Agency: Commerce, Community and Economic Development

Grants to Named Recipients (AS 37.05.316)

Grant Recipient: Alaska Resource Agency **Federal Tax ID:** 45-0709876

Project Title: **Project Type:** Maintenance and Repairs

Alaska Resource Agency - Heating Appliance Upgrade and Replacement Program

State Funding Requested: $188,000 **House District:** Fairbanks Areawide (7-11)
Future Funding May Be Requested

Brief Project Description:

Replacing or upgrading federally unqualified or otherwise deficient heating appliances to reduce harmful emissions.

Funding Plan:

Total Project Cost:	$188,000
Funding Already Secured:	($0)
FY2013 State Funding Request:	($188,000)
Project Deficit:	$0

Funding Details:

Future funding will only be requested if air quality tests warrant an additional project.

Detailed Project Description and Justification:

This project is primarily designed to replace or upgrade residential heating appliances that are non-certified EPA wood stoves or have emissions above 2.5 g/hr for catalytic wood stoves or above 4.5 g/hr for all other stoves. The program is also intended to upgrade or replace solid fuel burning appliances requiring greater than 100,000 BTUs (such as an outdoor hydronic heater) to achieve an emission standard of, at least, 0.15lb/Mbtus and/or under 20% opacity, for less than 10 minutes, using EPA Method 9 assessment (a more stringent result than the current local or federal standard). Pellet stoves are the primary, current appliance capable of efficient, clean burning--the choice appliance with this project where applicable.

A pellet stove burns small, compressed pellets made from ground, dried wood and other biomass wastes. The EPA states: "Pellet stoves are typically among the cleanest wood-burning heating appliances available today and deliver high overall efficiency." With increasing fuel costs, and concern about emissions from other biofuel appliances, pellet stoves are a means to decrease pollution, mitigate the high cost of energy and increase efficiency--especially in suburban areas where there is a greater need to eliminate nuisance emissions from other types of biofuel appliances. Locally, an indoor full pellet stove replacement/installation (stove, hearth, piping, and labor) can run ~$5,200.00/unit (depending upon the model and size). Replacement/installation of an outdoor unit exceeding 175,000 Btus: price estimation at $12,000/replacement.

This capital project is distinct from other programs in several important ways: 1) Official FNSB "hotspots" receive priority; 2) Only equipment with certifiably cleanest emissions, and commercially available, will be installed; 3) All residents, within the affected hotspot area, will be directly informed of the opportunity of this program as well as other energy-related programs

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Contact Number: 465-3887

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$850,000
Approved

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that may assist them. In order to properly address non-attainment, nuisance emissions, and increase residential heating efficiency, a high standard is necessary. For residents who are eligible and volunteer, the emission goals for each unit upgrade will be of a standard more stringent than the current federal, state, or municipal requirements. By targeting a specific high air pollution area, future modeling can be constructed for the purpose of producing a more complete and accurate state implementation plan [SIP].

Existing air quality sensors in the area can be used to assess overall program effectiveness.

Beyond immediate health concerns, the long term consequences of PM2.5 non-attainment may impact northern federal transportation funding and may enter into other formulas such as potential BRAC determinations when the Dept of Defense factors in "military value" of a given area. Alaska Resource Agency collaborates directly with the EPA in assessing the effectiveness of emission reduction efforts.

Project Timeline:

August-November, 2012; August-November, 2013

Entity Responsible for the Ongoing Operation and Maintenance of this Project:

Alaska Resource Agency

Grant Recipient Contact Information:

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Title:	Program Coordinator
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Has this project been through a public review process at the local level and is it a community priority? [ ] Yes [X] No

