Docket ID No. EPA-HQ-OAR-2018-0195

ATTACHMENT I TO HEARTH, PATIO & BARBECUE ASSOCIATION COMMENTS

James E. Houck, Ph.D., "A Comparison of Particulate Emission Rates from the In Home Use of Certified Wood Stove Models with USEPA Certification Emission Values and A Comparison Between In Home Uncertified and Certified Wood Stove Particulate Emissions" (Feb. 1, 2012), *previously docketed as* EPA-HQ-OAR-2009-0734-0143

A Comparison of Particulate Emission Rates from the In-Home Use of Certified Wood Stove Models with U.S. EPA Certification Emission Values

and

A Comparison between In-Home Uncertified and Certified Wood Stove Particulate Emissions

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Executive Summary

The ability of wood stove NSPS certification values to predict field rankings among wood stove models and the degree to which they correspond to the magnitude of actual in-situ emissions for a given model were investigated. In addition, real-world emissions from certified wood stove models were compared to uncertified models. Both emission rates (g/h) and emission factors (g/kg) were used in that comparison. The effect of efficiencies on emissions was also taken into consideration in the comparison of mean certified with mean uncertified emission factors because higher efficiencies correspond to less fuel being burned to satisfy a given heating demand; effectively lowering emissions of certified models.

Emission data from in-home sampling programs plus laboratory studies designed to simulate in-home use of wood stoves were reviewed. Two sampling systems that have undergone U.S. EPA quality assurance reviews were used for the field studies included in this evaluation. These were the Automated Woodstove Emission Sampler (AWES) and the Virginia Polytechnic Institute (VPI) sampler. Laboratory measurements were made using either Methods 5G or 5H (40 CFR Part 60 Appendix A) while the stoves were operated in a fashion simulating in-home burning conditions. The methods used to convert AWES and VPI data to method 5H equivalent data were developed as part of the documentation for AP-42 Section 1.10 Residential Wood Stoves and were followed here. Laboratory programs measured emissions directly by method 5H, method 5G, or both. Where necessary, Method 5G values were converted to 5H equivalent values as per 40CFR Part 60 Appendix A.

Published U.S. EPA certification values in units of grams/hour (g/h) were compared to measured 5H adjusted emission rates (g/h) for each certified woodstove model. Throughout this evaluation "5H equivalent" emission factors and emission rates were used.

A robust database comprised of 618 total measurements was used for this evaluation. For the certified stoves, in total 409 emissions tests from 85 wood stoves comprised of 41 models were reviewed. For the uncertified stoves, 209 emissions tests on 62 stoves were reviewed. (The number of uncertified models included in the tests could not be determined as the specific uncertified models used in the tests were not always reported.) For the certified models there were 208 valid AWES samples and 165 valid VPI samples in the database. In addition, there were 36 individual valid laboratory samples. For the uncertified models there were 124 valid AWES samples, 65 valid VPI samples and 20 individual valid laboratory samples.

For certified wood stoves, to be considered valid, a sample had to be for a certified wood stove model for which the certification value could be identified and the fuel species (or type), fuel moisture (% dry basis), and burn rate (dry kg/h) have had to been reported. Similarly, for uncertified wood stoves like criteria were considered necessary for a valid sample except, of course, there were no certification values.

The average of the default efficiencies reported in the CFR as part of the NSPS and the efficiencies tabulated in AP-42 were used as the efficiency values for the efficiency adjusted emissions comparisons made here. While both sources are based on limited data, they represent arguably the best and most credible efficiency data available. A cursory review of older

efficiency studies for uncertified models and miscellaneous studies with the laboratory operation of certified models suggests that the NSPS and AP-42 values are reasonable for the in-home operation of stoves.

Figure ES1 is a plot of the individual emission rates (g/h) determined for each of the 409 valid "real-world" samples versus the U.S. EPA certification values for each certified stove model. Figure ES2 shows the U.S. EPA certification value for each stove model and the mean emission rate for each stove model averaged across all samples for that stove model. As can be seen from the figures, there is no correlation between certification values and the in situ emission rates and in most cases the magnitude of the emission rate for given sample is larger than the certification value.

To mitigate (and to "smooth") the impact of the various in-home conditions on emissions and the demonstrated uncertainty of the certification testing process, means by certification category were compiled. The three certification categories were: (1) Low (<3 g/h), (2) Medium (3-5 g/h), and (3) High (> 5g/h). Figures ES3 and ES4 show the emission rate and emission factor means of these three categories of certification values for the stoves from which they were measured. As can be seen, even when grouped by category, the U.S. EPA certification values do not predict the relative ranking of the stoves under real-world use. In fact, the "Low" category had higher mean emission rate and factor values than the "High" category. In addition, the U.S. EPA certification values do not predict the magnitude of the real-world emissions. The overall average of all 409 samples was 10.5 g/h as compared to the average certification value of the 41 certified stove models reviewed here of 3.9 g/h.

In addition to the means for the certified stove categories, the means for uncertified stoves are also shown in Figures ES3 and ES4. The data for uncertified stoves shown in Figures ES3 and ES4 confirm that certified stoves do have substantially lower particulate emissions under real-world, in-home usage as compared to uncertified models.

Finally, when comparing particulate emissions on the basis of emission factors, the greater efficiency of certified stoves as compared to uncertified stoves was taken into consideration as less fuel would be burned in a stove with a higher efficiency to satisfy the same heating demand and hence less emissions would be produced. Figure ES5 shows that the effective mean emission factor of certified wood stoves when adjusted for efficiency is 52% of that uncertified ones which compares favorably with the fact that the mean emission rate of certified wood stoves is 47% of the uncertified wood stove mean (Figure ES3).

While it was not among the primary objectives of this study, because both wood moistures and burn rates have been strongly implicated in affecting emissions from wood stoves and because both parameters were quantified in the studies from which the data compiled here were obtained, burn rates and wood moistures were plotted against emission rates and emission factors. Figures ES6 and ES7 are the plots of emission rates and emission factors versus the burn rate and wood moisture data. As can be seen in reviewing Figures ES5 and ES6 any clear relationship that these two parameters alone might have with emissions is clearly obscured by other real-world variables. It should, however, be noted that while there is no statistical trend Figure ES6 shows that higher emission factors (g/kg) are more common at lower burn rates.

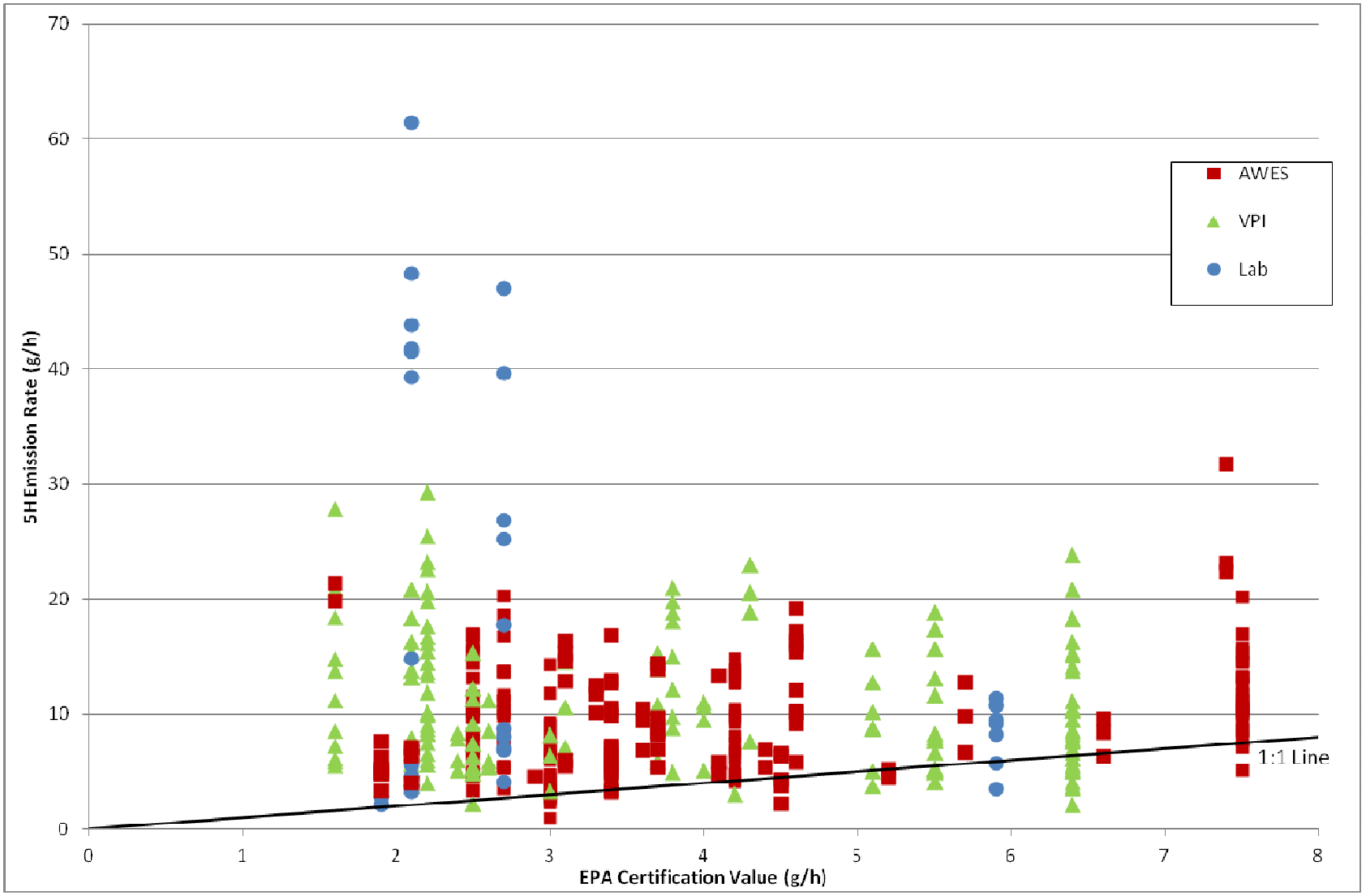

Figure ES1. Emission Rates by Test Run versus EPA Certification Values for Stove Models . ("Lab" refers to tests conducted in the laboratory using consumer burn practices not EPA Method 28.)

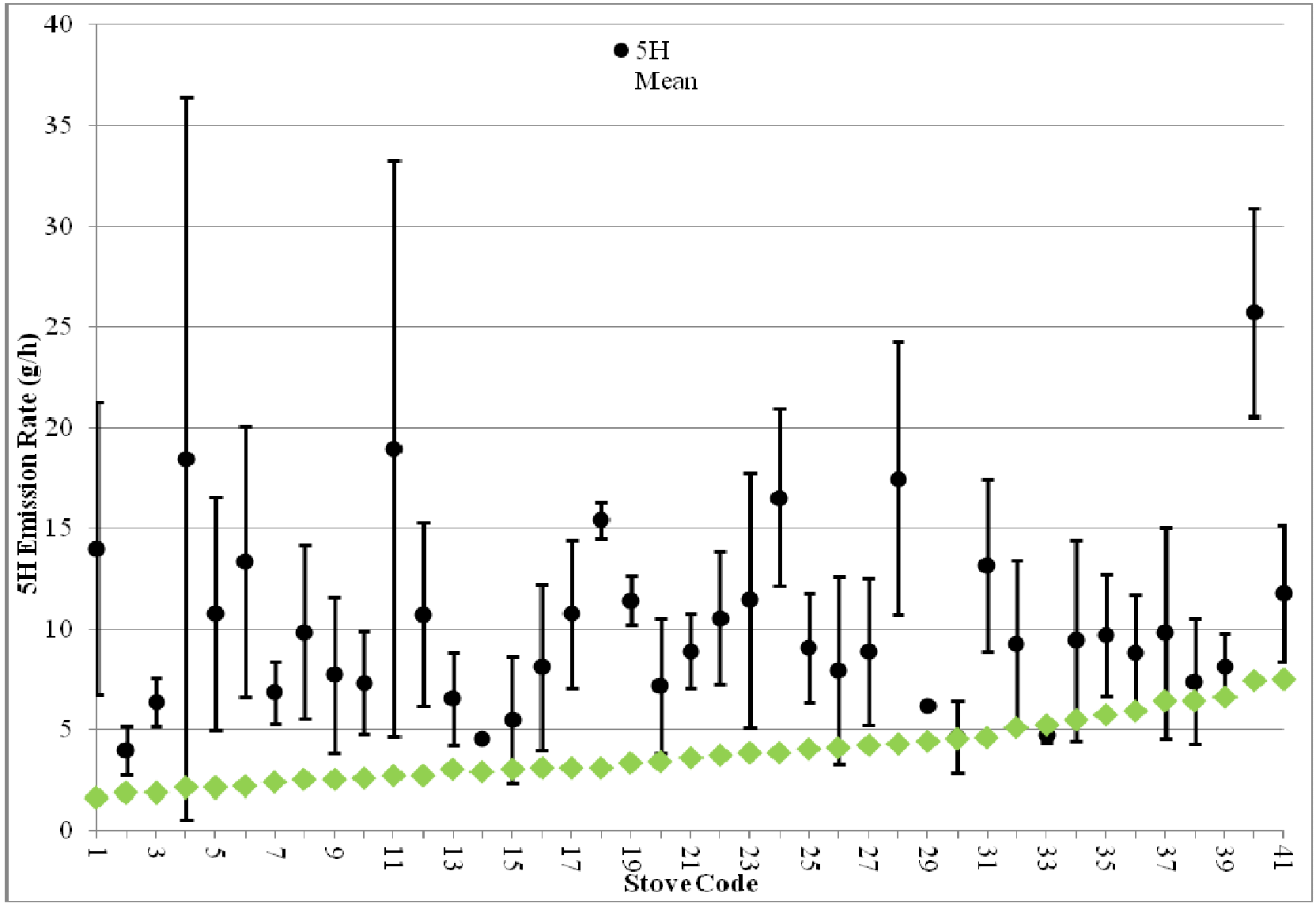

Figure ES2. Mean Emission Rates, Standard Deviations around Means, and EPA Certification Values by Stove Model. (Each stove model was assigned a stove code.)

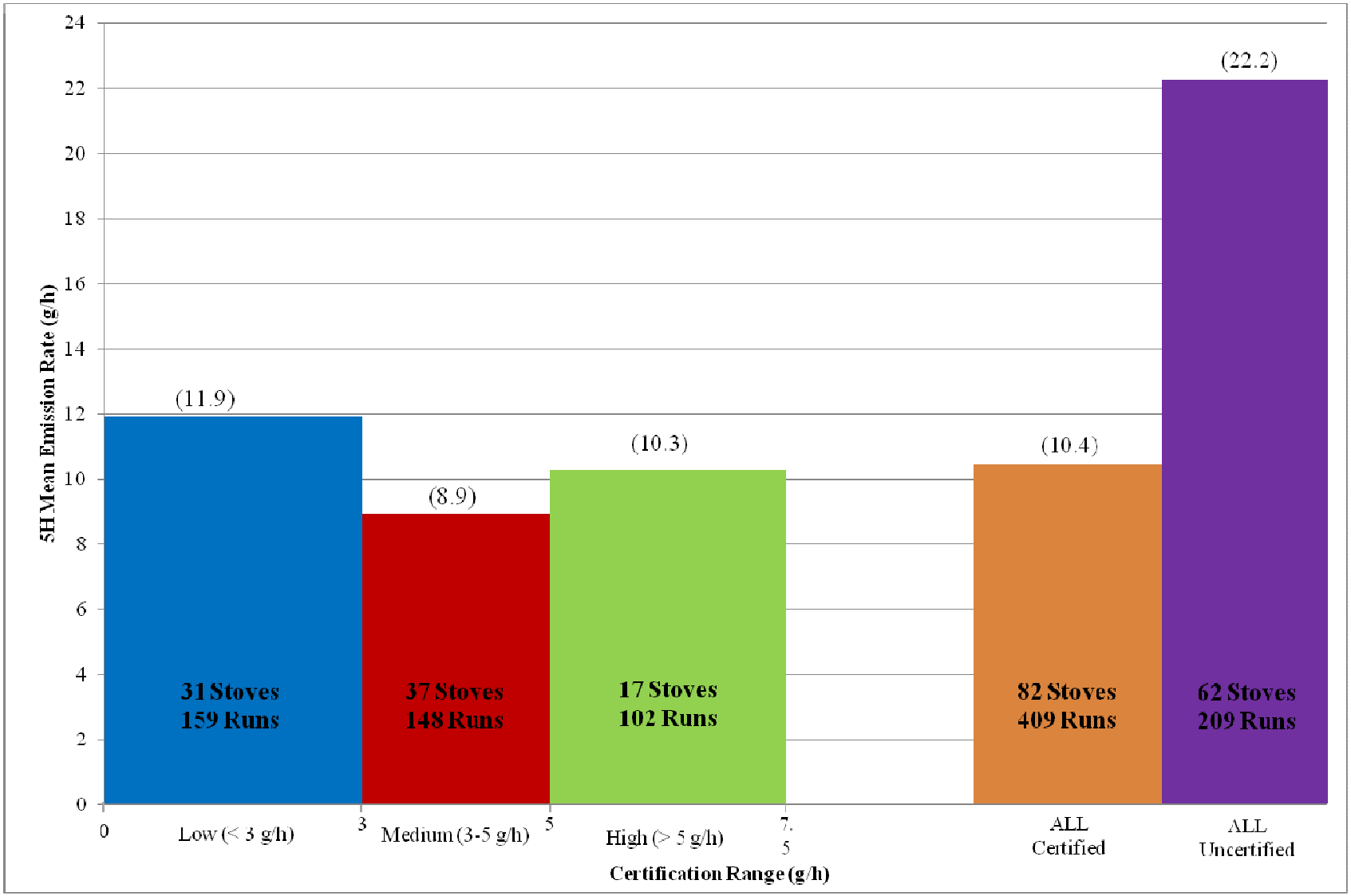

Figure ES3. Mean Emission Rates for Uncertified Stoves and for Certified Stoves by Low, Medium, and High Certification Categories. The mean of all certified emission rates is 47% of the mean of all uncertified emission rates (10.4/22.2 X 100%).

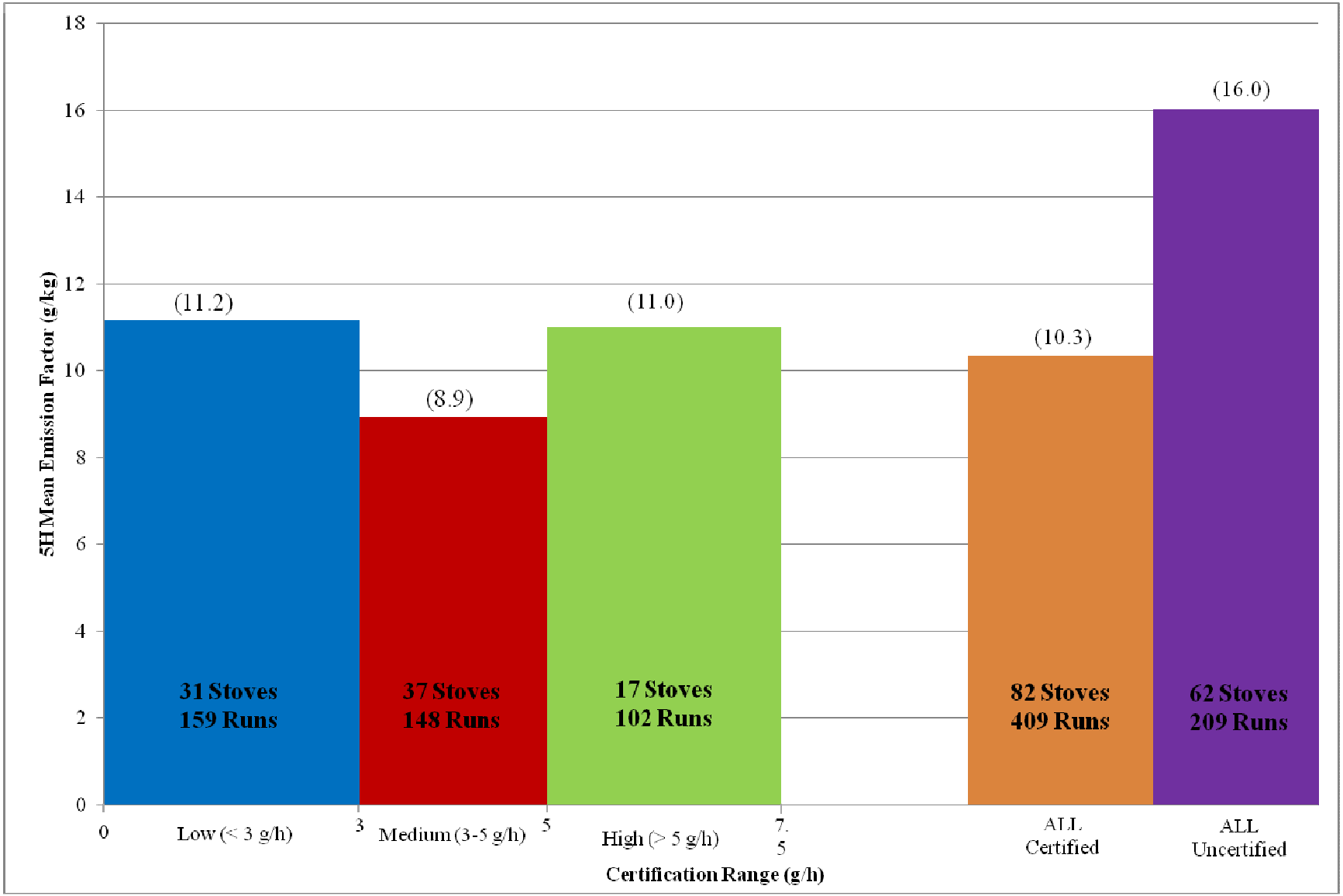

Figure ES4. Mean Emission Factors for Uncertified Stoves and for Certified Stoves by Low, Medium, and High Certification Categories. The mean of all certified emission factors is 64% of the mean of all uncertified emission factors (10.3/16.0 X 100%).

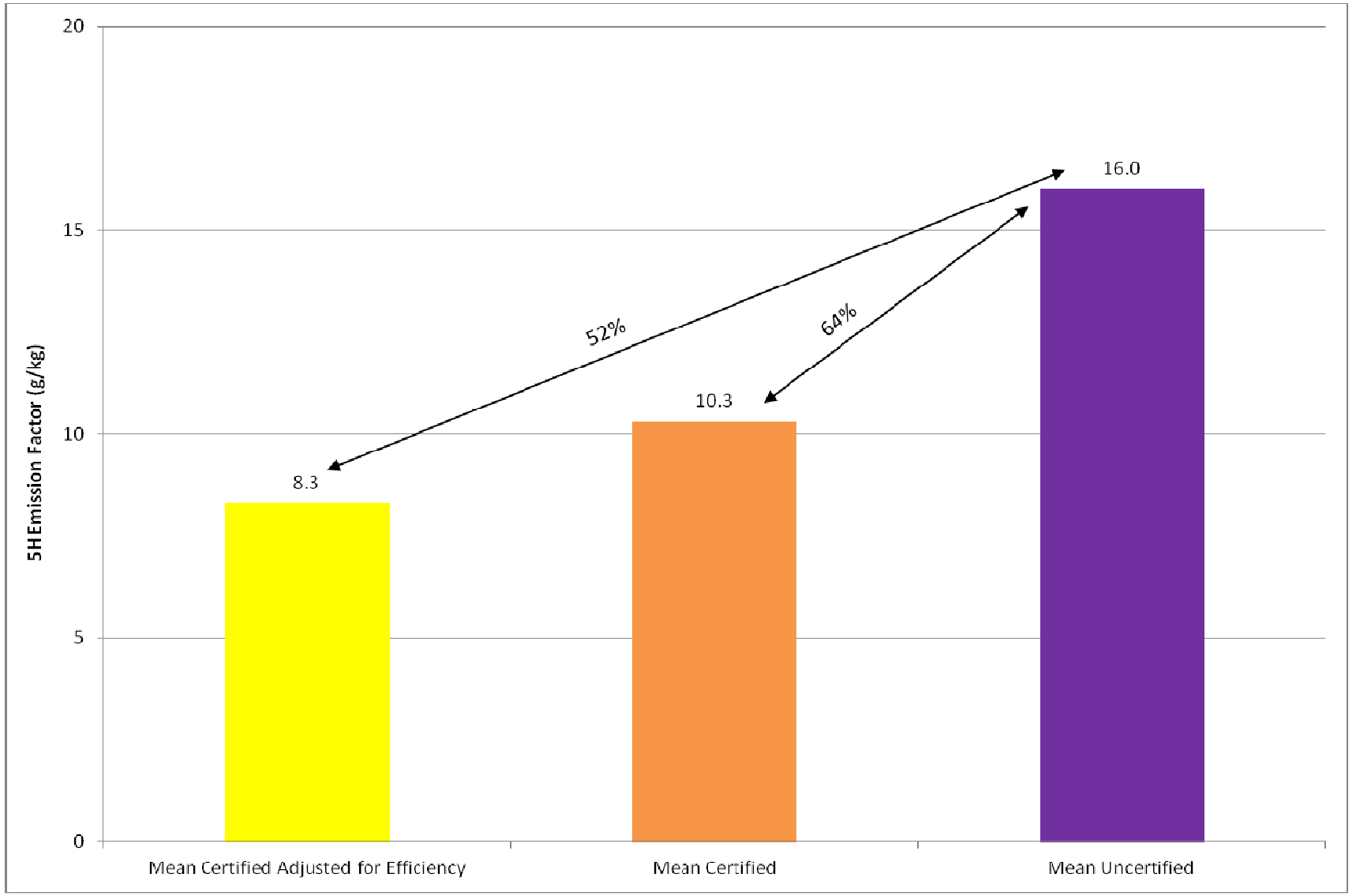

Figure ES5. Comparison of the Mean Effective Emission Factor of Certified Cordwood Stoves (Adjusted for Efficiency) with the Mean Emission Factor of Uncertified Stoves. The mean of all certified emission factors adjusted for efficiency is 52% of the mean of all uncertified emission factors (8.3/16.0 X 100%).

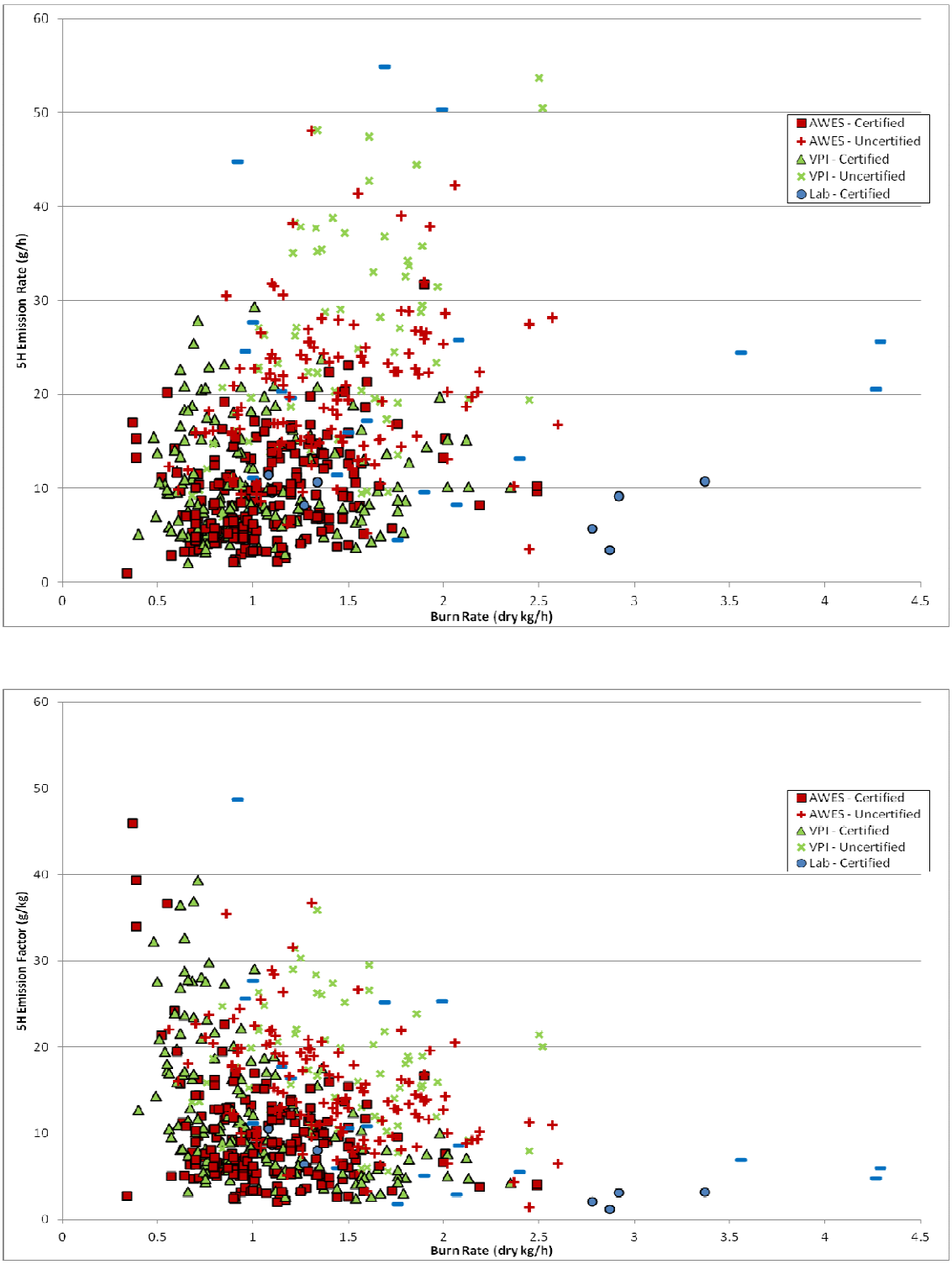

Figure ES6. Emision Rates (top) and Emission Factors (bottom) versus Burn Rates for All Stove Tests. ("Lab" refers to tests conducted in the laboratory using consumer burn practices not EPA Method 28.)

