Journal of the Air & Waste Management Association

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/uawm20

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To cite this article: Arthur Marin, Lisa Rector, Barbara Morin & George Allen (2022) Residential wood heating: An overview of U.S. impacts and regulations, Journal of the Air & Waste Management Association, 72:7, 619-628, DOI: 10.1080/10962247.2022.2050442

To link to this article: https://doi.org/10.1080/10962247.2022.2050442

JOURNAL OF THE AIR & WASTE MANAGEMENT ASSOCIATION
2022, VOL. 72, NO. 7, 619–628
https://doi.org/10.1080/10962247.2022.2050442

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Residential wood heating: An overview of U.S. impacts and regulations

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ABSTRACT
Air pollution from residential wood heating poses a significant public health risk and is a primary cause of PM nonattainment in some areas of the United States. Those emissions also play a role in regional haze and climate change. While regulatory programs have focused on emissions reductions from large facilities, the residential heating sector has received limited attention. The failure to develop effective programs to address this emission source hampers the ability of state and local air quality programs to meet clean air goals. An updated New Source Performance Standard (NSPS) for Residential Wood Heaters was promulgated in 2015, which includes more stringent emissions standards for wood stoves and broadens its scope to regulate additional types of wood heating appliances. However, weaknesses in the test methods and programs used to certify compliance with the NSPS limits hamper the efficacy of those requirements. Current emissions certification tests measure stove performance under defined laboratory conditions that (1) do not adequately reflect operation and performance of appliances in homes, (2) are not sufficiently repeatable to allow for comparison of emissions of different appliances, and (3) allow manufacturers leeway to modify critical test fueling and operating parameters which can significantly impact performance outcomes. These foundational regulatory issues present substantial challenges to promoting the cleanest and most efficient wood heating systems. This paper provides an overview of the air quality and public health impacts of residential wood heating and discusses the weaknesses in the current emission certification approaches and work by the Northeast States for Coordinated Air Use Management (NESCAUM) and the New York State Energy Research and Development Authority to develop improved testing methods. Other articles in this issue discuss the development and testing of those methods in detail.

Implications: Air pollution from residential wood heating poses a significant public health risk and is a primary cause of PM nonattainment in some areas of the United States. Those emissions also play a role in regional haze and climate change. While regulatory programs have focused on emissions reductions from large facilities, the residential heating sector has received limited attention. The failure to develop effective programs to address this emission source hampers the ability of state and local air quality programs to meet clean air goals. This paper provides an overview of the issue.

PAPER HISTORY
Received October 20, 2021
Revised February 12, 2022
Accepted March 2, 2022

Introduction

While many view wood as a cleaner non-fossil energy source, wood combustion is responsible for a large portion of US particulate matter pollutant emissions. According to US EPA's National Emission Inventory, residential wood heating emitted approximately 340,000 tons of primary (directly emitted) $PM_{2.5}$ in the United States in 2017 (US EPA 2017). After road and agriculture dust and fires (wildfire and prescribed), residential wood heating was the largest source of primary $PM_{2.5}$ in the country, exceeding emissions from the highway and off-highway motor vehicle sectors, as shown in Figure 1.

In all but eight states,[1] residential wood heating is one of the top three contributors to PM2.5. Figure 2 provides emissions per year by state from residential wood heating based on 2017 NEI data. Residential wood heating is also a significant source of polycyclic aromatic hydrocarbons (PAH), carbon monoxide (CO), nitrogen oxides (NOx), black carbon, methane, benzene, acrolein, and formaldehyde. While the determination of carbon benefits of wood heating is influenced by the time horizon used in that calculation, it is clear is that wood combustion emits other climate-warming pollutants of concern, including methane, black carbon, and ozone precursors, which are indirect greenhouse gas emissions – NOx, and volatile organic compounds (VOCs).

