COLD CLIMATE HOUSING RESEARCH CENTER

CCHRC

Reducing PM2.5 Emissions from Residential Heating Sources in the Fairbanks North Star Borough:

Emission Estimates, Policy Options, and Recommendations

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Abstract

The Cold Climate Housing Research Center developed a model to estimate the baseline PM2.5 emissions from residential heating sources, and the PM2.5 emissions reductions caused by various policy options. CCHRC is recommending a combination of policy options that are effective, enforceable, and affordable. These recommended policy options are estimated to reduce PM2.5 emissions from residential heating sources from 874 tons/year to 422 tons/year, or 52%. The emission estimates, policy options, and recommendations are described in this report.

Preface

At the outset it is important to understand the scope of this work and the principal caveats and assumptions used herein; without this knowledge conclusions may be drawn out of context.

Firstly, neither the residential model developed by CCHRC nor the estimates of point source emissions incorporate any spatial, temporal, or atmospheric considerations. Also, we did not attempt to calculate the amount of PM2.5 generated that enters or leaves the airshed, penetrates the inversion, or reaches the monitoring stations used to measure PM2.5 concentrations. The estimates are simply used to compare the relative significance of PM2.5 emissions.

Secondly, the oil, natural gas, and coal PM2.5 emission estimates for residential, commercial, and point sources all rely on a secondary conversion factor for PM2.5 that is not well documented for the Fairbanks context. The secondary conversion factors assumed are 30% conversion for SO_X and 7.4% conversion for NO_X, as referenced in the report titled "Air Emissions from Residential Heating: The Wood Heating Option Put into Environmental Perspective. (Houck 1998)

Acronyms and Definitions

AP 42 – The full title is *AP 42 Compilation of Air Pollutant Emission Factors*, commonly referred to as AP 42. AP 42 is a comprehensive list of emission factors developed by the EPA to estimate the quantity of pollutants released into the atmosphere from a given activity. AP 42 is currently in its fifth edition.

CAP – Criteria Air Pollutant: The 1970 amendments to the Clean Air Act required EPA to set National Ambient Air Quality Standards for certain pollutants known to be hazardous to human health. EPA has identified and set standards to protect human health and welfare for six pollutants: ozone, carbon monoxide, total suspended particulates, sulfur dioxide, lead, and nitrogen oxide. The term, "criteria pollutants" derives from the requirement that EPA must describe the characteristics and potential health and welfare effects of these pollutants. It is on the basis of these criteria that standards are set or revised. (EPA Terms of the Environment)

CCHRC – Cold Climate Housing Research Center

DEC – Department of Environmental Conservation

EPA – Environmental Protection Agency

FNSB – Fairbanks North Star Borough

HAP – Hazardous Air Pollutant: Air pollutants which are not covered by ambient air quality standards but which, as defined in the Clean Air Act, may present a threat of adverse human health effects or adverse environmental effects. Such pollutants include asbestos, beryllium, mercury, benzene, coke oven emissions, radionuclides, and vinyl chloride. (EPA Terms of the Environment)

NESCAUM – Northeast States for Coordinated Air Use Management.

NEI – National Emission Inventory

NO_X – nitrogen oxide: The result of photochemical reactions of nitric oxide in ambient air; major component of photochemical smog. Product of combustion from transportation and stationary sources and a major contributor to the formation of ozone in the troposphere and to acid deposition.

PM2.5 – particulate matter 2.5 micrometers or smaller in diameter.

PM10 – particulate matter 10 micrometers or smaller in diameter.

SIP – Statewide Implementation Plan.

SO_X – sulfur oxide: The family of compounds containing SO_2, which is a precursor to the formation of PM2.5. SO_2 is a pungent, colorless, gas formed primarily by the combustion of fossil fuels; it becomes a pollutant when present in large amounts.

Wood-fired Hydronic Heater – devices that burn wood to heat a liquid that is piped to provide heat and hot water, typically to an occupied structure.

