from a 70-year lifetime continuous exposure to a concentration of one µg/m^3 of a pollutant.

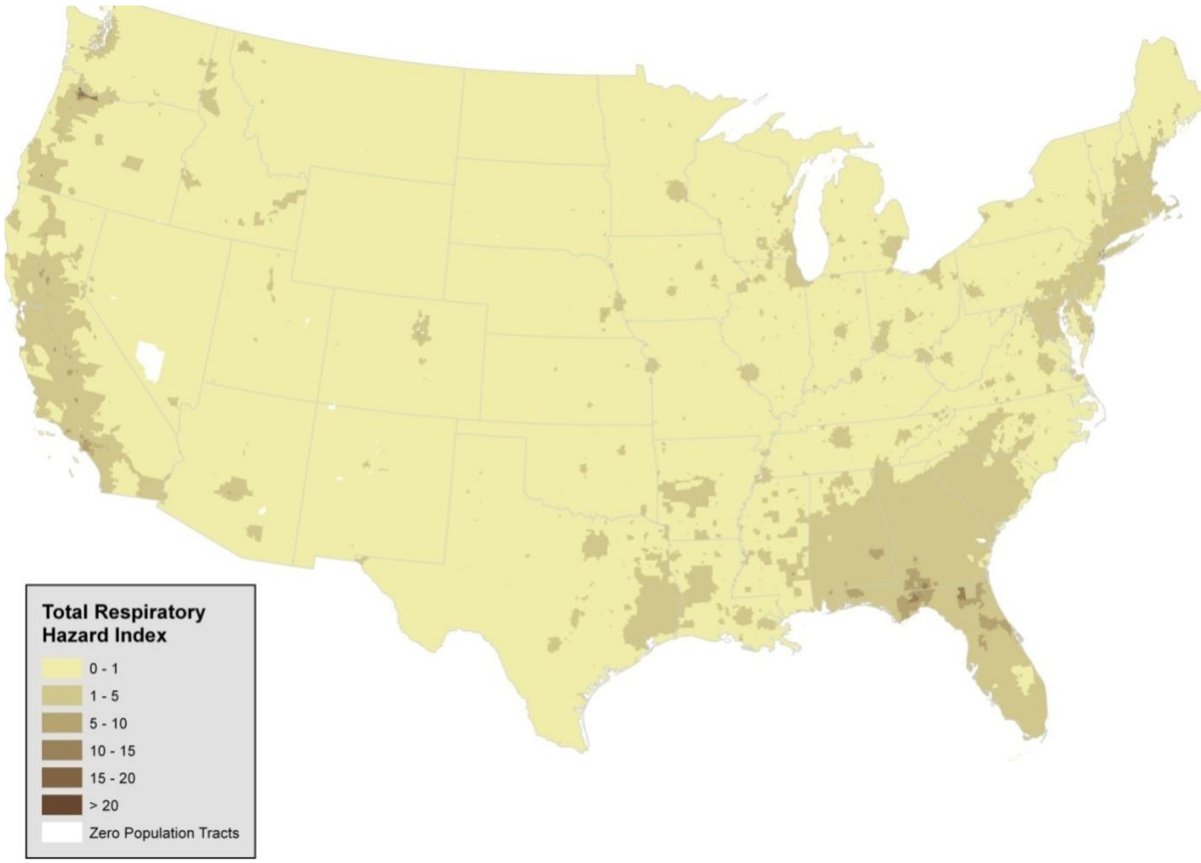


Figure 7-6. 2005 NATA Model Estimated Census Tract Noncancer Risk from HAP Exposure from Emissions of All Outdoor Sources (inclusive of Residental Wood Heaters) based on the 2005 National Toxic Inventory

represent the high end of the distribution of risk rather than a best or most likely estimate of risk. An RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious noncancer health effects during a lifetime. As the purpose of a benefit analysis is to describe the benefits most likely to occur from a reduction in pollution, use of high-end, conservative risk estimates would overestimate the benefits of the regulation. While we used high-end risk estimates in past analyses, advice from the EPA's Science Advisory Board (SAB) recommended that we avoid using high-end estimates in benefit analyses (U.S. EPA-SAB, 2002). Since this time, EPA has continued to develop better methods for analyzing the benefits of reductions in HAP.

As part of the second prospective analysis of the benefits and costs of the Clean Air Act (U.S. EPA, 2011a), EPA conducted a case study analysis of the health effects associated with reducing exposure to benzene in Houston from implementation of the Clean Air Act (IEc, 2009). While reviewing the draft report, EPA's Advisory Council on Clean Air Compliance Analysis concluded that "the challenges for assessing progress in health improvement as a result of reductions in emissions of hazardous air pollutants (HAPs) are daunting…due to a lack of exposure-response functions, uncertainties in emissions inventories and background levels, the difficulty of extrapolating risk estimates to low doses and the challenges of tracking health progress for diseases, such as cancer, that have long latency periods" (U.S. EPA-SAB, 2008).

In 2009, EPA convened a workshop to address the inherent complexities, limitations, and uncertainties in current methods to quantify the benefits of reducing HAP. Recommendations from this workshop included identifying research priorities, focusing on susceptible and vulnerable populations, and improving dose-response relationships (Gwinn et al., 2011).

In summary, monetization of the benefits of reductions in cancer incidences requires several important inputs, including central estimates of cancer risks, estimates of exposure to carcinogenic HAP, and estimates of the value of an avoided case of cancer (fatal and non-fatal). Due to methodology limitations, we did not attempt to monetize the health benefits of reductions in HAP in this analysis. Instead, we provide a qualitative analysis of the health effects associated with the HAP anticipated to be reduced by these rules. EPA remains committed to improving methods for estimating HAP benefits by continuing to explore additional concepts of benefits, including changes in the distribution of risk.

Below we describe the health effects associated with the HAPs that would be reduced by this rulemaking.

7.3.1.1 Benzene

The EPA's IRIS database lists benzene as a known human carcinogen (causing leukemia) by all routes of exposure, and concludes that exposure is associated with additional health effects, including genetic changes in both humans and animals and increased proliferation of bone marrow cells in mice.[105,106,107] EPA states in its IRIS database that data indicate a causal relationship between benzene exposure and acute lymphocytic leukemia and suggest a relationship between benzene exposure and chronic non-lymphocytic leukemia and chronic lymphocytic leukemia. The IARC has determined that benzene is a human carcinogen and the U.S. Department of Health and Human Services has characterized benzene as a known human carcinogen.[108,109]

A number of adverse noncancer health effects including blood disorders, such as preleukemia and aplastic anemia, have also been associated with long-term exposure to benzene.[110,111]

7.3.1.2 Dioxins (Chlorinated dibenzodioxins (CDDs)[112]

Exposure to 2,3,7,8- tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) at high enough levels may cause a number of adverse health effects. The most obvious noncancer health effect in people exposed to relatively large amounts of 2,3,7,8-TCDD is Chloracne. Chloracne is a severe skin disease with acne-like lesions that occur mainly on the face and upper body. Other skin effects noted in people exposed to high doses of 2,3,7,8-TCDD include skin rashes, discoloration, and excessive body hair. Exposure to large amounts of dioxin may also induce other noncancer effects including developmental and reproductive effects, damage to the immune system, interference with hormones and possibly mild liver damage.

[105] U.S. Environmental Protection Agency (U.S. EPA). 2000. Integrated Risk Information System File for Benzene. Research and Development, National Center for Environmental Assessment, Washington, DC. This material is available electronically at: http://www.epa.gov/iris/subst/0276.htm.

[106] International Agency for Research on Cancer, IARC monographs on the evaluation of carcinogenic risk of chemicals to humans, Volume 29, Some industrial chemicals and dyestuffs, International Agency for Research on Cancer, World Health Organization, Lyon, France, p. 345-389, 1982.

[107] Irons, R.D.; Stillman, W.S.; Colagiovanni, D.B.; Henry, V.A. (1992) Synergistic action of the benzene metabolite hydroquinone on myelopoietic stimulating activity of granulocyte/macrophage colony-stimulating factor in vitro, Proc. Natl. Acad. Sci. 89:3691-3695.

[108] International Agency for Research on Cancer (IARC). 1987. Monographs on the evaluation of carcinogenic risk of chemicals to humans, Volume 29, Supplement 7, Some industrial chemicals and dyestuffs, World Health Organization, Lyon, France.

[109] U.S. Department of Health and Human Services National Toxicology Program 11th Report on Carcinogens available at: http://ntp.niehs.nih.gov/go/16183 .

[110] Aksoy, M. (1989). Hematotoxicity and carcinogenicity of benzene. Environ. Health Perspect. 82: 193-197.

[111] Goldstein, B.D. (1988). Benzene toxicity. Occupational medicine. State of the Art Reviews. 3: 541-554.

[112] The health effects language for this section came from: EPA's Dioxin Assessment Consumer Fact Sheet, available at http://www.epa.gov/dioxin/pdfs/EPA-Dioxin-Factsheet-2012.pdf, and Agency for Toxic Substances and Disease Registry (ATSDR). 1999. ToxFAQs for Chlorinated Dibenzo-p-dioxins (CDDs) (CAS#: 2,3,7,8-TCDD 1746-01-6). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available at http://www.atsdr.cdc.gov/tfacts104.html.

The EPA has classified 2,3,7,8 TCDD as carcinogenic to humans in accordance with EPA's 2005 Guidelines for Carcinogenic Risk Assessment.[113] IARC and NTP have classified 2,3,7,8 TCDD as Group 1 (carcinogenic to humans)[114] and known human carcinogen[115], respectively.

7.3.1.3 Formaldehyde

Since 1987, EPA has classified formaldehyde as a probable human carcinogen based on evidence in humans and in rats, mice, hamsters, and monkeys.[116] Substantial additional research since that time informs current scientific understanding of the health effects associated with exposure to formaldehyde. These include recently published research conducted by the National Cancer Institute (NCI) which found an increased risk of nasopharyngeal cancer and lymphohematopoietic malignancies such as leukemia among workers exposed to formaldehyde.[117,118] In an analysis of the lymphohematopoietic cancer mortality from an extended follow-up of these workers, NCI confirmed an association between lymphohematopoietic cancer risk and peak formaldehyde exposures.[119] A recent NIOSH study of garment workers also found increased risk of death due to leukemia among workers exposed to formaldehyde.[120] Extended follow-up of a cohort of British chemical workers did not find evidence of an increase in nasopharyngeal or lymphohematopoietic cancers, but a continuing statistically significant excess in lung cancers was reported.[121]

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113 U.S. EPA. 2012. EPA's Reanalysis of Key Issues Related to Dioxin Toxicity and Response to NAS Comments Volume 1. EPA/600/R-10?038F. Available at: http://www.epa.gov/iris/supdocs/dioxinv1sup.pdf.

114 International Agency for Research on Cancer (IARC). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, 2012. Available at: http://monographs.iarc.fr/ENG/Classification/index.php.

115 U.S. Department of Health and Human Services. National Toxicology Program.13th Report on the Carcinogens (RoC). Available at: http://ntp.niehs.nih.gov/ntp/roc/content/listed_substances_508.pdf.

116 U.S. EPA. 1987. Assessment of Health Risks to Garment Workers and Certain Home Residents from Exposure to Formaldehyde, Office of Pesticides and Toxic Substances, April 1987. Docket EPA-HQ-OAR-2010-0162.

117 Hauptmann, M.; Lubin, J. H.; Stewart, P. A.; Hayes, R. B.; Blair, A. 2003. Mortality from lymphohematopoetic malignancies among workers in formaldehyde industries. Journal of the National Cancer Institute 95: 1615-1623. Docket EPA-HQ-OAR-2010-0162.

118 Hauptmann, M.; Lubin, J. H.; Stewart, P. A.; Hayes, R. B.; Blair, A. 2004. Mortality from solid cancers among workers in formaldehyde industries. American Journal of Epidemiology 159: 1117-1130. Docket EPA-HQ-OAR-2010-0162.