From an air quality and public health perspective, the relative importance of emissions from wood heating has grown as regulations for other air pollution source categories such as motor vehicles, power plants, and industrial sources have effectively reduced emissions from those sources (Ciaizzo et al. 2013; Penn et al. 2017). By contrast, effective regulation of emissions from the wood heating sector has been limited. In 1988, US EPA adopted

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[1]Based on 2017 NEI data District of Columbia, Hawaii, Louisiana, North Dakota, Tennessee, Texas, Utah, Wyoming

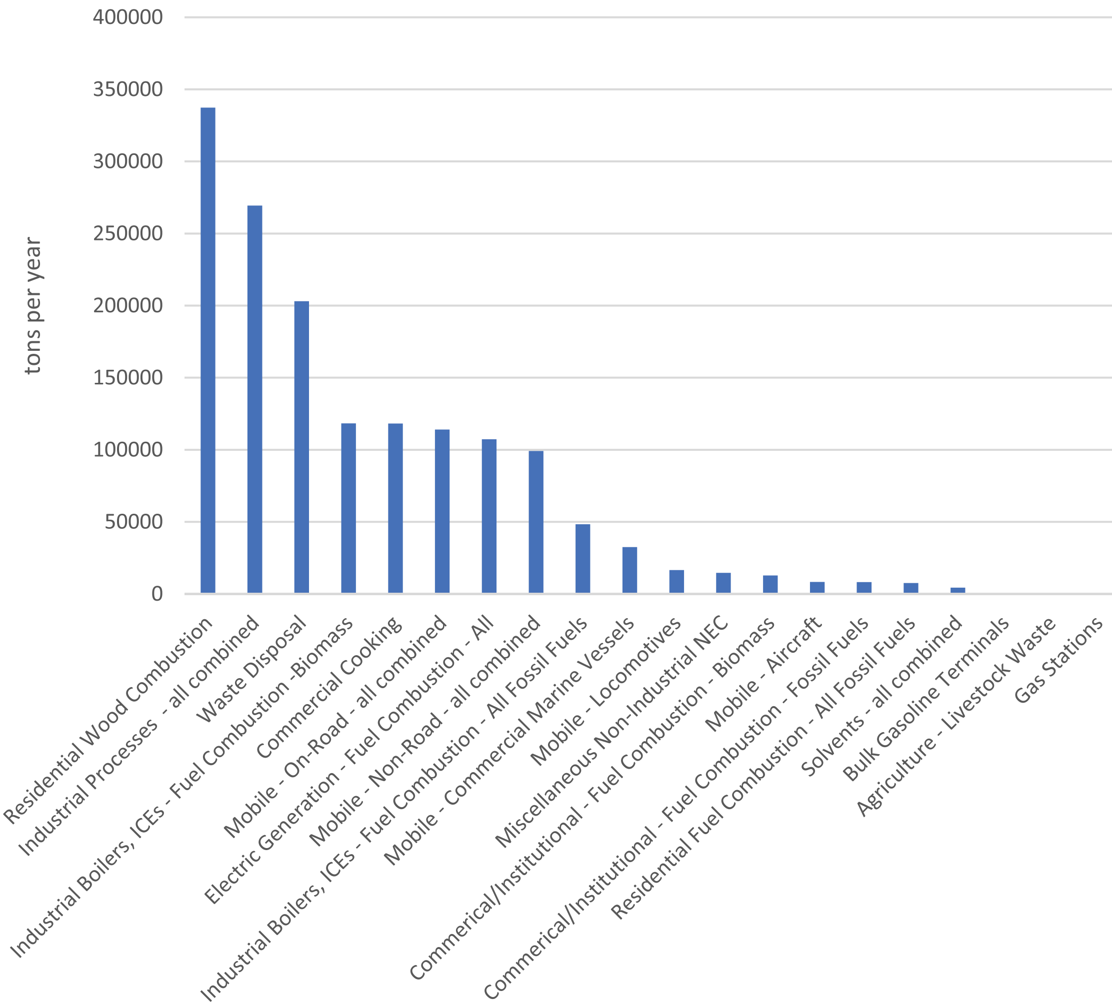

Figure 1. National $PM_{2.5}$ inventory by sector, excluding dust and fire categories (2017 NEI).

New Source Performance Standards (NSPS) for Residential Wood Heaters, which were limited to wood stoves (Federal Register 1988). Revisions of the NSPS in 2015 established more stringent limits and expanded the universe of regulated devices to include single burn-rate and adjustable burn-rate wood stoves, pellet stoves and furnaces, outdoor and indoor wood boilers, and indoor wood-burning forced air furnaces. Those requirements became fully effective in 2020 (Federal Register 2015). The 2015 rule continues to exempt other solid fuel appliances, such as coal units, which can burn wood, and nonresidential appliances.

Emission testing is a highly technical aspect of residential wood heating regulatory requirements, but those tests are critical to identifying low emitting technologies. Certification tests that do not reflect in-use appliance performance hamper the effectiveness of state consumer incentive programs in promoting the cleanest and most efficient wood-fired heating and maximizing emissions reductions.