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Introduction

Background

EPA and the PM2.5 Emission Criteria

The Clean Air Act requires the Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQS) for six criteria pollutants including PM10 (particulate matter 10 micrometers in diameter or smaller) and PM2.5 (particulate matter 2.5 micrometers in diameter or smaller). Although both sizes of PM pose a health concern, fine particulates (PM2.5) are considered a greater health risk because their small size enables them to lodge in the lungs:

> Health studies have shown a significant association between exposure to fine particles premature mortality, aggravation of respiratory and cardiovascular disease, lung disease, decreased lung function, asthma attacks, and certain cardiovascular problems such as heart attacks and cardiac arrhythmia. Individuals particularly sensitive to fine particle exposure include older adults, people with heart and lung disease, and children. (EPA Basic Information)

On September 21st, 2006, the EPA implemented a more stringent 24 hour PM2.5 standard of 35 micrograms per cubic meter (µg/m3). The previous standard established in 1997 was 65 µg/m3. EPA requires states to designate non-attainment areas based on applying the new standard to air quality data for the period 2004-2006. The FNSB is a designated area meaning it is required to prepare a PM2.5 mitigation plan within three years of the effective date of the designation, and reach attainment within five years. A timeline of the important milestones and deadlines are exhibited in Table 1.

Table 1. EPA Planning Requirements

Timeline for Implementing 24-hour PM2.5 Standard

Milestones	Deadline	Note
Final Rule for PM2.5 Designations	December 22, 2008	EPA decision date
Effective Date of Designation	April 2009	90 days after FR publication
SIPs Due	April 2012	3 years after effective date of designation
Attainment Date	April 2014	5 years after effective date of designation
Attainment Date with Extension	April 2019	No later than 10 years after effective date of designation

Source: Bob Dulla, Sierra Research

EPA Listed Source Categories of PM2.5

In order to address PM2.5 emissions the cause of PM2.5 must be understood. Table 2 lists the twelve major PM2.5 emission source sectors established in the National Emission Inventory (NEI). The NEI is the national database of air pollutants established by the EPA to estimate both criteria air pollutants (CAP) and hazardous air pollutants (HAP) across the United States.

Table 2.

12 Major Source Sectors	Detailed Category Names	12 Major Source Sectors	Detailed Category Names
Fertilizer & Livestock	Livestock Waste Fertilizer Application	On Road Vehicles	On-Road Vehicles - Gasoline On-Road Vehicles - Diesel
Electricity Generation	Fuel Combustion - Electric Utilities	Non Road Equipment	Non-Road Equipment - Gasoline Non-Road Equipment - Diesel Planes, Trains, & Ships
Fossil Fuel Combustion	Fuel Combustion - Industrial Boilers, Internal Combutions Engines Fuel Combustion - Commercial/Institutional Fuel Combustion - Residential Fossil	Road Dust	Unpaved Roads Paved Roads
Residential Wood Combustion	Fuel Combustion - Residential Fireplaces Fuel Combustion - Residential Woodstoves	Solvent Use	Solvent - Non-industrial Surface Coating - Industrial Degreasing Surface Coating - Architectural Graphic Arts Solvent - Not Classified Elsewhere Dry Cleaning
Waste Disposal	Waste Disposal Waste Disposal - Open Burning		
Fires	Wildfires Prescribed Fires Agricultural Field Burning Logging Slash Burning		
Industrial Processes	Industrial Process - NEC Commercial Cooking Industrial Process - Metals Industrial Process - Chemical Manufacturing Industrial Process - Storage & Transfer Industrial Process - Petroleum Refineries Industrial Process - Oil & Gas Production Industrial Process - Pulp & Paper Industrial Process - Cement Manufacturing	Miscellaneous	Agriculture - Crop Tilling & Livestock Dust Construction Gas Stations Bulk Gasoline Terminals Other Miscellaneous Sources

PM2.5 Exceedance Considerations

The two largest potential sources of PM2.5 on an annual basis are wild fires and road dust, yet during the winter when exceedances occur these sources are non-factors. This means the focus must shift to other potential sources of PM2.5 that contribute to concentration levels during the winter months.