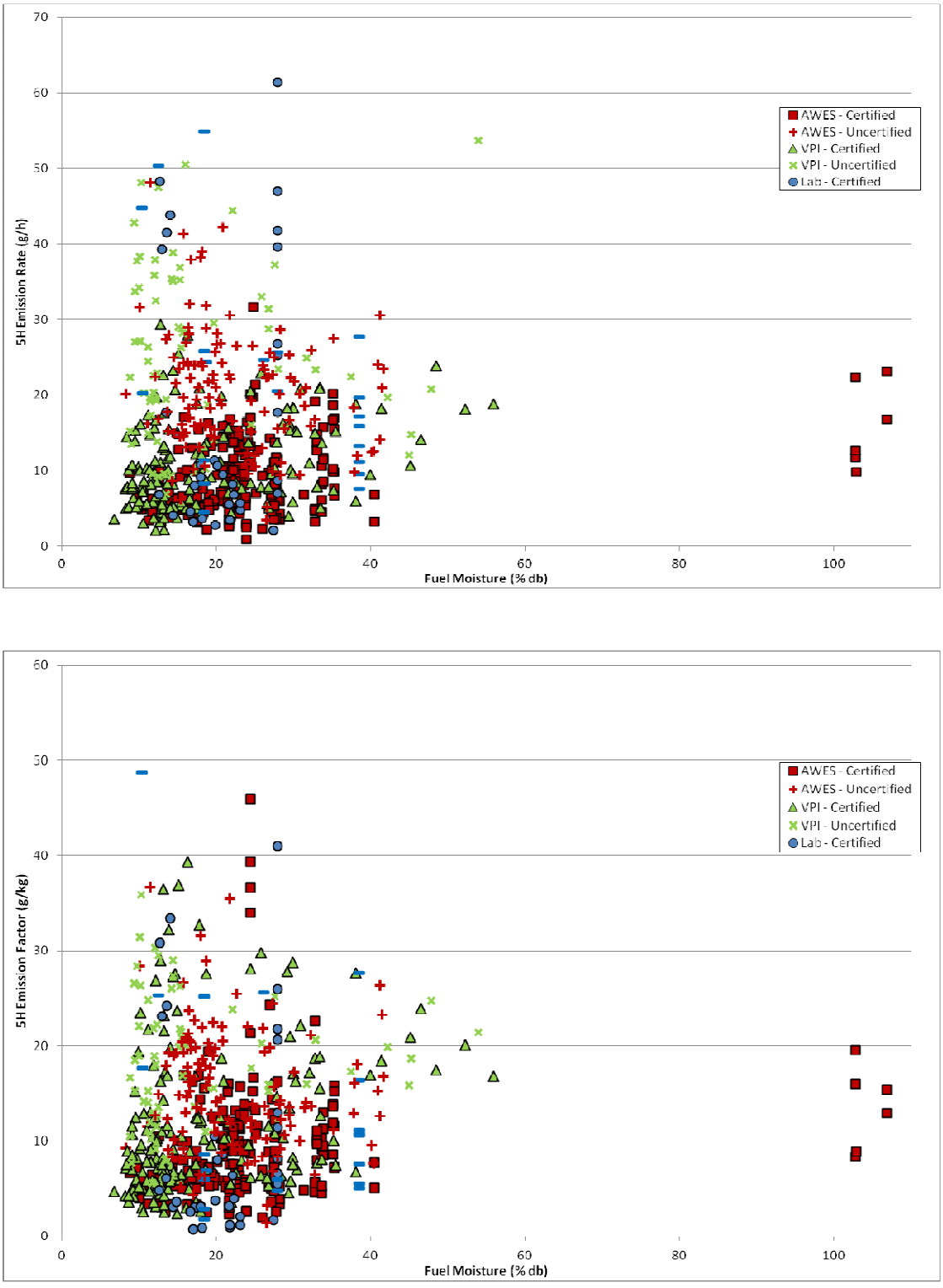

Figure ES7. Emision Rates (top) and Emission Factors (bottom) versus Wood Moisutre for All Stove Tests. ("Lab" refers to tests conducted in the laboratory using consumer burn practices not EPA Method 28.)

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1. Introduction

The ability of wood stove NSPS certification values to predict field rankings among wood stove models and the degree to which they correspond to the magnitude of actual in-situ emissions for a given model were investigated. In addition, real-world emissions from certified wood stove models were compared to uncertified models. Both emission rates (g/h) and emission factors (g/kg) were used in the comparison. The effect of efficiencies on emissions were also taken into consideration in the comparison of mean certified and mean uncertified emission factors because higher efficiencies correspond to less fuel being burned to satisfy a given heating demand effectively lowering emissions. Emission data from in-home sampling programs plus laboratory studies designed to simulate in-home use of wood stoves were reviewed. Published U.S. EPA certification values in units of grams/hour (g/h) were compared to measured 5H adjusted emission rates (g/h) for each certified woodstove model.

The in-situ data were collected with two sampling systems. These were the Automated Woodstove Emissions Sampler (AWES)[1] and the Virginia Polytechnic Institute (VPI) sampler[2]. A description of these samplers is provided as Section 3. The AWES system was deployed in homes in Klamath Falls, OR[3-6], Portland, OR[6-9], Whitehorse, YK[10], Glens Falls, NY[11-12,] as well as other areas in upstate New York and Vermont[13]. The VPI sampler was deployed in homes in Crested Butte, CO[14-18]. The field studies were sponsored by the U.S. Department of Energy BPA, the U.S. Environmental Protection Agency, Environment Canada, Oregon Department of Environmental Quality, Wood Heating Alliance, CONEG Policy Research Center, and the New York State Energy Research and Development Authority.

Laboratory studies collected emissions utilizing either the U.S. EPA reference method 5G or 5H with the stoves operating as they would normally be operated in homes. The laboratory studies were sponsored by the U.S. Department of Energy BPA[7], the U.S. Environmental Protection Agency[19, 20], and Environment Canada[21-23].

For the certified stoves, in total 409 emissions tests from 85 wood stoves comprised of 41 models were reviewed. The names of the certified stove models were intentionally not identified in this report but instead each model was provided a unique model code number. For the uncertified stoves, the models were not identified in some of the studies hence the total number of stove models that make up the database cannot be determined, however the total number stoves for which data were collected could be determined and was 62. A total of 209 emissions tests were conducted with uncertified models.

The in-situ samples were generally collected over a time period of approximately one week each. For the certified models there were 208 valid AWES samples and 165 valid VPI samples in the database. In addition, there were 36 individual valid laboratory samples. For the uncertified models there were 124 valid AWES samples, 65 valid VPI samples and 20 individual valid laboratory samples. For certified wood stoves, to be considered valid a sample had to be for a certified wood stove model for which the certification value could be identified and the fuel species (or type), fuel moisture (% dry basis), and burn rate (dry kg/h) have had to been reported.

Similarly, for uncertified wood stoves like criteria were considered necessary for a valid sample except, of course, there were no certification values.

The methods used to convert AWES and VPI data to method 5H equivalent data were developed as part of the documentation for AP-42 Section 1.10 Residential Wood Stoves and were followed here[24]. The method used to convert 5G laboratory test results to 5H equivalents was as specified in 40 CFR Part 60 Appendix A, Method 5G. Laboratory programs measured emissions directly by method 5H, method 5G, or both. Where necessary, Method 5G values were converted 5H values as per 40CFR Part 60 Appendix A.

The results are summarized in following Section 2. As previously noted a description of the AWES and VPI samplers is provided in Section 3. The conversion equations are presented in Section 4. A discussion on the methods used to determine burn rates and the differences in methods used in the field studies and laboratory tests simulating in home burn patterns using cordwood as compared to that used in Method 28 are provided in Section 5. A brief discussion of efficiencies is provided in Section 6. The database is provided in tabular form as Section 7. References are provided as Section 8.

2. Results and Discussion

Figure 1 is a plot of the individual emission rates (g/h) determined for each of the 409 valid "real-world" samples versus the U.S. EPA certification values for each certified stove model. As can be seen in the figure, there is no correlation between certification values and the emission rates and in most cases the magnitude of the emission rate for given sample is larger than the certification value.

Because both wood moistures and burn rates have been strongly implicated in affecting emissions from wood stoves and because both parameters were quantified in the studies from which the data compiled here were obtained, burn rates and wood moistures were plotted against emission rates and factors (Figures 2-13). The burn rate and wood moisture data were shown in three ways: (1) certified stoves only, (2) uncertified stoves only, and (3) all stoves. As can be seen in reviewing Figures 2-13, any clear relationship that these two parameters alone might have with emissions is clearly obscured by other real-world variables. It should, however, be noted that while there is no statistical trend, higher emission factors (g/kg) are more common at lower burn rates (Figures 3, 5 and 7).

Table 1 and accompanying Figure 14 show the U.S. EPA certification value for each stove model and the mean emission rate for each stove model averaged across all samples for that stove model. In some cases, data from more than one unit comprises the "stove model" mean. The data in Table 1 and Figure 14 are arranged in ascending order from the lowest certification value to the highest. As can be seen in reviewing the data in Tables 1 and Figure 14, the U.S. EPA certification values are not good predicators of the relative ranking of emissions from individual models or the actual magnitude of their emissions.

A caveat needs to be considered in reviewing the data shown in Table 1 and Figure 14. Many different in-home parameters may affect emissions. Notably these are: (1) wood moisture, (2) burn rate, (3) the species of tree used for fuel, (4) wood fuel piece size and shape, (5) kindling practices and wood addition patterns, (6) chimney draft (height, condition, and geometry of chimney and chimney connectors), (7) the stove's condition (new versus various levels of wear), (8) barometric pressure (home elevation and meteorological conditions), and (9) hot versus cold starts. The caveat is that the data shown in Table 1 and Figure 14 did not (and within reason could not) account for the effect of all nine aforementioned variables and hence different stove model averages were comprised of measurements made under different sets of real-world conditions and for that reason may not be directly comparable. It should also be noted that burn rates reported for the AWES studies, the VPI studies, and the laboratory studies were calculated using different end points, which causes the burn rates not to be directly comparable among all studies. The methods used to determine burn rates are discussed in detail in Section 5.

Adding to the lack of correlation between the in-home data and the certification data is the large uncertainty that has been seen in the certification test results themselves. Primarily by using U.S. EPA proficiency data, which allows for the comparison of repetitive testing of the same wood stove model (within a given laboratory and among laboratories) it has been concluded that although the certification testing process is certainly capable of reliably distinguishing between good and bad performance, it cannot reliably distinguish between "good, better and best" performance[25,26].

To mitigate (and to "smooth") the impact of the various in-home conditions and the demonstrated uncertainty of the certification testing process, means and medians by certification category were compiled. The three certification categories were: (1) Low (<3 g/h), (2) Medium (3-5 g/h), and (3) High (> 5g/h). Table 2 and accompanying Figures 15-18 show the emission rate and emission factor means and medians of these three categories of certification values for the stoves from which they were measured. As can be seen, the U.S. EPA certification values do not predict the relative ranking of the stoves under real-world use. In fact, the "Low" category had higher mean emission rate and factor values than the "High" category. In addition, the U.S. EPA certification values do not predict the magnitude of the real-world emissions. The overall average of all 409 samples was 10.5 g/h as compared to the average certification value of the 41 stove models reviewed here of 3.9 g/h.

In addition to the means and medians for the certified stove categories, the means and medians for uncertified stoves are also shown in Table 2 and associated Figures 15-18. The data for uncertified stoves shown in Table 2 confirm that certified stoves do have substantially lower particulate emissions under real-world, in-home usage as compared to uncertified models.

Finally, when comparing particulate emissions on the basis of emission factors, the greater efficiency of certified stoves as compared to uncertified stoves should be taken into consideration as less fuel would be burned in a stove with a higher efficiency to satisfy the same heating demand and hence less emissions would be produced. Figure 19 shows that the effective mean emission factor of certified wood stoves when adjusted for efficiency is 52% of that uncertified ones which compares favorably with the fact that the mean emission rate of certified wood stoves is 47% of the uncertified wood stove mean (Figure 15).

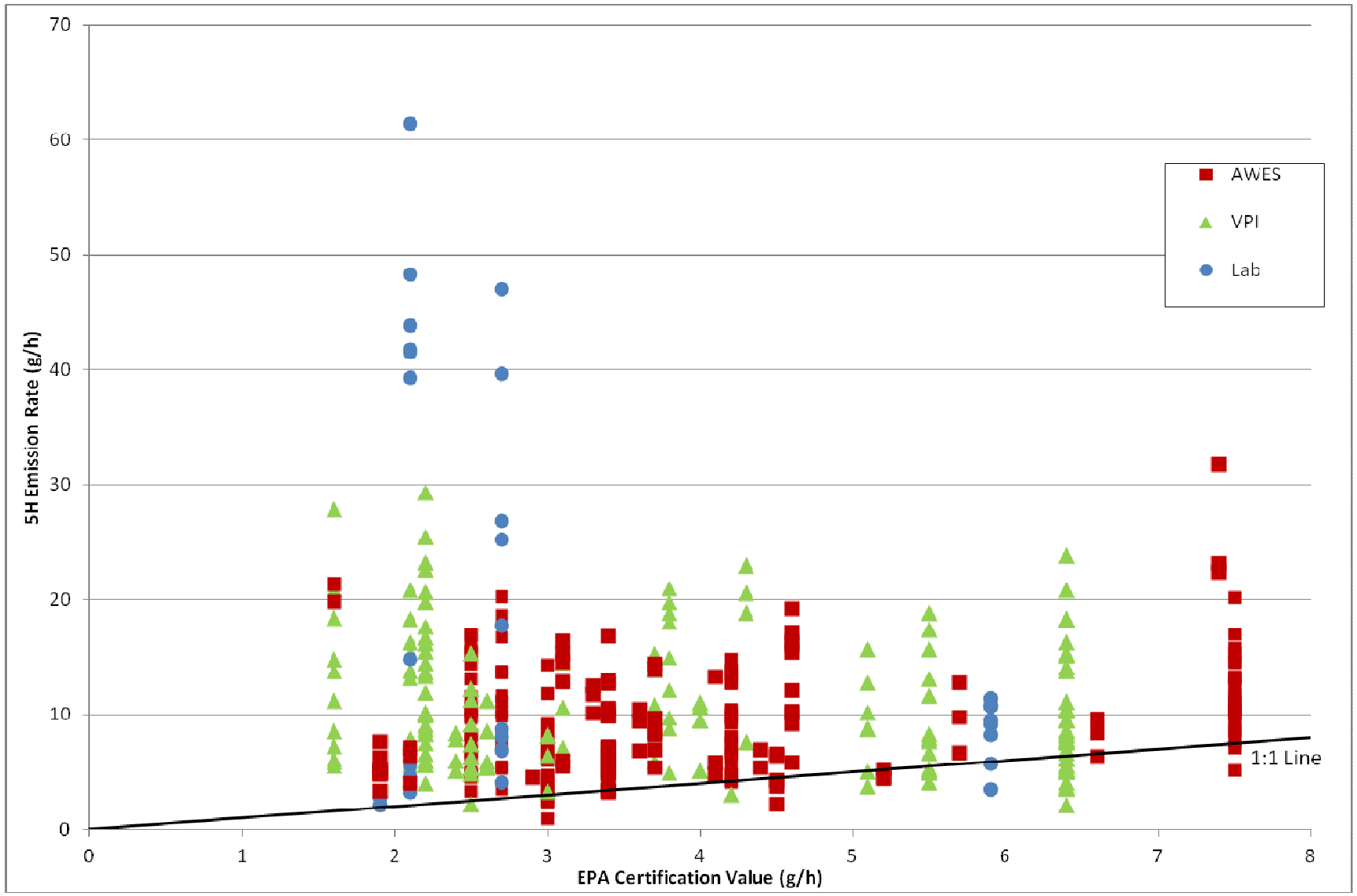

Figure 1. Emission Rates by Test Run versus EPA Certification Values for Stove Models. ("Lab" refers to tests conducted in the laboratory using consumer burn practices not EPA Method 28.)

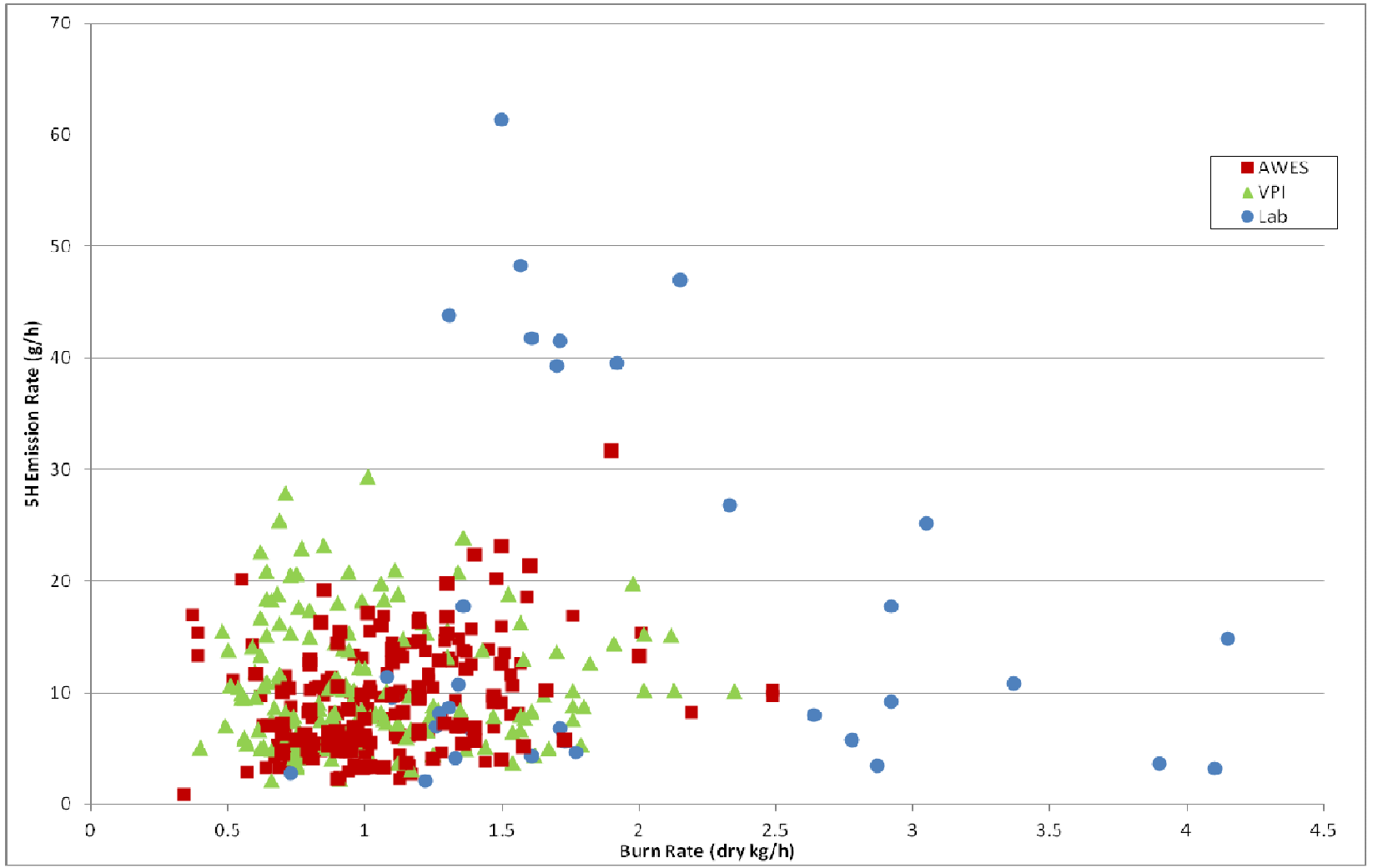

Figure 2. Emission Rates by Test Run versus Burn Rates – Certified Stoves Only. (Burn rate data are as reported in the various in-home AWES studies, in-home VPI studies, and laboratory studies that simulate in-home usage with cordwood. They are not as described in 40CFR Part 60 Appendix A Method 28 for certification.)

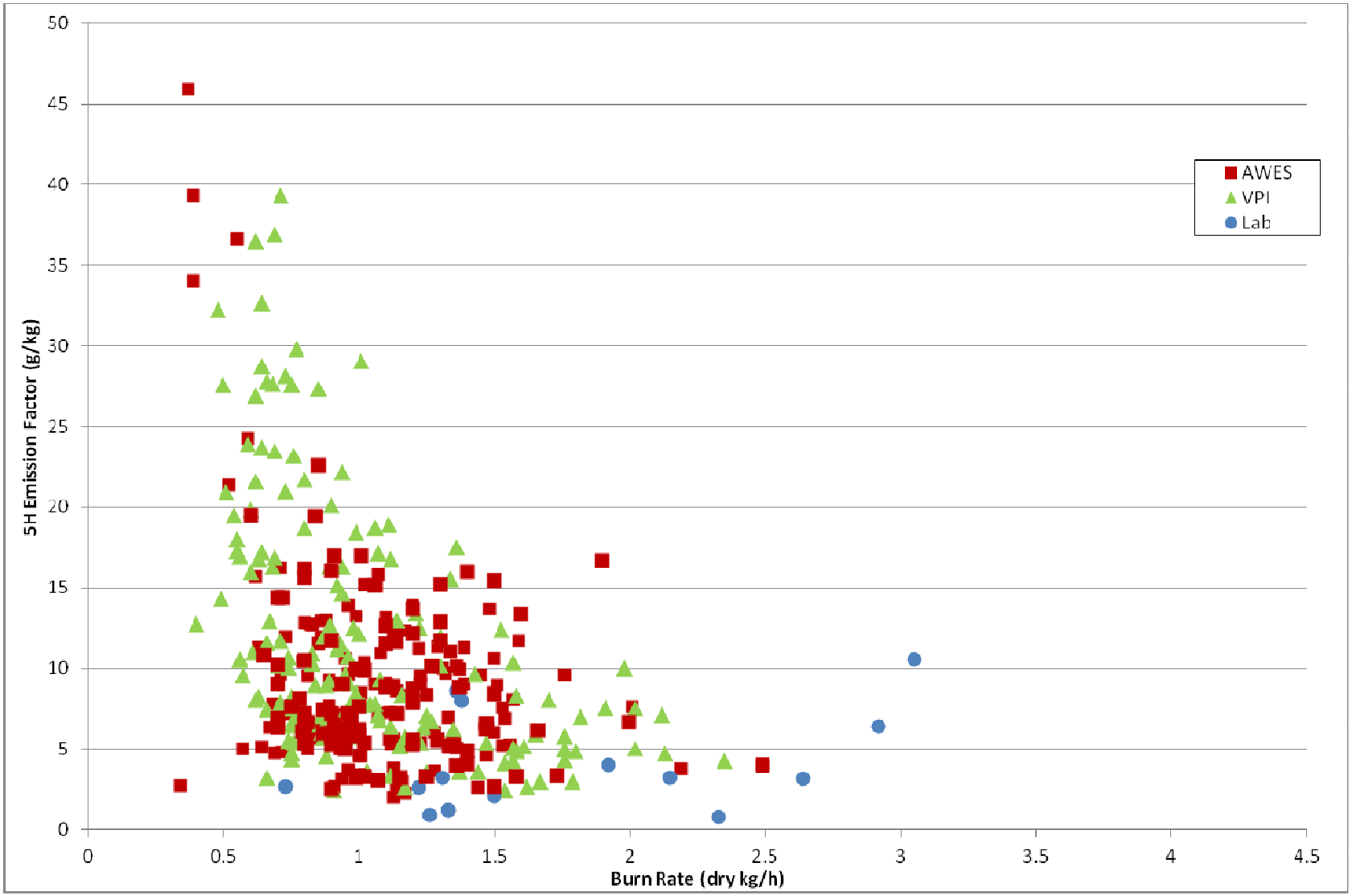

Figure 3. Emission Factors by Test Run versus Burn Rates – Certified Stoves Only. (Burn rate data are as reported in the various in-home AWES studies, in-home VPI studies, and laboratory studies that simulate in-home usage with cordwood. They are not as described in 40CFR Part 60 Appendix A Method 28 for certification.)

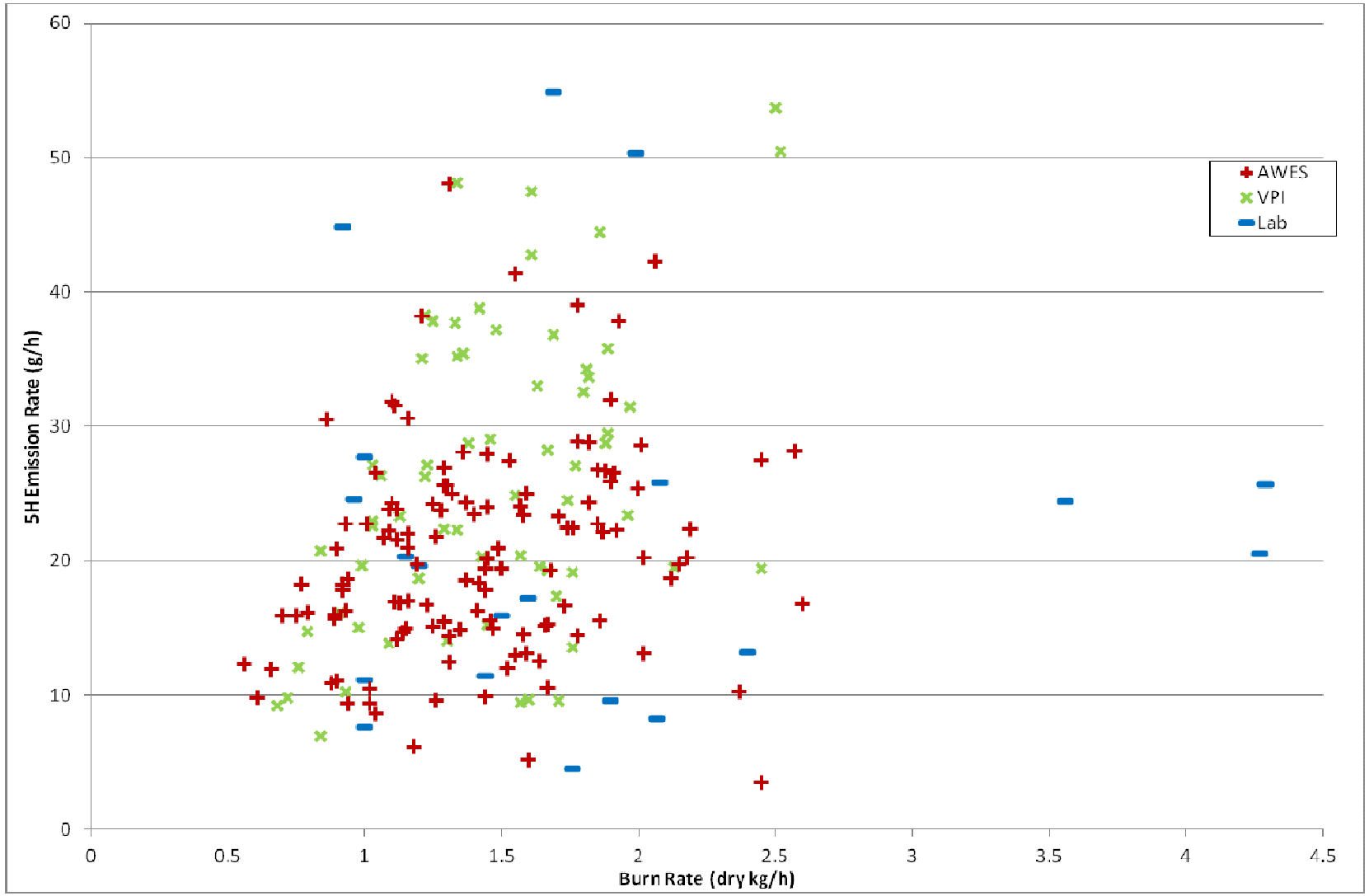

Figure 4. Emission Rates by Test Run versus Burn Rates – Uncertified Stoves Only. (Burn rate data are as reported in the various in-home AWES studies, in-home VPI studies, and laboratory studies that simulate in-home usage with cordwood. They are not as described in 40CFR Part 60 Appendix A Method 28 for certification.)