Current test methods used in the U.S., Canada, and Europe measure emissions under defined laboratory conditions that are not representative of real-world appliance operation. Typically, those tests measure emissions only under steady-state conditions and allow the manufacturer or testing laboratory broad discretion in determining fueling and other testing parameters. When operated in a home, an appliance responds to calls for heat from thermostats or, for manually operated appliances, is subject to homeowner fueling and operating practices. Therefore, appliance operation is characterized by highly variable loads and transitory conditions over the course of a day, including warm and cold starts and burnout periods, which affect efficiency and emissions. (Ahmadi et al. 2020) To reflect in-use operations, testing protocols for manually operated technologies must measure emissions under a range of fueling load and operating conditions, including cold start-ups, varying fuel load sizes, and piece configurations. Protocols that accurately measure emissions from

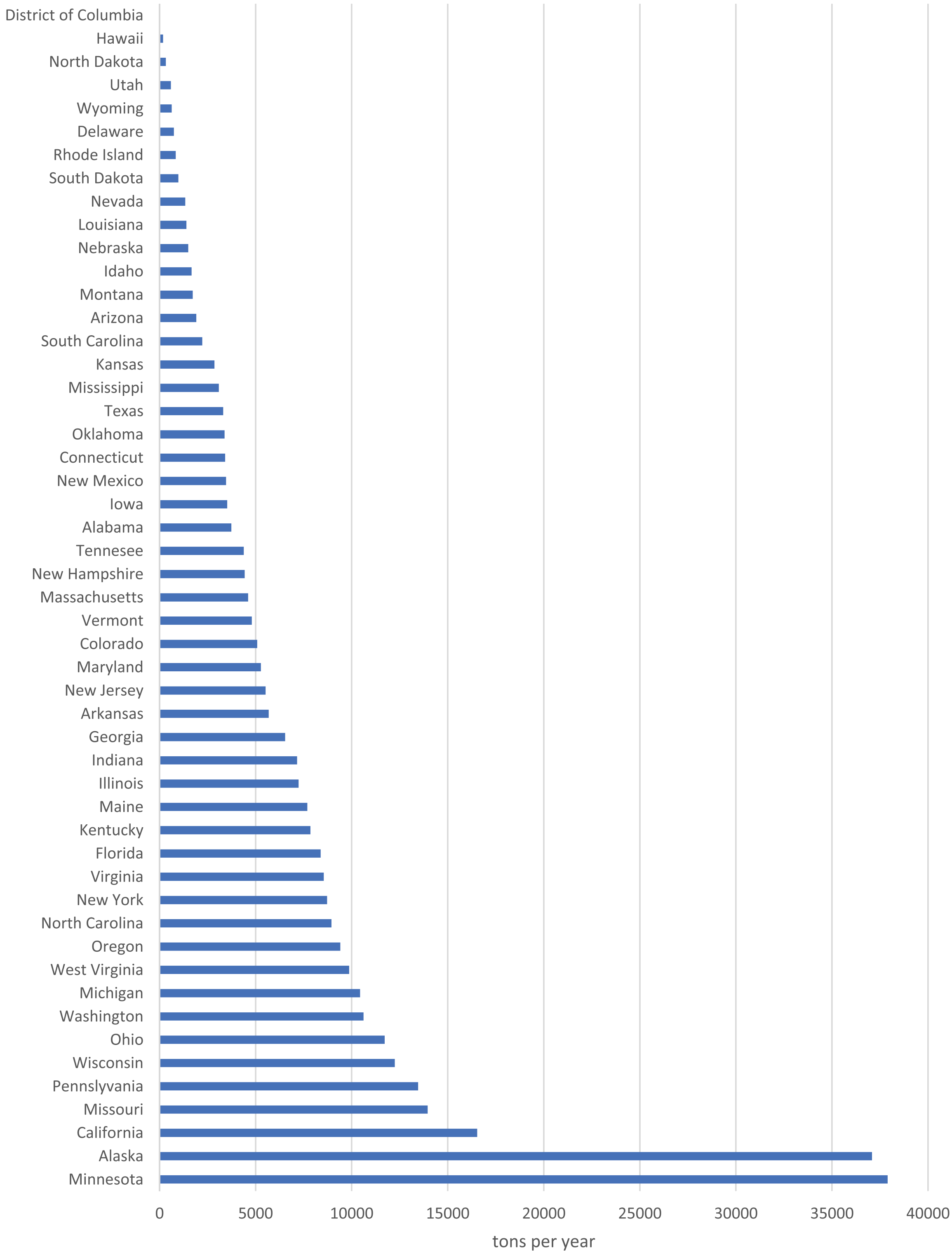

Figure 2. Residential wood heating $PM_{2.5}$ emission by state in tons per year (EPA 2017 NEI).