119 Beane Freeman, L. E.; Blair, A.; Lubin, J. H.; Stewart, P. A.; Hayes, R. B.; Hoover, R. N.; Hauptmann, M. 2009. Mortality from lymphohematopoietic malignancies among workers in formaldehyde industries: The National Cancer Institute cohort. J. National Cancer Inst. 101: 751-761. Docket EPA-HQ-OAR-2010-0162.

120 Pinkerton, L. E. 2004. Mortality among a cohort of garment workers exposed to formaldehyde: an update. Occup. Environ. Med. 61: 193-200. Docket EPA-HQ-OAR-2010-0162.

121 Coggon, D, EC Harris, J Poole, KT Palmer. 2003. Extended follow-up of a cohort of British chemical workers exposed to formaldehyde. J National Cancer Inst. 95:1608-1615. Docket EPA-HQ-OAR-2010-0162.

In the past 15 years there has been substantial research on the inhalation dosimetry for formaldehyde in rodents and primates by the Chemical Industry Institute of Toxicology (CIIT, now renamed the Hamner Institutes for Health Sciences), with a focus on use of rodent data for refinement of the quantitative cancer dose-response assessment.[122,123,124] CIIT's risk assessment of formaldehyde incorporated mechanistic and dosimetric information on formaldehyde. These data were modeled using a biologically-motivated two-stage clonal growth model for cancer and also a point of departure based on a Benchmark Dose approach. However, it should be noted that recent research published by EPA indicates that when two-stage modeling assumptions are varied, resulting dose-response estimates can vary by several orders of magnitude.[125,126,127,128] These findings are not supportive of interpreting the CIIT model results as providing a conservative (health protective) estimate of human risk.[129] EPA research also examined the contribution of the two-stage modeling for formaldehyde towards characterizing the relative weights of key events in the mode-of-action of a carcinogen. For example, the model-based inference in the published CIIT study that formaldehyde's direct mutagenic action is not relevant to the compound's tumorigenicity was found not to hold under variations of modeling assumptions.[130]

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[122] Conolly, RB, JS Kimbell, D Janszen, PM Schlosser, D Kalisak, J Preston, and FJ Miller. 2003. Biologically motivated computational modeling of formaldehyde carcinogenicity in the F344 rat. Tox Sci 75: 432-447. Docket EPA-HQ-OAR-2010-0162.

[123] Conolly, RB, JS Kimbell, D Janszen, PM Schlosser, D Kalisak, J Preston, and FJ Miller. 2004. Human respiratory tract cancer risks of inhaled formaldehyde: Dose-response predictions derived from biologically-motivated computational modeling of a combined rodent and human dataset. Tox Sci 82: 279-296. Docket EPA-HQ-OAR-2010-0162.

[124] Chemical Industry Institute of Toxicology (CIIT).1999. Formaldehyde: Hazard characterization and dose-response assessment for carcinogenicity by the route of inhalation. CIIT, September 28, 1999. Research Triangle Park, NC. Docket EPA-HQ-OAR-2010-0162.

[125] U.S. EPA. Analysis of the Sensitivity and Uncertainty in 2-Stage Clonal Growth Models for Formaldehyde with Relevance to Other Biologically-Based Dose Response (BBDR) Models. U.S. Environmental Protection Agency, Washington, D.C., EPA/600/R-08/103, 2008. Docket EPA-HQ-OAR-2010-0162.

[126] Subramaniam, R; Chen, C; Crump, K; et al. (2008) Uncertainties in biologically-based modeling of formaldehyde-induced cancer risk: identification of key issues. Risk Anal 28(4):907-923. Docket EPA-HQ-OAR-2010-0162.

[127] Subramaniam RP; Crump KS; Van Landingham C; et al. (2007) Uncertainties in the CIIT model for formaldehyde-induced carcinogenicity in the rat: A limited sensitivity analysis–I. Risk Anal, 27: 1237–1254. Docket EPA-HQ-OAR-2010-0162.

[128] Crump, K; Chen, C; Fox, J; et al. (2008) Sensitivity analysis of biologically motivated model for formaldehyde-induced respiratory cancer in humans. Ann Occup Hyg 52:481-495. Docket EPA-HQ-OAR-2010-0162.

[129] Crump, K; Chen, C; Fox, J; et al. (2008) Sensitivity analysis of biologically motivated model for formaldehyde-induced respiratory cancer in humans. Ann Occup Hyg 52:481-495. Docket EPA-HQ-OAR-2010-0162.

[130] Subramaniam RP; Crump KS; Van Landingham C; et al. (2007) Uncertainties in the CIIT model for formaldehyde-induced carcinogenicity in the rat: A limited sensitivity analysis–I. Risk Anal, 27: 1237–1254. Docket EPA-HQ-OAR-2010-0162.

Based on the developments of the last decade, in 2004, the working group of the IARC concluded that formaldehyde is carcinogenic to humans (Group 1), on the basis of sufficient evidence in humans and sufficient evidence in experimental animals—a higher classification than previous IARC evaluations. After reviewing the currently available epidemiological evidence, the IARC (2006) characterized the human evidence for formaldehyde carcinogenicity as "sufficient," based upon the data on nasopharyngeal cancers; the epidemiologic evidence on leukemia was characterized as "strong."[131] The NTP has classified formaldehyde as "known to be human carcinogen." [132]

Formaldehyde exposure also causes a range of noncancer health effects, including irritation of the eyes (burning and watering of the eyes), nose and throat. Effects from repeated exposure in humans include respiratory tract irritation, chronic bronchitis and nasal epithelial lesions such as metaplasia and loss of cilia. Animal studies suggest that formaldehyde may also cause airway inflammation—including eosinophils infiltration into the airways. There are several studies that suggest that formaldehyde may increase the risk of asthma—particularly in the young.[133,134]

The above-mentioned rodent and human studies, as well as mechanistic information and their analyses, were evaluated in EPA's recent Draft Toxicological Review of Formaldehyde—Inhalation Assessment through the Integrated Risk Information System (IRIS) program. This draft IRIS assessment was released in June 2010 for public review and comment and external peer review by the National Research Council (NRC). The NRC released their review report in April 2011 (http://www.nap.edu/catalog.php?record_id=13142). The EPA is currently revising the draft assessment in response to this review.

[131] International Agency for Research on Cancer (2006) Formaldehyde, 2-Butoxyethanol and 1-tert-Butoxypropan-2-ol. Monographs Volume 88. World Health Organization, Lyon, France. Docket EPA-HQ-OAR-2010-0162.
[132] U.S. Department of Health and Human Services. National Toxicology Program.13th Report on the Carcinogens (RoC). Available at: http://ntp.niehs.nih.gov/pubhealth/roc/roc13/index.html#F

[133] Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological profile for Formaldehyde. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. http://www.atsdr.cdc.gov/toxprofiles/tp111.html. Docket EPA-HQ-OAR-2010-0162.
[134] WHO (2002) Concise International Chemical Assessment Document 40: Formaldehyde. Published under the joint sponsorship of the United Nations Environment Programme, the International Labour Organization, and the World Health Organization, and produced within the framework of the Inter-Organization Programme for the Sound Management of Chemicals. Geneva. Docket EPA-HQ-OAR-2010-0162.

7.3.1.4 Polycyclic Organic Matter (POM)

The term polycyclic organic matter (POM) defines a broad class of compounds that includes the polycyclic aromatic hydrocarbon compounds (PAHs). One of these compounds, naphthalene, is discussed separately below. POM compounds are formed primarily from combustion and are present in the atmosphere in gas and particulate form. Cancer is the major concern from exposure to POM. Epidemiologic studies have reported an increase in lung cancer in humans exposed to diesel exhaust, coke oven emissions, roofing tar emissions, and cigarette smoke; all of these mixtures contain POM compounds[135,136.] Animal studies have reported respiratory tract tumors from inhalation exposure to benzo[a]pyrene and alimentary tract and liver tumors from oral exposure to benzo[a]pyrene. EPA has classified seven PAHs (benzo[a]pyrene, benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene) as Group B2, probable human carcinogens.[137] Recent studies have found that maternal exposures to PAHs in a population of pregnant women were associated with several adverse birth outcomes, including low birth weight and reduced length at birth, as well as impaired cognitive development in preschool children (3 years of age).[138,139] EPA has not yet evaluated these recent studies.

7.3.1.5 Other Air Toxics

In addition to the compounds described above, other air toxic compounds would be affected by this rule. Information regarding the health effects of these compounds can be found in EPA's IRIS database.[140]

7.3.2 Carbon Monoxide Co-Benefits

Carbon monoxide in ambient air is formed primarily by the incomplete combustion of carbon-containing fuels and photochemical reactions in the atmosphere. The amount of CO emitted from these reactions, relative to carbon dioxide (CO_2), is sensitive to conditions in the

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[135] Agency for Toxic Substances and Disease Registry (ATSDR). 1995. Toxicological profile for Polycyclic Aromatic Hydrocarbons (PAHs). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available electronically at http://www.atsdr.cdc.gov/ToxProfiles/TP.asp?id=122&tid=25.

[136] U.S. EPA (2002). Health Assessment Document for Diesel Engine Exhaust. EPA/600/8-90/057F Office of Research and Development, Washington DC. Retrieved on March 17, 2009 from http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=29060. Docket EPA-HQ-OAR-2010-0162.

[137] U.S. EPA (1997). Integrated Risk Information System File of indeno(1,2,3-cd)pyrene. Research and Development, National Center for Environmental Assessment, Washington, DC. This material is available electronically at http://www.epa.gov/ncea/iris/subst/0457.htm.

[138] Perera, F.P.; Rauh, V.; Tsai, W-Y.; et al. (2002) Effect of transplacental exposure to environmental pollutants on birth outcomes in a multiethnic population. Environ Health Perspect. 111: 201-205.

[139] Perera, F.P.; Rauh, V.; Whyatt, R.M.; Tsai, W.Y.; Tang, D.; Diaz, D.; Hoepner, L.; Barr, D.; Tu, Y.H.; Camann, D.; Kinney, P. (2006) Effect of prenatal exposure to airborne polycyclic aromatic hydrocarbons on neurodevelopment in the first 3 years of life among inner-city children. Environ Health Perspect 114: 1287-1292.

[140] U.S. EPA Integrated Risk Information System (IRIS) database is available at: www.epa.gov/iris.

combustion zone, such as fuel oxygen content, burn temperature, or mixing time. Upon inhalation, CO diffuses through the respiratory system to the blood, which can cause hypoxia (reduced oxygen availability). Carbon monoxide can elicit a broad range of effects in multiple tissues and organ systems that are dependent upon concentration and duration of exposure. The *Integrated Science Assessment for Carbon Monoxide* (U.S. EPA, 2010a) concluded that short-term exposure to CO is "likely to have a causal relationship" with cardiovascular morbidity, particularly in individuals with coronary heart disease. Epidemiologic studies associate short-term CO exposure with increased risk of emergency department visits and hospital admissions. Coronary heart disease includes those who have angina pectoris (cardiac chest pain), as well as those who have experienced a heart attack. Other subpopulations potentially at risk include individuals with diseases such as chronic obstructive pulmonary disease (COPD), anemia, or diabetes, and individuals in very early or late life stages, such as older adults or the developing young. The evidence is suggestive of a causal relationship between short-term exposure to CO and respiratory morbidity and mortality. The evidence is also suggestive of a causal relationship for birth outcomes and developmental effects following long-term exposure to CO, and for central nervous system effects linked to short- and long-term exposure to CO.