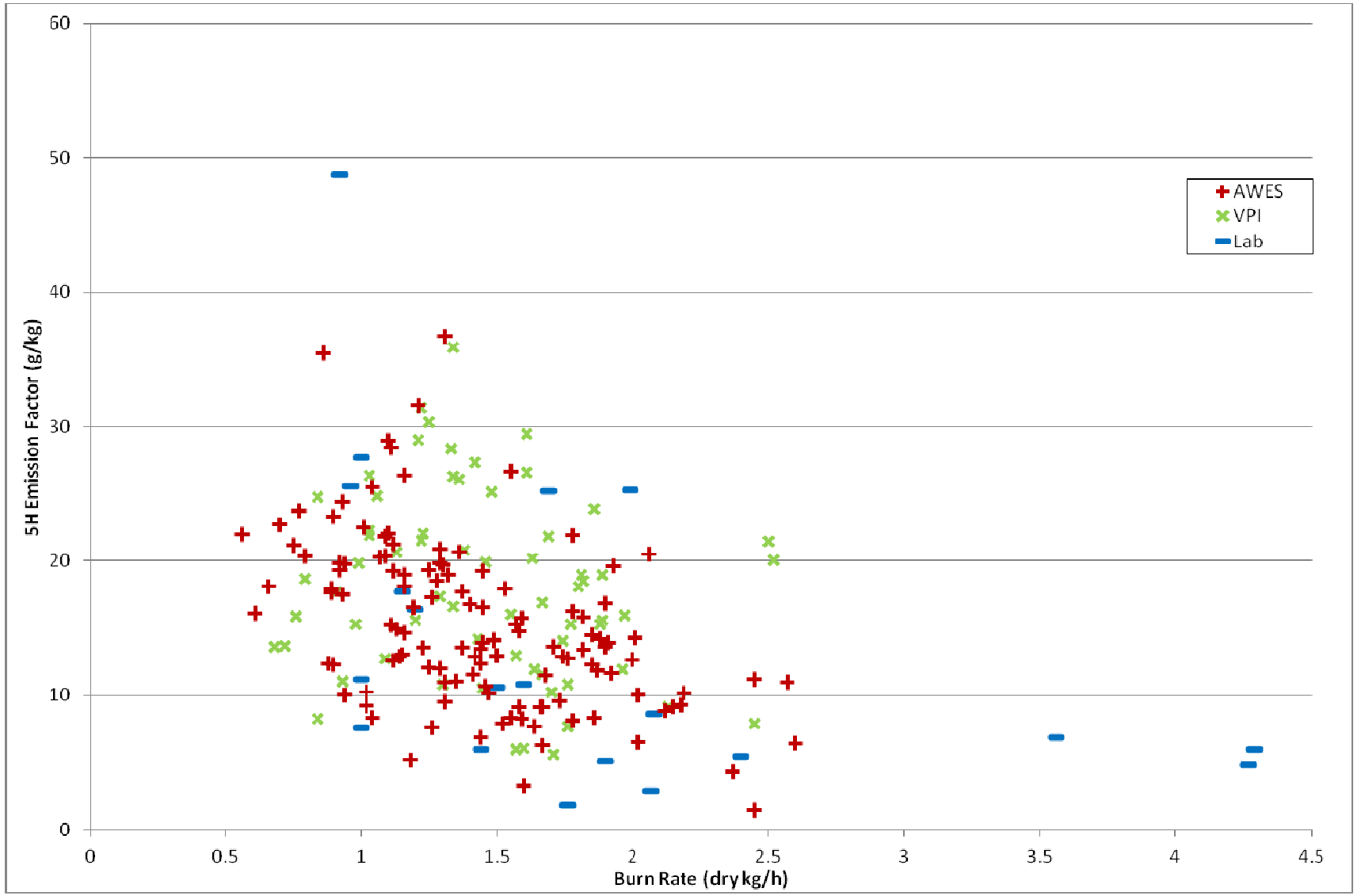

Figure 5. Emission Factors by Test Run versus Burn Rates – Uncertified Stoves Only. (Burn rate data are as reported in the various in-home AWES studies, in-home VPI studies, and laboratory studies that simulate in-home usage with cordwood. They are not as described in 40CFR Part 60 Appendix A Method 28 for certification.)

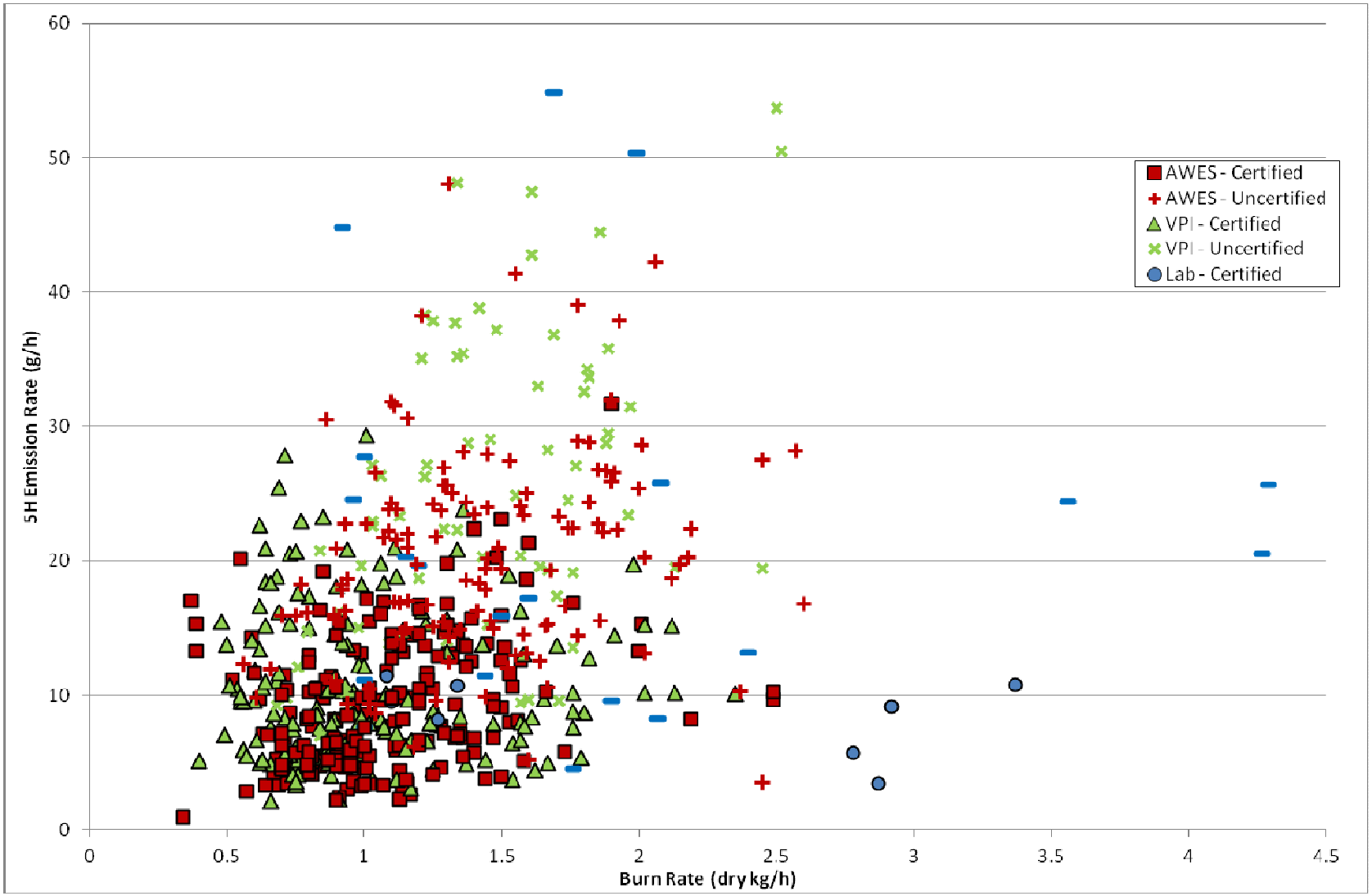

Figure 6. Emission Rates by Test Run versus Burn Rates – All Stoves. (Burn rate data are as reported in the various in-home AWES studies, in-home VPI studies, and laboratory studies that simulate in-home usage with cordwood. They are not as described in 40CFR Part 60 Appendix A Method 28 for certification.)

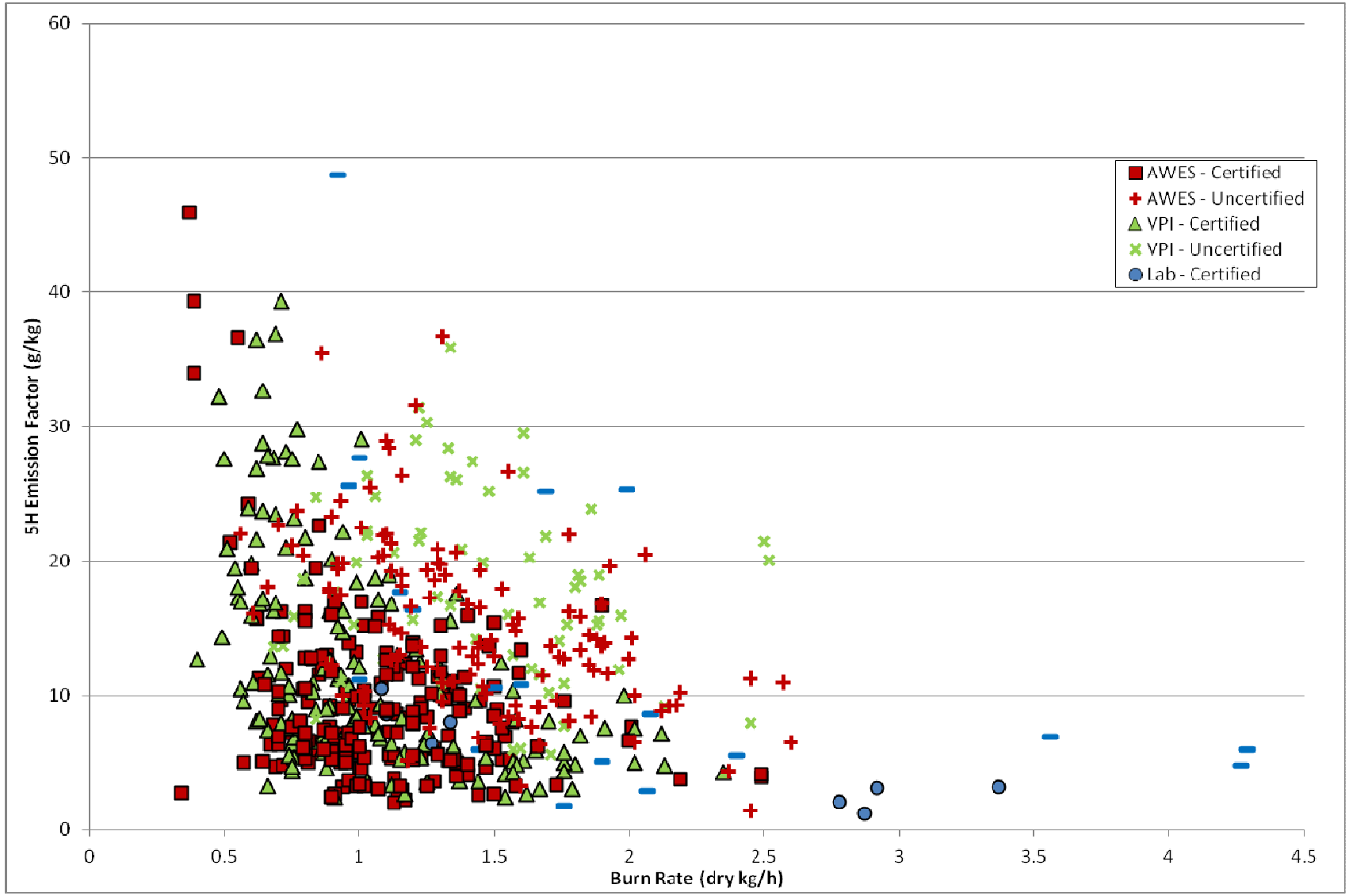

Figure 7. Emission Factors by Test Run versus Burn Rates – All Stoves. (Burn rate data are as reported in the various in-home AWES studies, in-home VPI studies, and laboratory studies that simulate in-home usage with cordwood. They are not as described in 40CFR Part 60 Appendix A Method 28 for certification.)

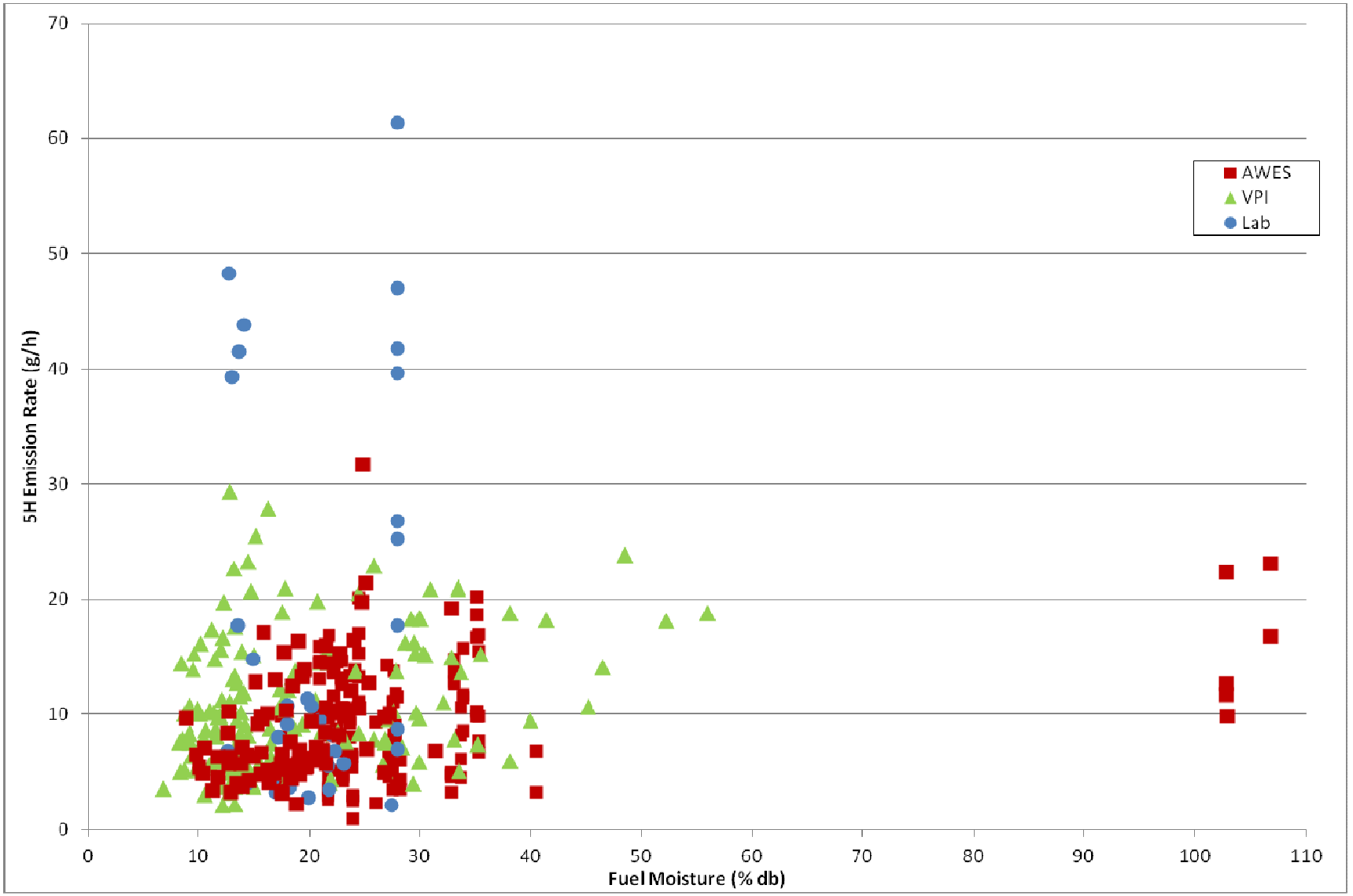

Figure 8. Emission Rates by Test Run versus Wood Moistures – Certified Stoves Only. ("Lab" refers to tests conducted in the laboratory using consumer burn practices not EPA Method 28.)

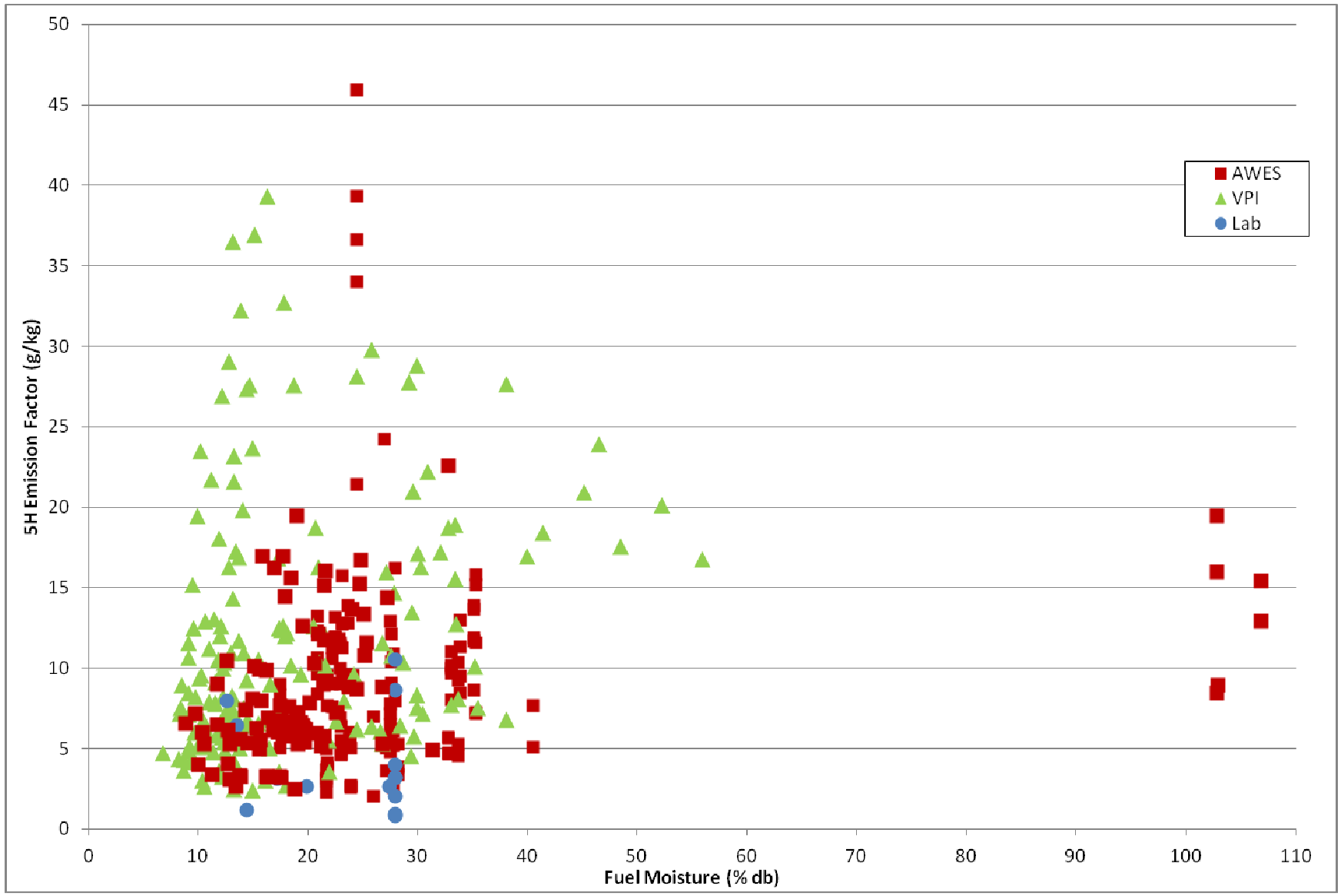

Figure 9. Emission Factors by Test Run versus Wood Moistures – Certified Stoves Only. ("Lab" refers to tests conducted in the laboratory using consumer burn practices not EPA Method 28.)

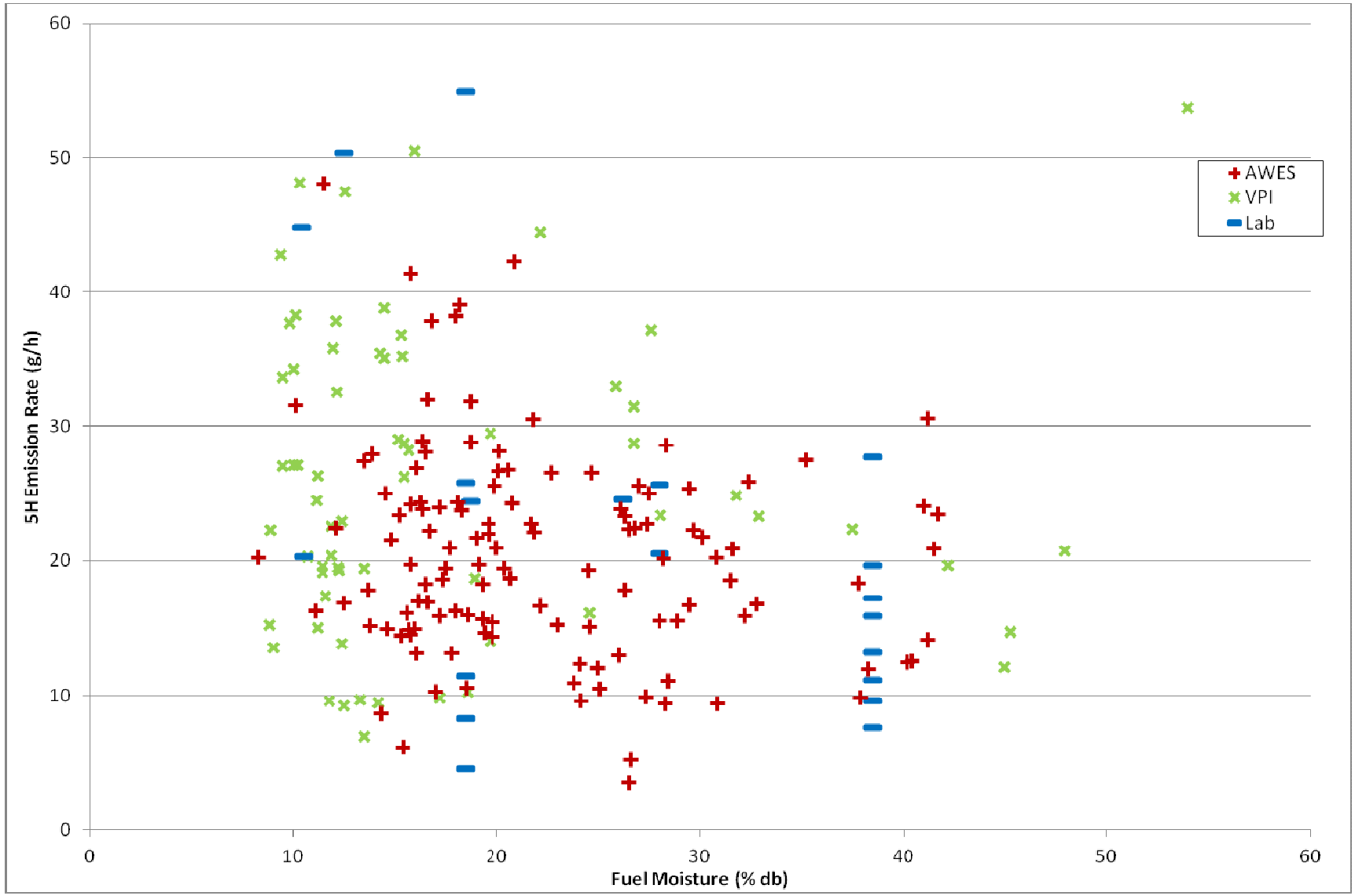

Figure 10. Emission Rates by Test Run versus Wood Moistures – Uncertified Stoves Only. ("Lab" refers to tests conducted in the laboratory using consumer burn practices not EPA Method 28.)

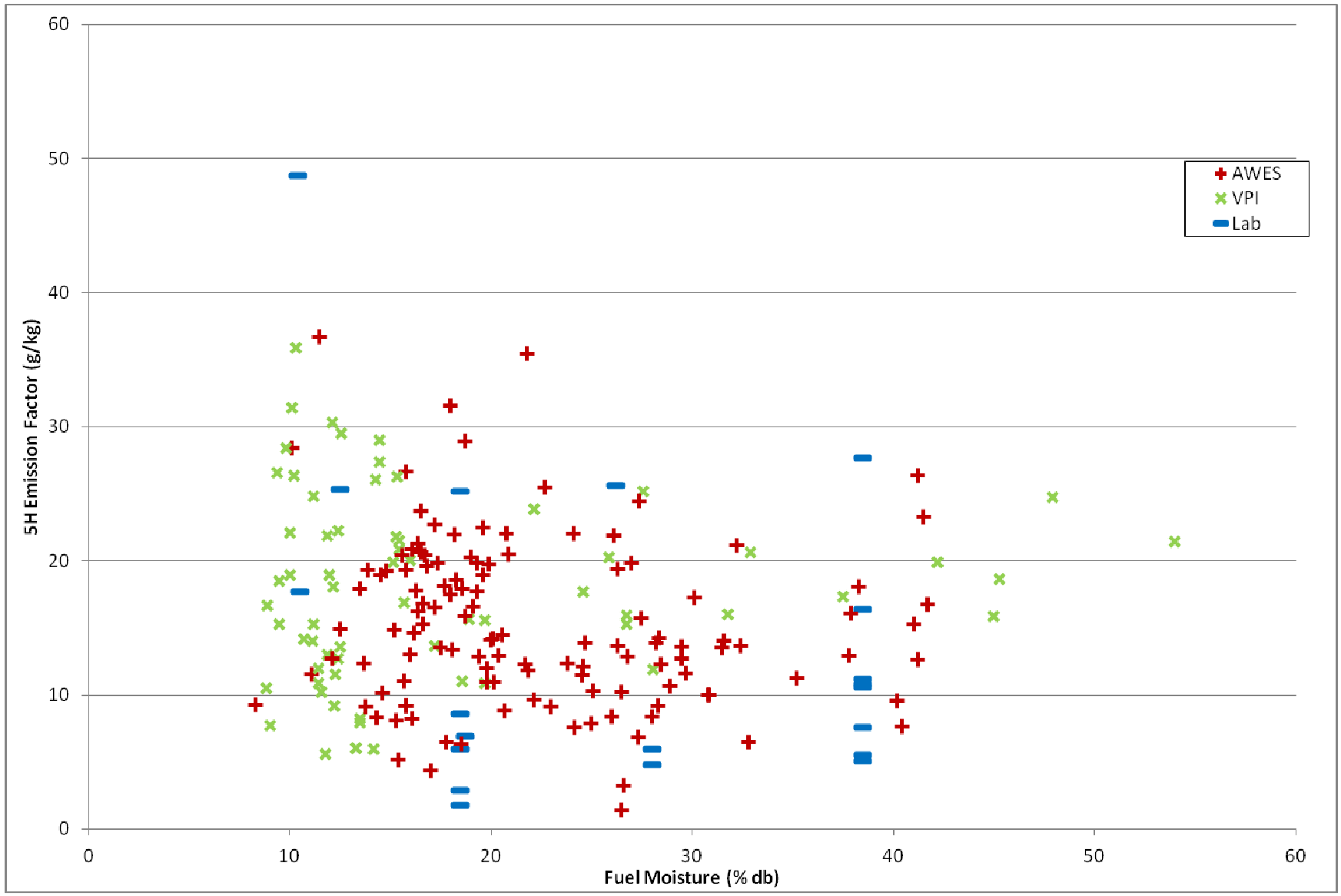

Figure 11. Emission Factors by Test Run versus Wood Moistures – Uncertified Stoves Only. ("Lab" refers to tests conducted in the laboratory using consumer burn practices not EPA Method 28.)