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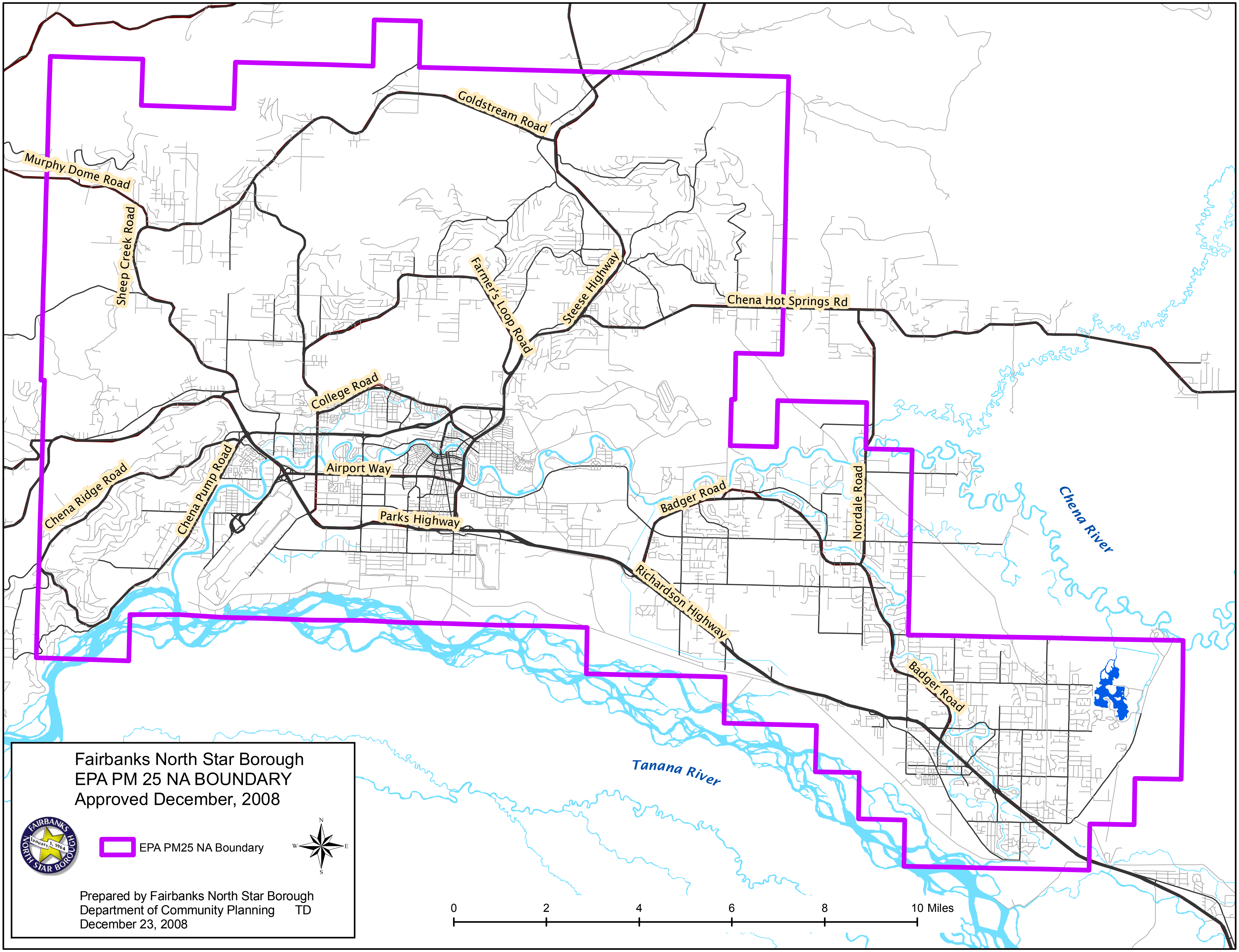
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Sheep Creek Road
Farmer's Loop Road
Steese Highway
Chena Hot Springs Rd
College Road
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Chena Ridge Road
Chena Pump Road
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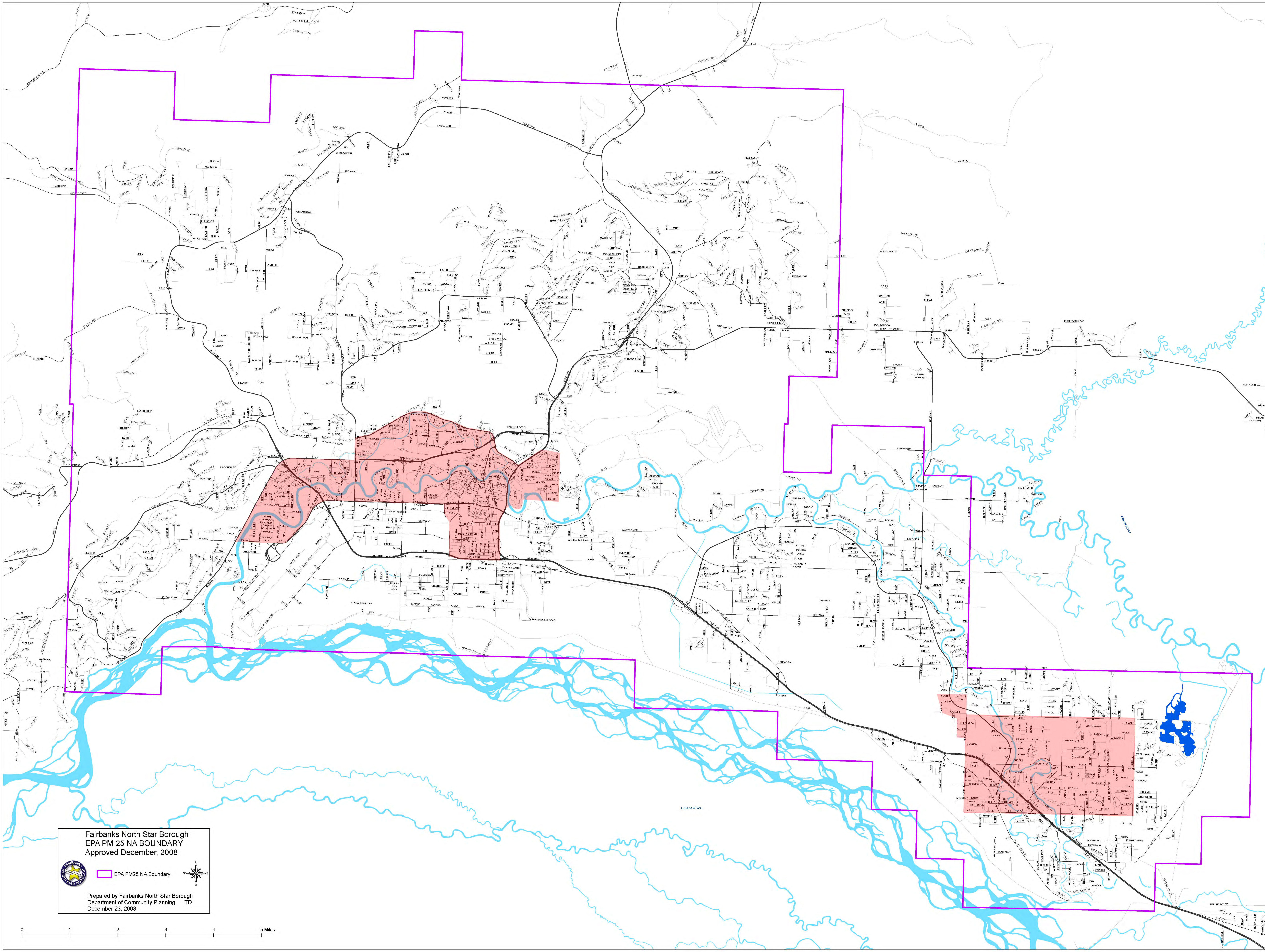
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3705 Arctic Blvd # 503
Anchorage, AK 99703