Generally, PM2.5 emissions from space heating and electrical generation increase in the winter due to an increase in the heating and electrical demand. Over 96% of all heating degree days occur between September and May, which indicates that a significant amount of the fuel used for space heating in a

year is used during the winter. Additionally, more electricity is used in the winter because it is dark, people spend more time indoors, cars are plugged in, and boiler pumps and other mechanical systems are operating more than in summer.

Given that the potential sources of PM2.5 are few during the winter, the options for reducing PM2.5 are few. Additionally, it is not known at this point in time how much of the PM2.5 generated from point sources (power plants) enters the airshed and contributes to PM2.5 concentrations. It is possible because of the stack height, inversion, and other atmospheric considerations that some or all of the PM2.5 emitted from point sources travels outside the non-attainment area. The FNSB is working to address those considerations through other entities. To the extent that emissions from point sources do not enter the airshed residential emission become an even more significant contributor to PM2.5 concentration levels.

Cold Climate Housing Research Center Scope of Work

The Fairbanks North Star Borough (FNSB) tasked the Cold Climate Housing Research Center (CCHRC) with estimating the emissions of PM2.5 (tons/year) from residential heating sources and recommending actions that could be taken to reduce PM2.5 emissions. The scope of work does not include consideration of spatial, temporal, or atmospheric aspects that affect PM2.5 concentration.

CCHRC worked in three semi-overlapping phases to fulfill the deliverables.

Phase I – Develop PM2.5 Model:

CCHRC developed a spreadsheet model to calculate the emissions of PM2.5 (tons/year) generated from residential heating sources that include estimates for wood, coal, heating oil, and natural gas. The model further details the estimates for wood by evaluating different appliances including wood stoves, pellet stoves, masonry heaters, and wood-fired hydronic heaters.

Model inputs can be changed to represent the effects of policy actions. The model is the primary tool to estimate the PM2.5 reduction from policy options.

Phase II - PM2.5 Mitigation Policy Review and Development:

CCHRC reviewed PM2.5 mitigation policies implemented in other parts of the country to establish a comprehensive list of policy ideas for consideration in the FNSB. CCHRC also brainstormed policy ideas to compliment the list of existing ideas. The policy options are listed in the Digest of Policy Options, each of which includes a summary level description and important implementation considerations.

Phase III – Evaluate Policy Options:

CCHRC evaluated policy options by adjusting the model's inputs to reflect the effect of implementing PM2.5 related policies. The policies were also considered based on affordability, enforceability, and efficacy.

Cold Climate Housing Research Center Model Summary

CCHRC developed a spreadsheet model to estimate the total emissions of PM2.5 (tons/year) generated from four primary types of fuel used in residential heating: wood, heating oil, natural gas, and coal. The model does not address spatial, temporal, or atmospheric issues and does not estimate concentration levels. Further, the model relies on information available at the time the report was being developed.

The following describes the basic approach of the two methods used to estimate PM2.5 emissions from the four categories of residential fuel. One method was developed for estimating emissions from wood burning, and another method was used to estimate emissions from heating oil, natural gas, and coal.

Wood:

The model calculates emissions of PM2.5 (tons/year) from wood burning by estimating the number of various wood burning devices, the emission rate (grams/hour) for each of the various wood burning devices, and the number of hours of operation for each device in a year.

Estimates of the number of devices in the FNSB during the 2006/2007 winter were developed for certified wood stoves, non-certified wood stoves, pellet stoves, masonry heaters, and wood-fired hydronic heaters.

The number of hours of operation is estimated based on responses to a Sierra Research (Dulla et al, January 2008) survey conducted during the winter of 2006/2007 in which those who indicated they heated with a wood stove also indicated which of seven use categories they identified with: evening, day and weekend, evening only, day only, weekend only, evening and weekend, occasional use, or no use. Based on this information, a usage factor was developed to define the number of hours a week the wood-fired device was in operation. The usage factor was then weighted by heating degree days to establish a year round usage profile, which established hours of operation that could be applied to the average rate (grams/hour) of emissions from the wood-fired device in each category.