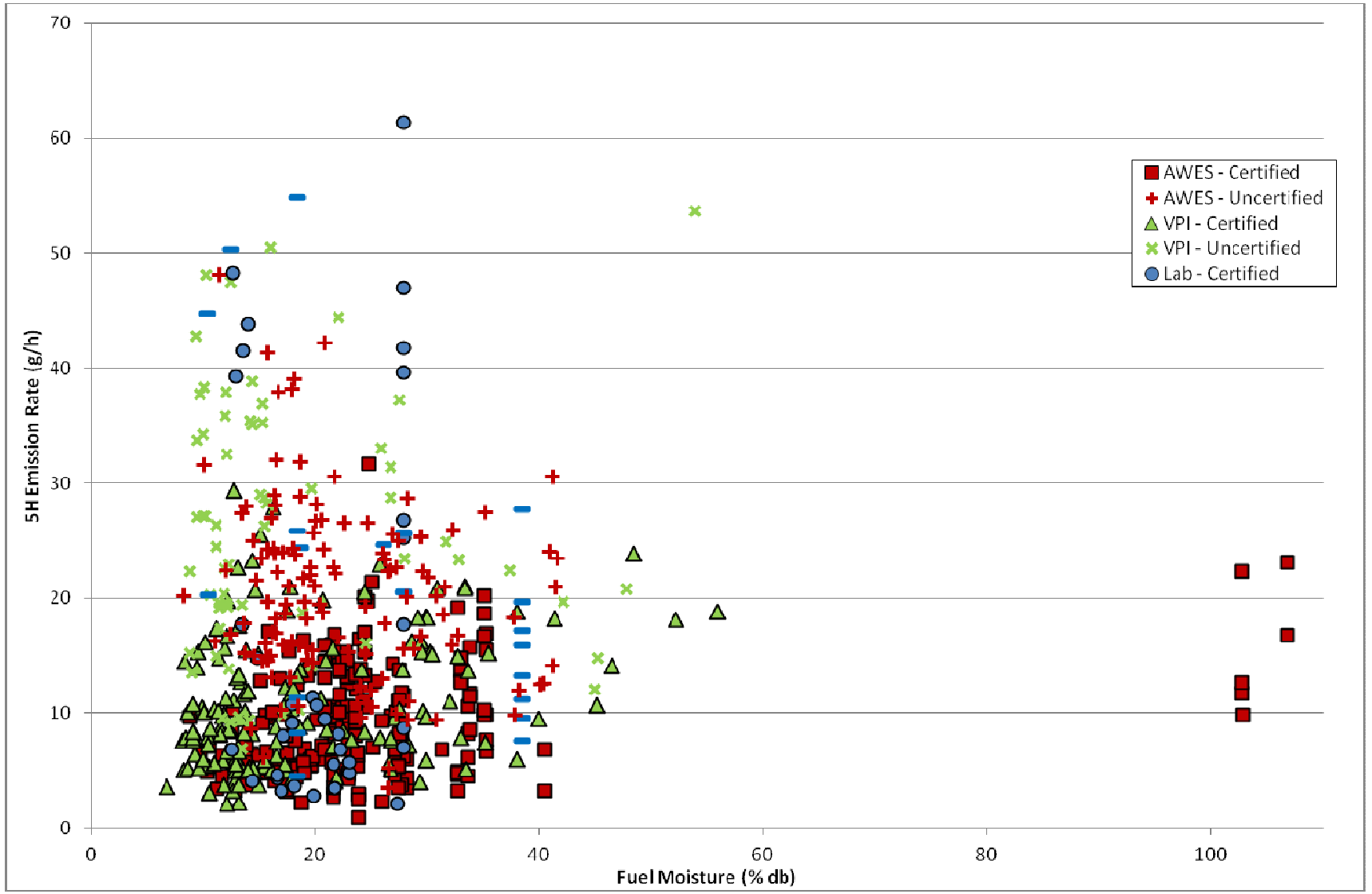

Figure12. Emission Rates by Test Run versus Wood Moistures – All Stoves. ("Lab" refers to tests conducted in the laboratory using consumer burn practices not EPA Method 28.)

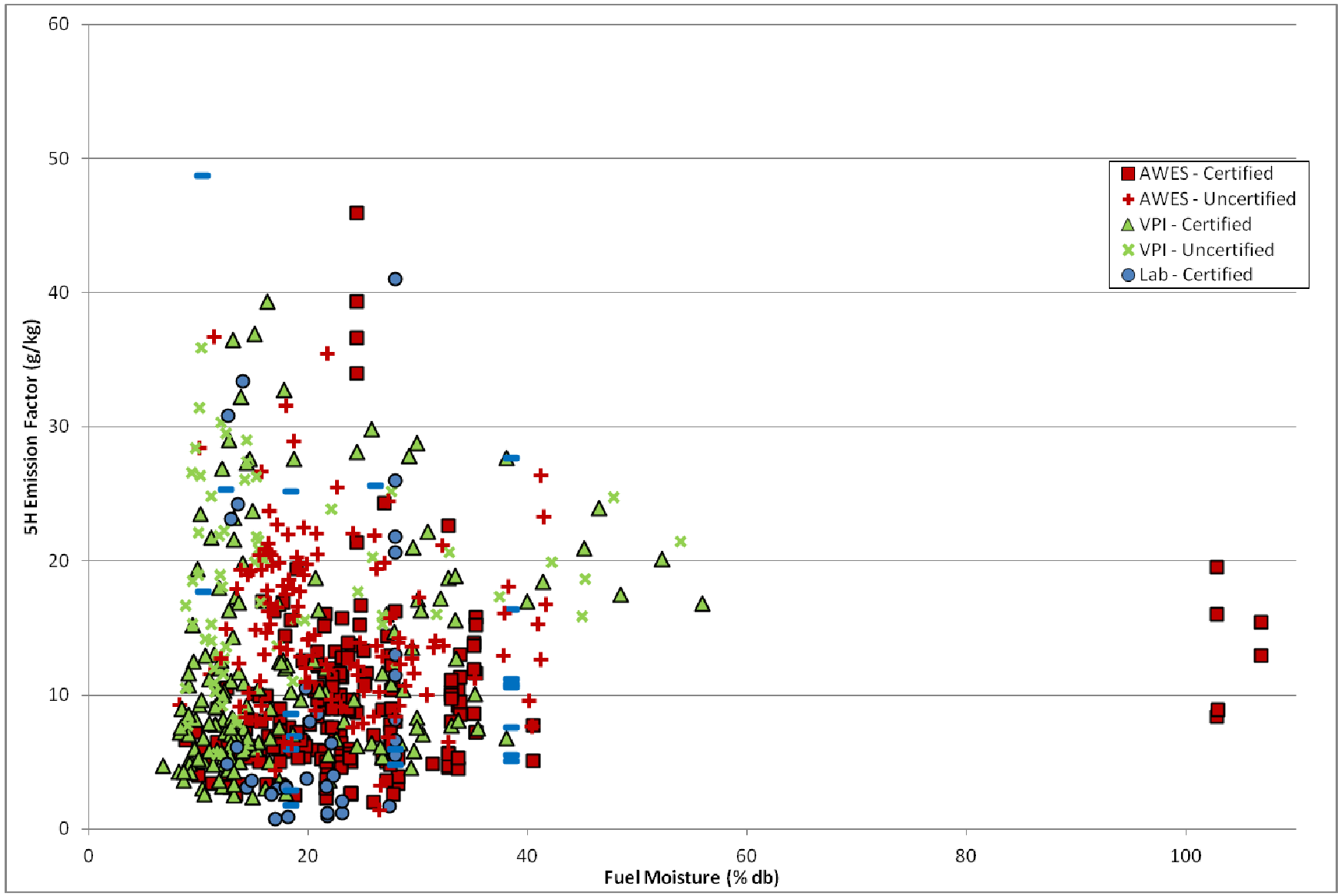

Figure 13. Emission Factors by Test Run versus Wood Moistures – All Stoves. ("Lab" refers to tests conducted in the laboratory using consumer burn practices not EPA Method 28.)

Table 1
Mean Emission Rates, Standard Deviations around Means, and EPA Certification Values by Stove Model

Stove Code	EPA Cert. Value (g/h)	5H Mean (g/h)	S.D.	# of Stoves	Total Runs
1	1.6	14.0	7.2	4	13
2	1.9	4.0	1.2	2	7
3	1.9	6.3	1.2	1	3
4	2.1	17.0	18.8	4	22
5	2.1	10.8	5.8	1	12
6	2.2	13.4	6.8	5	27
7	2.4	6.8	1.6	1	4
8	2.5	9.8	4.3	5	24
9	2.5	7.7	3.9	1	11
10	2.6	7.3	2.6	1	5
11	2.7	19.0	14.3	1	11
12	2.7	10.7	4.6	4	19
13	2.9	4.5	-	1	1
14	3.0	6.5	2.3	2	4
15	3.0	5.5	3.1	5	27
16	3.1	8.1	4.1	1	3
17	3.1	10.7	3.7	1	3
18	3.1	15.4	0.9	1	3
19	3.3	11.4	1.2	1	3
20	3.4	7.2	3.3	6	26
21	3.6	8.9	1.9	1	3
22	3.7	10.5	3.3	4	15
23	3.8	11.4	6.3	1	4
24	3.8	16.5	4.4	1	5
25	4.0	9.1	2.7	1	4

Table 1 (cont.)
Mean Emission Rates, Standard Deviations around Means, and EPA Certification Values by Stove Model

Stove Code	EPA Cert. Value (g/h)	5H Mean (g/h)	S.D.	# of Stoves	Total Runs
26	4.1	7.9	4.7	1	3
27	4.2	8.9	3.7	6	24
28	4.3	17.5	6.8	1	4
29	4.4	6.2	-	1	2
30	4.5	4.6	1.8	1	5
31	4.6	13.1	4.3	2	10
32	5.1	9.3	4.1	1	7
33	5.2	4.7	0.4	1	3
34	5.5	9.4	5.0	2	14
35	5.7	9.7	3.0	1	3
36	5.9	8.6	2.8	1	8
37	6.4	9.8	5.3	3	34
38	6.4	7.4	3.1	1	3
39	6.6	8.1	1.7	1	3
40	7.4	25.7	5.2	1	3
41	7.5	11.8	3.4	5	24

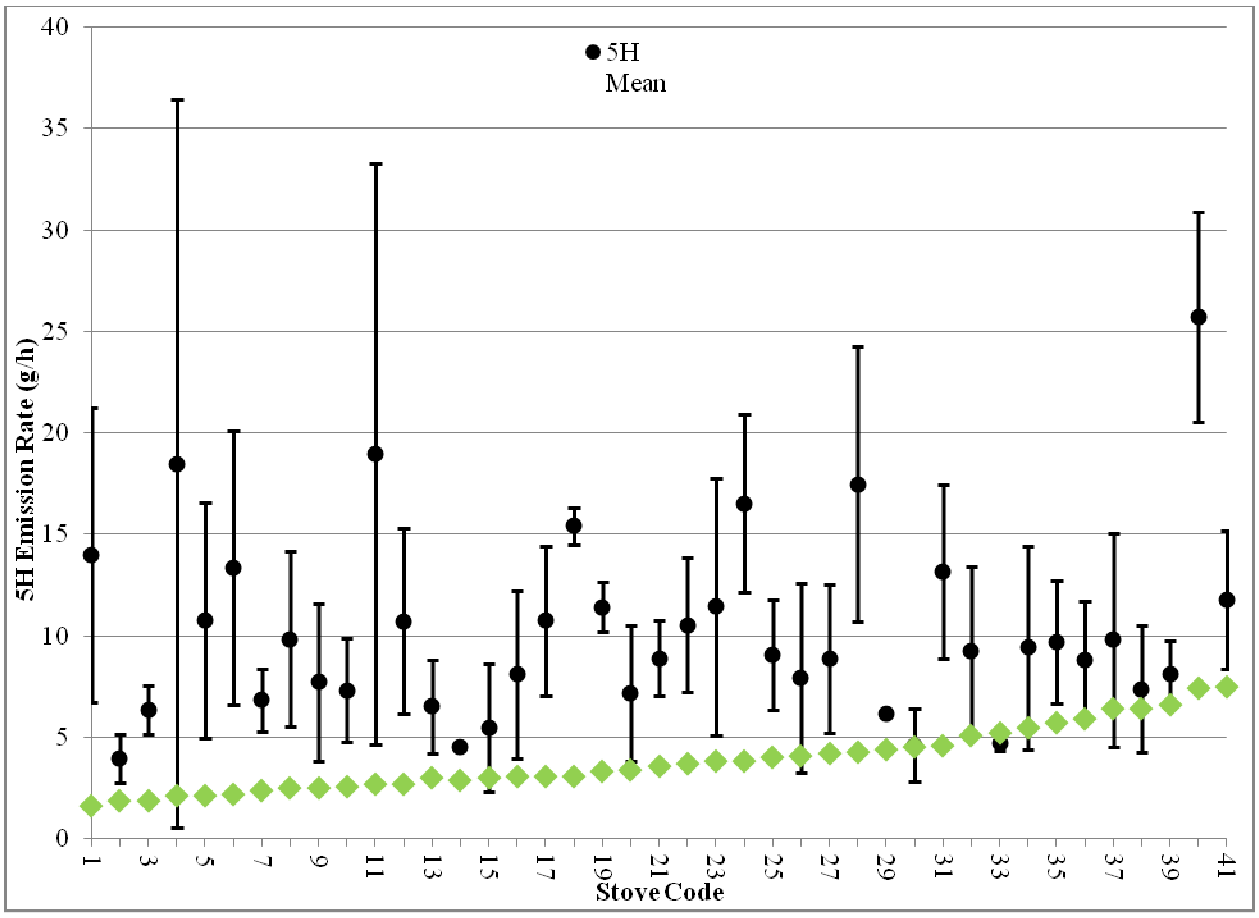

Figure 14. Mean Emission Rates, Standard Deviations around Means, and EPA Certification Values by Stove Model

Table 2
Overall Data Summary – Mean and Median Emission Rates for Uncertified Stoves and Certified Stoves by Low, Medium and High Certification Categories

Category	EPA Cert. Value	5H Emission Rate (g/h)			5H Emission Factor (g/kg)			# of Stove Models	Total # of Stoves	# of Runs
		Mean	S.D.	Median	Mean	S.D.	Median			
Low	< 3 g/h	11.9	9.8	8.4	11.2	8.5	8.2	13	31	159
Medium	3-5 g/h	8.9	4.7	8.1	8.9	5.6	7.2	18	37	148
High	> 5 g/h	10.3	5.2	9.5	11.0	7.5	9.2	10	17	102
All Certified	1.6-7.5*	10.4	7.3	8.6	10.3	7.4	8.1	41	85	409
All Uncertified	–	22.2	9.9	20.9	16.0	7.3	15.3	–	62	209
All Stoves	–	14.4	10.0	11.6	12.2	7.8	10.4	–	147	618

*The mean of all 41 stove certification values is 3.9 g/h with a standard deviation of 1.5

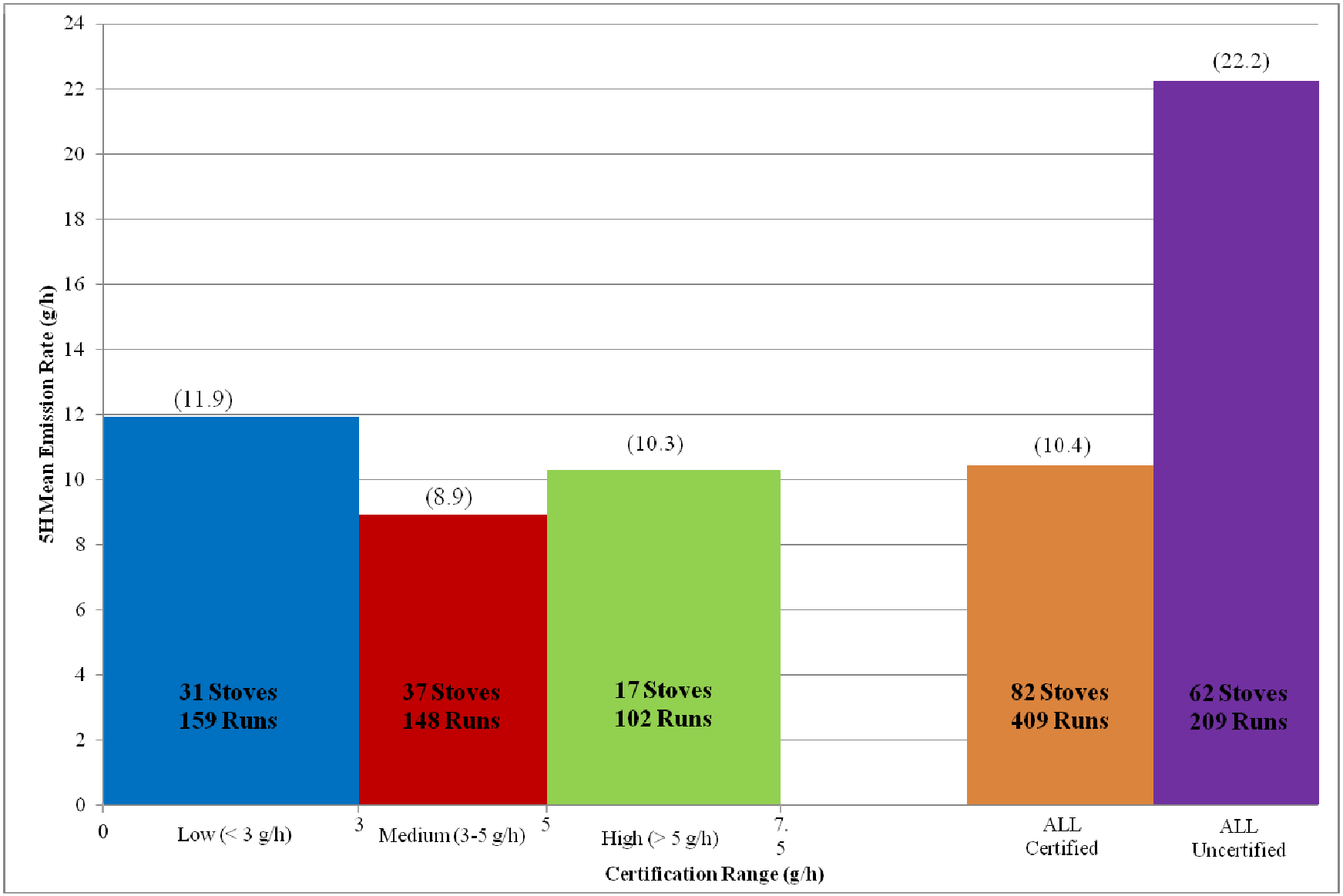

Figure 15. Mean Emission Rates for Uncertified Stoves and for Certified Stoves by Low, Medium, and High Certification Categories

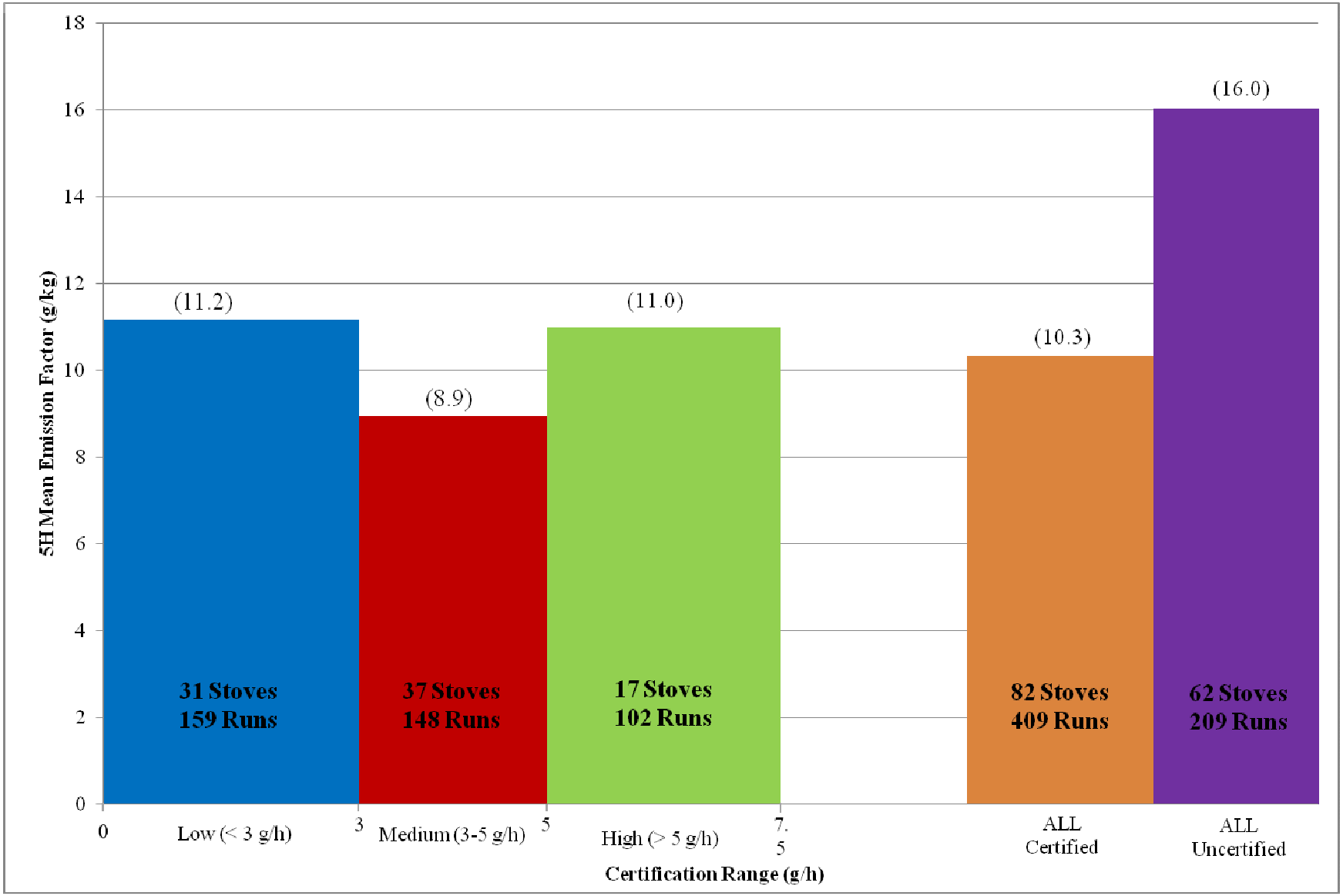

Figure 16. Mean Emission Factors for Uncertified Stoves and for Certified Stoves by Low, Medium, and High Certification Categories

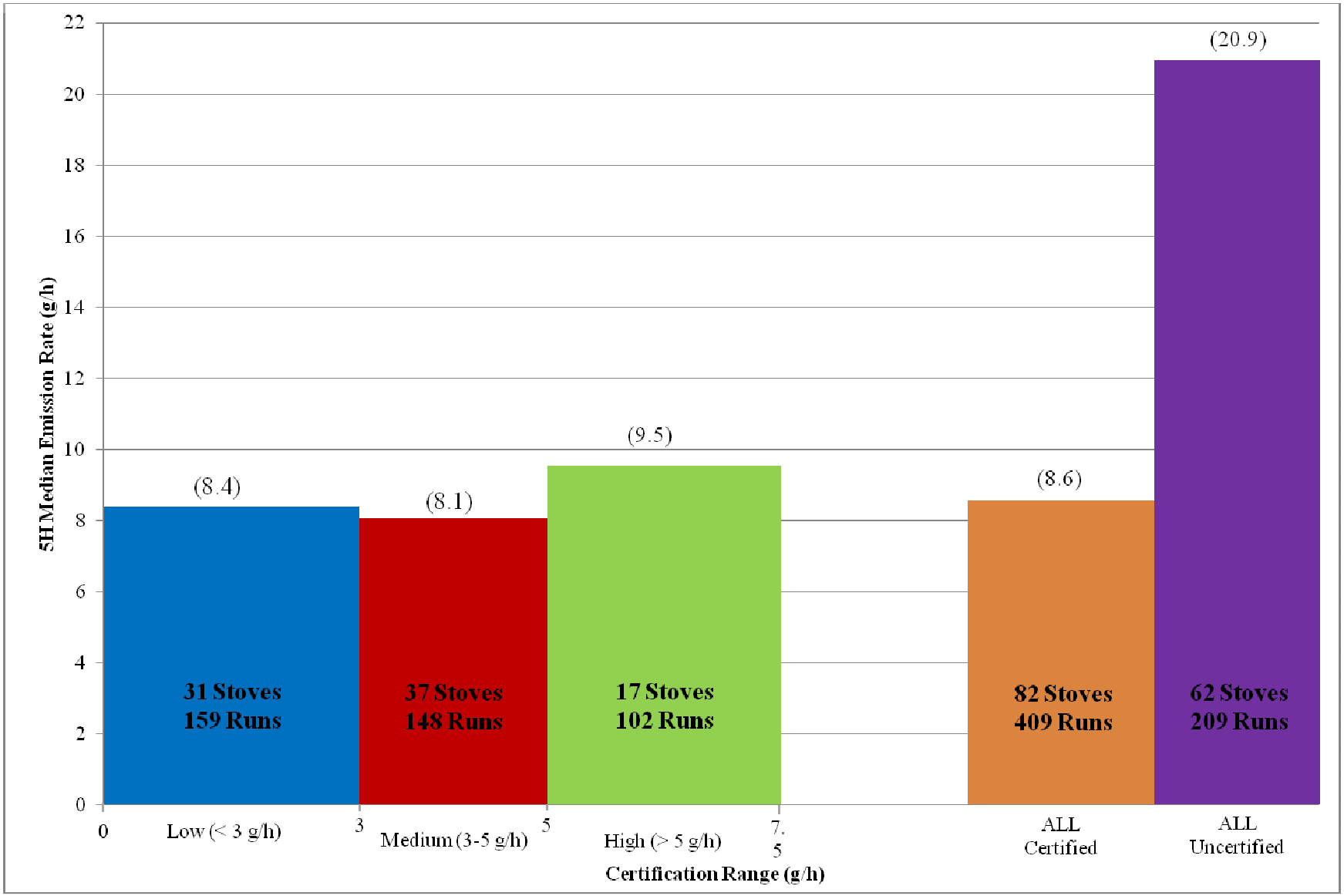

Figure 17. Median Emission Rates for Uncertified Stoves and for Certified Stoves by Low, Medium, and High Certification Categories