thermostatically controlled devices must mimic the cyclic operation patterns typical of those appliances, including start-up, cyclic and low load performance periods.

The papers in this issue primarily focus on work supported by NYSERDA to improve the understanding of residential wood heating impacts, evaluate existing test methods, and develop and evaluate improved procedures. However, compliance monitoring is also an essential element of an effective and robust certification program. US EPA has conducted little compliance oversight or audit testing to confirm the effectiveness of their residential wood heating regulations. Lack of proper oversight and auditing gives manufacturers an incentive to conduct tests under unrealistic conditions, which minimize emissions. Without that oversight, the current federal certification program provides little confidence that new residential wood heaters will improve air quality and public health protections than the heaters they replace.

Air quality impacts of residential wood burning

Cordwood, wood pellets, and wood chips are important residential heating fuels in the United States. Of the 12.5 million homes using wood fuel for heating, data indicate that use is more common in rural versus urban households. Data suggests that 27% of rural households used wood for heating while 6% of urban households use wood heating (US Energy Information Administration 2018). The US EPA estimates that residential wood combustion sources emitted approximately 340,000 tons of $PM_{2.5}$ in 2017. That year, wood-burning provided only 2.2% of residential energy in the United States (US EIA, 2020) but was responsible for 98% of fine particulate matter ($PM_{2.5}$) emissions from residential fuel combustion sources. (US EPA 2017) Residential wood heating emissions contribute significantly to nonattainment of the National Ambient Air Quality Standard (NAAQS) for $PM_{2.5}$ in some areas and are also seen as an increasingly important contributor to cold season regional haze in some areas of the country, including the Northeast and Mid-Atlantic regions.

Emissions from wood-burning contain polycyclic organic matter (POM), benzene, aldehydes, and other carcinogenic compounds. The US EPA estimates that residential wood heating accounts for 44% of POM emitted by all stationary and mobile sources (US EPA 2015). Wood heating appliances also emit CO, VOC, NOx, and other gaseous pollutants (McDonald et al. 2000; Johansson et al. 2004; Glasius et al., 2008; Bari et al. 2009; Schmidl et al. 2011; Pettersson et al. 2011; Piazzalunga et al. 2011). In 2017, New York State residential wood heating appliances emitted 17,217 tons of $PM_{2.5}$ and 13,103 tons of VOCs, accounting for 51% and 69%, respectively, of emissions of these pollutants from all fuel combustion in the commercial, industrial, institutional, and residential sectors combined. (US EPA 2017).

Wood heating is a significant source of ambient PM concentrations in many cities, towns, and villages in the northeast states and elsewhere. In the NESCAUM region (New England, New Jersey, and New York), residential wood combustion has a disproportionate impact on air quality due in large part to the Northeast's colder climate and the relative abundance of wood for fuel. Croft et al. (2017) determined that residential wood combustion contributed up to 30% of ambient PM levels in Rochester, New York during cold weather periods. Blanchard et al. (2021a) found that four source types showed declining contributions to EC and OC at the Pinnacle State Park location between 2001 and 2015: (1) fossil-fuel combustion associated with SO_2, (2) combustion not associated with SO_2 (tentatively identified as mobile sources), (3) crustal OC and EC, and (4) sulfate-associated OC and EC. However, OC and EC improvements from emission reductions were partly offset by increasing concentrations of biomass-burning. Biomass burning contributions increased the mean EC and OC concentrations by 13–18% and 23–30%, respectively at the monitoring location. Blanchard et al. (2021b) found that while PM 2.5 emissions decreased 29% in New York State between 2007 and 2019, biomass burning and photochemical secondary aerosol are the critical areas for further reductions. The study also found that wood heating emissions decreased from 2015 through 2019. These decreases could be associated with lower costs for home heating oil during this period.