7.3.3 Black Carbon (BC) Benefits

Incomplete combustion of wood results in emissions of fine and ultrafine particles, including black carbon (BC), brown carbon (BrC), and other non-light-absorbing organic carbon (OC) particles. BC and BrC are collectively considered light-absorbing carbon (LAC) with BC referring to the most strongly light-absorbing form of carbon per unit mass. BC impacts the earth's climate because of its high capacity for light absorption. The role of BC in key atmospheric processes links it to a range of climate impacts, including increased temperatures, accelerated ice and snow melt, and disruptions in precipitation patterns. A recent study by the UN Environment Programme (UNEP) concluded that reductions in BC and ozone will slow the rate of climate change within the first half of this century with a small number of targeted BC and ozone precursor emissions mitigation measures providing immediate protection for climate, public health, water and food security, and ecosystems (UNEP, 2011).[141]

While less effective in absorbing solar radiation than BC, BrC may contribute significantly to positive radiative forcing. At present the ability to quantify the climate impacts of BrC is limited. OC from incomplete combustion of wood (exclusive of BrC) is generally

[141] UN Environment Programme, World Meteorological Organization. 2011, February. *Integrated Assessment of Black Carbon and Tropospheric Ozone: Summary for Decision Makers.* Available at http://www.unep.org/gc/gc26/download.asp?ID=2197.

considered non-light-absorbing carbon. Non-light-absorbing compounds scatter rather than absorb solar radiation and, therefore, provide a net direct cooling effect on climate. Thus, particles generated by residential wood combustion consist of components that are warming to the atmosphere (BC and BrC) and particles that are cooling (OC exclusive of BrC).

Residential wood combustion contributed about 380,000 tons of $PM_{2.5}$ emissions across the United States in 2005. Of these $PM_{2.5}$ emissions, approximately 21,000 tons are estimated to be elemental carbon (EC)[142] (EPA NEI, 2005).[143]

The EC/OC ratio is a metric sometimes used to crudely compare the warming potential of emissions from various BC sources with a ratio of less than 1 indicating that cooling potential exceeds warming. Based on the speciated 2005 NEI, the EC/OC for residential wood combustion is estimated to be less than one (~ 0.11), indicating a predominance of OC or light-scattering particles relative to light absorbing ones. Exactly how much of the OC from RWC sources is light absorbing (BrC) is not known currently, and the LAC may vary by fuel type, combustion conditions, and operating environment.

While OC emissions are generally considered to have a cooling effect, OC emissions over areas with snow and ice may be less reflective than OC over dark surfaces and may even have a slight warming effect (Flanner et al., 2007).[144] Significantly, the vast majority of residential wood smoke emissions occur during the winter months; the highest percentage of wood stove use is in the upper Midwest (e.g., Michigan), the Northeast (e.g., Maine), and the mountainous areas of the Pacific Northwest (e.g., Washington), where snow is present a good portion of the winter months. A recent study of the effect of soot-induced snow albedo on snowpack and hydrological cycles in the western United States concludes that radiative forcing induced by soot deposition on snow is an important anthropogenic source affecting the global climate. The study concludes that soot-induced snow albedo perturbations increase the surface net solar radiation flux during late winter to early spring, increase the surface air temperature, reduce the snow accumulation and spring snowmelt, and may alter stream flows with implications for water resources in the western United States (Qian, et al., 2009).[145] Further study is needed to better understand and quantify the impact of $PM_{2.5}$ emissions and deposition from the RWC sector on climate.

7.3.4 VOCs as a $PM_{2.5}$ Precursor

This rulemaking is expected to reduce emissions of VOCs, which are a precursor to $PM_{2.5}$. Most VOCs emitted are oxidized to carbon dioxide (CO_2) rather than to PM, but a portion

[142] BC is roughly equivalent to 'soot carbon' or the portion of soot that is closest to elemental carbon. The most commonly used measurement technique, the 'thermal optical method' quantifies the portion of PM that is EC. EC is frequently used for emissions characterization and ambient measurements. The terms EC and BC are used interchangeably in this discussion.

[143] U.S. EPA. 2005. *National Emissions Inventory.* 2005 Modeling Inventory. Available at. http://www.epa.gov/ttn/chief/emch/index.html.

[144] Flanner, M. G., Zender, C. S., Randerson, J. T., and Rasch, P. J. 2007. Present-day climate forcing and response from BC in snow. *Journal of Geophysical Research-Atmospheres*, 12(D11). doi:10.1029/2006JD008003

[145] Qian, Y., W. I. Gustafson, L. R. Leung, and S. J. Ghan. 2009. Effects of soot-induced snow albedo change on snowpack and hydrological cycle in western United States based on Weather Research and Forecasting chemistry and regional climate simulations, *J. Geophys. Res.* 114, D03108. doi:10.1029/2008JD011039

of VOC emission contributes to ambient $PM_{2.5}$ levels as organic carbon aerosols (U.S. EPA, 2009c). Therefore, reducing these emissions would reduce $PM_{2.5}$ formation, human exposure to $PM_{2.5}$, and the incidence of $PM_{2.5}$-related health effects. However, we have not quantified the $PM_{2.5}$-related benefits associated with VOC reductions in this analysis. Analysis of organic carbon measurements suggest only a fraction of secondarily formed organic carbon aerosols are of anthropogenic origin. The current state of the science of secondary organic carbon aerosol formation indicates that anthropogenic VOC contribution to secondary organic carbon aerosol is often lower than the biogenic (natural) contribution. Given that a fraction of secondarily formed organic carbon aerosols is from anthropogenic VOC emissions and the extremely small amount of VOC emissions from this sector relative to the entire VOC inventory it is unlikely this sector has a large contribution to ambient secondary organic carbon aerosols. Photochemical models typically estimate secondary organic carbon from anthropogenic VOC emissions to be less than 0.1 $\mu g/m^3$.

Due to limited resources, we were unable to perform air quality modeling for this rule. Therefore, given the high degree of variability in the responsiveness of $PM_{2.5}$ formation to VOC emission reductions, we are unable to estimate the effect that reducing VOCs will have on ambient $PM_{2.5}$ levels without air quality modeling.

7.3.5 VOCs as an Ozone Precursor

In the presence of sunlight, VOCs can undergo a chemical reaction in the atmosphere to form ozone. Reducing ambient ozone concentrations is associated with significant human health benefits, including mortality and respiratory morbidity (U.S. EPA, 2008a). Epidemiological researchers have associated ozone exposure with adverse health effects in numerous toxicological, clinical and epidemiological studies (U.S. EPA, 2006). These health effects include respiratory morbidity such as fewer asthma attacks, hospital and ER visits, school loss days, as well as premature mortality.

In addition to health impacts reduction, there are ecological benefits from reducing the formation of ozone and related exposure that leads to reduced net primary productivity and visible foliar injury which are associated with a range of ecosystems services.

7.3.6 Visibility Impairment Co-Benefits

Reducing secondary formation of $PM_{2.5}$ would improve visibility levels in the U.S. because suspended particles and gases degrade visibility by scattering and absorbing light (U.S. EPA, 2009). Fine particles with significant light-extinction efficiencies include sulfates, nitrates, organic carbon, elemental carbon, and soil (Sisler, 1996). Visibility has direct significance to people's enjoyment of daily activities and their overall sense of wellbeing. Good visibility increases the quality of life where individuals live and work, and where they engage in recreational activities. Particulate sulfate is the dominant source of regional haze in the eastern U.S. and particulate nitrate is an important contributor to light extinction in California and the upper Midwestern U.S., particularly during winter (U.S. EPA, 2009). Previous analyses (U.S. EPA, 2011a) show that visibility benefits can be a significant welfare benefit category. Without air quality modeling, we are not unable to estimate visibility related benefits, nor are we able to determine whether the emission reductions associated with this rule would be likely to have a significant impact on visibility in urban areas or Class I areas.

7.4 References

Abt Associates, Inc. 2012. *BenMAP User's Manual Appendices*. Prepared for U.S. Environmental Protection Agency Office of Air Quality Planning and Standards. Research Triangle Park, NC. September. Available on the Internet at http://www.epa.gov/air/benmap/models/BenMAPAppendicesOct2012.pdf.

Fann, N., C.M. Fulcher, B.J. Hubbell. 2009. "The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution." *Air Qual Atmos Health* 2:169–176.

Fann, N., K.R. Baker, and C.M. Fulcher. 2012. "Characterizing the $PM_{2.5}$-related health benefits of emission reductions for 17 industrial, area and mobile emission sectors across the U.S." *Environment International* 49 41–151.

Gwinn, M.R., J. Craig, D.A. Axelrad, R. Cook, C. Dockins, N. Fann, R. Fegley, D.E. Guinnup, G. Helfand, B. Hubbell, S.L. Mazur, T. Palma, R.L. Smith, J. Vandenberg, and B. Sonawane. 2011. "Meeting report: Estimating the benefits of reducing hazardous air pollutants—summary of 2009 workshop and future considerations." *Environ Health Perspect*. Jan; 119(1): p. 125-30.

Industrial Economics, Inc (IEc). 2009. *Section 812 Prospective Study of the Benefits and Costs of the Clean Air Act: Air Toxics Case Study—Health Benefits of Benzene Reductions in Houston, 1990–2020*. Final Report, July 14, 2009. Available on the Internet at http://www.epa.gov/air/sect812/dec09/812CAAA_Benzene_Houston_Final_Report_July_2009.pdf.

Industrial Economics, Incorporated (IEc). 2006. *Expanded Expert Judgment Assessment of the Concentration-Response Relationship Between $PM_{2.5}$ Exposure and Mortality*. Prepared for: Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC. September. Available on the Internet at http://www.epa.gov/ttn/ecas/regdata/Uncertainty/pm_ee_tsd_expert_interview_summaries.pdf.

Krewski D, Jerrett M, Burnett RT, Ma R, Hughes E, Shi, Y, et al. 2009. *Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality.* HEI Research Report, 140, Health Effects Institute, Boston, MA.

Lepeule J, Laden F, Dockery D, Schwartz J 2012. "Chronic Exposure to Fine Particles and Mortality: An Extended Follow-Up of the Harvard Six Cities Study from 1974 to 2009." *Environ Health Perspect.* Jul;120(7):965-70.

National Research Council (NRC). 2002. *Estimating the Public Health Benefits of Proposed Air Pollution Regulations*. Washington, DC: The National Academies Press.

Office of Management and Budget (OMB). 2003. *Circular A-4: Regulatory Analysis.* Washington, DC. Available on the Internet at http://www.whitehouse.gov/omb/circulars/a004/a-4.html.

Roman, Henry A., Katherine D. Walker, Tyra L. Walsh, Lisa Conner, Harvey M. Richmond, Bryan J. Hubbell, and Patrick L. Kinney. 2008. "Expert Judgment Assessment of the Mortality Impact of Changes in Ambient Fine Particulate Matter in the U.S." *Environ. Sci. Technol*., 42(7):2268-2274.

Sisler, J.F. 1996. *Spatial and seasonal patterns and long-term variability of the composition of the haze in the United States: an analysis of data from the IMPROVE network.* CIRA Report, ISSN 0737-5352-32, Colorado State University.

U.S. Census Bureau. 2008a. Firm Size Data from the Statistics of U.S. Businesses: U.S. Detail Employment Sizes: 2002. <http://www2.census.gov/csd/susb/2002/ 02us_detailed%20sizes_6digitnaics.txt >

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2002. *Workshop on the Benefits of Reductions in Exposure to Hazardous Air Pollutants: Developing Best Estimates of Dose-Response Functions An SAB Workshop Report of an EPA/SAB Workshop (Final Report).* EPA-SAB-EC-WKSHP-02-001. January. Available on the Internet at http://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/34355712EC011A358525719A005BF6F6/$File/ecwkshp02001%2Bappa-g.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 1995. *Regulatory Impact Analysis for the Petroleum Refinery NESHAP. Revised Draft for Promulgation*. Office of Air Quality Planning and Standards, Research Triangle Park, N.C. Available on the Internet athttp://envinfo.com/caain/mact/petroria.html.