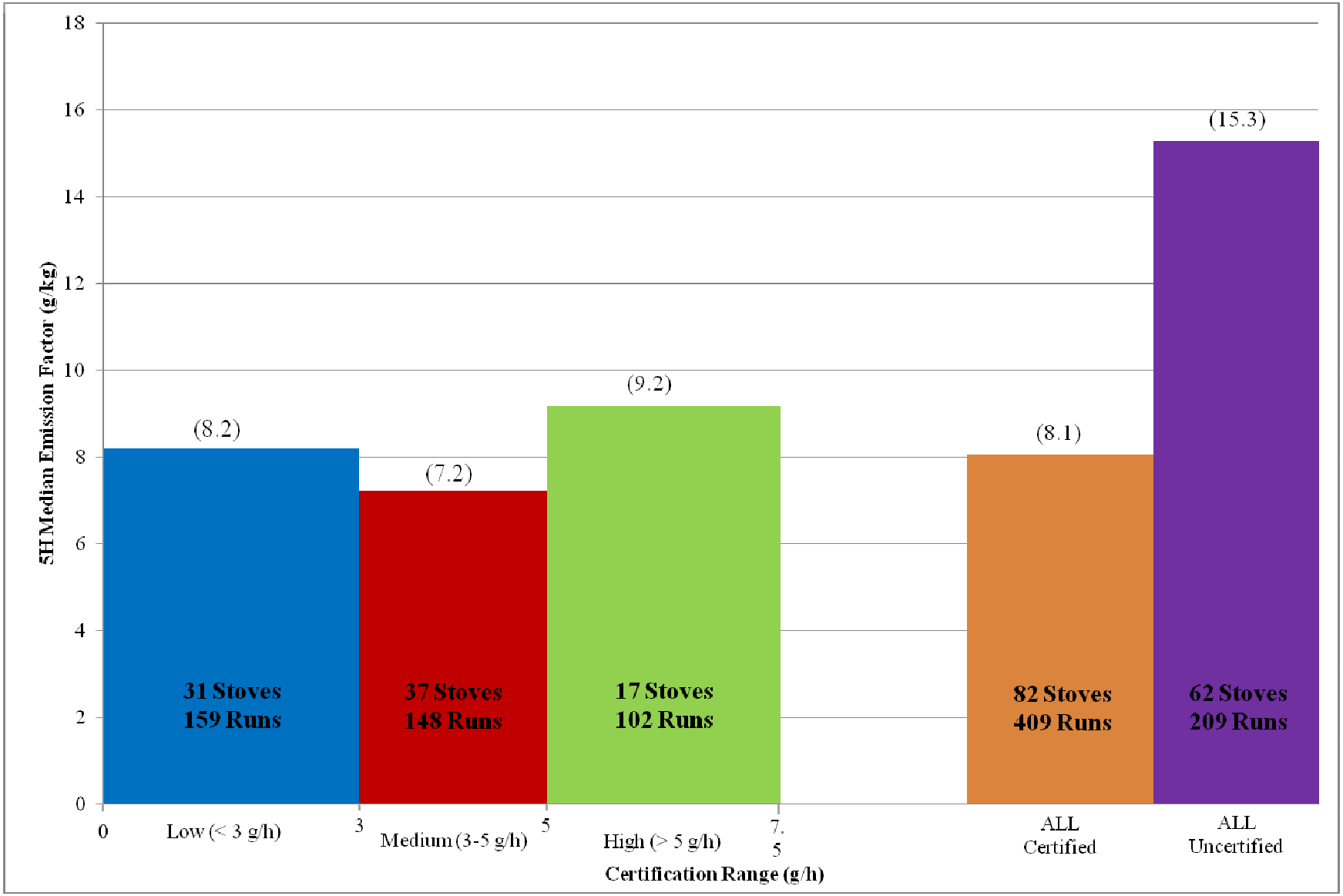

Figure 18. Median Emission Factors for Uncertified Stoves and for Certified Stoves by Low, Medium, and High Certification Categories

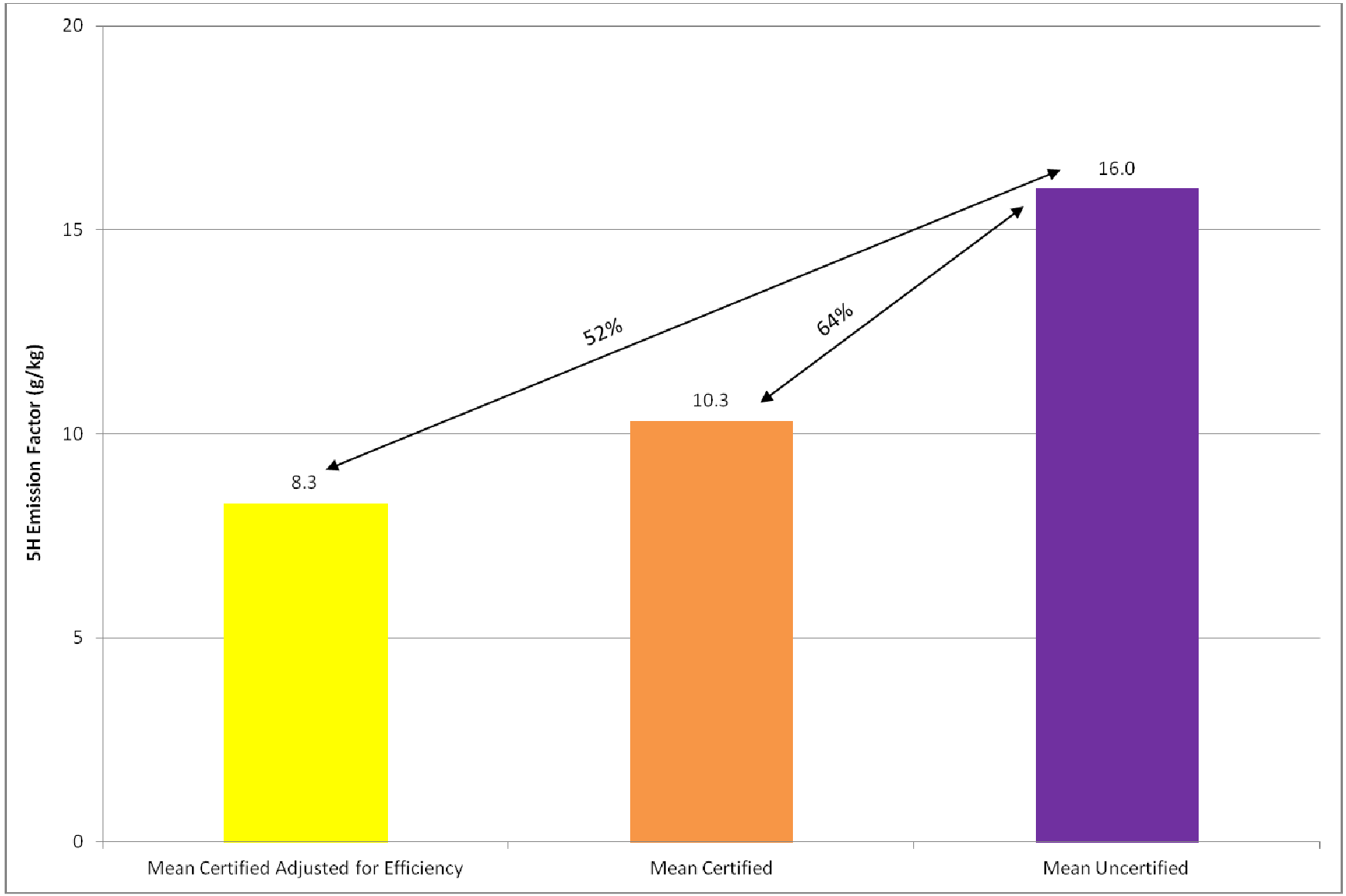

Figure19. Comparison of the Mean Effective Emission Factor of Certified Cordwood Stoves (Adjusted for Efficiency) with the Mean Emission Factor of Uncertified Stoves

3. Description of the AWES and VPI Samplers

Two samplers were used to collect the in-home data. They were the automated woodstove emission sampler (AWES) and the Virginia Polytechnic Institute (VPI) sampler.

The AWES was developed to quantify emissions of particles from residential wood burning appliances while they were in normal in-home use. It was small in size and operated unattended in home settings. Due to the temporal variability in emissions from wood burning appliances, the AWES was also designed to collect long-term integrated samples necessary to provide mean values.

Studies conducted with the AWES provided the majority of the database used for particulate emission factor development by the U.S. Environmental Protection Agency for residential wood combustion. The AWES was used to quantify emissions from woodstoves, masonry heaters, pellet stoves, and fireplaces. Due to its extensive use, the AWES underwent U.S. Environmental Protection Agency supported quality assurance evaluations during the period 1986 to 1992. Detailed descriptions of its principles of operation, supporting laboratory requirements, calibration, associated data reduction and uncertainty estimates were published in U.S. Environmental Protection Agency and U.S. Department of Energy reports and in various quality assurance plans.

The AWES was placed adjacent to the wood-burning appliance in study homes. For woodstove applications, a stainless steel inlet probe was typically attached to the chimney (stove pipe) one foot above the flue collar of the stove. Sample was withdrawn at a rate of approximately one liter per minute. The flow rate was maintained by a calibrated orifice. Particulate samples, including condensible particles, were captured with a heated filter followed by an XAD-2 resin cartridge. All interconnecting tubing, holders and hardware exposed to the sample were made either of stainless steel or Teflon to maintain sample integrity. After sample collection, the chimney gas was passed through silica gel to protect downstream components from condensate. The oxygen content of the chimney gas was measured with an electrochemical cell. The sample flow was then returned to the wood-burning appliance chimney above the point where the sample was withdrawn. Room temperature and chimney gas temperature were measured with type K thermocouples. The chimney gas temperature was measured within the chimney at the same location as the sample was withdrawn. A key component of the AWES was the data logging system. The system recorded date, time, oxygen content, room temperature, and chimney gas temperature at regular intervals. The oxygen content of the chimney gas, along with the mass of wood burned, allowed for the estimation of total chimney gas flow during sampling which was needed for the subsequent calculation of emission rates and emission factors. The record of chimney gas temperatures allowed for the total time of appliance operation over the course of the sampling duration to be determined. In addition to data recording, the system was programed to control the sampling frequency, sampling duration and sampling period. For example, in the last study which used the AWES, the AWES was programed to sample for two minutes once every 15 minutes for one week. The system was further programed to turn the sampling pump on during the programmed two minute sampling time only if the woodstove was in operation as determined by the chimney temperature in order

to avoid collection of sample material when the appliance was not in operation. A threshold chimney temperature of 100°F was used as an indicator of woodstove operation.

The VPI sampler was designed for similar in-home application as the AWES. It however was only ever deployed in Crested Butte, CO and in a follow-up laboratory study of Crested Butte stoves. It relied on an evacuated 74 liter cylinder to withdraw a sample from the woodstove chimney rather than a pump as did the AWES. The VPI sampler continuously drew sample from the wood stove chimney while the stove was in operation. The flue gases passed through a quartz probe, Teflon line, and a 30 ml glass trap. The glass trap collected condensate and particles. The sample was them passed through two 47 mm glass fiber filters and dried with calcium sulfate before passing into the pre-evacuated 74 liter cylinder. The desired sample flow was obtained by the use of a metering valve. A solenoid valve activated by a temperature controller allowed sample to flow only during stove operation. The sample gas collected in the cylinder was later analyzed for carbon monoxide and carbon dioxide. A 3 mm diameter sheathed thermocouple connected to a temperature controller sensed when the gas temperature beside the tip of the quartz probe was above the pre-set "on" temperature of 140° F. An time elapsed meter and a solenoid valve were turned on by the temperature controller. The time elapsed meter readings defined when the flue gas temperature was above the "on" temperature of 140° F and when the stove was in operation.

4. Conversion Equations

The equation that was used to convert emission rates (g/h) measured with the AWES system into Method 5G equivalency is:

$$M5G = (0.8635)\ X\ (AWES)^{0.9289} \quad (1)$$

The equation that was used to convert emission rates (g/h) measured with the VPI system into Method 5G equivalency is:

$$M5G = (0.6748)\ X\ (VPI)^{1.007} \quad (2)$$

Once a Method 5G equivalent emission rate was calculated with either equations 1 or 2 for the AWES data or VPI data, respectively, it then was converted to Method 5H equivalency by the equation:

$$M5H = (1.619)\ X\ (M5G)^{0.905} \quad (3)$$

These conversion equations were developed by performing linear regressions on data taken from simultaneous AWES-M5G and VPI-M5G tests for use in AP-42[24].

It should be noted that the equation specified in 40 CFR Part 60 Appendix A Method 28 for the conversion of Method 5G data into Method 5H equivalency is:

$$M5H = (1.82)\ X\ (M5G)^{0.83} \quad (4)$$

Equations 3 and 4 do produce slightly different results, although not enough to affect the overall findings of this evaluation. More significant is the fact that the conversion from Method 5G (5G1 and 5G3) to 5H have the greatest limitations at the lower emission rates with the highest percentage difference between a converted 5G to 5H number and a "true" 5H number at the lower emission rates[27]. While this issue adds uncertainty to the comparison of in-home emission values and certification values, particularly for stove models with lower certification values, the effect is not large enough to impact the overall findings of this study.

For the AWES, and VPI data, as per the AP-42 support document instructions[24], once 5H equivalent emission rate values were calculated by equations 1-3, 5H equivalent emission factors were calculated by dividing by the burn rate. For the laboratory data if a 5H equivalent emission factor was reported it was placed directly into this database. If only an emission rate was available (5H or a 5G valued converted to 5H by equation 4) it was divided by the burn rate to obtain an emission factor.

5. Burn Rates

Burn rates are simply calculated by dividing the dry mass of wood burned by the duration of the fire. The duration of the fire has been defined a number of ways by different test methods[28]. For a given fire, methods for defining the fire duration that produce a larger numerical value produce a smaller calculated burn rate and vice versa because the burn rate is a simple ratio and the mass of wood in the numerator remains unchanged. The AWES system monitored temperature in the connector chimney pipe at one foot above the wood heater. The endpoint of a "burn" was determined to be when the temperature dropped to 100° F in the chimney connector pipe at the one-foot monitoring point. Similarly, the VPI sampler monitored temperature at 0.3 meters downstream of the flue collar and used 140° F as the endpoint temperature. In contrast to the "one-foot, 100° F" and "0.3 meter 140° F" endpoints used to calculate burn rates from the AWES and VPI data, respectively, the NSPS Method 28 test procedures use an endpoint defined as "The test run is completed when the remaining weight of the test fuel charge is 0.00 Kg (0.0 lb)." In other words the end-point of the burn as defined by Method 28 is essentially when the mass of fuel remaining is less than the detection limit of the scale or about 0.1 lb. The temperature at one-foot above the wood heater is generally well above 100/140° F when the remaining weight of the test fuel charge reaches the detection limit of the scale. This dichotomy will cause a burn rate for the same fire as calculated by the Method 28 test procedure to be numerically larger than would be defined by the one-foot, 100° F and 0.3 meter, 140° F endpoints used with the AWES and VPI samplers. This issue has profound significance for the low burn rate specification and the weighting scheme in Method 28[28] , but has limited significance for this paper, since Method 28 data are not included in the data sets analyzed here. However, the lack of a statistical trend between burn rate and emission rate in the AWES, VPI, and in-home simulated laboratory data, as shown in Figures 2-7, is an important point and is illustrative of the number of factors affecting particulate emissions besides burn rates alone.

6. Efficiencies

Certified wood heaters are more efficient than pre-EPA-certified conventional wood heaters. When a particulate reduction benefit analysis is conducted not only do the differences in emission factors need to be taken into consideration but the differences in efficiencies also need to be considered. This is because wood heaters with higher efficiencies will burn less wood, which means less total particulate emissions for a given heating demand. Even though there is uncertainty in reported efficiency values the relative differences between pre-EPA-certified conventional cordwood heaters and certified cordwood heaters, not the absolute values allow estimations of the difference in characteristic emission levels. It should be noted that the relative difference between uncertified and certified stoves may be greater than tabulated here and correspondingly the magnitude of the emission benefit for certified wood heaters as compared to uncertified ones may be conservative. This is because the only efficiency values tabulated for uncertified wood heaters are provided in AP-42 and are believed to be based on a limited number of uncertified heaters in reasonable working order. However, many uncertified heaters that are replaced are in poor condition and have low efficiency. (Poor condition is often the reason for their replacement.)

The NSPS wood certification protocol does not require efficiency to be measured but assigns default values which were set at one standard deviation below the mean efficiency values claimed for Oregon certified wood heaters at that time[29-31]. The default values are 63% for certified non-catalytic wood heaters and 72% for certified catalytic wood heaters. AP-42 also lists efficiencies which are also based on a limited number of data points. The efficiency for conventional wood heaters listed in AP-42 is 54%. The efficiency for both catalytic and non-catalytic wood heaters listed in AP-42 is 68%[32]. For AP-42 it was assumed while the efficiency of a new catalytic wood heater is higher than a new non-catalytic wood heater, the catalytic stove's performance will degrade more rapidly than the non-catalytic stove and hence on average their efficiencies over their lifetimes will be the same. A third data source is a paper recently provided to EPA by HPBA entitled, "An Evaluation of Overall Efficiency for EPA Certified Non-catalytic Wood Heaters"[33]. This paper includes CSA B415.1-2010 weighted average efficiency values for 68 EPA certified non-catalytic wood heaters which meet the Washington State emission standard (PM emissions $\leq$ 4.5 g/h). It should be noted that these latter efficiency values were developed in large part to support marketing claims and to document efficiency levels under optimal conditions needed to receive federal tax credits and as such may tend to be higher than efficiencies under real-world in-home use.

Table 3 shows the default efficiency values listed in the NSPS regulations, the values listed in AP-42, and the mean weighted average efficiency for non-catalytic heaters from the HPBA report. The average of the NSPS data and the AP-42 data was used to adjust the certified stove emission factors to an effective emission factor for comparison with uncertified stove emission factors. The efficiency value from the data in the HPBA report, while shown in Table 3, was not used in the calculation of the mean as it is suspected that it over predicts the efficiency of certified non-catalytic heaters in real-world, in-home use plus it did not contain enough data for catalytic heaters to provide a meaningful average. It is interesting to note that while not appropriate to use in the calculation of averages it does support the reasonableness of the other data.

Table 3
Efficiencies of Cordwood Stoves

Category	AP-42	NSPS Default	HPBA report	Average
Uncertified Conventional Cordwood Stove	54%	-	-	54%
Certified Non-Catalytic Cordwood Stove	68%	63%	71%†	66%
Certified Catalytic Cordwood Stove	68%	72%	-	70%
All Certified Cordwood Stoves	-	-	-	67%*

*Based on 30% certified catalytic cordwood stoves and 70% certified non-catalytic cordwood stoves. Data in Table 3 are from references 29-33. Recent anecdotal information suggests that the percentage of catalytic stoves now sold may be lower than the 1990's estimate of 30%.
†Not used in average, see text for explanation.

In summary, the higher efficiencies of certified cordwood heaters as compared to conventional cordwood heaters should be taken into consideration. The fact that certified cordwood heaters use less wood than conventional woodstoves for the same heating demand means that less PM will be emitted.

7. Database

The database is provided in Tables 4-15. Tables 4-9 are for certified stoves and are discussed in Section 7.1. Tables 10-15 are for uncertified stoves and are discussed in Section 7.2.

6.1 Certified Stove Database

Table 4 is the AWES database for certified stoves in Klamath Falls, OR. Four studies conducted in Klamath Falls included certified stoves[3-6]. Table 5 is the AWES database for certified stoves in Portland, OR. Three studies conducted in Portland included certified stoves[6-8]. Table 6 is the AWES database for Whitehorse, YK. One study conducted in Whitehorse included certified stoves[10]. Table 7 is the AWES database for Glens Falls NY. Two studies conducted in Glens Falls included certified stoves[11,12]. For the Klamath Falls, Portland, and Glens Falls databases some stoves were tested in more than one study (houses were revisited) and are shown as such in the tables.

Each of the AWES data tables for certified stoves for the different cities is in two parts due to the number of parameters tabulated. Part 1 contains: (1) the run number assigned the sample in this study, (2) the stove model code, the unit number when there was more than one stove of a given model evaluated in this study, and whether the stove is catalytic (CAT) or non-catalytic (NC), (3) the year of the AWES study and the reference to the study, (4) the sample identification number

in the AWES study, (5) the tree species or type used for fuel, and (6) the fuel moisture on a dry basis (db). It should be noted that the typical method for measuring moisture is with a hand-held resistance pin-type moisture meter. Moisture measurements with this type of meter have a high uncertainty when the moisture is in excess of 35%. Part 2 repeats the run number assigned the sample in this study, the stove model code, the unit number, its CAT/NC status and the AWES study sample identification number. Part 2 then lists: (1) the burn rate in dry kg/h, (2) the emission factor in grams/dry kg fuel as reported in the study, (3) the emission rate in g/h as reported in the studies, (4) the emission rate in g/h converted to the 5H equivalent value, (5) the 5H emission factor (g/kg) calculated from the 5H emission rate and burn rate, and (6) the certification value in g/h obtained from U.S. EPA woodstove certification lists for each stove model.

Table 8 is the VPI database for Crested Butte, CO. Five studies were funded by the USEPA (EPA Region 8 or EPA Office of Research and Development) with co-sponsorship from the Town of Crested Butte and the Colorado Department of Health for the first two studies. The first four studies were field conducted in Crested Butte [14-17]. The first was conducted in the 1988-89 heating season[14]. No useful data for certified stoves were obtainable from that study due in part to its age, the fact that most stoves were either conventional stoves or coal stoves, and that the models of the certified stoves were intentionally kept confidential. Three more studies were conducted in homes in Crested Butte. They were conducted in the 1989-90, 1991-92 and 1995-96 heating seasons[15-17]. Some homes were revisited in several studies. These multi-season data are included in Table 8 for individual stove models tested in more than one heating season. All the certified stove models were kept confidential in the 1989-90 heating season study and some were kept confidential in the 1991-22 heating season study. A portion of the models that were kept intentionally confidential were able to be identified by cross-reference using information from the fifth study that was conducted in 1998. For this study, 12 of the used certified stoves were removed from homes for evaluation of their long-term for laboratory testing with the VPI sampler in Virginia with simulated in-home burning conditions[18]. Also four new stoves were tested with the VPI sampler using the Crested Butte cordwood. These stoves were the same models as four of the used stoves examined in the first phase of the study. This was a parametric laboratory study using the VPI sampler and examined the variables of fuel species, fuel moisture and stove air setting, again with simulated in-home burning scenarios. All 1998 data are included in Table 8. .

Table 8 contains: (1) the run number assigned the sample in this study, (2) the stove model code, the unit number when there was more than one stove of a given model evaluated in this study, whether the stove is catalytic (CAT) or non-catalytic (NC), and the reference to the VPI study, (3) the tree species or type used for fuel, (4) the fuel moisture on a dry basis (db), (5) the burn rate in dry kg/h, (6) the emission factor in grams/dry kg fuel as reported in the study, (7) the emission rate in g/h as reported in the studies, (7) the emission rate in g/h converted to the 5H equivalent value, (8), the 5H emission factor (g/kg) calculated from the 5H emission rate and burn rate, and (9) the certification value in g/h obtained from U.S. EPA woodstove certification lists for each stove model.

Table 9 contains laboratory data for three studies that used cordwood and simulated the in-home operation of a certified wood stove. One study was sponsored by the U.S. Department of Energy

BPA[7]. One study was sponsored by the U.S. Environmental Protection Agency[20]. One study was sponsored by Environment Canada[23]. Several other studies that were designed to simulate the in-home use of certified wood stoves were reviewed in the conduct of this work but were unusable due to the incomplete reporting of key data.

Table 9 contains: (1) the run number assigned the sample in this study, (2) the test sponsor and the reference to the study, (3) the stove model code, the unit number when there was more than one stove of a given model evaluated in this study, and whether the stove is catalytic (CAT) or non-catalytic (NC), (4) the description of the run regarding how it relates to the normal in-home use of a wood stove, (5) the tree species used for fuel, (6) the fuel moisture on a dry basis (db), (7) the burn rate in dry kg/h, (8) the emission rate in g/h on a 5H equivalent basis, (9) the 5H equivalent emission factor (g/kg) either directly reported in the study or calculated from the 5H equivalent emission rate and burn rate, and (10) the certification value in g/h obtained from U.S. EPA woodstove certification lists for each stove model.

It should be noted that the U.S EPA has periodically updated its list of certified wood stoves. As manufacturers have re-certified models and redesigned models while maintaining the same model or similar model designations, archived copies of the U.S. EPA lists in the time frame of each study were used to acquire the correct certification value applicable to a given model. In some cases ancillary information such as photographs or heat output ranges were used to confirm the model status.

7.2 Uncertified Stove Database

Table 10 is the AWES database for uncertified stoves in Klamath Falls, OR. Two studies conducted in Klamath Falls included uncertified stoves[4,5]. Table 11 is the AWES database for uncertified stoves in Portland, OR. Two studies conducted in Portland included uncertified stoves[7,9]. Table 12 is the AWES database for Whitehorse, YK. One study conducted in Whitehorse included uncertified stoves[10]. Table 13 is the AWES database for upstate New York and Vermont. One study conducted in upstate New York and Vermont included uncertified stoves[13].

Each of the AWES data tables for uncertified stoves for the different cities/regions contain: (1) the run number assigned the sample in this study, (2) the sample identification number in the AWES study, (3) the tree species or type used for fuel, (4) the fuel moisture on a dry basis (db), (4) the burn rate in dry kg/h, (5) the emission factor in grams/dry kg fuel as reported in the study, (6) the emission rate in g/h as reported in the studies, (7) the emission rate in g/h converted to the 5H equivalent value, and (8) the 5H emission factor (g/kg) calculated from the 5H emission rate and burn rate. In several of the AWES studies with uncertified stoves unusual experimental and "high tech." woodstove models were tested. Even though these unusual models were uncertified they were not included in the database. Only models that would be considered usual, well-established commercially available models were included.

Table 14 is the VPI database for Crested Butte, CO. Two studies were conducted in Crested Butte that included uncertified stoves[14,15]. During the development of the VPI sampler one run was conducted in the laboratory using cordwood and that data point is also included in the Table.

Table 14 contains: (1) the run number assigned the sample in this study, (2) the study sample I.D. and run number, and the reference year and number, (3) the tree species or type used for fuel, (4) the fuel moisture on a dry basis (db), (5) the burn rate in dry kg/h, (6) the emission factor in grams/dry kg fuel as reported in the study, (7) the emission rate in g/h as reported in the studies, (8) the emission rate in g/h converted to the 5H equivalent value, and (9) the 5H emission factor (g/kg) calculated from the 5H emission rate and burn rate..

Table 15 contains laboratory data for five studies that used cordwood and simulated the in-home operation of an uncertified wood stove. One study was sponsored by the U.S. Department of Energy BPA[7]. Two studies were sponsored by the U.S. Environmental Protection Agency[19, 20]. Two studies were sponsored by Environment Canada[21-22]. Several other studies that were designed to simulate the in-home use of uncertified wood stoves were reviewed in the conduct of this work but were unusable due to the incomplete reporting of key data.

Table 15 contains: (1) the run number assigned the sample in this study, (2) the test sponsor and the reference to the study, (3) the study sample description, (4) the description of the run regarding how it relates to the normal in-home use of a wood stove, (5) the tree species used for fuel, (6) the fuel moisture on a dry basis (db), (7) the burn rate in dry kg/h, (8) the emission rate in g/h on a 5H equivalent basis, and (9) the 5H equivalent emission factor (g/kg) either directly reported in the study or calculated from the 5H equivalent emission rate and burn rate.