Studies conducted by the Vermont Department of Environmental Conservation and NESCAUM found that, during the coldest and calmest winter days in Rutland, Vermont, wood combustion accounted for half or more of measured ambient $PM_{2.5}$ concentrations (Allen, Babich, and Poirot 2004). In the first two months of 2014, Rutland experienced daily $PM_{2.5}$ concentrations of almost 20 micrograms per cubic meter ($\mu g/m^3$), nearly twice the level of the annual $PM_{2.5}$ NAAQS of 12 μg/m3. During this same period, the area also experienced maximum hourly concentrations greater than the 35 μg/m3 daily NAAQS on more than half the days, with peak hourly concentrations exceeding 90 $\mu g/m^3$ at the Rutland $PM_{2.5}$ monitoring site.

More than 90% of ambient carbonaceous PM2.5 is from wood combustion in rural counties in New York State, and winter nighttime town/village peak levels can exceed 100 $\mu g/m^3$ (Graham and Johnson 2008; Allen et al., 2020). These results are consistent with a field study by NESCAUM in the Adirondacks region that found significant localized pollution from wood heating was closely associated with the higher population densities of the towns and villages (Allen et al. 2011). Since many rural areas lack air quality monitors, the true magnitude of this problem is difficult to quantify, but wood heating presents a public health risk in many areas. Since there is no clear evidence to the contrary, for the purposes of this work, we are assuming the health risks from wood smoke exposure on a mass concentration basis are similar to the risks of ambient PM2.5 and that the magnitude of the health risks quantified in the epidemiological literature applies to wood smoke PM2.5 also. Wood combustion pollution is not isolated to mountainous areas where valley temperature inversions exacerbate PM emission levels. Studies in

Connecticut have found that, on cold winter days, observed wood smoke contributes over 50% of hourly $PM_{2.5}$ when ambient concentrations are elevated (CT-DEP, 2011). These data suggest that residential wood heating emissions substantially contribute to elevated daily and long-term average $PM_{2.5}$ levels in these and similar areas across the country.

Wood heating also has been identified as a contributor to regional haze in some parts of the country (NESCAUM 2012). Wood combustion particles are generally smaller than 1 μm, with a peak in the size distribution between 0.15 and 0.4 μm (Kleeman, Schauer, and Cass 1999). Wood heating emissions contain many ultrafine particles, less than 100 nm, which rapidly agglomerate as they cool and age. Particles below 0.5 μm are not easily removed by gravitational settling and, therefore, can be transported over long distances (Echalar et al. 1995).

Public health impacts of residential wood burning

Wood combustion emission constituents, including $PM_{2.5}$, CO, and NOx, are associated with adverse respiratory and cardiac health effects and increased mortality. (Boman 2006; Naeher et al. 2007; Pope and Dockery 2006). Short-term exposures to wood combustion emissions aggravate many types of lung diseases, can cause asthma attacks and acute bronchitis, and may increase susceptibility to respiratory infections. Low-level exposure to wood combustion products can reduce pulmonary function and lower blood oxygen concentrations (Environment & Human Health, Inc 2018). Those exposures are especially harmful to children, the elderly, and people with lung and heart disease.

Wood heating emissions also contain a number of carcinogenic compounds, including POM, benzene, and aldehydes. US EPA estimates that this source is responsible for 25% of cancer risk and 15% of all non-cancer respiratory effects attributed to area source air toxics emissions (US EPA 2018). Given that rates of wood heating appear to be underestimated by the sources used to develop these risk assessments, the actual impact may be more significant.

Exposure to wood smoke is associated with a risk of developing COPD due to airway obstruction. Among women and smokers exposed to wood combustion emissions, the prevalence of COPD is especially high. The incidence of COPD in individuals exposed to wood combustion emissions increases significantly with the duration of exposure. These emissions also exacerbate asthma symptoms with higher rates in areas where wood burning takes place over a sustained period (Naeher et al. 2007). Hopke et al. (2020) found a positive association between asthma emergency department visits and biomass burning.

Tsiodra et al. (2021) found that local winter biomass burning for heating purposes was one the most important contributors to the carcinogenic toxicity of PAH emissions in their inventory. The wintertime exposure from wood heating was identified as the most important contributor (76%) to increased excess lifetime cancer risk. The increased risk was attributed to nineteen of the 105 evening episodes measured.