U.S. Environmental Protection Agency (U.S. EPA). 2006. *Air Quality Criteria for Ozone and Related Photochemical Oxidants (Final).* EPA/600/R-05/004aF-cF. Washington, DC: U.S. EPA. February. Available on the Internet at http://cfpub.epa.gov/ncea/CFM/recordisplay.cfm?deid=149923.

U.S. Environmental Protection Agency (U.S. EPA). 2008a. *Integrated Science Assessment for Sulfur Oxides—Health Criteria (Final Report)*. National Center for Environmental Assessment, Research Triangle Park, NC. September. Available on the Internet at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=198843.

U.S. Environmental Protection Agency (U.S. EPA). 2008c. *Integrated Science Assessment for Oxides of Nitrogen—Health Criteria (Final Report).* National Center for Environmental Assessment, Research Triangle Park, NC. July. Available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=194645.

U.S. Environmental Protection Agency (U.S. EPA). 2008d. *Integrated Science Assessment for Oxides of Nitrogen and Sulfur–Ecological Criteria National (Final Report*). National Center for Environmental Assessment, Research Triangle Park, NC. EPA/600/R-08/139. December. Available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=201485.

U.S. Environmental Protection Agency (U.S. EPA). 2009. *Integrated Science Assessment for Particulate Matter (Final Report)*. EPA-600-R-08-139F. National Center for Environmental Assessment—RTP Division. December. Available on the Internet at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=216546.

U.S. Environmental Protection Agency (U.S. EPA). 2010a. *Integrated Science Assessment for Carbon Monoxide.* National Center for Environmental Assessment, Research Triangle Park, NC. EPA/600/R-09/019F. January. Available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=218686.

U.S. Environmental Protection Agency (U.S. EPA). 2010b. *Technical Support Document: Summary of Expert Opinions on the Existence of a Threshold in the Concentration-Response Function for $PM_{2.5}$-related Mortality.* Research Triangle Park, NC. June. Available on the Internet at www.epa.gov/ttn/ecas/regdata/Benefits/thresholdstsd.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2010c. *Valuing Mortality Risk Reductions for Environmental Policy: A White Paper: SAB Review Draft*. National Center for Environmental Economics December. Available on the Internet at http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0563-1.pdf/$file/EE-0563-1.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2010e. *Guidelines for Preparing Economic Analyses*. EPA 240-R-10-001. National Center for Environmental Economics, Office of Policy Economics and Innovation. Washington, DC. December. Available on the Internet at http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568- 50.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2011a. *The Benefits and Costs of the Clean Air Act from 1990 to 2020*. Office of Air and Radiation, Washington, DC. March. http://www.epa.gov/air/sect812/feb11/fullreport.pdf. Accessed March 30, 2011.

U.S. Environmental Protection Agency (U.S. EPA). 2011b. *Regulatory Impact Analysis for the Final Mercury and Air Toxics Standards.* EPA-452/R-11-011. December. Available on the Internet at http://www.epa.gov/ttn/ecas/regdata/RIAs/matsriafinal.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2011c. *2005 National-Scale Air Toxics Assessment.* Office of Air Quality Planning and Standards, Research Triangle Park, NC. March. Available on the Internet at http://www.epa.gov/ttn/atw/nata2005/.

U.S. Environmental Protection Agency (U.S. EPA). 2011d. *Regulatory Impact Analysis: National Emission Standards for Hazardous Air Pollutants for Industrial, Commercial, and Institutional Boilers and Process Heaters.* February. Available on the Internet at http://www.epa.gov/ttnecas1/regdata/RIAs/boilersriafinal110221_psg.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2012a. *Regulatory Impact Analysis for the Final Revisions to the National Ambient Air Quality Standards for Particulate Matter*. EPA-452/R-12-003. Office of Air Quality Planning and Standards, Health and Environmental Impacts Division. December. Available at http://www.epa.gov/pm/2012/finalria.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2012b. *Regulatory Impact Analysis: Petroleum Refineries New Source Performance Standards Ja.* Office of Air Quality Planning and Standards, Health and Environmental Impacts Division. June. Available at http://www.epa.gov/ttnecas1/regdata/RIAs/refineries_nsps_ja_final_ria.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2013. *Technical Support Document: Estimating the Benefit per ton of Reducing $PM_{2.5}$ Precursors from 17 sectors*. Office of Air Quality Planning and Standards, Research Triangle Park, NC. February.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2008. *Characterizing Uncertainty in Particulate Matter Benefits Using Expert Elicitation.* EPA-COUNCIL-08-002. July. Available on the Internet at http://yosemite.epa.gov/sab/sabproduct.nsf/0/43B91173651AED9E85257487004EA6CB/$File/EPA-COUNCIL-08-002-unsigned.pdf.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2000. *An SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reduction.* EPA-SAB-EEAC-00-013. July. Available on the Internet at http://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/41334524148BCCD6852571A700516498/$File/eeacf013.pdf.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2004c. *Advisory Council on Clean Air Compliance Analysis Response to Agency Request on Cessation Lag.* EPA-COUNCIL-LTR-05-001. December. Available on the Internet at <. http://yosemite.epa.gov/sab/sabproduct.nsf/0/39F44B098DB49F3C85257170005293E0/$File/council_ltr_05_001.pdf>

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2008. *Benefits of Reducing Benzene Emissions in Houston, 1990–2020*. EPA-COUNCIL-08-001. July. Available at http://yosemite.epa.gov/sab/sabproduct.nsf/D4D7EC9DAEDA8A548525748600728A83/$File/EPA-COUNCIL-08-001-unsigned.pdf.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2009b. *Review of EPA's Integrated Science Assessment for Particulate Matter (First External Review Draft, December 2008)*. EPA-COUNCIL-09-008. May. Available on the Internet at http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/73ACCA834AB44A10852575BD0064346B/$File/EPA-CASAC-09-008-unsigned.pdf.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2009c. *Review of Integrated Science Assessment for Particulate Matter (Second External Review Draft, July 2009)*. EPA-CASAC-10-001. November. Available on the Internet at http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/151B1F83B023145585257678006836B9/$File/EPA-CASAC-10-001-unsigned.pdf.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2010a. *Review of EPA's DRAFT Health Benefits of the Second Section 812 Prospective Study of the Clean Air Act*. EPA-COUNCIL-10-001. June. Available on the Internet at http://yosemite.epa.gov/sab/sabproduct.nsf/9288428b8eeea4c885257242006935a3/59e06b6c5ca66597852575e7006c5d09!OpenDocument&TableRow=2.3#2.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2011. *Review of Valuing Mortality Risk Reductions for Environmental Policy: A White Paper (December 10, 2010)*. EPA-SAB-11-011 July. Available on the Internet at http://yosemite.epa.gov/sab/sabproduct.nsf/298E1F50F844BC23852578DC0059A616/$File/EPA-SAB-11-011-unsigned.pdf .

SECTION 8
COMPARISON OF MONETIZED BENEFITS AND COSTS

8.1 Summary

Because we are unable to monetize the co-benefits associated with reducing other pollutants such as VOCs and CO, all monetized benefits reflect improvements in ambient $PM_{2.5}$ concentrations due to the reductions of about 8,300 tons of $PM_{2.5}$ emissions. This results in an underestimate of the monetized benefits. Using a 3% discount rate, we estimate the total monetized benefits of this rule to be $3.4 billion to $7.6 billion in the 2015–2020 time frame (Table 8-1). We estimate the impacts for the time frame from 2015 to 2020 in order to provide an average of annualized results for these options from the time of rule promulgation in 2015 to the time of full implementation, which occurs by 2020. The variability of annual impacts provides an appropriate rationale for presenting impacts averaged over this time frame. Using a 7% discount rate, we estimate the total annual monetized benefits to be $3.1 billion to $6.9 billion in the 2015–2020 time frame. The annualized social costs are $45.7 million for the final rule in the 2015–2020 time frame (2013 dollars), and are $40.2 million for the final rule in the same time frame using a 3% interest rate. The net benefits (benefits – costs) are therefore $3.4 billion to $7.6 billion at a 3% discount rate for the benefits and $3.1 billion to $6.9 billion at a 7% discount rate for the final rule in the 2015–2020 time frame. All estimates are in 2013$. The benefits from reducing other air pollutants have not been monetized in this analysis, including reducing nearly 9,300 tons of VOC, 461000 tons of CO, black carbon and emissions of several HAPs such as formaldehyde and benzene among others each year.

Figure 8-1 shows the full range of net annual benefits estimates (i.e., annual benefits minus annualized costs) quantified in terms of $PM_{2.5}$ benefits reflecting the average annual impact for the 2015–2020 time frame of the analysis under the final rule. The net annual benefits reflect a 3% discount rate for the benefits. Figure 8-2 shows the full range of net annual benefits estimates reflecting a 7% discount rate for the benefits.

Table 8-1. Summary of the Annual Monetized Benefits, Social Costs, and Net Benefits for the Residential Wood Heater NSPS in the 2015–2020 Time Frame ($2013 millions)[a]

Final Rule	3% Discount Rate			7% Discount Rate		
Total Annual Monetized Benefits[b]	$3,400	to	$7,600	$3,100	to	$6,900
Total Social Costs[c]		40			$46	
Net Benefits	$3,400	to	$7,600	$3,100	To	$6,900
Nonmonetized Benefits	46,100 tons of CO					
	9,300 tons of VOC					
	Reduced exposure to HAPs, including formaldehyde, benzene, and polycyclic organic matter					
	Reduced Climate effects due to reductions in black carbon emissions					
	Reduced ecosystem effects					
	Reduced visibility impairment					

[a] All estimates are for the time frame from 2015 to 2020 inclusive and are rounded to two significant figures. These results include units anticipated to come online and the lowest cost disposal assumption. Total annualized social costs are presented at a 3% and a 7% interest rate to be consistent with OMB guidance.

[b] The total monetized benefits reflect the human health benefits associated with reducing exposure to $PM_{2.5}$ through reductions of directly emitted $PM_{2.5}$. It is important to note that the monetized benefits include many but not all health effects associated with $PM_{2.5}$ exposure. Benefits are shown as a range from Krewski et al. (2009) to Lepeule et al. (2012). These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. Because these estimates were generated using benefit-per-ton estimates, we do not break down the total monetized benefits into specific components here. See Figure 7-1 in this RIA for an illustration of the breakdown, or the RIA for the final Cross-States Air Pollution Rule (EPA, 2011) for more information.

[c] We assume that annual compliance costs serve as an approximation of the social costs of the rule.