Table 4
Certified Stove Field Data (Part 1) – Automated Woodstove Emission Sampler (AWES), Klamath Falls, OR

Run #	Stove Model Code, Unit #, NC/CAT	Location, Year, Ref.#	Study Sample Identification	Fuel Tree Species	Fuel Moisture (% db)
1	Stove Code 20, Stove #1, NC	Klamath Falls, OR, 1990, Ref 3	CKO101	50% Lodgepole Pine, 50% Laurel	26.8
2			CK0102	Lodgepole Pine	19.5
3			CK0103	Lodgepole Pine	17.7
4			CK0104	Lodgepole Pine	17.5
5		1992, Ref. 5	KF0501	Lodgepole Pine	12.7
6	Stove Code 20, Stove #2, NC	Klamath Falls, OR, 1990, Ref. 3	CK0202	Lodgepole Pine	14.3
7			CK0203	Lodgepole Pine	17.9
8			CK0204	Lodgepole Pine	16.9
9	Stove Code 20, Stove #3, NC	Klamath Falls, OR, 1990, Ref. 3	CK0301	Red Fir	17.6
10			CK0302	Red Fir	17.5
11			CK0303	Red Fir	16.4
12			CK0304	Red Fir	16.2
13		1999, Ref 6	KF02, Run A	Ponderosa Pine	20.8
14			KF02, Run B	Ponderosa Pine	21.5
15			KF02, Run C	Ponderosa Pine	19.6
16	Stove Code 22, Stove 1,CAT	Klamath Falls, OR,1990, Ref. 4	H-1, CAT, wk 2	Yellow Pine	10.0
17			H-1, CAT, wk 3	60% Juniper, 40% Red Fir	21.4
18		Klamath Falls, OR, 1992, Ref. 5	KF0201	Lodgepole Pine	8.9
19	Stove Code 29, NC	Klamath Falls, OR, 1990, Ref. 4	H-2, NC, wk 2	Juniper	19.1
20			H-2, NC, wk 3	Juniper	18.4

Table 4 (cont.)
Certified Stove Field Data (Part 1) – Automated Woodstove Emission Sampler (AWES), Klamath Falls, OR

Run #	Stove Model Code, Unit #, NC/CAT	Location, Year, Ref.#	Study Sample Identification	Fuel Tree Species	Fuel Moisture (% db)
21	Stove Code 16, CAT	Klamath Falls, OR, 1992, Ref 4	H-3, CAT, wk 2	White Fir	19.7
22			H-3, CAT, wk 3	White Fir	19.6
23		1992, Ref 5	KF0301	Lodgepole Pine	15.1
24	Stove Code 4, Stove 1, NC	Klamath Falls, OR, 1990, Ref. 4	H-4, NC, wk 2	50% Lodgepole Pine, 25% Juniper, 35% Oak	13.4
25			H-4, NC, wk 3	Juniper 70%, Oak 30%	12.9
26		1992, Ref. 5	KF0101	Lodgepole Pine, Juniper	10.6
27	Stove Code 30, NC	Klamath Falls, OR, 1990, Ref. 4	H-5, NC, wk 2	Juniper	17.6
28			H-5, NC, wk 3	Juniper	15.0
29		1992, Ref. 5	KF0401	Lodgepole Pine, Douglas Fir	13.9
30		1999, Ref. 6	KF03, Run B	95% Lodgepole Pine, 5% Juniper	14.6, 13.2
31			KF03, Run C	95% Lodgepole Pine, 5% Juniper	18.8, 18.3
32	Stove Code 22, Stove 2, CAT	Klamath Falls, OR, 1990, Ref. 4	H-6, CAT, wk 2	Red Fir	21.2
33			H-6, CAT, wk 3	50% Red Fir, 50% Lodgepole Pine	22.7
34	Stove Code 21, NC	Klamath Falls, OR, 1999, Ref. 6	KF01, Run A	Lodgepole Pine	20.2
35			KF01, Run B	Lodgepole Pine	24.5
36			KF01, Run C	Ponderosa Pine	31.4

Table 4 (cont.)
Certified Stove Field Data (Part 1) – Automated Woodstove Emission Sampler (AWES), Klamath Falls, OR

Run #	Stove Model Code, Unit #, NC/CAT	Location, Year, Ref.#	Study Sample Identification	Fuel Tree Species	Fuel Moisture (% db)
37	Stove Code 22, CAT, Stove 3	Klamath Falls, OR, 1999, Ref. 6	KF04, Run A	50% Lodgepole Pine, 50% Douglas Fir	21.8, 21.4
38			KF04, Run B	Lodgepole Pine	19.5
39	Stove Code 20, Stove #4, NC	Klamath Falss, OR, 1999, Ref. 6	KF05, Run A	Juniper	10.4
40			KF05, Run B	Juniper	9.8
41			KF05, Run C	Juniper	11.3
42	Stove Code 13, NC	Klamath Falls, OR, 1999, Ref. 6	KF06, Run A	Lodgepole Pine	11.7
43	Stove Code 39, NC	Klamath Falls, OR, 1999, Ref. 6	KF07, Run A	Lodgepole Pine	12.6
44			KF07, Run B	Lodgepole Pine	11.7
45			KF07, Run C	Lodgepole Pine	15.8
46	Stove Code 35, NC	Klamath Falls, OR, 1999, Ref. 6	KF08, Run A	Ponderosa Pine	26.8
47			KF08, Run B	Ponderosa Pine	25.4
48			KF08, Run C	Ponderosa Pine	15.7

Table 4
Certified Stove Field Data (Part 2) – Automated Woodstove Emission Sampler (AWES), Klamath Falls, OR

Run #	Stove Model Code, Unit #, NC/CAT	Study Sample Identification	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Certification Value
1	Stove Code 20, Stove #1, NC	CKO101	0.94	4.77	4.46	5.0	5.3	3.4
2		CK0102	0.91	5.95	5.44	5.9	6.5	
3		CK0103	0.95	5.31	5.05	5.5	5.8	
4		CK0104	0.75	7.01	5.27	5.7	7.6	
5		KF0501	1.40	3.73	5.21	5.7	4.1	
6	Stove Code 20, Stove #2, NC	CK0202	0.87	7.01	6.07	6.5	7.4	3.4
7		CK0203	0.72	14.86	10.68	10.4	14.4	
8		CK0204	0.80	17.42	13.91	13.0	16.2	
9	Stove Code 20, Stove #3, NC	CK0301	0.99	2.66	2.62	3.2	3.2	3.4
10		CK0302	1.02	2.73	2.78	3.3	3.3	
11		CK0303	1.25	2.81	3.52	4.1	3.3	
12		CK0304	1.58	2.93	4.64	5.2	3.3	
13		KF02, Run A	1.0	5.7	5.5	5.9	5.9	
14		KF02, Run B	1.0	5.1	5.3	5.8	5.8	
15		KF02, Run C	0.9	5.5	4.9	5.4	6.0	
16	Stove Code 22, Stove 1,CAT	H-1, CAT, wk 2	1.36	3.6	4.9	5.4	4.0	3.7
17		H-1, CAT, wk 3	0.94	8.9	8.4	8.5	9.0	
18		KF0201	1.47	6.66	9.80	9.7	6.6	
19	Stove Code 29, NC	H-2, NC, wk 2	0.96	6.8	6.6	6.9	7.2	4.4
20		H-2, NC, wk 3	0.81	6.0	4.9	5.4	6.7	

Table 4 (cont.)
Certified Stove Field Data (Part 2) – Automated Woodstove Emission Sampler (AWES), Klamath Falls, OR

Run #	Stove Model Code, Unit #, NC/CAT	Study Sample Identification	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Certification Value
21	Stove Code 16, CAT	H-3, CAT, wk 2	1.02	4.9	5.0	5.5	5.4	3.1
22		H-3, CAT, wk 3	0.95	5.8	5.5	5.9	6.3	
23		KF0301	1.27	10.87	13.79	12.9	10.1	
24	Stove Code 4, Stove 1, NC	H-4, NC, wk 2	1.50	2.2	3.4	4.0	2.6	2.1
25		H-4, NC, wk 3	1.20	2.6	5.9	6.3	5.3	
26		KF0101	1.35	5.04	6.79	7.1	5.3	
27	Stove Code 30, NC	H-5, NC, wk 2	0.97	6.5	6.2	6.6	6.8	4.5
28		H-5, NC, wk 3	0.78	7.5	5.9	6.3	8.1	
29		KF0401	1.15	2.77	3.17	3.7	3.3	
30		KF03, Run B	0.8	3.7	3.7	4.3	5.3	
31		KF03, Run C	0.9	1.9	1.7	2.2	2.5	
32	Stove Code 22, Stove 2, CAT	H-6, CAT, wk 2	1.34	4.9	6.6	6.9	5.2	3.7
33		H-6, CAT, wk 3	1.14	7.1	8.1	8.2	7.2	
34	Stove Code 21, NC	KF01, Run A	1.2	7.8	9.5	9.4	7.8	3.6
35		KF01, Run B	1.2	8.7	10.8	10.5	8.7	
36		KF01, Run C	1.4	4.8	6.5	6.8	4.9	

Table 4 (cont.)
Certified Stove Field Data (Part 2) – Automated Woodstove Emission Sampler (AWES), Klamath Falls, OR

Run #	Stove Model Code, Unit #, NC/CAT	Study Sample Identification	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate(g/h)	5H Emission Factor (g/kg)	Certification Value
37	Stove Code 22, CAT, Stove 3	KF04, Run A	0.9	17.5	15.8	14.4	16.0	3.7
38		KF04, Run B	1.1	14.2	15.1	13.9	12.6	
39	Stove Code 20, Stove #4, NC	KF05, Run A	0.8	5.2	4.3	4.8	6.0	3.4
40		KF05, Run B	0.9	7.2	6.1	6.5	7.2	
41		KF05, Run C	1.0	2.8	2.8	3.4	3.4	
42	Stove Code 13, NC	KF06, Run A	0.7	6.0	4.0	4.5	6.5	2.9
43	Stove Code 39, NC	KF07, Run A	0.8	9,9	8.3	8.4	10.5	6.6
44		KF07, Run B	0.7	7.9	5.9	6.3	9.0	
45		KF07, Run C	1.2	8.2	9.7	9.6	8.0	
46	Stove Code 35, NC	KF08, Run A	1.1	8.9	9.9	9.7	8.9	5.7
47		KF08, Run B	1.1	12.3	13.6	12.7	11.6	
48		KF08, Run C	1.2	5.2	6.3	6.7	5.5	

Table 5
Certified Stove Field Data (Part 1) – Automated Woodstove Emission Sampler (AWES), Portland, OR

Run #	Stove Model Code, Unit #, NC/CAT	Location, Year, Ref.#	Study Sample Identification	Fuel Tree Species	Fuel Moisture (% db)
49	Stove Code 18, CAT	Portland, OR, 1999, Ref. 6	P01, Run A	Douglas Fir	24.0
50			P01, Run B	Douglas Fir	21.0
51			P01, Run C	Douglas Fir	22.8
52	Stove Code 19, NC	Portland, OR, 1999, Ref .6	P02, Run A	20% Maple, 5% Douglas Fir, 75% Alder	105.3, 36.4, 106.6
53			P02, Run B	Oak	18.5
54			P02, Run C	50% Douglas Fir, 50% Oak	35.4, 19.1
55	Stove Code 3, NC	Portland, OR, 1999, Ref. 6	P03, Run A	Douglas Fir	18.3
56			P03, Run B	Douglas Fir	18.3
57			P03, Run C	50% Douglas Fir, 50% Birch	19.8
58	Stove Code 33, CAT	Portland, OR, 1999, Ref. 6	P04, Run A	Oak	18.3
59			P04, Run B	Oak	18.5
60			P04, Run C	Oak	18.4
61	Stove Code 26, CAT	Portland, OR, 1999, Ref. 6	P05, Run A	50% Lodgepole Pine, 50% Cherry	20.6, 18.1
62			P05, Run B	50% Lodgepole Pine, 50% Cherry	19.8, 18.2
63			P05, Run C	50% Lodgepole Pine, 50% Cherry	19.3, 18.8

Table 5 (cont.)
Certified Stove Field Data (Part 1) – Automated Woodstove Emission Sampler (AWES), Portland, OR

Run #	Stove Model Code, Unit #, NC/CAT	Location, Year, Ref.#	Study Sample Identification	Fuel Tree Species	Fuel Moisture (% db)
64	Stove Code 20, Stove #5, NC	Portland, OR, 1999, Ref. 3	P06, Run A	20% Maple, 5% Douglas Fir, 75% Alder*	105.3, 36.4, 106.6
65			P06, Run B	20% Maple, 5% Douglas Fir, 75% Alder*	104.2, 38, 112.1
66			P06, Run C	20% Maple, 5% Douglas Fir, 75% Alder	101.1, 35.4, 107.9
67	Stove Code 40, NC	Portland, OR, 1999, Ref. 3	P07, Run A	20% Maple, 5% Douglas Fir, 75% Alder*	105.3, 36.4, 106.6
68			P07, Run B	20% Maple, 5% Douglas Fir, 75% Alder*	104.2, 38, 112.1
69			P07, Run C	Douglas Fir	24.8
70	Stove Code 1, Stove 1, CAT	Portland, OR, 1999, Ref. 3	P08, Run A	10% Douglas Fir, 90% Oak	21.8, 25.1
71			P08, Run B	10% Douglas Fir, 90% Oak	21.9, 25.4

*Same wood was used for runs 64 and 67 and for runs 65 and 68.

Table 5 (cont.)
Certified Stove Field Data (Part 1) – Automated Woodstove Emission Sampler (AWES), Portland, OR

Run #	Stove Model Code, Unit #, NC/CAT	Location, Year, Ref.#	Study Sample Identification	Fuel Tree Species	Fuel Moisture (% db)
72	Stove Code 20, Stove #6, NC	Portland, OR, 1988, Ref. 7	P04,1	50% Lodgepole Pine, 50% Douglas Fir	16.5, 11.3
73			P04,2	50% Lodgepole Pine, 50% Douglas Fir	19.8, 11.3
74			P04,3	33% Douglas Fir, 33% Alder, 34% Maple	24.5, 21.3, 18.9
75			P04,4	50% Maple, 50% Alder	25.0, 25.3
76			P04,5	50% Maple, 50% Alder	21.7, 19.5
77	Stove Code 2, CAT	Portland, OR, 1988, Ref. 7	P02,1	Apple	12.9
78			P02,2	Douglas Fir	15.6
79			P02,3	20% Apple, 80% Douglas Fir	16.2, 17.6
80			P02,4	20% Apple, 80% Douglas Fir	16.2, 17.0
81		Portland, OR, 1988, Ref. 8	SP1	Douglas Fir	16.4

Table 5
Certified Stove Field Data (Part 2) – Automated Woodstove Emission Sampler (AWES), Portland, OR

Run #	Stove Model Code, Unit #, NC/CAT	Study Sample Identification	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Certification Value
49	Stove Code 18, CAT	P01, Run A	1.2	15.0	18.4	16.4	13.7	3.1
50		P01, Run B	1.2	12.9	16.0	14.6	12.1	
51		P01, Run C	1.3	13.5	16.9	15.3	11.7	
52	Stove Code 19, NC	P02, Run A	0.6	19.4	12.3	11.7	19.5	3.3
53		P02, Run B	0.8	17.5	13.3	12.5	15.6	
54		P02, Run C	0.7	14.3	10.3	10.1	14.4	
55	Stove Code 3, NC	P03, Run A	0.8	5.9	4.7	5.2	6.5	1.9
56		P03, Run B	1.0	7.1	7.4	7.6	7.6	
57		P03, Run C	1.0	5.8	5.8	6.2	6.2	
58	Stove Code 33, CAT	P04, Run A	0.7	5.4	4.0	4.5	6.5	5.2
59		P04, Run B	0.9	5.0	4.7	5.2	5.8	
60		P04, Run C	0.7	5.9	3.9	4.5	6.4	
61	Stove Code 26, CAT	P05, Run A	2.0	7.0	14.3	13.3	6.6	4.1
62		P05, Run B	0.8	6.4	5.3	5.8	7.2	
63		P05, Run C	0.9	4.4	4.2	4.7	5.3	

Table 5 (cont.)
Certified Stove Field Data (Part 2) – Automated Woodstove Emission Sampler (AWES), Portland, OR

Run #	Stove Model Code Unit #, NC/CAT	Study Sample Identification	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Certification Value
64	Stove Code 20, Stove #5, NC	P06, Run A	1.5	9.1	13.5	12.6	8.4	3.4
65		P06, Run B	1.3	14.7	18.9	16.8	12.9	
66		P06, Run C	1.1	8.7	10.0	9.8	8.9	
67	Stove Code 40, NC	P07, Run A	1.4	18.4	26.6	22.3	16.0	7.4
68		P07, Run B	1.5	18.5	27.7	23.1	15.4	
69		P07, Run C	1.9	20.8	40.3	31.7	16.7	
70	Stove Code 1, Stove 1, CAT	P08, Run A	1.3	17.1	23.0	19.8	15.2	1.6
71		P08, Run B	1.6	15.5	25.2	21.4	13.3	
72	Stove Code 20, Stove #6, NC	P04,1	1.29	5.3	6.9	7.2	5.6	3.4
73		P04,2	0.99	10.1	10.0	9.8	9.9	
74		P04,3	0.90	12.1	10.9	10.6	11.7	
75		P04,4	0.65	10.3	6.7	7.0	10.8	
76		P04,5	0.70	9.9	6.9	7.2	10.3	
77	Stove Code 2, CAT	P02,1	1.07	2.5	2.7	3.3	3.1	1.9
78		P02,2	0.95	4.4	4.2	4.7	5.0	
79		P02,3	0.87	5.4	4.7	5.2	6.0	
80		P02,4	0.79	5.4	4.3	4.8	6.1	
81		SP1	0.70	5.8	4.3	4.8	6.9	

Table 6
Certified Stove Field Data (Part 1) – Automated Woodstove Emission Sampler (AWES), Whitehorse, YK

Run #	Stove Model Code, Unit #, NC/CAT	Location, Year, Ref.#	Study Sample Identification	Fuel Tree Species	Fuel Moisture (% db)
82	Stove Code 31, Stove 1, NC	Whitehorse, YK, 1987, Ref.10	W04,5	Lodgepole Pine	12.7
83			W04,6	Lodgepole Pine	15.3
84			W04,7	Lodgepole Pine	13.8
85			W04,8	50% Spruce, 50% Lodgepole Pine	31.9, 15.6
86			W04,9	50% Spruce, 50% Lodgepole Pine	16.2, 16.2
87	Stove Code 31, Stove 2, NC	Whitehorse, YK, 1987, Ref.10	W09,5	Lodgepole Pine	15.9
88			W09,6	Lodgepole Pine	19.0
89			W09,7	Lodgepole Pine	17.7
90			W09,8	Spruce	21.5
91			W09,9	Spruce	32.8

Table 6
Certified Stove Field Data (Part 2) – Automated Woodstove Emission Sampler (AWES), Whitehorse, YK

Run #	Stove Model Code, Unit #, NC/CAT	Study Sample Identification	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Certification Value
82	Stove Code 31, Stove 1, NC	W04,5	1.66	8.1	10.5	10.2	6.2	4.6
83		W04,6	1.47	8.5	9.2	9.2	6.2	
84		W04,7	1.73	3.5	5.3	5.8	3.3	
85		W04,8	1.37	10.7	12.8	12.1	8.8	
86		W04,9	1.02	9.3	10.3	10.1	9.9	
87	Stove Code 31, Stove 2, NC	W09,5	1.01	19.2	19.4	17.1	17.0	4.6
88		W09,6	0.84	21.8	18.3	16.3	19.4	
89		W09,7	0.91	18.7	17.1	15.4	16.9	
90		W09,8	1.06	16.8	17.9	16.0	15.1	
91		W09,9	0.85	26.0	22.2	19.2	22.6	

Table 7
Certified Stove Field Data (Part 1) – Automated Woodstove Emission Sampler (AWES), Glens Falls, NY

Run #	Stove Model Code, Unit #, NC/CAT	Location, Year, Ref.#	Study Sample Identification	Fuel Tree Species	Fuel Moisture (% db)
92	Stove Code 8, CAT, Stove 1	Glens Falls, NY, 1989, Ref.11	Y01,2	Hardwoods	32.8
93			Y01,3	Hardwoods	32.8
94			Y01,4	Hardwoods	32.8
95			Y01,5	Hardwoods	32.8
96		Glens Falls, NY, 1990, Ref. 12	2^{nd}yr	80% Maple, 20% Ash	28.0
97	Stove Code 8, CAT, Stove 2	Glens Falls, NY, 1989, Ref.11	Y02,1	Hardwoods	21.8
98			Y02,2	Hardwoods	21.8
99			Y02,3	Hardwoods	21.8
100			Y02,4	Hardwoods	21.8
101			Y02,5	Hardwoods	21.8
102	Stove Code 8, CAT, Stove 3	Glens Falls, NY, 1989, Ref.11	Y12,1	Hardwoods	33.7
103			Y12,2	Hardwoods	33.7
104			Y12,3	Hardwoods	33.7
105			Y12,4	Hardwoods	33.7
106	Stove Code 8, CAT, Stove 4	Glens Falls, NY, 1989, Ref.11	Y23,1	Hardwoods	20.9
107			Y23,2	Hardwoods	20.9
108			Y23,3	Hardwoods	20.9
109			Y23,4	Hardwoods	20.9
110			Y23,5	Hardwoods	20.9
111	Stove Code 8, CAT, Stove 5	Glens Falls, NY, 1989, Ref117	Y25,1	Hardwoods	35.3
112			Y25,2	Hardwoods	35.3
113			Y25,3	Hardwoods	35.3
114			Y25,4	Hardwoods	35.3
115			Y25,5	Hardwoods	35.3

Table 7 (cont.)
Certified Stove Field Data (Part 1) – Automated Woodstove Emission Sampler (AWES), Glens Falls, NY

Run #	Stove Model Code, Unit #, NC/CAT	Location, Year, Ref.#	Study Sample Identification	Fuel Tree Species	Fuel Moisture (% db)
116	Stove Code 41, NC, Stove 1	Glens Falls, NY, 1989, Ref.11	Y04,1	Hardwoods	22.5
117			Y04,2	Hardwoods	22.5
118			Y04,3	Hardwoods	22.5
119			Y04,4	Hardwoods	22.5
120			Y04,5	Hardwoods	22.5
121	Stove Code 41, NC, Stove 2	Glens Falls, NY, 1989, Ref.11	Y06,1	Hardwoods	23.1
122			Y06,2	Hardwoods	23.1
123			Y06,3	Hardwoods	23.1
124			Y06,4	Hardwoods	23.1
125			Y06,5	Hardwoods	23.1
126	Stove Code 41, NC, Stove 3	Glens Falls, NY, 1989, Ref.11	Y08,2	Hardwoods	33.9
127			Y08,3	Hardwoods	33.9
128			Y08,4	Hardwoods	33.9
129			Y08,5	Hardwoods	33.9
130	Stove Code 41, NC, Stove 4	Glens Falls, NY, 1989, Ref.11	Y11,1	Hardwoods	24.5
131			Y11,2	Hardwoods	24.5
132			Y11,3	Hardwoods	24.5
133			Y11,4	Hardwoods	24.5
134			Y11,5	Hardwoods	24.5
135	Stove Code 41, NC, Stove 5	Glens Falls, NY, 1989, Ref.11	Y21,1	Hardwoods	22.9
136			Y21,2	Hardwoods	22.9
137			Y21,3	Hardwoods	22.9
138			Y21,4	Hardwoods	22.9
139			Y21,5	Hardwoods	22.9

Table 7 (cont.)
Certified Stove Field Data (Part 1) – Automated Woodstove Emission Sampler (AWES), Glens Falls, NY

Run #	Stove Model Code, Unit #, NC/CAT	Location, Year, Ref.#	Study Sample Identification	Fuel Tree Species	Fuel Moisture (% db)
140	Stove Code 15, CAT, Stove 1	Glens Falls, NY, 1989, Ref.11	Y07,1	Hardwoods	21.7
141			Y07,2	Hardwoods	21.7
142			Y07,3	Hardwoods	21.7
143			Y07,4	Hardwoods	21.7
144			Y07,5	Hardwoods	21.7
145	Stove Code 15, CAT, Stove 2	Glens Falls, NY, 1989, Ref.11	Y010,1	Hardwoods	28.2
146			Y010,2	Hardwoods	28.2
147			Y010,3	Hardwoods	28.2
148			Y010,4	Hardwoods	40.5
149			Y010,5	Hardwoods	40.5
150		Glens Falls, NY, 1990, Ref. 12	2^{nd}yr	70% Beech, 20% Oak, 10% Birch	28.0
151	Stove Code 15, CAT, Stove 3	Glens Falls, NY, 1989, Ref.11	Y13,1	Hardwoods	27.8
152			Y13,2	Hardwoods	27.8
153			Y13,3	Hardwoods	27.8
154			Y13,4	Hardwoods	27.8
155			Y13,5	Hardwoods	27.8
156			2^{nd}yr	55% Oak, 35% Maple, 10% Beech	27.0
157	Stove Code 15, CAT, Stove 4	Glens Falls, NY, 1989, Ref.11	Y14,1	Hardwoods	27.2
158			Y14,2	Hardwoods	27.2
159			Y14,3	Hardwoods	27.2
160			Y14,4	Hardwoods	27.2
161		Glens Falls, NY, 1990, Ref. 12	2^{nd}yr	Ash	26.0

Table 7 (cont.)
Certified Stove Field Data (Part 1) – Automated Woodstove Emission Sampler (AWES), Glens Falls, NY

Run #	Stove Model Code, Unit #, NC/CAT	Location, Year, Ref.#	Study Sample Identification	Fuel Tree Species	Fuel Moisture (% db)
162	Stove Code 15, CAT, Stove 5	Glens Falls, NY, 1989, Ref.11	Y19,1	Hardwoods	23.9
163			Y19,2	Hardwoods	23.9
164			Y19,3	Hardwoods	23.9
165			Y19,5	Hardwoods	23.9
166		Glens Falls, NY, 1990, Ref. 12	2^{nd}yr	Maple	26.0
167	Stove Code 12, CAT, Stove 1	Glens Falls, NY, 1989, Ref.11	Y03,1	Hardwoods	27.5
168			Y03,2	Hardwoods	27.5
169			Y03,3	Hardwoods	27.5
170			Y03,4	Hardwoods	27.5
171			Y03,5	Hardwoods	27.5
172	Stove Code 12, CAT, Stove 2	Glens Falls, NY, 1989, Ref.12	Y05,1	Hardwoods	27.6
173			Y05,2	Hardwoods	27.6
174			Y05,3	Hardwoods	27.6
175			Y05,4	Hardwoods	27.6
176			Y05,5	Hardwoods	27.6
177	Stove Code 12, CAT, Stove 3	Glens Falls, NY, 1989, Ref.11	Y09,1	Hardwoods	22.2
178			Y09,2	Hardwoods	22.2
179			Y09,4	Hardwoods	22.2
180			Y09,5	Hardwoods	22.2
181	Stove Code 12, CAT, Stove 4	Glens Falls, NY, 1989, Ref.11	Y22,1	Hardwoods	35.1
182			Y22,2	Hardwoods	35.1
183			Y22,3	Hardwoods	35.1
184			Y22,4	Hardwoods	35.1
185			Y22,5	Hardwoods	35.1

Table 7 (cont.)
Certified Stove Field Data (Part 1) – Automated Woodstove Emission Sampler (AWES), Glens Falls, NY

Run #	Stove Model Code, Unit #, NC/CAT	Location, Year, Ref.#	Study Sample Identification	Fuel Tree Species	Fuel Moisture (% db)
186	Stove Code 27, NC, Stove 1	Glens Falls, NY, 1989, Ref.11	Y15,2	Hardwoods	17.5
187			Y15,3	Hardwoods	17.5
188			Y15,4	Hardwoods	17.5
189			Y15,5	Hardwoods	17.5
190	Stove Code 27, NC, Stove 2	Glens Falls, NY, 1989, Ref.11	Y16,1	Hardwoods	23.7
191			Y16,2	Hardwoods	23.7
192			Y16,3	Hardwoods	23.7
193			Y16,4	Hardwoods	23.7
194			Y16,5	Hardwoods	23.7
195	Stove Code 27, NC, Stove 3	Glens Falls, NY, 1989, Ref.11	Y17,1	Hardwoods	33.1
196			Y17,2	Hardwoods	33.1
197			Y17,3	Hardwoods	33.1
198			Y17,4	Hardwoods	33.1
199			Y17,5	Hardwoods	33.1
200	Stove Code 27, NC, Stove 4	Glens Falls, NY, 1989, Ref.11	Y20,1	Hardwoods	23.0
201			Y20,2	Hardwoods	23.0
202			Y20,3	Hardwoods	23.0
203			Y20,4	Hardwoods	23.0
204			Y20,5	Hardwoods	23.0
205	Stove Code 27, NC, Stove 5	Glens Falls, NY, 1989, Ref.11	Y24,2	Hardwoods	23.8
206			Y24,3	Hardwoods	23.8
207			Y24,4	Hardwoods	23.8
208			Y24,5	Hardwoods	24.1

[†]Maple was the dominant species; beech, oak, ash and cherry were also common

Table 7
Certified Stove Field Data (Part 2) – Automated Woodstove Emission Sampler (AWES), Glens Falls, NY

Run #	Stove Mode Code, Unit #, NC/CAT	Study Sample Identification	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Certification Value
92	Stove Code 8, CAT, Stove 1	Y01,2	1.00	4.1	4.1	4.6	4.6	2.5
93		Y01,3	0.86	5.1	4.4	4.9	5.7	
94		Y01,4	0.69	3.9	2.7	3.3	4.7	
95		Y01,5	0.84	5.0	4.2	4.7	5.6	
96		2^{nd}yr	0.71	17.06	12.09	11.5	16.2	
97	Stove Code 8, CAT, Stove 2	Y02,1	2,49	3.9	9.8	9.7	3.9	2.5
98		Y02,2	2.19	3.7	8.1	8.2	3.8	
99		Y02,3	2.49	4.2	10.5	10.2	4.1	
100		Y02,4	2.01	8.5	17.0	15.3	7.6	
101		Y02,5	1.76	10.8	19.0	16.8	9.6	
102	Stove Code 8, CAT, Stove 3	Y12,1	1.00	4.0	4.0	4.5	4.5	2.5
103		Y12,2	1.16	4.9	5.7	6.1	5.3	
104		Y12,3	1.02	10.7	10.9	10.6	10.4	
106		Y12,4	0.89	9.0	8.1	8.2	9.2	
107	Stove Code 8, CAT, Stove 4	Y23,1	0.71	9.2	6.5	6.8	9.6	2.5
107		Y23,2	1.25	8.6	10.8	10.5	8.4	
108		Y23,3	1.50	11.9	17.8	15.9	10.6	
109		Y23,4	1.17	13.5	15.8	14.4	12.3	
110		Y23,5	0.99	14.2	14.1	13.1	13.2	
111	Stove Code 8, CAT, Stove 5	Y25,1	1.07	7.0	7.5	7.7	7.2	2.5
112		Y25,2	0.93	6.8	6.3	6.7	7.2	
113		Y25,3	0.85	11.7	10.0	9.8	11.6	
114		Y25,4	1.07	17.9	19.1	16.9	15.8	
115		Y25,5	1.02	16.9	17.2	15.5	15.2	