Interior Coordinator
2010 Steese Highway
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March 29, 2012

Dear Senator Coghill

Representative Wilson,

Per your request for information, to date, we have completed over thirty upgrades (along with follow-up public education on best burn practices), some unit tests, three complete system replacements, and R&D on a stove and four boilers. We have approximately eighteen more upgrades underway. As you know, one of our contractors provided a tour to EPA personnel on key upgrades, and we continue working with them on assessing the effectiveness of emission reduction efforts. The upgrade network has expanded to include at least two retrofit companies and several local contractors. While introducing economic activity into the Borough was not the primary purpose of the emission reduction project, it has certainly occurred; manufacturers are finding their way to the area to recruit distributors, and Interior contractors are being trained to install new technology.

Based on the experience of last Summer and Fall, monitoring ongoing product development of pollution control technology, and survey data, we estimate approximately twenty furnaces, in high risk areas, can be upgraded between July 2012 and January 2013. Some of these will be hydronic heaters—both EPA unqualified and Phase II units can be upgraded and see a reduction of emission to a level of approx. 0.15 lb/MMBtu and practically eliminate visible emissions. This is a level satisfying EPA's current Phase II requirements and local/federal opacity tests (Method 9). Taking into account the average cost of an emission control device, extra chimney stack, installation labor, follow-up monitoring with a certified emission reader, personal one-on-one coaching of the furnace owner on "best burn practices," and misc. parts, we estimate the comprehensive average upgrade at ~$4,800.00/unit. Some of those costs may be covered by FNSB's AQIP, and we inform residents of all current programs to assure the best fit.

In order to complete the hydronic heater upgrade project within the district and begin the requested pellet stove installation project, the following estimated budget applies –

- Continued monitoring and testing is necessary to assure adequate performance of equipment and assess areawide effectiveness. For equipment, O2 & temperature sensors with loggers, instrument installation, survey and outreach to homeowners, and analysis of the upgrade effect on air quality from these installations, $45,000.00.
- ~10 hydronic heater upgrades, $48,000.00.
- ~$5,200.00/ pellet stove installation (includes the stove, piping, hearth, and labor). It is not yet precisely known how many units, per district, use biomass as a primary heat source, and the number surely fluxuates in conjunction with the price of heating oil. Our

Interior contractors are, however, able to communicate with residents, and determine how to help in each case.

Thank you for your inquiry. Please let me know if we can be of further assistance.