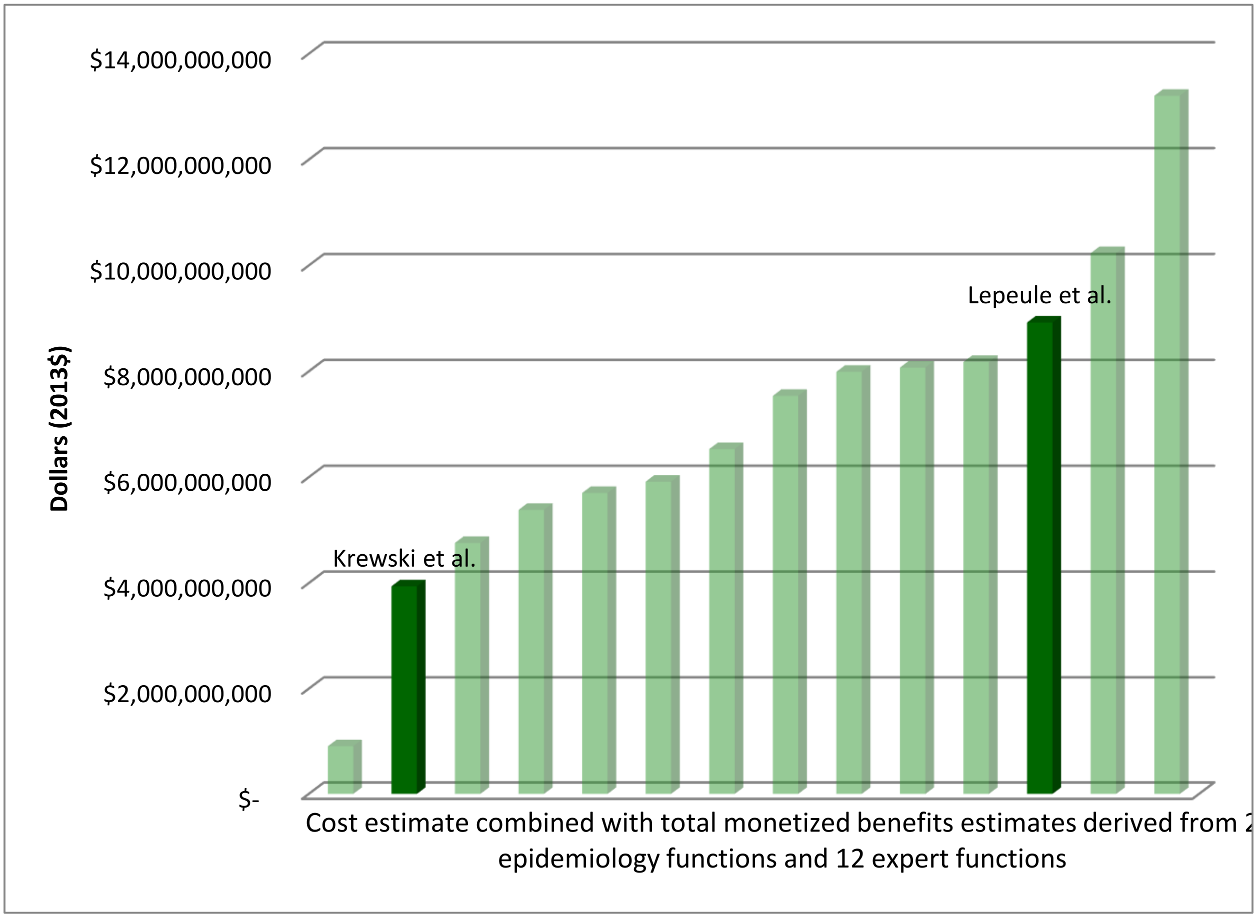

Figure 8-1. Net Annual Benefits Range in 2015–2020 Time Frame for $PM_{2.5}$ Reductions for the NSPS with Benefits Discounted at 3%

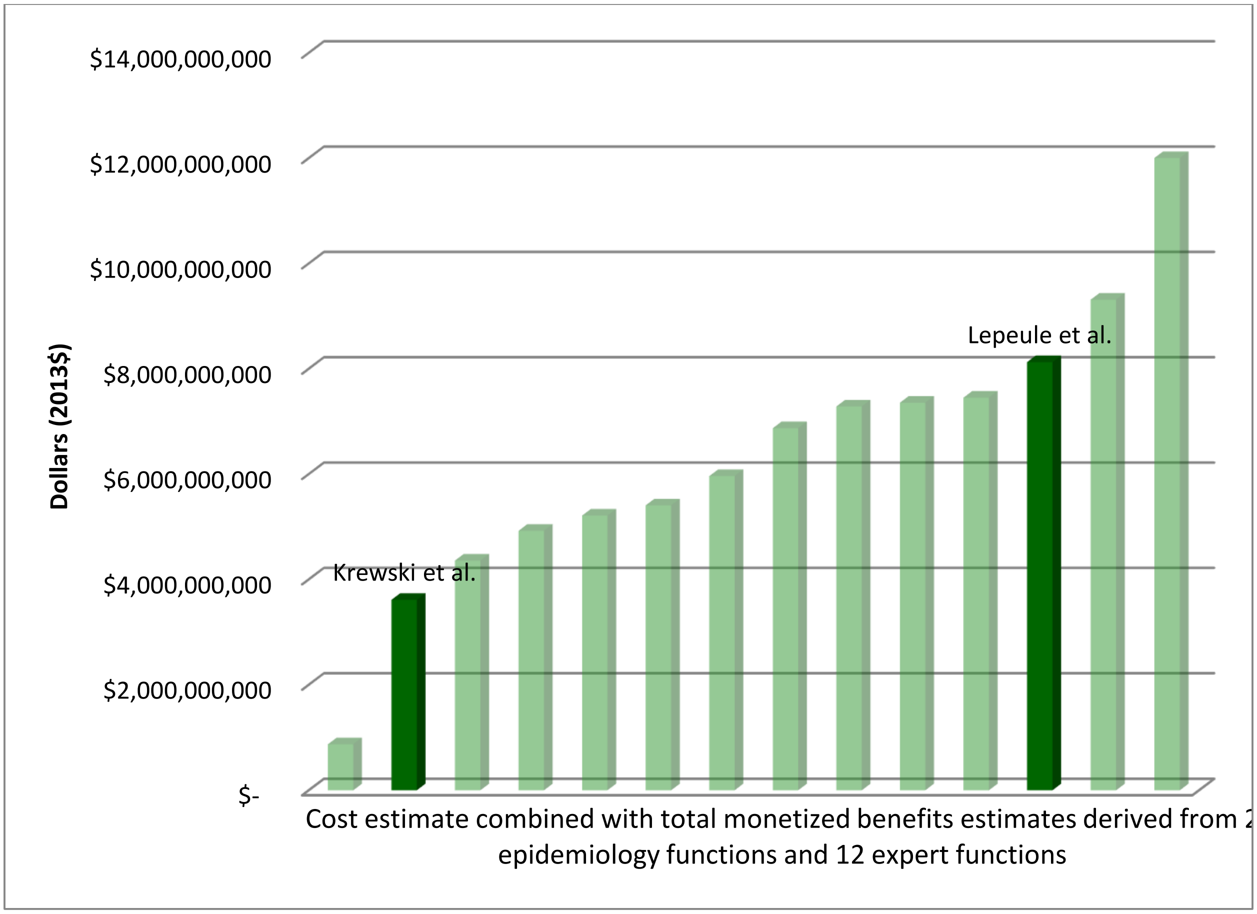

Figure 8-2. Net Annual Benefits Range in 2015–2020 Time Frame for $PM_{2.5}$ Reductions for the NSPS with Benefits Discounted at 7%

Table 8-2 provides estimates of annualized costs and benefits for each affected source category for the final NSPS.

Table 8-2. Compliance Costs, Monetized Benefits, and Monetized Net Benefits (2013 dollars) by Source Category in the 2015–2020 Time Frame—Final NSPS

Source Category	Total Annualized Costs ($ millions)	Monetized Benefits ($ millions)[a]	Monetized Net Benefits ($ millions)
Wood stoves	$3	$14 to $31	$11 to $28
Single burn rate stoves	$1	$280 to $630	$280 to $630
Pellet stoves	$2	$2 to $5	$0. to $3
Forced-air furnaces	$15	$1,700 to $3,700	$1,700 to $3,700
Hydronic heating systems	$25	$1,400 to $3,200	$1,400 to $3,200

[a] All estimates are an average of annual impacts for the time frame from 2015 to 2020 inclusive. All estimates are in 2013 dollars. These results include units anticipated to come online and the lowest cost disposal assumption. Total annualized costs are estimated at a 7% interest rate to be consistent with OMB guidance. Total annualized costs are also estimated at a 3% interest rate for each source category to be consistent with OMB guidance, and these costs are about 13% less than the total annualized costs presented in this table. These costs are presented in Section 5 of this RIA and in the cost memoranda for this final rule. The monetized net benefits with total annualized costs at a 3% interest rate are minimally different than those calculated with total annualized costs at a 7% interest rate.

[b] Total monetized benefits are estimated at a 3% discount rate. The total monetized benefits reflect the human health benefits associated with reducing exposure to $PM_{2.5}$ through reductions of directly emitted $PM_{2.5}$. It is important to note that the monetized benefits include many but not all health effects associated with $PM_{2.5}$ exposure. Benefits are shown as a range from Krewski et al. (2009) to Lepeule et al. (2012). These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. Because these estimates were generated using benefit-per-ton estimates, we do not break down the total monetized benefits into specific components here. See Figure 7-1 in this RIA for an illustration of the breakdown, or the RIA for the final Cross-States Air Pollution Rule (EPA, 2011) for more information.

SECTION 9
REFERENCES AND COST APPENDIX

Abt Associates, Inc. 2012. *BenMAP User's Manual Appendices*. Prepared for U.S. Environmental Protection Agency Office of Air Quality Planning and Standards. Research Triangle Park, NC. September. Available on the Internet at http://www.epa.gov/air/benmap/models/BenMAPAppendicesOct2012.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR). 1995. *Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs)*. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available at: http://www.atsdr.cdc.gov/ToxProfiles/TP.asp?id=122&tid=25

American Enterprise Institute (AEI) and Brookings Institution Joint Center for Regulatory Studies. 1986. *NSPS for Residential Wood Heaters. Regulatory Impact Analysis.* RIN: 2060-AB68. Available at: http://reg-markets.org/admin/authorpdfs/redirect-safely.php?fname=../pdffiles/2060-AB68.RIA.pdf

Bernstein, M.A., and J. Griffin. 2005. *Regional Differences in the Price-Elasticity of Demand for Energy*. The RAND Corporation. Available at: http://www.rand.org/pubs/technical_reports/2005/RAND_TR292.pdf.

Chernov, A. 2008. *Masonry Heaters: Planning Guide for Architects, Home Designers, and builders*. Stovemaster Web site. Available at: http://www.stovemaster.com/files/masonry.pdf.

Dagan, D. January 7, 2005. "Warming Up to Stoves." *Central Penn Business Journal.* Available at: http://www.allbusiness.com/sales/1033217-1.html

Dun & Bradstreet (D&B). 2010. *D&B Marketplace*. A company information database searchable by NAICS code. Accessed on July 15, 2010.

Fann, N., C.M. Fulcher, B.J. Hubbell. 2009. "The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution." *Air Qual Atmos Health* 2:169–176.

Fann, N., K.R. Baker, and C.M. Fulcher. 2012. "Characterizing the $PM_{2.5}$-related health benefits of emission reductions for 17 industrial, area and mobile emission sectors across the U.S." *Environment International* 49 41–151.

Gwinn, M.R., J. Craig, D.A. Axelrad, R. Cook, C. Dockins, N. Fann, R. Fegley, D.E. Guinnup, G. Helfand, B. Hubbell, S.L. Mazur, T. Palma, R.L. Smith, J. Vandenberg, and B. Sonawane. 2011. "Meeting report: Estimating the benefits of reducing hazardous air pollutants—summary of 2009 workshop and future considerations." *Environ Health Perspect*. Jan; 119(1): p. 125-30.

Industrial Economics, Inc (IEc). 2009. *Section 812 Prospective Study of the Benefits and Costs of the Clean Air Act: Air Toxics Case Study—Health Benefits of Benzene Reductions in Houston, 1990–2020*. Final Report, July 14, 2009. Available on the Internet at http://www.epa.gov/air/sect812/dec09/812CAAA_Benzene_Houston_Final_Report_July_2009.pdf.

Industrial Economics, Incorporated (IEc). 2006. *Expanded Expert Judgment Assessment of the Concentration-Response Relationship Between $PM_{2.5}$ Exposure and Mortality*. Prepared for: Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC. September. Available on the Internet at http://www.epa.gov/ttn/ecas/regdata/Uncertainty/pm_ee_tsd_expert_interview_summaries.pdf.

Krewski D, Jerrett M, Burnett RT, Ma R, Hughes E, Shi, Y, et al. 2009. *Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality.* HEI Research Report, 140, Health Effects Institute, Boston, MA.