For wood-fired hydronic heaters and pellet stoves a final assumption was incorporated that weighted use toward the evening, day, and weekend category to better reflect the way in which those devices are used.

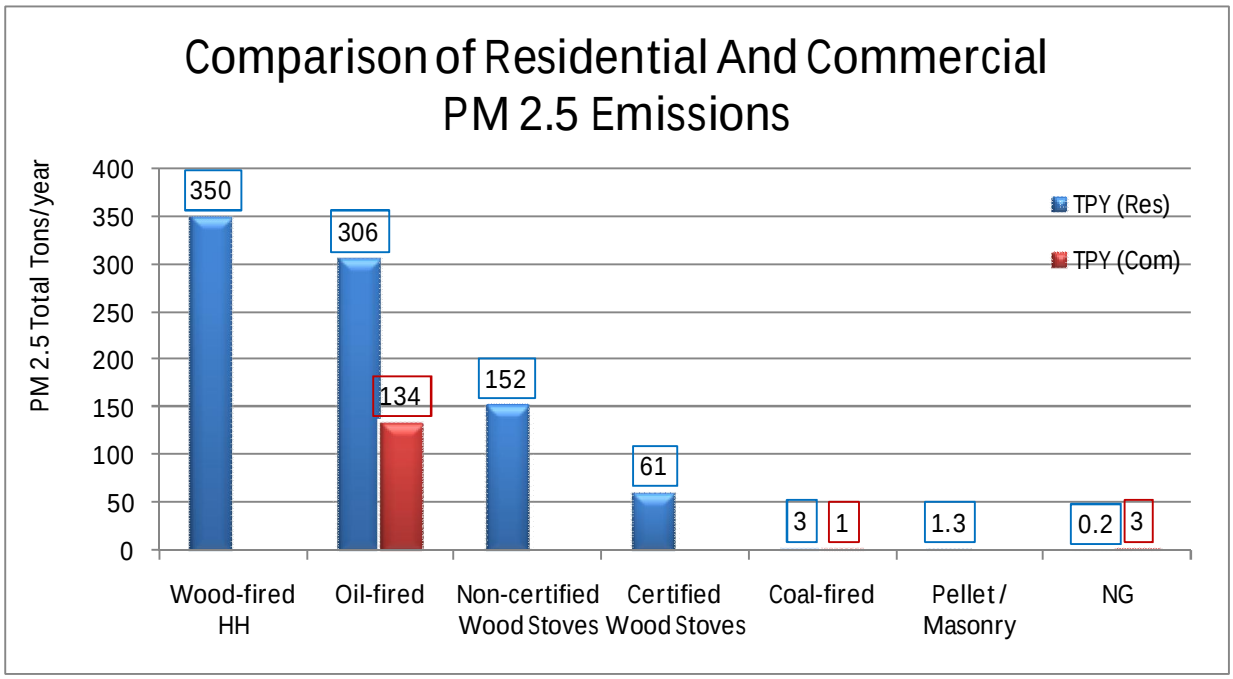
Heating oil, natural gas, and coal:

Calculations of the emissions of PM2.5 (tons/year) from burning heating oil, natural gas, and coal, were all based on emission rates (tons of PM2.5 per unit of fuel) from AP 42, Fifth Edition. The amounts of heating oil, natural gas, and coal used for residential heating were taken from the *Fairbanks North Star Borough Baseline Greenhouse Gas Emission Inventory, Base Year 2007* (Holdmann and Murphy, 2008). Heating degree days were used to weight fuel usage.

The PM2.5 estimate for these fuels involved two other assumptions. One, the amount of sulfur in residential heating oil and coal used in Fairbanks is 0.22% (Hartig, 2007) and 0.25% (Usibelli, 2008) weight by volume respectively. Two, the conversion of SO_X and NO_X to PM2.5 is 30% and 7.4% respectively. (Houck, 1998)

The model was used to establish a baseline estimate of the amount of PM2.5 emissions from certified wood stoves, non-certified wood stoves, pellet stoves, masonry heaters, wood-fired hydronic heaters, heating oil, natural gas, and coal devices. Graph 1 displays the model baseline results for residential, and also for commercial heating oil, natural gas, and coal devices.