Exposure to wood smoke causes the arteries to become stiffer, which raises the risk of dangerous cardiac events. (Unosson et al. 2013). For pregnant women, wood combustion exposure can result in a higher risk of hypertensive pregnancy disorders, including preeclampsia and gestational high blood pressure (Assibey-Mensah et al. 2019).

The impacts of wood smoke are not distributed equally across the population base, and likely have disproportionate impacts on rural and some low-income communities. Reliance on wood heating as a primary fuel source is most prevalent in rural communities. While wood heating devices are more likely to be found in homes with higher incomes, the amount of wood burned during the heating season is highest in households with annual incomes less than $40,000 per year. The amount of wood used for heating decreases with increasing income, suggesting a heavier reliance on wood heating in lower-income households. (US EIA, 2018) Consequently, residents of rural and low-income communities are more likely to be affected by adverse public health outcomes associated with exposure to wood smoke. Rogalsky et al. (2014) estimated that between 500,000 and 600,000 low-income people in the United States are likely exposed to hazardous air pollutants from burning solid fuels in their homes.

Disparities in exposures across communities were further demonstrated in the Oregon Department of Environmental Quality Project (Portland Air Toxics Solutions – PATS). Exposure modeling of the Portland metro region in that study determined that residential wood heating was the second-largest source of air toxics in the area, after gasoline and diesel engines, largely due to emissions of 15 PAH (polycyclic aromatic hydrocarbons) and naphthalene. The PATS study also found that three of the four major residential wood heating pollutants analyzed negatively impacted children's health. In addition, the PATS study found that Hispanics/Latinos and Asian communities tended to be disproportionately impacted by residential wood combustion in the Portland metro area (Oregon DEQ 2018).

Regulating emissions from wood burning devices

The 2015 NSPS for residential wood heaters established emission limits for new wood-fired stoves and wood-fired central heating systems. Compliance with emissions limits is determined by testing a prototype unit. There are no emission limits or stack testing requirements for installed appliances in the US. Compliance certificates are granted for five-year periods but are typically renewed every five years without retesting if the manufacturer did not make design changes. US EPA regulations require the agency to review NSPS requirements every eight years and revise the emissions standards accordingly if improved technology has been demonstrated. However, the 2015 revisions to the NSPS for residential wood heating devices were the first revisions since the original promulgation of the NSPS in 1988. Some state and local governments have also implemented strategies intended to reduce exposure from wood heater emissions.

The 2015 NSPS established two sets of emission limits; Step 1 standards, which were in effect from May 2015 to May 2020, and more stringent Step 2 standards, which became effective in May 2020. In most areas of the country, the Step 1 standards provided minimal emission reductions because 90% of appliances sold already met that standard when the rule took effect. Step 1 was included to allow the industry five years to develop and test new appliances to meet the Step 2 standards. The 2015 revisions also broadened the universe of residential wood heating devices subject to emission standards, including central heating devices such as hydronic heaters (outdoor wood boilers) and other appliances not previously covered by the NSPS. In November 2018, the US EPA proposed extending the sale of non-Step 2 compliant units until November 30, 2020, but this proposal was withdrawn (Federal Register 2020).

The federal emission certification program requires manufacturers to demonstrate under laboratory conditions that a prototype wood-burning device can meet applicable emissions standards. The test methods used for certifying compliance prescribe the fuel use and configuration in the firebox, the burn cycle, and emission measurement techniques. States, industry, and US EPA are all on record supporting changing the procedures used to test wood heat devices in order to make the emission certification process more representative of real-world emissions than with the current test methods.

Given the long useful life of these devices, the benefits of new emissions standards accrue slowly over time, as new cleaner and more efficient units replace older, high-emitting appliances. Problems with the efficacy of the current testing and enforcement approach hamper the assessment of the performance of new models and further reduce actual emission reductions attributable to the standards (NESCAUM 2021). Under the provisions of the Clean Air Act, the next NSPS review for this source category should be completed by 2023, providing an important opportunity for updating and improving the certification testing and compliance and enforcement elements of the program. Recommendations for strengthening the program are discussed in the following sections of this article.

US EPA's certification testing program

Currently, the only assessment of an appliance's emissions performance occurs during the certification test. Tests are conducted by US EPA-approved laboratories on prototype appliances before a model line is in production. Appliances available in the retail market may also be subject to random tests to ensure that production models meet the standards. Third-party certifiers accredited by the International Standards Organization (ISO) and paid by the manufacturer are charged with reviewing certification test reports, conducting compliance inspections, and issuing certificates of conformity for test reports. The NSPS allows the same company to conduct the certification test and complete third-party review activities. Applications for certification must include a quality assurance program, but those programs' details and efficacy are often submitted to US EPA as confidential business information.