With Best Regards,

Ward Sattler

Ward Sattler

President
Alaska Resource Agency

LOW EMISSION AND HIGH EFFICIENCY RESIDENTIAL PELLET-FIRED HEATERS

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1601 N. Kent St., Ste. 1001, Arlington, VA 22209

ABSTRACT

There are an estimated 350,000 residential pellet-fired heaters currently in use in the United States. In recent years about 30,000 to 40,000 units have been sold annually. There are two fundamental technology types: under-feed and top-feed. Pellets originating from both hardwood and softwood residue are available. During the 1995-1996 heating season 654,000 tons of pellets were sold nationwide.

Nearly all pellet-fired heaters have been sold since 1989. Even with this recent introduction, there has been significant improvement in reliability, efficiency, and air pollutant emissions in current models as compared to the earliest models. Electronic and microprocessor control of combustion air, fuel feed, and convection fans is primarily responsible for the improvement. Unfortunately, air emissions and efficiency data in the open literature and in government reports available to air quality and energy planners and regulators are still based on the performance of the earliest models introduced ca. 1989-1990.

Even the old-technology pellet-fired heaters are more efficient than traditional cordwood stoves. They have lower greenhouse gas and acid precipitation impacts than home heating options based on fossil fuels, and their particulate and carbon monoxide emissions are lower than cordwood stoves.

Air emissions testing and efficiency testing on new under-feed and top-feed commercially available heaters burning hardwood- and softwood-based pellets were conducted. The results were compared with data from earlier models. Reductions in air emissions were documented. The data from both the old- and new-technology stoves confirm that pellet-fired heaters offer an environmentally sound option for the utilization of wood waste for home heating.
Keywords: air emissions, pellet heaters

INTRODUCTION

The use of wood for home heating represents about 9% of the Nation's space heating needs (Houck et al., 1998). As with all energy options, there are environmental benefits and drawbacks associated with residential space heating with wood. Clear environmental benefits are low greenhouse gas emissions and low acid precipitation impacts as well as the renewable nature of wood as a fuel. The major environmental concerns have been particulate matter (PM) and carbon monoxide (CO) emissions.

In the late 1980's pellet stoves and low emission cordwood stoves were developed. The PM and CO emissions from the pellet stoves were documented as being dramatically lower than from traditional cordwood stoves (Barnett and Roholt, 1990, Barnett and Fields, 1991, Barnett et al., 1991 and U.S. EPA 1996). Since the introduction of the first pellet stove models, considerable improvements have been made in their design with commensurate decreases in PM and CO emissions.

There have been four studies which have evaluated the air emissions from pellet stoves. These are: (1) An in-home study of early-technology U.S. Environmental Protection Agency (EPA)-certified pellet stoves conducted for the U.S. Department of Energy (DOE) during the 1989/1990 heating season (Barnett and Roholt, 1990 and Barnett et al., 1991) – six stoves (two models) and 23 one-week long test periods make up the data base for the study; (2) An in-home study of early-technology pellet stoves exempt from EPA certification conducted for the DOE during the 1990/1991 heating season (Barnett and Fields, 1991 and Barnett et al., 1991) – six stoves (four models) and 24 one-week long test periods make up the data base for the study; (3) Recent laboratory testing of an early model (ca. 1990) pellet stove for the EPA under four burn rates; and (4) Laboratory testing of new under-feed and top-feed pellet stove models using both hardwood and softwood pellets for the Pellet Fuels Institute (PFI) and Hearth Products Association (HPA). The results of the first two studies have been published. They are the basis for the PM and CO emissions factors compiled by the EPA in the AP-42 emissions factor document (U.S.EPA, 1996) and have been generally used to represent PM with aerodynamic diameters <10 μm (PM_{10}) and CO emissions characteristic of pellet stoves. The results of the latter two studies are presented here for the first time.

Burn rates, PM emissions, and CO emissions were measured in all four studies. Particle sizing was done as part of the two new studies. The elemental, organic, and carbonate fractions of particles were also quantified in the PFI/HPA study.

Additional particulate emission data beyond those available from the four studies are also obtainable from EPA certification records of pellet stoves (U.S.EPA, 1998). The EPA certification records provide PM emission rates at the method-prescribed weighted burn rate for 23 different models.