Lepeule J, Laden F, Dockery D, Schwartz J 2012. "Chronic Exposure to Fine Particles and Mortality: An Extended Follow-Up of the Harvard Six Cities Study from 1974 to 2009." *Environ Health Perspect.* Jul;120(7):965-70.

National Research Council (NRC). 2002. *Estimating the Public Health Benefits of Proposed Air Pollution Regulations*. Washington, DC: The National Academies Press.

Office of Management and Budget (OMB). 2003. *Circular A-4: Regulatory Analysis.* Washington, DC. Available on the Internet at http://www.whitehouse.gov/omb/circulars/a004/a-4.html.

Roman, Henry A., Katherine D. Walker, Tyra L. Walsh, Lisa Conner, Harvey M. Richmond, Bryan J. Hubbell, and Patrick L. Kinney. 2008. "Expert Judgment Assessment of the Mortality Impact of Changes in Ambient Fine Particulate Matter in the U.S." *Environ. Sci. Technol*., 42(7):2268-2274.

Sisler, J.F. 1996. *Spatial and seasonal patterns and long-term variability of the composition of the haze in the United States: an analysis of data from the IMPROVE network.* CIRA Report, ISSN 0737-5352-32, Colorado State University.

U.S. Census Bureau. 2008a. Firm Size Data from the Statistics of U.S. Businesses: U.S. Detail Employment Sizes: 2002. <http://www2.census.gov/csd/susb/2002/ 02us_detailed%20sizes_6digitnaics.txt >

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2002. *Workshop on the Benefits of Reductions in Exposure to Hazardous Air Pollutants: Developing Best Estimates of Dose-Response Functions An SAB Workshop Report of an EPA/SAB Workshop (Final Report).* EPA-SAB-EC-WKSHP-02-001. January. Available on the Internet at http://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/34355712EC011A358525719A005BF6F6/$File/ecwkshp02001%2Bappa-g.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 1995. *Regulatory Impact Analysis for the Petroleum Refinery NESHAP. Revised Draft for Promulgation*. Office of Air Quality Planning and Standards, Research Triangle Park, N.C. Available on the Internet at http://envinfo.com/caain/mact/petroria.html.

U.S. Environmental Protection Agency (U.S. EPA). 2006. *Air Quality Criteria for Ozone and Related Photochemical Oxidants (Final)*. EPA/600/R-05/004aF-cF. Washington, DC: U.S. EPA. February. Available on the Internet at http://cfpub.epa.gov/ncea/CFM/recordisplay.cfm?deid=149923.

U.S. Environmental Protection Agency (U.S. EPA). 2008a. *Integrated Science Assessment for Sulfur Oxides—Health Criteria (Final Report)*. National Center for Environmental Assessment, Research Triangle Park, NC. September. Available on the Internet at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=198843.

U.S. Environmental Protection Agency (U.S. EPA). 2008c. *Integrated Science Assessment for Oxides of Nitrogen—Health Criteria (Final Report).* National Center for Environmental Assessment, Research Triangle Park, NC. July. Available at at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=194645.

U.S. Environmental Protection Agency (U.S. EPA). 2008d. *Integrated Science Assessment for Oxides of Nitrogen and Sulfur–Ecological Criteria National (Final Report*). National Center for Environmental Assessment, Research Triangle Park, NC. EPA/600/R-08/139. December. Available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=201485.

U.S. Environmental Protection Agency (U.S. EPA). 2009. *Integrated Science Assessment for Particulate Matter (Final Report)*. EPA-600-R-08-139F. National Center for Environmental Assessment—RTP Division. December. Available on the Internet at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=216546.

U.S. Environmental Protection Agency (U.S. EPA). 2010a. *Integrated Science Assessment for Carbon Monoxide.* National Center for Environmental Assessment, Research Triangle Park, NC. EPA/600/R-09/019F. January. Available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=218686.

U.S. Environmental Protection Agency (U.S. EPA). 2010b. *Technical Support Document: Summary of Expert Opinions on the Existence of a Threshold in the Concentration-Response Function for* $PM_{2.5}$*-related Mortality.* Research Triangle Park, NC. June. Available on the Internet at www.epa.gov/ttn/ecas/regdata/Benefits/thresholdstsd.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2010c. *Valuing Mortality Risk Reductions for Environmental Policy: A White Paper: SAB Review Draft*. National Center for Environmental Economics December. Available on the Internet at http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0563-1.pdf/$file/EE-0563-1.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2010e. *Guidelines for Preparing Economic Analyses*. EPA 240-R-10-001. National Center for Environmental Economics, Office of Policy Economics and Innovation. Washington, DC. December. Available on the Internet at http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568- 50.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2011a. *The Benefits and Costs of the Clean Air Act from 1990 to 2020*. Office of Air and Radiation, Washington, DC. March. http://www.epa.gov/air/sect812/feb11/fullreport.pdf. Accessed March 30, 2011.

U.S. Environmental Protection Agency (U.S. EPA). 2011b. *Regulatory Impact Analysis for the Final Mercury and Air Toxics Standards.* EPA-452/R-11-011. December. Available on the Internet at http://www.epa.gov/ttn/ecas/regdata/RIAs/matsriafinal.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2011c. *2005 National-Scale Air Toxics Assessment.* Office of Air Quality Planning and Standards, Research Triangle Park, NC. March. Available on the Internet at http://www.epa.gov/ttn/atw/nata2005/.

U.S. Environmental Protection Agency (U.S. EPA). 2011d. *Regulatory Impact Analysis: National Emission Standards for Hazardous Air Pollutants for Industrial, Commercial, and Institutional Boilers and Process Heaters.* February. Available on the Internet at http://www.epa.gov/ttnecas1/regdata/RIAs/boilersriafinal110221_psg.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2012a. *Regulatory Impact Analysis for the Final Revisions to the National Ambient Air Quality Standards for Particulate Matter*. EPA-452/R-12-003. Office of Air Quality Planning and Standards, Health and Environmental Impacts Division. December. Available at http://www.epa.gov/pm/2012/finalria.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2012b. *Regulatory Impact Analysis: Petroleum Refineries New Source Performance Standards Ja.* Office of Air Quality Planning and Standards, Health and Environmental Impacts Division. June. Available at http://www.epa.gov/ttnecas1/regdata/RIAs/refineries_nsps_ja_final_ria.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2013. *Technical Support Document: Estimating the Benefit per ton of Reducing $PM_{2.5}$ Precursors from 17 sectors*. Office of Air Quality Planning and Standards, Research Triangle Park, NC. February.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2008. *Characterizing Uncertainty in Particulate Matter Benefits Using Expert Elicitation.* EPA-COUNCIL-08-002. July. Available on the Internet at http://yosemite.epa.gov/sab/sabproduct.nsf/0/43B91173651AED9E85257487004EA6CB/$File/EPA-COUNCIL-08-002-unsigned.pdf.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2000. *An SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reduction.* EPA-SAB-EEAC-00-013. July. Available on the Internet at http://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/41334524148BCCD6852571A700516498/$File/eeacf013.pdf.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2004c. *Advisory Council on Clean Air Compliance Analysis Response to Agency Request on Cessation Lag.* EPA-COUNCIL-LTR-05-001. December. Available on the Internet at <. http://yosemite.epa.gov/sab/sabproduct.nsf/0/39F44B098DB49F3C85257170005293E0/$File/council_ltr_05_001.pdf

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2008. *Benefits of Reducing Benzene Emissions in Houston, 1990–2020*. EPA-COUNCIL-08-001. July. Available at http://yosemite.epa.gov/sab/sabproduct.nsf/D4D7EC9DAEDA8A548525748600728A83/$File/EPA-COUNCIL-08-001-unsigned.pdf.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2009b. *Review of EPA's Integrated Science Assessment for Particulate Matter (First External Review Draft, December 2008)*. EPA-COUNCIL-09-008. May. Available on the Internet at http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/73ACCA834AB44A10852575BD0064346B/$File/EPA-CASAC-09-008-unsigned.pdf.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2009c. *Review of Integrated Science Assessment for Particulate Matter (Second External Review Draft, July 2009)*. EPA-CASAC-10-001. November. Available on the Internet at http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/151B1F83B023145585257678006836B9/$File/EPA-CASAC-10-001-unsigned.pdf.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2010a. *Review of EPA's DRAFT Health Benefits of the Second Section 812 Prospective Study of the Clean Air Act*. EPA-COUNCIL-10-001. June. Available on the Internet at http://yosemite.epa.gov/sab/sabproduct.nsf/9288428b8eeea4c885257242006935a3/59e06b6c5ca66597852575e7006c5d09!OpenDocument&TableRow=2.3#2.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2011. *Review of Valuing Mortality Risk Reductions for Environmental Policy: A White Paper (December 10, 2010).* EPA-SAB-11-011 July. Available on the Internet at http://yosemite.epa.gov/sab/sabproduct.nsf/298E1F50F844BC23852578DC0059A616/$File/EPA-SAB-11-011-unsigned.pdf .

Fann, N., C. M. Fulcher, and B. J. Hubbell. 2009. "The Influence of Location, Source, and Emission Type in Estimates of the Human Health Benefits of Reducing a Ton of Air Pollution." *Air Quality, Atmosphere, and Health* 2:169-176.

Fireplaces & Woodstoves. 2010. "Masonry Heaters." http://www.fireplacesandwoodstoves.com/indoor-fireplaces/masonry-fireplaces.aspx.

Frost & Sullivan. 2010. *Project: Market Research and Report on North American Residential Wood Heaters, Fireplaces, and Hearth Heating Products Market* (P.O. # PO1-IMP402-F&S). Prepared for EC/R.

Fullerton, D., and G. Metcalf. 2002. "Tax Incidence." In A. Auerbach and M. Feldstein, eds., Handbook of Public Economics, Vol. 4, Amsterdam: Elsevier.Hearth, Patio, and Barbeque Association (HPBA). 2010a. "Comments for the Small Business Advocacy Review (SBAR) Panel, Regarding the Revision of New Source Performance Standards for New Residential Wood Heaters." Comments submitted to EPA on September 12, 2010.

Gwinn, M.R., J. Craig, D.A. Axelrad, R. Cook, C. Dockins, N. Fann, R. Fegley, D.E. Guinnup, G. Helfand, B. Hubbell, S.L. Mazur, T. Palma, R.L. Smith, J. Vandenberg, and B. Sonawane. 2011. "Meeting report: Estimating the benefits of reducing hazardous air pollutants—summary of 2009 workshop and future considerations." *Environ Health Perspect.* 119(1): p. 125-30.

Hearth, Patio, and Barbeque Association (HPBA). 2010b. "Fireplace Insert Fact Sheet." Available at: http://static.hpba.org/fileadmin/factsheets/product/FS_FireplaceInsert.pdf.

Hearth, Patio, and Barbecue Association (HPBA). 2010c. "Outdoor Heating Options." Available at: http://www.hpba.org/consumers/outdoor-living/outdoor-heating-options.

Houck, J. 2009. "Let's Not Forget about Coal." *Hearth & Home.* December. Available at: http://www.hearthandhome.com/articles.html.

Houck, J., and P. Tiegs. 2009. "There's a Freight Train Comin'." *Hearth & Home*. December. Available at: http://www.hearthandhome.com/articles.html.

Industrial Economics, Inc (IEc). 2006. *Expanded Expert Judgment Assessment of the Concentration-Response Relationship Between $PM_{2.5}$ Exposure and Mortality*. Prepared for the U.S. EPA, Office of Air Quality Planning and Standards, September. Available at: http://www.epa.gov/ttn/ecas/regdata/Uncertainty/pm_ee_report.pdf.

Industrial Economics, Inc (IEc). 2009. *Section 812 Prospective Study of the Benefits and Costs of the Clean Air Act: Air Toxics Case Study—Health Benefits of Benzene Reductions in Houston, 1990–2020*. Final Report, July 14, 2009. http://www.epa.gov/air/sect812/dec09/812CAAA+Benzene_Houston_Final_Report_July_2009.pdf. Accessed March 30, 2011.