Table 7 (cont.)
Certified Stove Field Data (Part 2) – Automated Woodstove Emission Sampler (AWES), Glens Falls, NY

Run #	Stove Model Code, Unit #, NC/CAT	Study Sample Identification	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Certification Value
116	Stove Code 41, NC, Stove 1	Y04,1	1.10	14.5	15.9	14.5	13.2	7.5
117		Y04,2	1.10	9.2	10.2	10.0	9.1	
118		Y04,3	0.71	6.4	4.6	5.1	7.2	
119		Y04,4	0.87	12.3	10.7	10.4	11.9	
120		Y04,5	0.73	11.8	8.7	8.7	12.0	
121	Stove Code 41, NC, Stove 2	Y06,1	0.83	13.2	10.9	10.6	12.7	7.5
122		Y06,2	0.81	9.2	7.5	7.7	9.5	
123		Y06,3	0.80	13.1	10.5	10.2	12.8	
124		Y06,4	0.63	10.8	6.8	7.1	11.3	
125		Y06,5	0.62	16.0	9.9	9.7	15.7	
126	Stove Code 41, NC, Stove 3	Y08,2	1.23	10.0	12.3	11.7	9.5	7.5
127		Y08,3	1.39	12.6	17.5	15.7	11.3	
128		Y08,4	1.01	8.4	8.5	8.6	8.5	
129		Y08,5	0.88	13.6	12.0	11.4	13.0	
130	Stove Code 41, NC, Stove 4	Y11,1	0.55	42.7	23.5	20.1	36.6	7.5
131		Y11,2	0.52	22.3	11.6	11.1	21.4	
132		Y11,3	0.39	36.7	14.3	13.3	34.0	
133		Y11,4	0.37	52.0	19.2	17.0	45.9	
134		Y11,5	0.39	44.0	17.0	15.3	39.3	
135	Stove Code 41, NC, Stove 5	Y21,1	1.29	12.4	16.1	14.7	11.4	7.5
136		Y21,2	1.54	7.2	11.0	10.6	6.9	
137		Y21,3	1.39	9.6	13.4	12.6	9.0	
138		Y21,4	1.31	10.8	14.1	13.1	10.0	
139		Y21,5	1.14	12.4	14.2	13.2	11.6	

Table 7 (cont.)
Certified Stove Field Data (Part 2) – Automated Woodstove Emission Sampler (AWES), Glens Falls, NY

Run #	Stove Model Code, Unit #, NC/CAT	Study Sample Identification	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Certification Value
140	Stove Code 15, CAT, Stove 1	Y07,1	0.94	2.6	2.4	3.0	3.1	3.0
141		Y07,2	1.17	1.8	2.1	2.6	2.3	
142		Y07,3	1.16	2.5	2.9	3.5	3.0	
143		Y07,4	0.96	3.2	3.0	3.6	3.7	
144		Y07,5	0.93	4.4	4.1	4.6	5.0	
145	Stove Code 15, CAT, Stove 2	Y010,1	1.02	2.8	2.9	3.5	3.4	3.0
146		Y010,2	1.13	3.4	3.8	4.4	3.9	
147		Y010,3	1.12	4.9	5.5	5.9	5.3	
148		Y010,4	0.64	4.2	2.7	3.3	5.1	
149		Y010,5	0.89	7.4	6.5	6.8	7.7	
150		2^{nd}yr	0.78	7.39	5.79	6.2	8.0	
151	Stove Code 15, CAT, Stove 3	Y13,1	1.44	2.2	3.2	3.8	2.6	3.0
152		Y13,2	1.53	5.1	7.8	8.0	5.2	
153		Y13,3	1.56	5.1	8.0	8.1	5.2	
154		Y13,4	1.50	6.0	9.1	9.1	6.0	
155		Y13,5	1.08	11.4	12.4	11.8	10.9	
156		2^{nd}yr	0.59	26.32	15.65	14.3	24.3	
157	Stove Code 15, CAT, Stove 4	Y14,1	1.11	5.2	5.8	6.2	5.6	3.0
158		Y14,2	1.28	3.2	4.1	4.6	3.6	
159		Y14,3	1.33	4.9	6.5	6.8	5.1	
160		Y14,4	1.36	4.8	6.5	6.8	5.0	
161		2^{nd}yr	1.33	7.02	9.34	9.3	7.0	

Table 7 (cont.)
Certified Stove Field Data (Part 2) – Automated Woodstove Emission Sampler (AWES), Glens Falls, NY

Run #	Stove Model Code, Unit #, NC/CAT	Study Sample Identification	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Certification Value
162	Stove Code 15, CAT, Stove 5	Y19,1	0.57	4.1	2.3	2.9	5.0	3.0
163		Y19,2	1.14	2.1	2.4	3.0	2.6	
164		Y19,3	0.34	1.9	0.6	0.9	2.7	
165		Y19,5	0.91	2.0	1.9	2.4	2.7	
166		2^{nd}yr	1.13	1.56	1.77	2.3	2.0	
167	Stove Code 12, CAT, Stove 1	Y03,1	0.68	7.0	4.8	5.3	7.8	2.7
168		Y03,2	0.86	13.4	11.6	11.1	12.9	
169		Y03,3	0.72	4.0	2.9	3.5	4.8	
170		Y03,4	0.84	5.9	5.0	5.5	6.5	
171		Y03,5	0.75	6.6	4.9	5.4	7.2	
172	Stove Code 12, CAT, Stove 2	Y05,1	1.28	5.9	7.5	7.7	6.0	2.7
173		Y05,2	1.26	6.0	7.6	7.8	6.2	
174		Y05,3	1.23	9.4	11.6	11.1	9.0	
175		Y05,4	1.13	13.2	14.9	13.7	12.2	
176		Y05,5	0.79	10.3	8.1	8.2	10.4	
177	Stove Code 12, CAT, Stove 3	Y09,1	1.53	8.0	12.2	11.6	7.6	2.7
178		Y09,2	1.51	9.7	14.7	13.6	9.0	
179		Y09,4	1.22	12.2	14.9	13.7	11.3	
180		Y09,5	0.95	10.8	10.3	10.1	10.6	
181	Stove Code 12, CAT, Stove 4	Y22,1	1.20	15.7	18.8	16.7	13.9	2.7
182		Y22,2	1.14	8.8	10.0	9.8	8.6	
183		Y22,3	1.59	13.5	21.4	18.6	11.7	
184		Y22,4	1.48	15.9	23.6	20.2	13.7	
185		Y22,5	0.86	12.2	10.5	10.2	11.9	

Table 7 (cont.)
Certified Stove Field Data (Part 2) – Automated Woodstove Emission Sampler (AWES), Glens Falls, NY

Run #	Stove Model Code, Unit #, NC/CAT	Study Sample Identification	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Certification Value
186	Stove Code 27, NC, Stove 1	Y15,2	1.11	7.1	7.9	8.1	7.3	4.2
187		Y15,3	1.18	8.5	10.0	9.8	8.3	
188		Y15,4	1.13	9.2	10.4	10.1	9.0	
189		Y15,5	0.81	4.3	3.5	4.1	5.0	
190	Stove Code 27, NC, Stove 2	Y16,1	0.82	13.2	10.8	10.5	12.8	4.2
191		Y16,2	0.90	9.1	7.9	8.1	9.0	
192		Y16,3	0.96	9.7	9.3	9.2	9.6	
193		Y16,4	1.06	9.2	9.7	9.6	9.0	
194		Y16,5	0.96	15.0	14.4	13.3	13.9	
195	Stove Code 27, NC, Stove 3	Y17,1	1.36	11.0	15.0	13.8	10.2	4.2
196		Y17,2	1.37	10.8	14.8	13.7	10.0	
197		Y17,3	1.32	10.4	13.7	12.8	9.7	
198		Y17,4	1.57	8.6	13.5	12.6	8.0	
199		Y17,5	1.34	12.2	16.3	14.8	11.1	
200	Stove Code 27, NC, Stove 4	Y20,1	1.47	4.4	6.5	6.8	4.7	4.2
201		Y20,2	1.35	5.3	7.2	7.5	5.5	
202		Y20,3	0.95	4.5	4.2	4.7	5.0	
203		Y20,4	1.01	4.1	4.1	4.6	4.6	
204		Y20,5	0.67	5.5	3.7	4.3	6.4	
205	Stove Code 27, NC, Stove 5	Y24,2	0.90	5.5	4.9	5.4	6.0	4.2
206		Y24,3	1.13	5.2	5.9	6.3	5.6	
207		Y24,4	1.23	5.0	6.2	6.6	5.3	
208		Y24,5	1.45	10.4	15.1	13.9	9.6	

Table 8
Certified Stove Field Data – Virginia Polytechnic Institute (VPI) Sampler, Crested Butte, CO

Run #	Stove Model Code, Unit #, NC/CAT, Year, Ref. #	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Cert. Value
1	Stove Code 9, CAT, 89/90, Ref. 15	Lodgepole Pine	16.56	0.93	7.2	6.6	6.3	6.8	2.5
2			15.30	0.88	6.1	5.4	5.3	6.0	
3			15.50	0.82	6.7	5.5	5.4	6.5	
4			13.30	0.91	2.3	2.1	2.2	2.5	
5			14.60	0.75	6.5	4.9	4.8	6.4	
6			13.40	0.77	7.1	5.5	5.4	7.0	
7	91/92, Ref. 16	Pine	17.4	0.98	13.9	13.6	12.2	12.5	
8			17.7	0.90	13.9	12.5	11.3	12.6	
9			35.2	0.74	10.7	7.9	7.5	10.1	
10			19.4	0.95	10.5	9.9	9.2	9.6	
11	1998, Ref.18 (lab test)	Pine	9.6	1.224	14.2	17.4	15.3	12.5	
12	Stove Code 34, CAT, Stove 1, 89/90, Ref.159	80% Apple, 20% Pine	12.90	0.76	5.4	4.1	4.1	5.4	5.5
13			12.90	0.66	7.6	5.0	4.9	7.4	
14			13.30	0.62	8.1	5.1	5.0	8.1	
15			14.20	0.70	7.7	5.4	5.3	7.5	
16			14.50	0.76	7.0	5.3	5.2	6.8	
17			13.00	0.61	11.4	7.0	6.7	11.0	
18	1998, Ref. 18 (lab test)	Apple	21.6	1.301	13.7	17.8	15.6	12.0	
19			10.5	1.568	5.4	8.5	8.0	5.1	
20	Stove Code 32, NC, 89/90, Ref. 15	Pine	14.96	1.54	2.4	3.7	3.7	2.4	5.1
21			13.46	1.82	7.8	14.2	12.7	7.0	
22			13.81	2.02	5.5	11.1	10.2	5.0	

Table 8 (cont.)
Certified Stove Field Data – Virginia Polytechnic Institute (VPI) Sampler, Crested Butte, CO

Run #	Stove Model Code, Unit #, NC/CAT, Year, Ref. #	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Cert. Value
23			12.46	1.80	5.2	9.4	8.7	4.9	
24			16.16	1.67	3.1	5.1	5.0	3.0	
24			16.50	1.76	5.4	9.5	8.8	5.0	
26	1998, Ref. 18 (lab test)	Aspen	12.0	1.301	13.7	17.8	15.6	12.0	
27	Stove Code 37, Stove 1 NC, 89/90, Ref. 15	Pine	12.46	0.86	7.4	6.4	6.2	7.2	6.4
28			14.09	0.87	5.9	5.1	5.0	5.8	
29			14.40	0.89	9.8	8.8	8.2	9.2	
30			12.80	0.68	17.8	12.2	11.1	16.3	
31			15.00	0.64	26.8	17.2	15.2	23.7	
32			13.40	0.55	18.7	10.3	9.5	17.3	
33	91/92, Ref. 16	Spruce	27.2	0.60	17.2	10.4	9.6	16.0	
34		Pine	17.9	0.87	13.1	11.4	10.4	12.0	
35			41.4	0.99	21.3	21.1	18.3	18.4	
36			46.5	0.59	27.0	15.9	14.1	23.9	
37	95/96, Ref. 17	Softwood	12.2	0.66	3.1	2.0	2.1	3.2	
38			9.9	0.54	21.6	11.5	10.5	19.4	
39			12.3	0.75	8.6	6.4	6.2	8.2	
40			13.2	0.49	15.2	7.4	7.0	14.3	
41	1998, Ref. 18 (lab test)	Douglas Fir	48.5	1.361	20.8	28.3	23.9	17.5	
42			22.6	1.269	7.2	9.1	8.5	6.7	
43	Stove Code 1, Stove 2, CAT, 91/92, Ref. 16	Apple, Pine	17.8	0.64	38.4	24.5	20.9	32.7	1.6

Table 8 (cont.)
Certified Stove Field Data – Virginia Polytechnic Institute (VPI) Sampler, Crested Butte, CO

Run #	Stove Model Code, Unit #, NC/CAT, Year, Ref. #	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Cert. Value
44			18.7	0.50	31.0	15.5	13.8	27.6	
45			16.3	0.71	47.6	33.6	27.9	39.3	
46			29.9	0.64	33.3	21.3	18.4	28.8	
47	1998, Ref. 18 (lab test)	Pine	10.5	1.079	7.2	7.7	7.3	6.8	
48	Stove Code 38, NC, 91/92, Ref. 16	Pine	21.9	0.74	5.5	4.1	4.1	5.5	6.4
49			23.3	0.97	8.5	8.2	7.7	8.0	
50			27.6	0.96	11.8	11.3	10.3	10.8	
51	Stove Code 17, CAT, 91/92, Ref. 16	Pine	21.0	0.89	18.4	16.4	14.5	16.3	3.1
52			17.3	0.63	18.3	11.6	10.6	16.8	
53			21.6	0.70	10.8	7.5	7.1	10.2	
54	Stove Code 23, CAT, 91/92, Ref. 16	Apple	17.4	1.37	3.6	5.0	4.9	3.6	3.8
55			18.6	1.25	7.5	9.5	8.8	7.1	
56		Spruce	20.7	1.06	21.7	23.1	19.8	18.7	
57			18.1	1.00	13.4	13.5	12.2	12.2	
58	Stove Code 1, Stove 3, CAT, 91/92, Ref. 16	Pine	13.0	0.87	7.4	6.4	6.2	7.1	1.6
59			11.5	1.14	14.8	16.8	14.8	13.0	
60	Stove Code 7, CAT, 91/92, Ref. 16	Spruce	38.1	0.88	24.8	6.2	6.0	6.8	2.4
61			24.5	1.35	17.7	9.0	8.4	6.2	
62			25.8	1.24	21.9	8.4	7.9	6.4	

Table 8 (cont.)
Certified Stove Field Data – Virginia Polytechnic Institute (VPI) Sampler, Crested Butte, CO

Run #	Stove Model Code, Unit #, NC/CAT, Year, Ref. #	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Cert. Value
63		Apple, Pine	26.8	0.95	8.5	5.2	5.1	5.4	
64	Stove Code 28, CAT, 91/92, Ref. 16	Oak, Pine	38.1	0.68	9.2	21.8	18.8	27.7	4.3
65			24.5	0.73	12.3	24.0	20.5	28.1	
66			25.8	0.77	10.9	27.1	22.9	29.8	
67			26.8	0.66	7.9	8.1	7.6	11.6	
68	Stove Code 25, CAT, 91/92, Ref. 16	Apple, Pine	32.1	0.64	19.0	12.1	11.0	17.2	4.0
69			40.0	0.56	18.5	10.3	9.5	17.0	
70			45.2	0.51	22.8	11.7	10.7	20.9	
71			33.5	0.40	12.9	5.2	5.1	12.7	
72	Stove Code 34, CAT, Stove 2, 95/96, Ref. 17	Pine	11.2	0.80	25.1	20.0	17.4	21.7	5.5
73			13.7	0.69	18.7	12.9	11.7	16.9	
74	1998, Ref. 18 (lab test)	Pine	17.6	1.525	14.4	21.9	18.9	12.4	
75			13.1	1.579	9.3	14.6	13.1	8.3	
76			9.2	1.609	5.5	8.9	8.3	5.2	
77			9.2	1.584	5.2	8.2	7.7	4.9	
78	Stove Code 6, CAT, Stove 1, 95/96, Ref. 17	Softwood	15.1	0.69	44.1	30.4	25.5	36.9	2.2
79			14.7	0.75	32.8	24.2	20.7	27.6	
80			12.8	1.01	35.7	35.5	29.3	29.0	
81			14.4	0.85	32.5	27.5	23.2	27.3	
82	1998, Ref. 18 (lab test)	Pine	11.6	0.960	9.8	9.4	8.7	9.1	

Table 8 (cont.)
Certified Stove Field Data – Virginia Polytechnic Institute (VPI) Sampler, Crested Butte, CO

Run #	Stove Model Code, Unit #, NC/CAT, Year, Ref. #	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Cert. Value
83			10.1	1.079	10.2	11.0	10.1	9.3	
84	Stove Code 6, CAT, Stove 2, 95/96, Ref. 17	Softwood	13.0	0.90	6.5	5.8	5.6	6.3	2.2
85			16.6	0.84	9.6	8.0	7.5	9.0	
86			14.2	0.83	11.9	9.8	9.1	10.9	
87			13.7	0.71	12.6	8.9	8.3	11.7	
88	1998, Ref. 18 (lab test)	Pine	12.4	1.227	5.6	6.9	6.6	5.4	
89	Stove Code 6, CAT, Stove 3, 95/96, Ref. 17	Softwood	13.3	0.62	24.5	15.0	13.4	21.6	2.2
90			13.2	0.62	43.8	26.7	22.6	36.5	
91			11.9	0.55	19.6	10.8	9.9	18.0	
92	Stove Code 6, CAT, Stove 4, 95/96, Ref. 17	Pine	14.1	0.60	22.1	13.2	11.9	19.8	2.2
93			13.9	0.48	37.3	17.6	15.5	32.2	
94			13.3	0.76	27.0	20.3	17.6	23.2	
95			10.2	0.69	27.2	18.5	16.2	23.5	
96			12.2	0.62	31.2	19.1	16.7	26.9	
97	Stove Code 24, CAT, 95/96, Ref. 16	Pine, Oak	32.8	0.80	21.5	17.0	15.0	18.7	3.8
98			52.3	0.90	23.4	20.9	18.1	20.1	
99			55.9	1.12	19.6	21.8	18.8	16.8	
100			33.4	1.11	22.4	24.6	21.0	18.9	
101	1998, Ref. 18 (lab tests)	Pine	11.7	1.652	6.4	10.6	9.8	5.9	

Table 8 (cont.)
Certified Stove Field Data – Virginia Polytechnic Institute (VPI) Sampler, Crested Butte, CO

Run #	Stove Model Code, Unit #, NC/CAT, Year, Ref. #	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Cert. Value
102	Stove Code 1, Stove 4, CAT, 95/96, Ref. 17	Hardwood, Softwood	13.0	0.73	8.0	5.7	5.5	7.6	1.6
103			11.8	0.56	11.1	6.1	5.9	10.5	
104			12.1	0.89	14.1	12.4	11.2	12.6	
105			12.4	0.83	11.2	9.2	8.6	10.3	
106	Stove Code 14, NC, Stove 1, 95/96, Ref. 17	Pine	9.3	1.54	4.4	6.7	6.4	4.2	3.0
107	Stove Code 14, NC, Stove 2, 95/96, Ref. 17	Softwood	12.7	0.75	4.3	3.2	3.3	4.4	3.0
108	1998, Ref. 18 (lab test)	Pine	11.6	1.040	8..32	8.7	8.1	7.8	
109			11.6	1.058	8.31	8.8	8.2	7.8	
110	Stove Code 10, NC, 95/96, Ref. 17	Pine	17.4	0.73	8.0	5.7	5.5	7.6	2.6
111			15.5	0.56	11.1	6.1	5.9	10.5	
112			20.5	0.89	14.1	12.4	11.2	12.6	
113			21.1	0.83	11.2	9.2	8.6	10.3	
114	1998, Ref. 18 (lab test)	Pine	10.4	1.789	3.1	5.5	5.4	3.0	
115	Stove Code 4, NC, Stove 2, 95/96, Ref. 17	Aspen	18.0	1.62	2.8	4.4	4.4	2.7	2.1
116			18.5	1.30	11.5	14.8	13.2	10.2	
117			28.4	1.12	6.9	7.6	7.2	6.4	
118			22.0	1.25	3.6	4.5	4.5	3.6	

Table 8 (cont.)
Certified Stove Field Data – Virginia Polytechnic Institute (VPI) Sampler, Crested Butte, CO

Run #	Stove Model Code, Unit #, NC/CAT, Year, Ref. #	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Cert. Value
119	Stove Code 37, NC, Stove 2, 95/96 Ref. 17	Softwood	11.0	0.92	12.5	11.3	10.3	11.2	6.4
120			10.7	0.67	14.0	9.3	8.7	12.9	
121			9.8	0.63	8.5	5.3	5.2	8.2	
122			10.3	0.57	9.9	5.6	5.5	9.6	
123			8.3	0.70	7.3	5.1	5.0	7.2	
124			6.8	0.75	4.7	3.5	3.6	4.7	
125	Stove Code 27, NC, Stove 6, 1998, Ref.18 (lab test)	Pine	10.6	1.168	2.6	3.0	3.1	2.6	4.2
126	Stove Code 37, NC, Stove 3, 1998, Ref 18 (new stove, 12 tests, parametric study)	Douglas Fir	33.4	1.34	18.3	24.4	20.8	15.6	6.4
127		Black Locust	13.3	1.12	3.3	3.7	3.7	3.3	
128		Douglas Fir	8.2	1.76	4.6	8.1	7.6	4.3	
129		Black Locust	11.0	0.97	6.0	5.8	5.6	5.8	
130		Black Locust	24.2	1.43	10.8	15.5	13.8	9.6	
131		Douglas Fir	30.0	1.07	19.9	21.2	18.3	17.1	
132		Black Locust	13.3	1.57	4.4	7.0	6.7	4.3	
133		Black Locust	26.8	1.47	5.7	8.4	7.9	5.4	
134		Douglas Fir	28.7	1.57	11.9	18.6	16.3	10.4	
135		Douglas Fir	8.7	1.44	3.7	5.3	5.2	3.6	
136		Douglas Fir	8.5	0.88	9.5	8.4	7.9	9.0	
137		Black Locust	30.3	0.94	18.6	17.4	15.3	16.3	

Table 8 (cont.)
Certified Stove Field Data – Virginia Polytechnic Institute (VPI) Sampler, Crested Butte, CO

Run #	Stove Mode Code, Unit #, NC/CAT, Year, Ref. #	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Cert. Value
138	Stove Code 32, NC, 1998, Ref. 18 (new stove, 12 tests, parametric study)	Douglas Fir	30.9	0.94	26.8	24.4	20.8	22.2	2.1
139		Black Locust	11.9	1.03	7.4	3.7	3.7	3.6	
140		Douglas Fir	9.1	1.07	12.1	8.1	7.6	7.1	
141		Black Locust	11.0	0.71	8.6	5.8	5.6	7.9	
142		Black Locust	27.9	0.94	22.1	15.5	13.8	14.7	
143		Douglas Fir	29.2	0.66	23.9	21.2	18.3	27.8	
144		Black Locust	12.2	1.17	10.8	7.0	6.7	5.7	
145		Black Locust	33.1	1.02	11.9	8.4	7.9	7.7	
146		Douglas Fir	29.5	1.21	17.4	18.6	16.3	13.5	
147		Douglas Fir	9.7	0.86	17.9	5.3	5.2	6.0	
148		Douglas Fir	9.1	0.74	15.5	8.4	7.9	10.7	
149		Black Locust	29.6	0.73	19.4	17.4	15.3	21.0	
150	Stove Code 6, CAT, Stove 5, 1998, Ref. 18 (new stove, 8 tests, parametric study)	Douglas Fir	8.4	1.91	8.3	16.3	14.4	7.6	2.2
151		Black Locust	10.0	1.15	5.4	6.2	6.0	5.2	
152		Douglas Fir	29.4	0.88	4.6	4.0	4.0	4.6	
153		Black Locust	12.3	1.98	11.7	23.0	19.8	10.0	
154		Black Locust	29.7	1.76	6.3	11.1	10.2	5.8	
155		Douglas Fir	33.7	1.70	9.1	15.4	13.7	8.1	
156		Douglas Fir	9.1	0.99	9.2	9.0	8.4	8.5	
157		Black Locust	26.6	0.93	6.3	5.8	5.6	6.1	

Table 8 (cont.)
Certified Stove Field Data – Virginia Polytechnic Institute (VPI) Sampler, Crested Butte, CO

Run #	Stove Model Code, Unit #, NC/CAT, Year, Ref. #	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Cert. Value
158	Stove Code 22, CAT, Stove 4, 1998 Ref. 18 (new stove, 8 tests, parametric study)	Douglas Fir	8.7	2.35	4.7	11.0	10.1	4.3	3.7
159		Black Locust	9.5	0.92	17.0	15.7	13.9	15.2	
160		Douglas Fir	29.9	1.16	9.1	10.5	9.7	8.3	
161		Black Locust	11.4	2.13	5.2	11.1	10.2	4.8	
162		Black Locust	30.5	2.12	8.1	17.2	15.2	7.1	
163		Douglas Fir	35.5	2.02	8.6	17.3	15.2	7.5	
164		Douglas Fir	9.1	0.93	12.7	11.8	10.8	11.6	
165		Black Locust	29.9	0.78	7.8	6.1	5.9	7.6	

Table 9
Laboratory Tests Simulating the In-Home Use of Certified Wood Stoves

Run #	Test, Year, Ref.	Stove Model Code, CAT/NC	Description of Run	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (kg/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Cert. Value
1	BPA, 1988, Ref. 7	Stove Code 2, CAT	Portland, OR, burn cycle	Douglas Fir	19.92	0.73	2.8	3.8*	1.9
2			Northeast burn cycle	50% Red Oak, 50% Sugar Maple	27.4	1.22	2.1	1.72*	
3	EPA, 2000, Ref.20	Stove Code 11, CAT	Homeowner cycle, cold start	Oak	28	1.92	39.6	20.6	2.7
4			Homeowner cycle, cold start		28	2.15	47.0	21.8	
5			Homeowner cycle, cold start		28	1.26	7.0	5.5	
6			Homeowner cycle, cold start		28	2.33	26.8	11.5	
7			Homeowner cycle, cold start		28	3.05	25.2	8.2	
8			Homeowner cycle, cold start		28	1.36	17.7	13.0	
9			Homeowner cycle, cold start		13.5	2.92	17.7	6.1	
10			Homeowner cycle, cold start		12.6	1.38	6.8	4.9	
11			Homeowner cycle, hot start		28	1.31	8.7	6.6	
12			Homeowner cycle, cold start		17.2	2.64	8.0	3.0	
13			Homeowner cycle, cold start		14.4	1.33	4.1	3.1	

Table 9 (cont.)
Laboratory Tests Simulating the In-Home Use of Certified Wood Stoves

Run #	Test, Year, Ref.	Stove Model Code, CAT/NC	Description of Run	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (kg/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Cert. Value
14	EPA, 2000, Ref.20	Stove Code 4, NC, Stove 3	Homeowner cycle, cold start	Oak	28	1.50	61.4	41.0	2.1
15			Homeowner cycle, cold start		28	1.61	41.8	26.0	
16			Homeowner cycle, cold start		13.6	1.71	41.5	24.2	
17			Homeowner cycle, cold start		14.1	1.31	43.8	33.4	
18			Homeowner cycle, cold start		13	1.70	39.3	23.1	
19			Homeowner cycle, cold start		14.9	4.15	14.8	3.6	
20			Homeowner cycle, cold start		12.7	1.57	48.3	30.8	
21	EC, 2009, Ref. 23	Stove Code 4, NC, Stove 4	Softwood/Low BR/Cold Start	Douglas Fir	16.71	1.61	11.40	2.68	2.1
22			Softwood/Low BR/Cold Start		16.66	1.77	9.50	2.62	
23			Hardwood/Low BR/Cold Start	Maple	22.29	1.71	8.17	3.99	
24			Hardwood/Low BR/Cold Start		21.71	1.71	10.72	3.21	
25			Softwood/High BR/Hot Start	Douglas Fir	18.19	1.73	10.79	0.93	
26			Softwood/Low BR/Hot Start		17.06	3.90	9.15	0.79	

Table 9 (cont.)
Laboratory Tests Simulating the In-Home Use of Certified Wood Stoves

Run #	Test, Year, Ref.	Stove Model Code, CAT/NC	Description of Run	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (kg/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)	Cert. Value
27			Hardwood/High BR/Hot Start	Maple	21.80	2.87	3.46	1.0	
28			Hardwood/Low BR/Hot Start		23.15	2.78	5.74	1.2	
29	EC, 2009, Ref. 23	Stove Code 36, NC	Softwood/Low BR/Cold Start	Douglas Fir	19.83	1.08	11.40	10.55	5.9
30			Softwood/Low BR/Cold Start		20.92	1.10	9.81	8.62	
31			Hardwood/Low BR/Cold Start	Maple	22.10	1.27	8.33	6.43	
32			Hardwood/Low BR/Cold Start		20.12	1.34	11.19	7.99	
33			Softwood/High BR/Hot Start	Douglas Fir	17.98	3.37	11.28	3.20	
34			Softwood/Low BR/Hot Start		18.04	2.92	9.41	3.14	
35			Hardwood/High BR/Hot Start	Maple	21.80	2.87	3.26	1.21	
36			Hardwood/Low BR/Hot Start		23.15	2.78	5.66	2.06	

*Calculated from emission rate and burn rate.