EXPERIMENTAL

Because much of the PM from residential wood combustion is composed of organic compounds which are semivolatile (i.e., they are partitioned between the gas and PM phases), the method of sample collection will affect the mass of PM emissions measured. PM emissions from pellet stoves have been primarily measured by three techniques: (1) Dilution tunnel approaches of which Method 5G is used in the certification process (U.S. EPA, 1988) (2) A method based on the traditional EPA Method 5 industrial source sampling train which is referred to as Method 5H when used for woodstove certification (U.S. EPA, 1988), and (3) automated in-home samplers. The emissions factors compiled in AP-42 for pellet stoves measured in the two in-home studies (Barnett and Roholt, 1990, Barnett and Fields, 1991 and Barnett et al., 1991) were obtained by using an in-home sampler referred to as an automated emissions sampler (AES). For the two laboratory studies, PM emissions were determined in dilution tunnel systems similar to Method 5G. Emissions rates listed by the EPA for certified pellet stoves are reported as Method 5H equivalents. Equations to convert PM emissions data collected with the AES to equivalent 5G values have been developed by the EPA (1988). Similarly, equations also have been developed relating data collected by methods 5G and 5H (U.S. EPA, 1988 and E.H. Pechan & Associates, 1993). While it is generally accepted that the conversion equations are not highly accurate, to permit direct comparison of PM emissions, they were used here to put all data in a 5G-like dilution tunnel format.

CO for pellet stoves in homes with the AES systems was measured using Tedlar bags which collected a portion of the sampler's flow. CO concentrations in the bags were determined with commercial CO analyzers. CO emissions factors for the two recent laboratory studies were determined from periodic measurements of CO concentrations in the exhaust gas combined with periodic measurements of stack flows.

Efficiency values were calculated by combining the flue loss method (i.e., sensible and latent heat loss out the exhaust) and the combustion efficiency. The fraction of unburned residue was determined gravimetrically. Greenhouse gas and acid precipitation impacts were estimated by summing the emissions of greenhouse and acid gases in each step of the energy production process (energy trajectory) leading to the production of space heat from pellets produced from uncut standing trees (Houck, et al., 1998).

RESULTS AND DISCUSSION

CO and PM emissions from the four studies are the key results presented here. Ancillary data on stove efficiencies and solid waste issues, along with the results of a review of greenhouse and acid gas impacts for home space heating, are also included.

CO Emissions

CO emissions factors for new and early model pellet stoves, as well as the average value for conventional cordwood stoves, are shown in Table 1. The studies of emissions from early models under in-home use show that, on the average, CO is reduced by more than 75% under actual use as compared to traditional uncertified cordwood stoves. The laboratory testing of an early-model pellet stove at burn rates near those encountered in homes reveal similar CO emissions factors. However, at a higher burn rate (for example, see the data for the 1.6 kg/hr burn rate), CO emissions factors can become significantly larger for the early-model pellet stoves. This is consistent with acknowledged difficulty in optimizing combustion conditions with early pellet stoves with manual and/or independent controls of fuel feed rates, combustion air blowers, and dampers. Newer models generally have microprocessor control of one or more of these functions which permits better optimization of combustion conditions over all burn rates. However, the effect of varying combustion conditions can still be seen in CO emissions from new model stoves, as CO emissions are not uniform throughout the burn rate range (Figure 1). Although higher CO emissions are seen at both the low and high burn conditions, the CO emissions factors from new-technology pellet stoves are still markedly lower than for early pellet stove models. It should be further noted that, even with these differences between new- and old-technology pellet stoves, the CO emissions from both new- and early-technology pellet stoves, at typical in-home burn rates, are much lower than from traditional uncertified cordwood stoves. For the pellet stove models and pellet fuels tested, there was no significant difference in CO emissions from new-technology under-feed and top-feed technology types or between hardwood and softwood pellets used in them.

PM Emissions

Like CO emissions factors, the four studies demonstrate that PM emissions factors for early-model pellet stoves are much lower than the emissions factors for traditional uncertified cordwood stoves, and new-technology pellet stoves show considerable reduction in their PM emissions factors, compared to the early-model pellet stoves (Table 1).

In addition to the results from the four studies, information on particulate emissions can be obtained from emission certification tests. As with cordwood stoves, emission certification requirements have been promulgated for pellet stoves (U.S. EPA, 1988). There have been 23 pellet stove models certified since 1988 (U.S. EPA, 1998). However only one model is currently (as of October 21, 1999) listed as certified for sale (U.S. EPA, 1999). Most pellet stoves are exempt from certification requirements because they have a greater than 35:1 air-to-fuel ratio at one or more burn settings. The results of the certification test do confirm low PM emissions for pellet stoves. The average 5-G adjusted emissions factor for all 23 certified stove models, based on the 5-H rate data and a weighted burn rate of 1.16 dry kg/hr, is 0.70 g/dry kg (Table 1).