Kochi, I., B. Hubbell, and R. Kramer. 2006. "An Empirical Bayes Approach to Combining Estimates of the Value of Statistical Life for Environmental Policy Analysis." *Environmental and Resource Economics* 34:385-406.

Krewski D, Jerrett M, Burnett RT, Ma R, Hughes E, Shi, Y, et al. 2009. *Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality*. HEI Research Report, 140, Health Effects Institute, Boston, MA.

Laden, F., J. Schwartz, F.E. Speizer, and D.W. Dockery. 2006. Reduction in Fine Particulate Air Pollution and Mortality. *American Journal of Respiratory and Critical Care Medicine.* 173: 667-672.

Landsburg, S.H. 2005. *Price Theory and Applications. 6th Ed*. Thomson South Western.Mason, OH.

Mankiw, N.G. 1998. *Principles of Economics.* Orlando, Fl: Dryden Press.

Masonry Heater Association of North America (MHA). 1998. MHA Masonry Heater Definition. Available at: http://mha-net.org/docs/def-mha.htm.

Morgenstern, R. D., W. A. Pizer, and J. S. Shih. 2002. "Jobs versus the Environment: An Industry-Level Perspective." *Journal of Environmental Economics and Management* 43(3):412-436. Available at http://ac.els-cdn.com/S009506960191191X/1-s2.0-S009506960191191X-main.pdf?_tid=6bc8845e-7c56-11e2-84a7-00000aab0f26&acdnat=1361472319_4fe7ef315e9b2f8fc064c0a767895205 (subscription required).

Mrozek, J.R., and L.O. Taylor. 2002. "What Determines the Value of Life? A Meta-Analysis." Journal of Policy Analysis and Management 21(2):253-270.

National Research Council (NRC). 2002. *Estimating the Public Health Benefits of Proposed Air Pollution Regulations*. Washington, DC: The National Academies Press.

Nicholson, Walter. 1998. *Microeconomic Theory*. Orlando: The Dryden Press.

Northeast States for Coordinated Air Use Management (NESCAUM). 2006. *Assessment of Outdoor Wood-Fired Boilers*. March, 2006 (Revised June, 2006). Available at: http://www.nescaum.org/documents/assessment-of-outdoor-wood-fired-boilers.

Office of Management and Budget (OMB). 2003. *Circular A-4: Regulatory Analysis.* Washington, DC. Available on the Internet at http://www.whitehouse.gov/omb/circulars/a004/a-4.html.

Pope, C.A., III, R.T. Burnett, M.J. Thun, E.E. Calle, D. Krewski, K. Ito, and G.D. Thurston. 2002. "Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution." *Journal of the American Medical Association* 287:1132-1141.

Roman, Henry A., Katherine D. Walker, Tyra L. Walsh, Lisa Conner, Harvey M. Richmond, Bryan.J. Hubbell, and Patrick L. Kinney. 2008. "Expert Judgment Assessment of the Mortality Impact of Changes in Ambient Fine Particulate Matter in the U.S. Environmental Science & Technology 42(7):2268-2274.

Sisler, J.F. 1996. *Spatial and seasonal patterns and long-term variability of the composition of the haze in the United States: an analysis of data from the IMPROVE network*. CIRA Report, ISSN 0737-5352-32, Colorado State University.

The Risk Management Association. 2008. *Annual Statement Studies, Financial Ratio Benchmarks 2008–2009.* Risk Management Association, Philadelphia: 2008.

U.S. Census Bureau. 2007. *Survey of Plant Capacity: 2006.* "Table 1a. Full Capacity Utilization Rates by Industry Fourth Quarter 2002–2006." U.S. Census Bureau: Washington DC. Report No. MQ-C1(06). Available at: http://www.census.gov/manufacturing/capacity/historical_data/index.html.

U.S. Census Bureau. 2009. *American Community Survey: 2006–2008*. Available at: http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=ACS&submenId=&_lang+en&_ts=. U.S. Census Bureau. 2010a. American Fact Finder. Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2008 and 2007. Available at: http://factfinder.census.gov. Accessed July 20, 2010.

U.S. Census Bureau. 2010b. American Fact Finder. Sector 23: EC0723SG01: Construction: Summary Series: General Summary: Detailed Statistics for Establishments: 2007. Available at: http://factfinder.census.gov. Accessed July 20, 2010.

U.S. Census Bureau. 2010c. American Fact Finder. Sector 42: EC0742A1: Wholesale Trade: Geographic Area Series: Summary Statistics for the United States, States, Metro Areas, Counties, and Places: 2007. Available at: http://factfinder.census.gov. Accessed July 20, 2010.

U.S. Census Bureau. 2010d. American Fact Finder. Sector 44: EC0744A1: Retail Trade: Geographic Area Series: Summary Statistics for the United States, States, Metro Areas, Counties, and Places: 2007. Available at: http://factfinder.census.gov. Accessed July 20, 2010.

U.S. Census Bureau. 2010e. Census Regions and Divisions of the United States. Available at: http://www.census.gov/geo/www/us_regdiv.pdf. Accessed September 12, 2010.

U.S. Census Bureau. 2010f. North American Industrial Classification System [NAICS] Code Definitions Web site. Available at: http://www.census.gov/eos/www/naics/.

U.S. Department of Energy (DOE). 2009. "Your Home: Selecting Heating Fuel and System Types." ENERGYSTAR Web site. U.S. Department of Energy. Available at: http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12330..

U.S. Department of Energy (DOE). 2010. "Your Home: Masonry Heaters." ENERGYSTAR Web site. U.S. Department of Energy. Available at: http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12570.

U.S. Energy Information Administration (EIA). 2011. *Residential Energy Consumption Survey: 2009*. Available at: http://www.eia.doe.gov/emeu/recs/recspubuse05/pubuse05.html.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2007. *SAB Advisory on EPA's Issues in Valuing Mortality Risk Reduction.* EPA-SAB-08-001. October. Available on the Internet at <http://yosemite.epa.gov/sab/sabproduct.nsf/4128007E7876B8F0852573760058A978/$File/sab-08-001.pdf >.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2009a. *Review of EPA's Integrated Science Assessment for Particulate Matter (First External Review Draft, December 2008).* EPA-COUNCIL-09-008. May. Available on the Internet at <http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/73ACCA834AB44A10852575BD0064346B/$File/EPA-CASAC-09-008-unsigned.pdf>.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2009b. Consultation on EPA's Particulate Matter National Ambient Air Quality Standards: Scope and Methods Plan for Health Risk and Exposure Assessment. EPA-COUNCIL-09-009. May. Available on the Internet at <http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/723FE644C5D758DF852575BD00763A32/$File/EPA-CASAC-09-009-unsigned.pdf>.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2010. *Review of EPA's DRAFT Health Benefits of the Second Section 812 Prospective Study of the Clean Air Act. EPA-COUNCIL-10-001*. June. Available on the Internet at http://yosemite.epa.gov/sab/sabproduct.nsf/0/72D4EFA39E48CDB28525774500738776/$File/EPA-COUNCIL-10-001-unsigned.pdf.

U.S. Environmental Protection Agency (EPA). 2002. "Profile of the Pulp and Paper Industry." *Sector Notebook Project*. Available at: http://www.epa.gov/Compliance/resources/publications/assistance/sectors/notebooks/index.html.

U.S. Environmental Protection Agency (EPA). 2006a. *Final Guidance EPA Rulewriters: Regulatory Flexibility Act as Amended by the Small Business and Regulatory Enforcement Fairness Act***.** http://www.epa.gov/sbrefa/documents/rfaguidance11-00-06.pdf.

U.S. Environmental Protection Agency (EPA). 2006b. *Regulatory Impact Analysis. 2006 National Ambient Air Quality Standards for Particulate Matter*. Chapter 5. Available at: http://www.epa.gov/ttn/ecas/regdata/RIAs/Chapter%205--Benefits.pdf.

U.S. Environmental Protection Agency (EPA). 2008a. *Integrated Science Assessment for Sulfur Oxides—Health Criteria* (Final Report). National Center for Environmental Assessment, Research Triangle Park, NC. Available at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=198843.

U.S. Environmental Protection Agency (U.S. EPA). 2008b. *Integrated Science Assessment for Sulfur Oxides—Health Criteria* (Final Report). National Center for Environmental Assessment, Research Triangle Park, NC. Available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=198843.

U.S. Environmental Protection Agency (U.S. EPA). 2008c. *Integrated Science Assessment for Oxides of Nitrogen—Health Criteria (Final Report).* National Center for Environmental Assessment, Research Triangle Park, NC. July. Available at at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=194645.

U.S. Environmental Protection Agency (U.S. EPA). 2008d. *Integrated Science Assessment for Oxides of Nitrogen and Sulfur–Ecological Criteria National* (Final Report). National Center for Environmental Assessment, Research Triangle Park, NC. EPA/600/R-08/139. December. Available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=201485.

U.S. Environmental Protection Agency (U.S. EPA). 2009a. *Regulatory Impact Analysis: National Emission Standards for Hazardous Air Pollutants from the Portland Cement Manufacturing Industry*. Office of Air Quality Planning and Standards, Research Triangle Park, NC. April. Available on the Internet at <http://www.epa.gov/ttn/ecas/regdata/RIAs/portlandcementria_4-20-09.pdf >.

U.S. Environmental Protection Agency (U.S. EPA). 2009b. *Integrated Science Assessment for Particulate Matter (Final Report)*. EPA-600-R-08-139F. National Center for Environmental Assessment—RTP Division. December. Available on the Internet at <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=216546>.

U.S. Environmental Protection Agency (EPA). 2009c. *Subpart AAA-Standards of Performance for New Residential Wood Heaters*. Discussion Draft. Available at: http://www.hpba.org/admin/NSPS-Review-Document.pdf.

U.S. Environmental Protection Agency (EPA). 2010a. *Integrated Science Assessment for Carbon Monoxide*. National Center for Environmental Assessment, Research Triangle Park, NC. EPA/600/R-09/019F. January. Available at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=218686.

U.S. Environmental Protection Agency (EPA). 2010b. *Final Regulatory Impact Analysis (RIA) for the SO_2 National Ambient Air Quality Standards (NAAQS)*. Office of Air Quality Planning and Standards, Research Triangle Park, NC. June. Available at: http://www.epa.gov/ttn/ecas/regdata/RIAs/fso2ria100602full.pdf.

U.S. Environmental Protection Agency (EPA). 2010c. *Guidelines for Preparing Economic Analyses*. EPA 240-R-10-001. Washington, DC: National Center for Environmental Economics, Office of Policy Economics and Innovation. Available at: http://yosemite.epa.gov/ee/epa/eed.nsf/pages/guidelines.html.

U.S. Environmental Protection Agency (EPA). 2010d. *Lowest Measured Level (LML) Assessment for Rules without Policy-Specific Air Quality Data Available: Technical Support Document*. Office of Air Quality Planning and Standards, Research Triangle Park, NC. July. Available at: http://www.epa.gov/ttn/ecas/regdata/Benefits/thresholdstsd.pdf.

U.S. Environmental Protection Agency (EPA). 2010e. *Regulatory Impact Analysis for the Proposed Federal Transport Rule*. Office of Air Quality Planning and Standards, Research Triangle Park, NC. July. Available at: http://www.epa.gov/ttn/ecas/regdata/RIAs/proposaltrria_final.pdf.

U.S. Environmental Protection Agency (EPA). 2010f. *Regulatory Impact Analysis for the SO_2 NAAQS.* Office of Air Quality Planning and Standards, Research Triangle Park, NC. June. Available at: http://www.epa.gov/ttn/ecas/regdata/RIAs/fso2ria100602full.pdf.