The US EPA has the authority to conduct random compliance audit testing but has not done so in the seven years since the promulgation of the 2015 NSPS. Industry unsuccessfully challenged the compliance audit provisions of the 2015 NSPS in 2021 (US Court of AppealsCir, D. C. 2021). In 2021, NESCAUM issued a report evaluating the effectiveness of the ISO-accredited, third-party system for emission test certification and review created under the 2015 NSPS, and assessing US EPA oversight and enforcement of this process (Rector et al. 2021). The study completed a "screening" level desk audit of certification test reports which evaluated the following elements: (1) completeness of the data sets, (2) consistency of the test results, and (3) error magnitudes where they can be estimated. The evaluations identified models that require additional review by the US. EPA due to significant problems in their certification tests. The analysis found widespread failures in the third-party review system and a lack of effective oversight and enforcement by US EPA. The review concluded that the current state of US EPA's federal certification program provides little confidence that new residential wood heaters will meet the NSPS limits when operated in the field. Rector et al. (2021) is a report prepared by some of the authors that provides a detailed treatment of the issues raised in this paragraph.

Wood device emissions and test methods

Emission certification testing procedures are critical to designing, manufacturing, and selling cleaner-burning wood heating appliances. According to US EPA, "the fueling and operating test methods prescribed by the 2015 NSPS represent a step in the process toward better test methods, rather than the end goal." (US EPA 2016).

This source category poses unique regulatory challenges because emissions from wood heating devices are far more variable in their performance than from burning other fuels. Natural gas and heating oil are homogeneous fuels with consistent physical and chemical parameters. By contrast, the wood burned in residential wood heaters is highly heterogeneous, encompassing a range of species, moisture contents, piece sizes, densities, bark, and resin contents. Gas and oil fuels are mechanically fed to the heating appliances. The user manually fills cordwood stoves and central heating units, which introduces the potential for load-to-load variability in fueling. Further, users control many operating parameters, including door position, airflow, and other settings, which affect appliance performance and emissions.

Existing test protocols vary significantly in their design and rigor and do not all measure the same performance parameters. Because the NSPS allows multiple test methods, emission and efficiency results are often not comparable across models even within the same appliance category. While no test procedure can capture the full range of factors that affect emissions from wood heating devices in the real world, effective emission certification test methods must include some common practices that ensure appliances can operate well and within similar parameters under various conditions.

The current federal reference method (FRM) for certification of woodstoves, US EPA's Method 28 R (M28R) crib wood test, is a "hot-to-hot" steady-state test that burns a specified configuration of dimensional Douglas fir lumber with spacers, rather than typical cord firewood. Emissions are not measured during start-up or reload periods. The fueling and operating conditions specified in that test method are designed to increase the consistency of results. However, the results measured using this test method are not representative of in-use emissions. Moreover, "tuning" of stoves to minimize emissions in M28R laboratory tests can result in suboptimal performance during in-field operating conditions.

The 2015 NSPS acknowledged that, "Cord wood testing is a better measure of how the heaters will perform on the type of fuel commonly used in homes" and set a less stringent NSPS limit for stoves tested using a cordwood test method. The US EPA has approved the Canadian CSA B415.1–10 cordwood test as a FRM for emissions testing of furnaces and for calculating efficiency and carbon monoxide for all appliances. ASTM International has developed cordwood testing procedures for residential wood stoves (ASTM E3053) and central heating appliances (ASTM E2618-13). US EPA has accepted the central heating protocol as a FRM. In 2018, US EPA designated ASTM's woodstove protocol – ASTM E3053 – as a broadly applicable Alternative Test Method (ATM) in early 2018, which means it can be used in lieu of the FRM, M28R, for certifying wood stoves. However in January 2022 EPA revoked the broadly applicable ATM status to ASTM 3053- based test methods and withdrew its approval to use these test methods to demonstrate compliance with EPA emission standards. (Federal Register 2022)