PM emissions factors compiled in AP-42 assume that all PM emitted from pellet stoves is smaller than 10 μm in aerodynamic diameter (PM_{10}), and the emissions factors developed from the total PM data generated in the two field studies are represented as PM_{10} data. Measurements with the 1990 model pellet stove for the EPA and on the new under-feed and top-feed models for the PFI/HPA study show that not all, but on the average about 84%, of the total PM emissions are PM_{10}. Interestingly, the same data base also shows that about 81% of the PM emissions are smaller than 2.5 μm ($PM_{2.5}$). These results are consistent with the general understanding of the source of PM from biomass combustion. Most are submicron size particles formed from the chemically incomplete combustion of fuels, some are large particles of entrained ash or unburned char, and very little PM falls between the extremes. The ramification of the PM size distribution is that emissions factors based on total PM should be reduced to 84 and 81% for PM_{10} and $PM_{2.5}$ emissions factors, respectively.

The elemental, organic, and carbonate carbon contents of the PM emitted from the new under-feed and top-feed models studied for the PFI/HPA were quantified. From the organic carbon data, the organic compound content can be estimated using a multiplier of 2.0 to account for the mass of oxygen and hydrogen associated with carbon in organic compounds. Similarly, the fraction of the PM emissions composed of entrained ash can be estimated from the carbonate carbon content, using a multiplier of 3.0 since wood combustion ash is about one-third by weight carbonates. The carbon analysis revealed a dichotomy between PM emissions from under-feed and top-feed pellet stove models (Figure 2) and between pellet stoves in general and cordwood stoves. A large fraction of the PM emitted from the top-feed model was elemental carbon. Entrained ash, however, as indicated by the carbonate carbon, was not detectable. The elemental carbon fraction increased with increasing burn rate, reaching 88% of the total PM emissions at the highest burn rate. In contrast, virtually no elemental carbon was detected in the PM emitted from the under-feed model, but entrained ash was estimated as comprising 26 and 8% of the PM emissions at a medium burn rate for softwood and hardwood pellets, respectively. Visual observation of filters used to collect the PM samples confirmed the difference in chemical makeup of the PM. The filters used to collect PM from both the top-feed model used for the PFI/HPA study and the 1990 top-feed model used for the EPA study were black, characteristic of elemental carbon (also called graphitic carbon or soot). However, the filters used to collect PM from the under-feed model were light tan. The chemical makeup of PM emitted from a cordwood stove is unlike that from either top- or under-feed pellet stoves. Typically, particles from a cordwood stove are composed of 10 to 20% elemental carbon and less than 1% inorganic ash (Watson et al., 1988 and Houck et atl., 1989). In addition, cordwood stove PM filters are generally dark brown to black.

Total PM emissions have often been used as a surrogate for air emissions of specific toxic compounds such as polycyclic organic matter (POM). The gross chemical differences among PM emitted from top-feed pellet stoves, under-feed pellet stoves, and traditional cordwood stoves demonstrated that total PM emissions cannot reliably be used as a surrogate for individual or groups of specific organic species when comparing emissions among these different technology types.

Efficiency

The efficiencies of pellet stoves are considerably higher than those of cordwood stoves. Efficiencies for new-model pellet stoves have been measured, by OMNI Environmental Services, to be as high as 87%; whereas, the efficiencies for uncertified cordwood stoves are estimated as 54% (U.S. EPA, 1996). The efficiencies of new-technology pellet stoves are much higher than the earliest models which had efficiencies documented from the in-home studies of 56 and 68% for exempt and certified models, respectively (U.S. EPA, 1996). The significance of higher efficiency, beyond its obvious desirability, is that less fuel is used by a home occupant to produce the same amount of heat, consequently the effective reduction in air emissions per unit of heat produced is even greater than the emissions factors, reported in units of mass pollutant per mass of fuel burned, would imply.

Greenhouse Gas and Acid Precipitation Impacts

There are two well documented air quality advantages associated with all residential wood combustion (not just pellets) which are important to consider when evaluating the environmental implications of home heating options. These advantages are low greenhouse gas emissions and low acid precipitation impacts. When all the steps involved in energy production are taken into consideration, home heating with wood produces less than half the carbon equivalents of greenhouse gases per unit of energy than any other home heating option (Houck, et al., 1998). The release of methane and carbon dioxide into the atmosphere from the activities leading to the production of space heat is responsible for the greenhouse impacts from home heating. In addition to the high energy return on investment (EROI) associated with wood fuel, harvesting of mature trees for fuel permits more rapid carbon fixation in younger replacement trees and reduces the effective greenhouse impacts from wood fuel combustion.

Most acid precipitation impacts are produced by sulfur gases or nitrous oxide gases released during the extraction, processing, and the higher temperature combustion of fossil fuels. Little fossil fuel is invested in the production of space heat from wood (including pellets). A detailed analysis of emissions from each step of the energy production process shows that residential wood combustion produces the lowest amount of acid equivalents (a measure of the acid precipitation potential) per unit of heat among all the home space heating options (Houck, et al., 1998).