U.S. Environmental Protection Agency (EPA). May 2004. Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines. EPA420-R-04-007. Washington, DC: EPA. http://www.epa.gov/nonroad-diesel/2004fr/420r04007.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2010b. Technical Support Document: Summary of Expert Opinions on the Existence of a Threshold in the Concentration-Response Function for $PM_{2.5}$-related Mortality. Research Triangle Park, NC. June. Available on the Internet at www.epa.gov/ttn/ecas/regdata/Benefits/thresholdstsd.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2010c. *Guidelines for Preparing Economic Analyses*. EPA 240-R-10-001. National Center for Environmental Economics, Office of Policy Economics and Innovation. Washington, DC. December. Available on the Internet at <http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568-50.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2011a. *The Benefits and Costs of the Clean Air Act from 1990 to 2020*. Office of Air and Radiation, Washington, DC. March. http://www.epa.gov/air/sect812/feb11/fullreport.pdf. Accessed March 30, 2011.

U.S. Environmental Protection Agency (U.S. EPA). 2011b. *Regulatory Impact Analysis for the Final Transport Rule*. Office of Air Quality Planning and Standards, Research Triangle Park, NC. June. Available at http://www.epa.gov/airtransport/pdfs/FinalRIA.pdf.

U.S. Environmental Protection Agency. 2006. *Regulatory Impact Analysis, 2006 National Ambient Air Quality Standards for Particulate Matter*, Chapter 5. Available at <http://www.epa.gov/ttn/ecas/regdata/RIAs/Chapter%205--Benefits.pdf >.

U.S. Environmental Protection Agency. 2008a. *Regulatory Impact Analysis, 2008 National Ambient Air Quality Standards for Ground-level Ozone*, Chapter 6. Available at <http://www.epa.gov/ttn/ecas/regdata/RIAs/6-ozoneriachapter6.pdf>.

U.S. Housing and Urban Development (HUD). 2008. *American Housing Survey for the United States.* Multiple Years. Table 1A-5. Available at: http://www.census.gov/hhes/www/housing/ahs/nationaldata.html.

U.S. Small Business Administration (SBA), Office of Advocacy. May 2012. A Guide for Government Agencies, How to Comply with the Regulatory Flexibility Act, Implementing the President's Small Business Agenda and Executive Order 13272. Available at http://www.sba.gov/sites/default/files/rfaguide_0512_0.pdf.

U.S. Small Business Administration (SBA). 2013. Table of Small Business Size Standards Matched to North American Industry Classification System Codes. Effective July 14, 2014. http://www.sba.gov/sites/default/files/files/Size_Standards_Table(1).pdf.

Viscusi, V.K., and J.E. Aldy. 2003. "The Value of a Statistical Life: A Critical Review of Market Estimates throughout the World." *Journal of Risk and Uncertainty* 27(1):5-76.

Wade, S.H. 2003. "Price Responsiveness in the AEO2003 NEMS Residential and Commercial Buildings Sector Models." http://www.eia.doe.gov/oiaf/analysispaper/elasticity /pdf/buildings.pdf

Wood Heat Organization. 2010. "Fireplace Inserts: The Cure for Cold Fireplaces." Available at: http://www.woodheat.org/technology/inserts.htm.

APPENDIX

Documentation of Costs for Residential Wood Heaters NSPS

This appendix of the RIA documents the estimated nationwide cost impacts on manufacturers of emission reduction options being considered for residential wood heaters as part of the New Source Performance Standards (NSPS) review of residential wood heaters. Table A-1 presents the nationwide annual costs for each appliance type for manufacturers under the NSPS. The number of manufacturers and models for each appliance is included in this table. All cost estimates below are calculated using a 7% interest rate.

Table A-1. Nationwide Annual Costs to Manufacturers under the Final NSPS

				Nationwide Annual Costs[1]					
NSPS Subpart	Appliance Type	# Manufac-turers	# Models	(Step 1 compliance) 2015	2016	2017	2018	2019	(Ste compli 202
	Wood Stoves (R&D)[3]	34	125	$3,024,928	$3,024,928	$3,024,928	$3,024,928	$3,024,928	$3,0
	Pellet Stoves (R&D, R&R, cert)[4,7]	29	125	$1,484,192	$1,484,192	$1,484,192	$1,564,285	$1,564,285	$1,5
	Single Burn Rate Stoves (R&D, R&R, cert.)[5, 6, 7]	3	20	$1,057,518	$1,057,518	$1,057,518	$680,112	$680,112	$6
AAA: Room Heaters				$5,566,638	$5,566,638	$5,566,638	$5,269,325	$5,269,325	$5,2
	Forced Air Furnaces (R&D, R&R, cert.)[5, 6, 7]	7	50	$20,905,663	$20,905,663	$12,576,770	$12,593,240	$12,593,240	$12,5
	Hydronic Heaters (R&D, R&R, cert.)[7,8]	30	120	$24,855,398	$24,855,398	$24,855,398	$24,894,927	$24,894,927	$24,8
QQQQ: Central Heaters				$45,761,061	$45,761,061	$37,432,168	$37,488,168	$37,488,168	$37,4
Annual Cost of the Rule				$51,327,699	$51,327,699	$42,998,805	$42,757,493	$42,757,493	$42,7

It should be noted that Table A-1, is based on a 7% interest rate and are in 2013 dollars ($). We also prepared these cost estimates based on a 3% interest rate. Note also that costs vary by appliance type based on the average number of models per manufacturer. The estimate of the number of model types are described in the unit cost memo.[135] For numbers of manufacturers, we started with HPBA data, modified based on internet searches of manufacturers of the major appliance types. [136]

The total nationwide cost of the rule from years 2015 through 2020 differ based on the underlying cost and implementation assumptions described in this memo, and are summarized below in Table A-2. Annualized costs in Table A-2 are estimated based on a 7% interest rate.

Table A-2. Nationwide Annual Costs for 2015-2020

Year	Cost under Final Rule (2013$)
2015	51,327,699
2016	51,327,699
2017	42,998,805
2018	42,757,493
2019	42,757,493
2020	42,757,493

Finally, Table A-3 provides annual costs and emissions, and emission reductions respectively, for each year included in the analyses, including impacts of the rule beyond 2020, and cumulative impacts.

[135] Memo to Gil Wood, USEPA, from Jill Mozier, EC/R, Inc. Unit Cost Estimates of Residential Wood Heating Appliances. November 10, 2014.

[136] HPBA Solid Fuel Product List. Attachment to E-mail from John Crouch, HBPS, to Gil Wood, EPA. September 24, 2010.

Table A-3. Cost Effectiveness (CE) Based on Annual and Cumulative $PM_{2.5}$ Emissions from Central Heaters (Hydronic Heaters and Forced Air Furnaces) and Room Heaters (Wood Stoves, Pellet Stoves, and Single Burn Rate Stoves)

Table A-24. Cost Effectiveness (CE) based on annual and cumulative $PM_{2.5}$ emissions from Central Heaters (Forced Air Furnaces and Hydronic Heating Systems) and Room Heaters (Wood Stoves, Pellet Stoves, and Single Burn Rate Stoves)

Year [3]	Nationwide Annual Cost[1]	Nationwide Average Annual Cost	Annual Snapshots				Emission Reduction, cumulative per year			CE based on total cost & cumulative emission reduction over 20-year emitting lifespan (per ton)
			Baseline $PM_{2.5}$ Emissions[2] (tons)	NSPS $PM_{2.5}$ Emissions[2] (tons)	Emission Reduction (tons)[6]	CE based on nationwide average annual cost (per ton)	Baseline $PM_{2.5}$ Emissions (tons)	NSPS $PM_{2.5}$ Emissions (tons)	Emission Reduction (tons)[6]	
2015 [4]	$51,327,699	$19,075,401	12,120	8,075	4,046	$4,715	12,120	8,075	4,046	
2016 [4]	$51,327,699	$19,075,401	12,484	6,970	5,514	$3,459	24,604	15,044	9,560	
2017 [4]	$42,998,805	$19,075,401	12,858	3,016	9,842	$1,938	37,462	18,061	19,402	
2018	$42,757,493	$19,075,401	13,252	3,114	10,137	$1,882	50,714	21,175	29,539	
2019	$42,757,493	$19,075,401	13,649	3,208	10,441	$1,827	64,363	24,383	39,980	
2020 [4]	$42,757,493	$19,075,401	14,059	819	13,239	$1,441	78,421	25,202	53,219	
2021	$1,356,037	$19,075,401	14,480	844	13,636	$1,399	92,902	26,046	66,855	
2022	$1,356,037	$19,075,401	14,915	869	14,045	$1,358	107,817	26,916	80,901	
2023	$1,356,037	$19,075,401	15,362	895	14,467	$1,319	123,179	27,811	95,367	
2024	$1,356,037	$19,075,401	15,823	922	14,901	$1,280	139,002	28,734	110,268	
2025	$1,356,037	$19,075,401	16,298	950	15,348	$1,243	155,299	29,683	125,616	
2026	$1,356,037	$19,075,401	16,787	978	15,808	$1,207	172,086	30,662	141,424	
2027	$1,356,037	$19,075,401	17,290	1,008	16,282	$1,172	189,376	31,670	157,707	
2028	$1,356,037	$19,075,401	17,809	1,038	16,771	$1,137	207,185	32,708	174,477	
2029	$1,356,037	$19,075,401	18,343	1,069	17,274	$1,104	225,529	33,777	191,751	
2030							225,529	33,777	191,751	
2031							225,529	33,777	191,751	
2032							225,529	33,777	191,751	
2033							225,529	33,777	191,751	
2034							225,529	33,777	191,751	
2035							213,408	25,703	187,706	
2036							200,925	18,733	182,192	
2037							188,066	15,716	172,350	
2038							174,815	12,602	162,213	
2039							161,166	9,394	151,772	
2040							147,107	8,575	138,532	
2041							132,627	7,731	124,896	
2042							117,712	6,861	110,851	
2043							102,350	5,966	96,384	
2044							86,527	5,043	81,483	
2045							70,229	4,094	66,136	
2046							53,442	3,115	50,327	
2047 [3]							36,152	2,107	34,045	
2048 [3]							18,343	1,069	17,274	
Nationwide cumulative cost[5]		$286,131,014					Cumulative Emission Reduction over 20-year emitting lifespan		2,726,669	$105

[1] Estimated nationwide annual costs are in 2013 $ and are based on a 6-year amortization period of R&D costs at a 7% interest rate (during 2015-2020), plus annual certification and reporting & recordkeeping costs (ongoing through 2029, representing a 10-year model life). Years 2030 through 2048 are past the 10-year model design lifespan used in this analysis.

[2] Except for adjustments in years 2012 and 2018 based on an industry projections (NERA), estimated annual emissions are based on a forecasted revenue growth rate (as a surrogate for shipments) of 3% from 2015 through 2029, for the purposes of a sensitivity analysis.

[3] 2014 costs assume manufacturers will begin R&D phase and begin certifying models in anticipation of the 2015 rule compliance date. Emissions in 2014, however, are not included in this analysis because it is prior to the rule compliance date.

[4] Estimated emissions assume Step 1 standard becomes applicable in 2015 and Step 2 standard in 2020. No emission reductions are estimated to result from woodstoves and pellet stoves until 2020, although emission reductions are estimated for all other devices starting in 2015.

[5] The nationwide cumulative cost represents the cost to manufacturers resulting from the R&D re-design to meet the NSPS and the NSPS-caused certification and reporting & recordkeeping costs to bring these stoves to market from 2014 through 2029. These stoves have lifespans of 20 years or more; thus stoves shipped in 2029 will be emitting through 2048.

[6] In order to not overstate emission reductions caused by the NSPS, emissions are reduced to discount room heaters and central heaters already meeting the Step 2 limit (i.e., 26% of wood stoves, 70% of pellet stoves and 18% of hydronic heaters are estimated to already meet the Step 2 limit).

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