The companion papers in this issue report on research that demonstrates that moving from a dimensional lumber-based test to a cordwood test is not sufficient to generate laboratory results that correlate with field performance. Like M28R, the ASTM and CSA cordwood test methods rely on steady-state testing under single load conditions. In addition, those protocols allow manufacturers significantly leeway in determining the fueling and operating conditions used in laboratory testing, allow for the elimination of high-emitting valid runs, permit the use of alternative data to calculate efficiency values, and lack replicate runs that could be used to assess the reproducibility of the results and the consistency of the appliance's performance. Independent ASTM E3053 tests performed at a US EPA approved laboratory on seven stoves that had been Step 2 certified using that method measured emissions considerably higher than both the certification result and the NSPS emissions limit. In May 2021, nine state Attorneys General submitted a request to US EPA to revoke the Broadly Applicable ATM status granted to the ASTM 3053 test method. In January 2022, EPA formally revoked the broadly applicable use of ASTM 3053-based test method, but allowed the appliances certified with this test method to remain in the marketplace.

Currently, EPA only sets emission standards for total particulate matter. One of the primary approaches used to reduce PM from this source category are change-out programs, which remove old technology and replace it with newer technologies. Little data has been gathered to assess the greenhouse gas and air toxics impacts of new technologies. Other companion papers provide data on emissions that are not currently regulated but perhaps should be considered to provide a comprehensive assessment of appliance performance.

Several of the papers in this issue report on the development and evaluation of a new set of testing protocols for stoves and central heating units known as Integrated-Duty Cycle (IDC) tests. Those protocols are designed to produce accurate results that are representative of in-use conditions, repeatable, affordable, and address many of the shortcomings of the US EPA, ASTM, and CSA test methods. The IDC procedure for cordwood stoves, which US EPA approved as a broadly applicable ATM in 2021, assesses appliance emissions over a range of operating and fueling conditions representing typical consumer use patterns in a single integrated test run. Similarly, the IDC procedure for testing hydronic heaters, which is still in development, tests appliance performance under a range of heat demands and includes multiple fueling events, typical of field use patterns.

To effectively characterize in-use emissions in a reproducible manner, the IDC protocols address the three primary components of testing procedures: (1) fueling, (2) operations, and (3) PM measurement. The protocol requires emissions measurements under typical in-use fueling practices, including a range of piece sizes, loading densities, configurations, and fuel characteristics, such as species, moisture content, and bark content. The operating parameters in the protocols are also designed to reflect the range of conditions that the appliance will experience in field operations, including variable air settings and cold and warm start-up events. Real-time PM measurement methods, which allow for the assessment of peak short-duration emissions and the single value for a test run measured in traditional tests, are used in those methods. The protocols are designed to complete a run in a single day, making it feasible to conduct three replicate runs to assess the variability of stove performance.

Test method development is complex and requires significant resources for data gathering and analysis. NYSERDA and NESCAUM have conducted more than 500 tests on over 30 residential wood heating appliances. That research, presented in this issue and in subsequent journal articles, addresses US EPA's direction in their 2016 Discussion Paper on Cordwood test methods that "the goal of robust new test methods should be to assess an appliance's ability to operate cleanly under highly variable conditions, both in terms of fueling and operations." (US EPA 2016).

Conclusion

Reducing emissions from new residential wood heating appliances is essential to address the public health and environmental impacts associated with wood combustion. The 2015 NSPS update for this source category was an important step toward that goal. However, as described in this paper, weaknesses in the design and implementation of that program limit the potential benefits of the regulatory requirements. The NSPS Step 2 emission standards, which became effective in May 2020, are designed to promote the manufacture of cleaner-burning residential wood heating appliances. However, current federal emissions certification testing methods provide little confidence that the program can identify devices that will consistently operate well in the field. US EPA has announced its intent to promulgate new test methods as part of the next NSPS update, which is due to be completed in 2023. The pending NSPS review represents an important opportunity to address the weaknesses in the federal program by implementing new certification procedures and strengthening administrative and enforcement components of the residential wood heating program.

Acknowledgment

Funding for this project was provided by the New York State Energy Research and Development Authority (NYSERDA), Agreement #123059, and the authors thank Dr. Ellen Burkhard, NYSERDA Project Manager, for helpful comments throughout the project. The opinions expressed in this report do not necessarily reflect those of NYSERDA or the State of New York. Mention of product manufacturer names or trademarks does not imply endorsement by NESCAUM or NYSERDA.

Data Availability

The data that support the findings of this study are available from NESCAUM, upon reasonable request.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Funding

This work was supported by the New York State Energy Research and Development Authority [123059].

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