Solid Waste Disposal

The residue (unburned wood char and inorganic salts) remaining after combustion of fuel in a cordwood stove typically ranges from 1 to 5% of the fuel mass. The residue for a pellet stove averages less than 0.5% of the fuel mass. Due to the higher efficiencies of pellet stoves, less fuel mass is required to satisfy the same heat demand with a pellet stove than with a cordwood stove. The combination of less fuel mass burned and a lower percent residue production makes solid waste disposal from pellet stoves significantly less of an issue than for cordwood stoves. In addition, wood ash (derived from either cordwood or pellets) is relatively benign. In fact, its high calcium carbonate and potassium content makes it a good agricultural soil amendment.

CONCLUSIONS

The key conclusions that were reached by reviewing the pellet stove emission data are:

- New-technology pellet stoves produce much less CO than uncertified cordwood stoves.
- New-technology pellet stoves produce much less PM than uncertified cordwood stoves.
- The emissions factors for both CO and PM are lower for new-model pellet stoves than for earlier models.
- Not all PM emitted from pellet stoves are PM_{10} or $PM_{2.5}$. Approximately 84% of PM is PM_{10} and about 81% is $PM_{2.5}$. PM_{10} and $PM_{2.5}$ emissions factors, if based on total PM measurements, should be adjusted accordingly.
- The chemical makeup of PM emitted from top-feed pellet stoves and under-feed pellet stoves is different, and the chemical makeup of PM from both technology types is different from that emitted from cordwood stoves. Consequently, total PM emissions are not accurate surrogates for emissions of specific organic compounds such as those identified as "air toxics."
- Pellet stoves generate less solid waste than cordwood stoves.
- The high efficiencies and low emissions of PM and CO characteristic of new-technology pellet stoves, combined with low greenhouse gas impacts, low acid precipitation impacts, and minimal solid waste issues, make pellet stoves an environmentally sound home space heating option.

ACKNOWLEDGMENTS

The authors would like to thank: Dane Harman of Harman Stove Company for providing a pellet stove, Jerry Whitfield and Doug Jenks of Pyro Industries for providing a pellet stove and information on older model stoves, Averill Cook of Catamount Fuel Corporation for providing pellet fuel, Robert Cary of Sunset Laboratory for conducting carbon analyses, and Robert McCrillis, now retired from the U.S. EPA, for his participation in the pellet stove testing program.

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Table 1 Carbon Monoxide and Particulate Emissions

Description	Pellet burn rate (dry kg/hr)	CO emission factor (g CO/dry kg fuel)	PM emission factor (g PM/dry kg fuel)[a]
Conventional **cordwood** stove	NA[b]	115.4	12.0
90/91 exempt pellet stoves, avg. 24 one-week runs, softwood pellets	0.58	26.1	2.77
89/90 certified pellet stoves, avg. 23 one-week runs, softwood pellets	0.70	22.4	1.29
Certification test results, avg. 23 models	1.16	ND[c]	0.70
Lab tests **1990 model**, hardwood pellets	0.7	23.2	3.5
	0.8	27.8	2.0
	0.9	29.7	3.0
	1.6	155	7.6
New top-feed, softwd. pellets, test 1	0.72	7.19	0.44
New top-feed, softwd. pellets, test 2	1.46	2.34	0.60
New top-feed, softwd. pellets, test 3	2.45	8.17	1.0
New bottom-feed, softwd. pellets, test 4	1.55	1.8	0.26
New bottom-feed, hrdwd. pellets, test 5	1.55	2.7	0.40

[a] All PM data adjusted to U.S. EPA Method 5G (40CFR, Part 60, App. A) equivalent to permit comparisons. Data for conventional cordwood stove from AP-42 (reference 8).
[b] Not applicable.
[c] Not detected.