Table 10
Uncertified Stove Field Data – Automated Woodstove Emission Sampler (AWES), Klamath Falls, OR

Run #	Study Sample I.D., Ref. Year, Ref. #	Fuel Tree Species	Average Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
1	H-1, wk 1, 1990, Ref. 4	90 %Yellow Pine 10 % Lodgepole Pine	8.3	2.18	10.8	23.6	20.2	9.3
2	H-2, wk 1, 1990 Ref. 4	50% Yellow Pine 50% Cedar	15.8	1.55	34.5	55.3	41.4	26.7
3	H-3, wk 1, 1990, Ref. 4	100% White Fir	18.2	1.78	29.0	51.6	39.0	21.9
4	KF0601, 1992, Ref. 5	Lodgepole Pine Alder	20.9	2.06	27.21	56.68	42.2	20.5
5	KF0701, 1992, Ref. 5	Lodgepole Pine	10.1	1.11	36.25	40.07	31.5	28.4
6	KF0801, 1992, Ref. 5	Lodgepole Pine	11.5	1.31	50.40	66.13	48.1	36.7
7	KF0901, 1992, Ref. 5	Lodgepole Pine	11.1	1.41	12.97	18.25	16.3	11.6

Table 11
Uncertified Stove Field Data – Automated Woodstove Emission Sampler (AWES), Portland, OR

Run #	Study Sample I.D. Ref. Year, Ref. #	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
8	H001, wk 1, 1987, Ref. 9	80% Maple 20% Alder	42.0 38.2	1.16	33.2	38.6	30.6	26.4
9	H001, wk 2, 1987, Ref. 9	80% Maple 20% Alder	41.9 39.9	0.90	27.2	24.6	20.9	23.3
10	H002, wk 1, 1987, Ref. 9	60% Alder 40% Douglas Fir	22.0 19.0	1.10	26.6	29.3	24.2	22.0
11	H002, wk 2, 1987, Ref. 9	34% Alder 33% Douglas Fir 33% Maple	24.4 25.1 32.7	0.93	29.1	27.1	22.7	24.4
12	Home P03, 1, 1988, Ref. 7	90% Maple 10% Alder	25.3 17.9	1.68	13.3	22.3	19.3	11.5
13	Home P03, 2, 1988, Ref. 7	90% Maple 10% Alder	25.1 15.4	1.26	7.7	9.7	9.6	7.6
14	Home P03, 3, 1988, Ref. 7	50% Maple 50% Alder	30.8 19.4	1.02	10.5	10.8	10.5	10.3
15	Home P03, 4, 1988, Ref. 7	50% Maple 50% Alder	35.8 25.9	0.94	10.1	9.5	9.4	10.0
16	Home P03, 5, 1988, Ref. 7	50% Maple 50% Alder	25.4 23.8	1.25	13.4	16.7	15.1	12.1
17	Home P05, 1, 1988, Ref.7	75% Alder 25% Douglas Fir	16.6 15.3	1.37	21.4	29.4	24.3	17.8
18	Home P05, 2, 1988, Ref.7	75% Alder 25% Douglas Fir	16.6 15.7	1.12	25.6	28.7	23.8	21.3
19	Home P05, 3, 1988, Ref.7	33% Douglas Fir 34% Alder 33% Maple	15.7 19.9 16.4	0.94	22.9	21.4	18.6	19.8

Table 11 (cont.)
Uncertified Stove Field Data – Automated Woodstove Emission Sampler (AWES), Portland, OR

Run #	Study Sample I.D.,Ref. Year, Ref. #	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
20	Home P05, 4, 1988, Ref.7	50% Maple 50% Alder	17.3 21.9	1.01	26.7	27.1	22.7	22.5
21	Home P05, 5, 1988, Ref.7	50% Maple 50% Alder	17.7 20.9	0.92	22.7	20.9	18.3	19.8

Table 12
Uncertified Stove Field Data – Automated Woodstove Emission Sampler (AWES), Whitehorse, YK (data from ref. 10, 1987)

Run #	Study Sample I.D.*	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
22	W01,1	Lodgepole Pine	16.8	1.93	25.8	49.8	37.9	19.6
23	W01,2	Lodgepole Pine	14.5	1.32	23.1	30.4	25.0	18.9
24	W01,4	Lodgepole Pine	30.1	1.26	20.5	25.8	21.8	17.3
25	W01,5	Lodgepole Pine	13.5	1.53	22.2	33.9	27.4	17.9
26	W01,6	Lodgepole Pine	15.2	1.58	17.8	28.1	23.4	14.8
27	W01,7	Lodgepole Pine	15.8	2.15	10.7	22.9	19.7	9.2
28	W01,8	Lodgepole Pine	14.8	1.12	22.7	25.5	21.6	19.3
29	W01,9	Lodgepole Pine	15.6	0.79	22.7	18.0	16.1	20.4
30	W02,1	Lodgepole Pine	17.2	1.45	20.0	28.9	24.0	16.5
31	W02,2	Lodgepole Pine	19.8	1.29	13.3	17.2	15.5	12.0
32	W02,3	Spruce	28.9	1.46	11.8	17.3	15.6	10.7
33	W02,4	50% Lodgepole Pine 50% Spruce	41.8 15.1	0.90	12.8	11.5	11.0	12.3
34	W02,5bc	Lodgepole Pine	18.0	1.21	41.7	50.3	38.2	31.6
35	W02,6	Lodgepole Pine	21.8	0.86	44.5	38.5	30.5	35.5
36	W02,8	95% Spruce 5% Lodgepole Pine	33.0 17.5	0.75	23.6	17.7	15.9	21.2
37	W02,9	Spruce	24.1	0.56	23.3	13.1	12.3	22.0
38	W03,1	Lodgepole Pine	15.4	1.18	4.8	5.7	6.1	5.2
39	W03,2	Lodgepole Pine	14.3	1.04	8.3	8.6	8.7	8.3

Table 12 (cont.)
Uncertified Stove Field Data – Automated Woodstove Emission Sampler (AWES), Whitehorse, YK (data from ref. 10, 1987)

Run #	Study Sample I.D.*	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
40	W03,3	99% Spruce 1% Lodgepole Pine	40.4 17.3	1.31	10.2	13.3	12.5	9.5
41	W03,4	50% Spruce 50% Lodgepole Pine	40.1 14.6	1.44	7.0	10.1	9.9	6.9
42	W04,1	Lodgepole Pine	16.6	1.90	21.4	40.7	32.0	16.8
43	W04,2	Lodgepole Pine	15.8	1.25	23.3	29.2	24.2	19.3
44	W04,3	90% Spruce 10% Lodgepole Pine	30.2 11.7	2.01	17.8	35.7	28.6	14.2
45	W04, 4	50% Spruce 50% Lodgepole Pine	25.4 18.3	1.87	14.1	26.3	22.1	11.8
46	W05,1	50% Lodgepole Pine 50% Spruce	17.9 19.2	1.67	6.5	10.9	10.6	6.3
47	W05,2	Lodgepole Pine	16.1	1.59	8.9	14.1	13.1	8.2
48	W05,3	90% Spruce 10% Lodgepole Pine	43.4 13.7	1.64	8.1	13.4	12.6	7.7
49	W05,4	50% Spruce 50% Lodgepole Pine	30.7 13.6	1.73	10.8	18.7	16.6	9.6
50	W05,5bc	Lodgepole Pine	13.8	1.66	10.1	16.8	15.2	9.2
51	W05,6bc	Lodgepole Pine	14.6	1.47	11.2	16.5	15.0	10.2

Table 12 (cont.)
Uncertified Stove Field Data – Automated Woodstove Emission Sampler (AWES), Whitehorse, YK (data from ref. 10, 1987)

Run #	Study Sample I.D.*	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
52	W05,8bc	95% Spruce 5% Lodgepole Pine	32.4 14.4	1.37	15.6	21.3	18.5	13.5
53	W05,9bc	Lodgepole Pine	28.3	1.02	9.3	9.5	9.4	9.2
54	W06,1	Lodgepole Pine	16.2	1.16	16.5	19.2	17.0	14.7
55	W06,3	Spruce	29.5	1.23	15.3	18.8	16.7	13.6
56	W06,4	Spruce	19.8	1.31	12.0	15.7	14.4	11.0
57	W06,5	Lodgepole Pine	16.6	1.11	17.2	19.1	16.9	15.2
58	W06,6	Lodgepole Pine	16.5	0.77	27.4	20.9	18.3	23.7
59	W06,7	Lodgepole Pine	19.4	1.14	14.1	16.1	14.7	12.9
61	W06,9	Spruce	37.9	0.61	16.5	10.0	9.8	16.1
62	W07,2	Lodgepole Pine	20.1	1.88	17.5	32.8	26.7	14.2
63	W07,3	80% Spruce 20% Lodgepole Pine	21.2 18.7	2.12	10.1	21.5	18.7	8.8
64	W07,4	50% Spruce 50% Lodgepole Pine	21.2 19.1	2.57	13.6	35.0	28.2	11.0
65	W08,2	Lodgepole Pine	20.4	1.50	15.0	22.5	19.4	12.9
66	W08,3	Spruce	19.9	1.30	24.1	31.3	25.6	19.7
67	W08,4	Spruce	32.4	1.90	16.7	31.7	25.9	13.6

Table 12 (cont.)
Uncertified Stove Field Data – Automated Woodstove Emission Sampler (AWES), Whitehorse, YK (data from ref. 10, 1987)

Run #	Study Sample I.D.*	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
68	W08,5bc	Lodgepole Pine	19.6	1.16	22.4	26.1	22.0	19.0
69	W08,6bc	Lodgepole Pine	15.8	1.58	10.1	15.9	14.5	9.2
70	W08,7bc	Lodgepole Pine	16.4	1.78	20.3	36.1	28.9	16.2
71	W08,8bc	Spruce	27.0	1.29	24.1	31.2	25.6	19.8
72	W08,9bc	Spruce	26.1	1.09	26.3	28.7	23.8	21.9
73	W09,1	Lodgepole Pine	18.0	0.93	19.5	18.2	16.2	17.5
74	W09,2	Lodgepole Pine	17.2	0.70	25.4	17.7	15.9	22.7
75	W09,3	Spruce	23.8	0.88	12.8	11.3	10.9	12.4
76	W10,1	Lodgepole Pine	18.3	1.28	22.4	28.6	23.8	18.6
77	W10,2	Lodgepole Pine	16.0	1.15	14.4	16.5	15.0	13.0
78	W10,3	Spruce	17.5	1.44	15.6	22.5	19.4	13.5
79	W10,4	Spruce	31.6	1.49	16.5	24.6	20.9	14.0
80	W10,5	Lodgepole Pine	16.5	1.36	25.8	34.9	28.1	20.7
81	W10,6	Lodgepole Pine	16.7	1.09	24.3	26.4	22.2	20.4
82	W10,7	Lodgepole Pine	18.7	1.10	36.7	40.5	31.8	28.9
83	W10,8	Spruce	21.7	1.85	14.6	27.1	22.7	12.3
84	W10,9	Spruce	37.8	1.42	14.8	21.0	18.3	12.9
85	W11,1	Lodgepole Pine	17.0	2.37	4.4	10.5	10.2	4.3
86	W11,2	Lodgepole Pine	17.8	2.02	7.0	14.1	13.1	6.5
87	W11,3	Spruce	30.8	2.02	11.7	23.6	20.2	10.0
88	W11,4	Spruce	32.8	2.60	7.2	18.9	16.8	6.5

Table 12 (cont.)
Uncertified Stove Field Data – Automated Woodstove Emission Sampler (AWES), Whitehorse, YK (data from ref. 10, 1987)

Run #	Study Sample I.D.*	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
89	W12,1	Lodgepole Pine	12.1	1.76	15.1	26.7	22.4	12.7
90	W12,2	Lodgepole Pine	13.7	1.44	14.1	20.3	17.8	12.4
91	W12,3	Lodgepole Pine	20.0	1.49	16.6	24.7	21.0	14.1
92	W12,4	Lodgepole Pine	18.1	1.82	16.2	29.4	24.3	13.4
93	W12,5bc	Lodgepole Pine	18.7	1.82	19.7	36.0	28.8	15.8
94	W12,6bc	Lodgepole Pine	15.3	1.78	8.8	15.8	14.4	8.1
95	W12,7bc	Lodgepole Pine	13.9	1.45	23.9	34.7	28.0	19.3
96	W12,8bc	95% Spruce 5% Lodgepole Pine	43.2 13.5	1.40	20.1	28.2	23.5	16.8
97	W12,9bc	Lodgepole Pine	12.5	1.13	16.9	19.0	16.8	14.9
98	W13,2	Lodgepole Pine	20.6	1.85	17.9	33.0	26.8	14.5
99	W13,3	Spruce	26.8	1.74	15.4	26.7	22.4	12.9
100	W13,5	Lodgepole Pine	16.1	1.29	25.7	33.2	26.9	20.9
101	W13,6	Lodgepole Pine	15.7	1.35	12.2	16.4	14.9	11.0
102	W13,7	Lodgepole Pine	19.1	1.19	19.3	22.9	19.7	16.6
103	W13,8	80% Spruce 20% Lodgepole Pine	19.6 18.1	0.89	19.6	17.5	15.7	17.7
104	W13,9	Spruce	18.6	0.89	20.0	17.8	15.9	17.9
105	W14,1	Lodgepole Pine	17.7	1.16	21.4	24.7	21.0	18.1
106	W14,2	Lodgepole Pine	19.0	1.07	23.9	25.7	21.7	20.3
107	W14,3	Spruce	22.7	1.04	31.4	32.6	26.5	25.5
108	W14,4	Spruce	26.3	1.71	16.4	28.0	23.3	13.6

*bc = before catalytic retrofit device

Table 13
Uncertified Stove Field Data – Automated Woodstove Emission Sampler (AWES), New York and Vermont (data from ref. 13, 1987)

Run #	Study Sample I.D.	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
109	V06-1	Mixed hardwoods	26.5	2.45	1.2	2.9	3.5	1.4
110	V06-2	Mixed hardwoods	26.6	1.60	2.9	4.7	5.2	3.3
111	V06-3	Mixed hardwoods	27.5	1.59	19.1	30.4	25.0	15.7
112	V06-5	Mixed hardwoods	25.0	1.52	8.4	12.7	12.0	7.9
113	V06-6	Mixed hardwoods	28.0	1.86	9.3	17.3	15.6	8.4
114	V09-1	Mixed hardwoods	41.2	1.12	13.7	15.4	14.1	12.6
115	V14-1	Mixed hardwoods	23.0	1.67	10.2	16.9	15.3	9.1
116	V14-2	Mixed hardwoods	28.2	1.45	16.3	23.5	20.1	13.9
117	V14-3	Mixed hardwoods	26.3	0.92	22.0	20.3	17.8	19.4
118	N08-3	Mixed hardwoods	29.7	1.92	13.8	26.5	22.3	11.6
119	N08-4	Mixed hardwoods	24.7	1.91	17.1	32.6	26.5	13.9
120	N08-6	Mixed hardwoods	26.5	2.19	12.2	26.6	22.4	10.2
121	N08-7	Mixed hardwoods	29.5	2.00	15.4	30.9	25.4	12.7
122	N14-6	Mixed hardwoods	35.2	2.45	13.9	34.0	27.5	11.2
123	N14-7	Mixed hardwoods	41.0	1.57	18.4	29.0	24.0	15.3
124	N16-1	Mixed hardwoods	26.0	1.55	9.0	13.9	13.0	8.4

Table 14
Uncertified Stove Field Data – Virginia Polytechnic Institute (VPI) Sampler, Crested Butte, CO

Run #	Study Sample I.D., Ref. Year, Ref. #	Fuel Tree Species*	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
125	Run 1, Conv.01, 1989, Ref.14	ND	13.3	1.60	6.56	10.5	9.7	6.0
126	Run 5, Conv.01, 1989, Ref.14	ND	12.4	1.09	14.31	15.6	13.9	12.7
127	Run 12, Conv.01, 1989, Ref.14	ND	11.9	1.57	15.16	23.8	20.4	13.0
128	Run 20, Conv.01, 1989, Ref.14	ND	13.5	2.45	9.22	22.6	19.4	7.9
129	Run 40, Conv.01, 1989, Ref.14	ND	19.7	1.89	10.09	35.7	29.5	15.6
130	Run 3, Conv. 02, 1989, Ref.14	ND	13.5	0.84	8.69	7.3	6.9	8.3
131	Run 8, Conv. 02, 1989, Ref.14	ND	17.2	0.72	14.86	10.7	9.8	13.7
132	Run 16, Conv. 02, 1989, Ref.14	ND	18.6	0.93	12.04	11.2	10.3	11.0
133	Run 24, Conv. 02, 1989, Ref.14	ND	19.7	1.30	12.23	15.9	14.1	10.9
134	Run 30, Conv. 02, 1989, Ref.14	ND	14.2	1.57	6.50	10.2	9.4	6.0
135	Run 4 Conv. 03, 1989, Ref.14	ND	9.5	1.77	18.36	32.5	27.1	15.3
136	Run 9, Conv. 03, 1989, Ref.14	ND	11.2	0.98	17.35	17	15.0	15.3
137	Run 15, Conv. 03, 1989, Ref.14	ND	8.9	1.34	19.63	26.3	22.3	16.7
138	Run 23, Conv. 03, 1989, Ref.14	ND	10.7	1.43	16.57	23.7	20.3	14.2
139	Run 10 Conv. 04, 1989, Ref.14	ND	45.0	0.76	17.63	13.4	12.1	15.9
140	Run 17, Conv. 04, 1989, Ref. 14	ND	45.3	0.79	21.14	16.7	14.8	18.7
141	Run 22, Conv. 04, 1989, Ref. 14	ND	47.9	0.84	28.93	24.3	20.8	24.7
142	Run 28, Conv. 04, 1989, Ref. 14	ND	42.2	0.99	23.13	22.9	19.7	19.9
143	Run 11 Conv. 05, 1989, Ref. 14	ND	10.2	1.03	31.65	32.6	27.1	26.4
144	Run 18, Conv. 05, 1989, Ref. 14	ND	10.0	1.23	26.50	32.6	27.1	22.1
145	Run 25, Conv. 05, 1989, Ref. 14	ND	9.8	1.33	35.19	46.8	37.7	28.4
146	Run 29, Conv. 05, 1989, Ref. 14	ND	10.1	1.22	39.02	47.6	38.3	31.4
147	Run 31, Conv. 06, 1989, Ref. 14	ND	12.,4	1.03	26.31	27.1	22.9	22.3
148	Run 33, Conv. 06, 1989, Ref. 14	ND	11.9	1.03	25.83	26.6	22.6	21.9
149	Run 38, Conv. 06, 1989, Ref. 14	ND	11.2	1.06	29.17	31.5	26.3	24.8

Table 14 (cont.)
Uncertified Stove Field Data – Virginia Polytechnic Institute (VPI) Sampler, Crested Butte, CO

Run #	Study Sample I.D., Ref. Year, Ref. #	Fuel Tree Species*	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
150	Run 32, Conv. 07, 1989, Ref. 14	ND	24.6	0.91	20.22	18.4	16.1	17.7
151	Run 36, Conv. 07, 1989, Ref. 14	ND	18.9	1.20	18.08	21.7	18.7	15.6
152	Run 41, Conv. 07, 1989, Ref. 14	ND	37.5	1.29	20.47	26.4	22.4	17.4
153	Run 34, Conv. 08, 1989, Ref. 14	ND	12.5	0.68	14.71	10.0	9.2	13.6
154	Run 39, Conv. 08, 1989, Ref. 14	ND	12.2	2.13	10.66	22.7	19.5	9.2
155	Run 43, Conv. 08, 1989, Ref. 14	ND	10.0	1.81	23.26	42.1	34.3	18.9
156	Run 35, Conv. 09, 1989, Ref. 14	ND	16.0	2.52	25.56	64.4	50.5	20.0
157	Run 42, Conv. 09, 1989, Ref. 14	ND	15.7	1.67	20.36	34.0	28.2	16.9
158	Run 45, Conv. 09, 1989, Ref. 14	ND	15.3	1.69	26.98	45.6	36.9	21.8
159	Run 37, Conv. 10, 1989, Ref. 14	ND	32.9	1.13	24.42	27.6	23.3	20.6
160	Run 44, Conv. 11, 1989, Ref. 14	ND	12.1	1.25	37.60	47.0	37.9	30.3
161	Run 46, Conv. 11, 1989, Ref. 14	ND	10.3	1.34	25.60	61.1	48.1	35.9
162	Run 1, Conv. 01, 1991, Ref. 15	Pine	8.86	1.45	11.9	17.3	15.2	10.5
163	Run 6, Conv. 01, 1991, Ref. 15	Pine	9.06	1.76	8.7	15.2	13.5	7.7
164	Run 15, Conv. 1, 1991, Ref. 15	Pine	11.46	1.64	13.8	22.8	19.6	11.9
165	Run 22, Conv. 01 1991, Ref. 15	Pine	11.76	1.71	6.1	10.4	9.6	5.6
166	Run 3, Conv. 03, 1991, Ref. 15	25% Oak 75% Pinion Pine	12.26	1.67	13.4	22.4	19.3	11.5
167	Run 9, Conv. 03, 1991, Ref. 15	25% Oak 75% Pinion Pine	11.56	1.70	11.7	20.0	17.4	10.2
168	Run 17, Conv. 03, 1991, Ref. 15	25% Oak 75% Pinion Pine	11.46	1.76	12.6	22.2	19.1	10.9

Table 14 (cont.)
Uncertified Stove Field Data – Virginia Polytechnic Institute (VPI) Sampler, Crested Butte, CO

Run #	Study Sample I.D., Ref. Year, Ref. #	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
169	Run 21, Conv. 03, 1991, Ref. 15	25% Oak 75% Pinion Pine	11.16	1.74	16.7	29.1	24.5	14.1
170	Run 4, Conv. 04, 1991, Ref. 15	50% Oak 50% Pine	25.86	1.63	24.8	40.4	33.0	20.2
171	Run 8, Conv. 04, 1991, Ref. 15	50% Oak 50% Pine	26.76	1.97	19.4	38.3	31.4	16.0
172	Run 14, Conv. 04, 1991, Ref. 15	50% Oak 50% Pine	31.76	1.55	19.1	29.6	24.9	16.0
173	Run 26, Conv. 04, 1991, Ref. 15	50% Oak 50% Pine	27.56	1.48	31.1	46.1	37.2	25.2
174	Run 13, Conv. 05, 1991, Ref. 15	Pine	12.16	1.80	22.1	39.8	32.6	18.1
175	Run 20, Conv. 05, 1991, Ref. 15	Pine	12.56	1.61	37.4	60.2	47.5	29.5
176	Run 25, Conv. 05, 1991, Ref. 15	Pine	14.46	1.21	35.6	43.2	35.1	29.0
177	Run 29, Conv. 05, 1991, Ref. 15	Pine	14.46	1.42	34.2	48.3	38.8	27.4
178	Run 32, Conv. 09, 1991, Ref. 15	Pine	9.46	1.82	22.6	41.3	33.7	18.5
179	Run 36, Conv. 09, 1991, Ref. 15	Pine	11.96	1.89	23.3	44.2	35.8	19.0
180	Run 42, Conv. 09, 1991, Ref. 15	Pine	15.16	1.46	24.0	35.1	29.0	19.9
181	Run 53, Conv. 09, 1991, Ref. 15	Pine	9.36	1.61	33.3	53.7	42.8	26.6
182	Run 33, Conv. 10, 1991, Ref. 15	50% Oak 50% Pine	22.16	1.86	30.1	56.0	44.4	23.9
183	Run 37, Conv. 10, 1991, Ref. 15	50% Oak 50% Pine	26.76	1.88	18.5	34.7	28.7	15.3
184	Run 43, Conv. 10, 1991, Ref. 15	50% Oak 50% Pine	28.06	1.96	14.1	27.7	23.4	11.9
185	Run 34, Conv. 11, 1991, Ref. 15	Pine	15.36	1.34	32.3	43.4	35.2	26.3
186	Run 39, Conv. 11, 1991, Ref. 15	Pine	15.46	1.22	25.6	31.4	26.2	21.5

Table 14 (cont.)
Uncertified Stove Field Data – Virginia Polytechnic Institute (VPI) Sampler, Crested Butte, CO

Run #	Study Sample I.D., Ref. Year, Ref. #	Fuel Tree Species	Fuel Moisture (% db)	Burn Rate (dry kg/h)	Emission Factor (g/kg)	Emission Rate (g/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
187	Run 45, Conv. 11, 1991, Ref. 15	Pine	15.46	1.38	25.1	34.7	28.7	20.8
188	Run 50, Conv. 11, 1991, Ref. 15	Pine	14.26	1.36	32.0	43.7	35.5	26.1
189	VPI 6, Conv 1 (lab), 1989, Ref.14	Oak	54	2.5	28.1	68.9	53.7	21.5

*The fuel tree species for runs for which there are no data was assumed to be either pine or oak or a mixture of both based on other studies in Crested Butte.

Table 15
Laboratory Tests Simulating the In-Home Use of Uncertified Wood Stoves

Run #	Study, Year, Ref. #	Study Sample Description	Description of Test	Fuel Tree Species	Moisture (% db)	Burn Rate (dry kg/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
1	BPA, 1988, Ref. 7	L01	Portland OR burn cycle	Douglas Fir	26.2	0.96	24.6	25.6*
2	EPA, 2000, Ref 20	Test 5	Homeowner cycle, cold start	Oak	28	4.29	25.7	6
3		Test 6			28	4.27	20.5	4.8
4		Test 28			18.7	3.56	24.4	6.9
5	EC, 2006, Ref. 22	Stove 1	"Fashion representative of normal in-home use." Burn rate endpoint 100°F. Oak cordwood, Douglas fir kindling	Oak	18.5	2.08	25.8	8.6
6		Stove 2				1.44	11.4	6
7		Stove 3				1.76	4.5	1.8
8		Insert				1.69	54.9	25.2
9		Stove 4				2.07	8.3	2.9
10	VPI/SRI, 1989, Ref.19 (EPA)	SRI 1, Conv. 2	"Began with cold stove and ended with up to three kilograms of fuel in stove, fueling patterns were deliberately varied"	Pine	13	2.0	50.3	25.3*
11		SRI 4, Conv. 2		Pine	11	1.2	28.3	17.7*
12		SRI 7, Conv 3		Pine	10	0.9	44.8	48.7*

Table 15 (cont.)
Laboratory Tests Simulating the In-Home Use of Uncertified Wood Stoves

Run #	Study, Year, Ref. #	Study Sample Description	Description of Test	Fuel Tree Species	Moisture (% db)	Burn Rate (dry kg/h)	5H Emission Rate (g/h)	5H Emission Factor (g/kg)
13	CCRL, 1991, Ref. 21 (EC)	Non-Catalyst Stove	"typical wood fuel in actual home use, split firewood"	Maple	38.5	1.0	11.2	11.2
14						1.0	7.6	7.6
15						1.0	27.7	27.7
16						1.2	19.7	16.4
17						1.5	15.9	10.6
18						1.6	17.2	10.8
19						1.9	9.6	5.1
20						2.4	13.2	5.5

*Calculated from emission rate and burn rate.

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