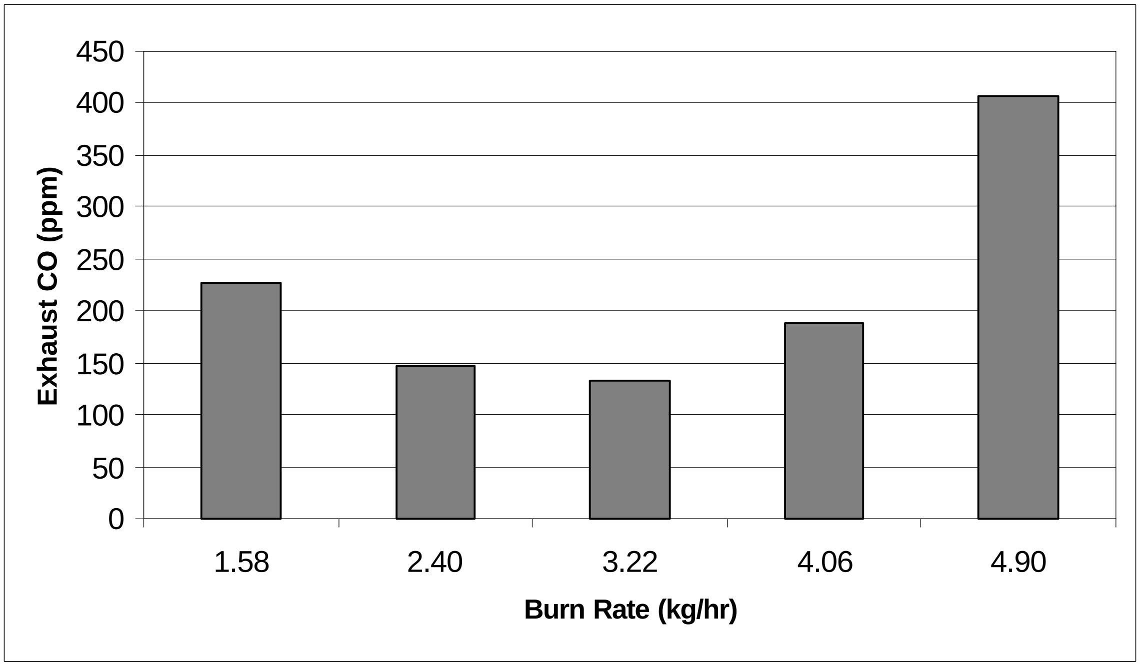

Figure 1. Carbon Monoxide Concentration in Exhaust Gas versus Burn Rate with a New Top-Feed Pellet Stove Model Burning Softwood Pellets.

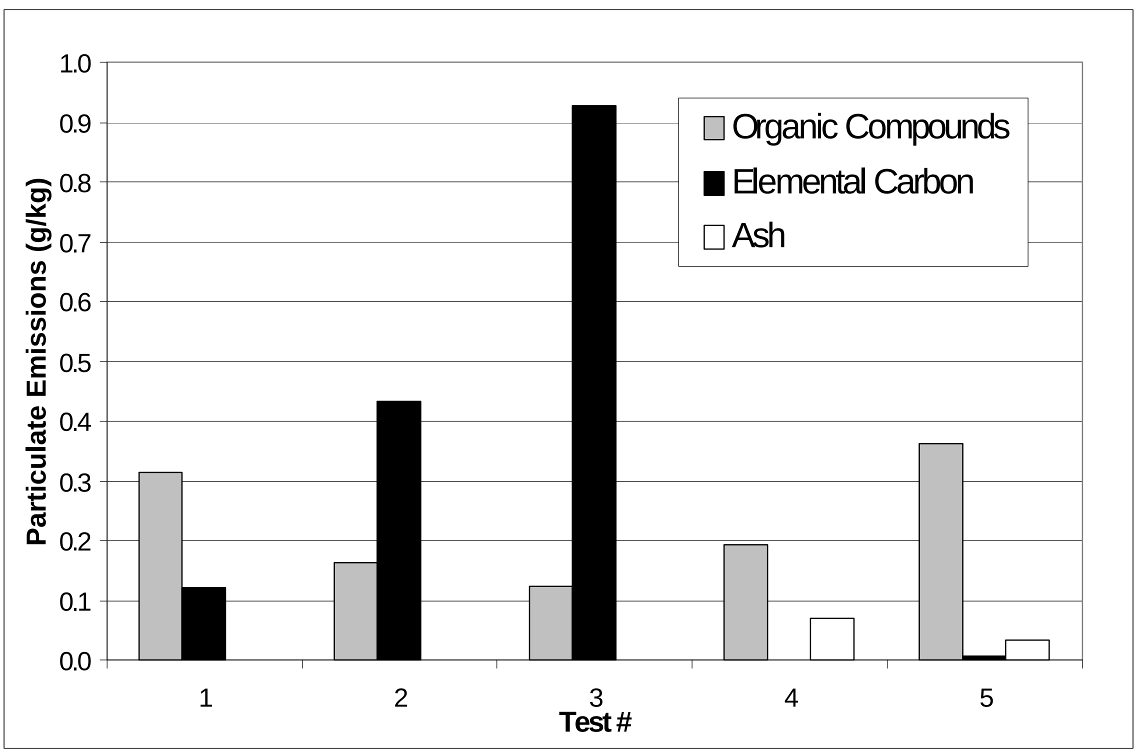

Figure 2. Composition of PM emissions. (Tests 1-3 are for a top-feed model burning softwood pellets at 0.72, 1.46, and 2.45 kg/hr. Tests 4 & 5 are for an under-feed model. Softwood pellets at 1.55 kg/hr were burned in test 4, hardwood at 1.55 kg/hr in test 5.)