Graph 1.



The baseline estimates were used to reach conclusions about the fuels, devices, and factors that were most correlative to PM2.5 emissions. The observations are discussed in the following section.

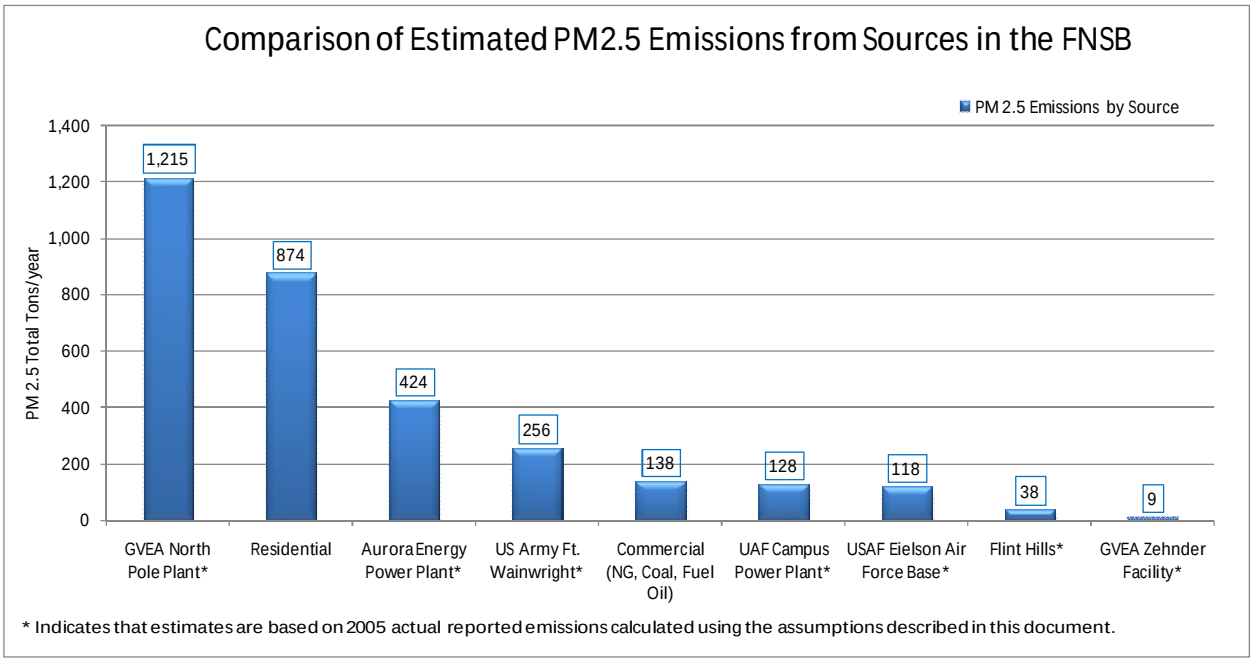
Evaluation of PM2.5 Sources in the Fairbanks North Star Borough

Comparison of PM2.5 from Residential Heating and Other Sources in the Fairbanks North Star Borough

CCHRC used the model to estimate the emissions of PM2.5 (tons/year) from residential heating sources. Graph 2 displays the tons/year of PM2.5 emissions from residential heating sources compared to the estimated emissions of PM2.5 (tons/year) from other potential major sources in the FNSB. Because there is no published estimate of PM2.5 emissions from point sources in the FNSB, CCHRC estimated PM2.5 emissions by using reported actual emissions for calendar year 2005 (Hartig, 2008), modified by adding the same secondary conversion factor for SO_X and NO_X used in the residential heating model and assuming that 85.8% of all reported PM10 was PM2.5. The estimated amount of PM2.5 in PM10 ranges between 65%-90%. The 85.8% figure is based on the percentage of PM2.5 in PM10 in Fairbanks area wild fires. (Hartig, 2008)

The following observations are based on results from the baseline model comparing residential emissions to those from other sources and residential emissions from wood combustion to those from other fuels.

Graph 2.



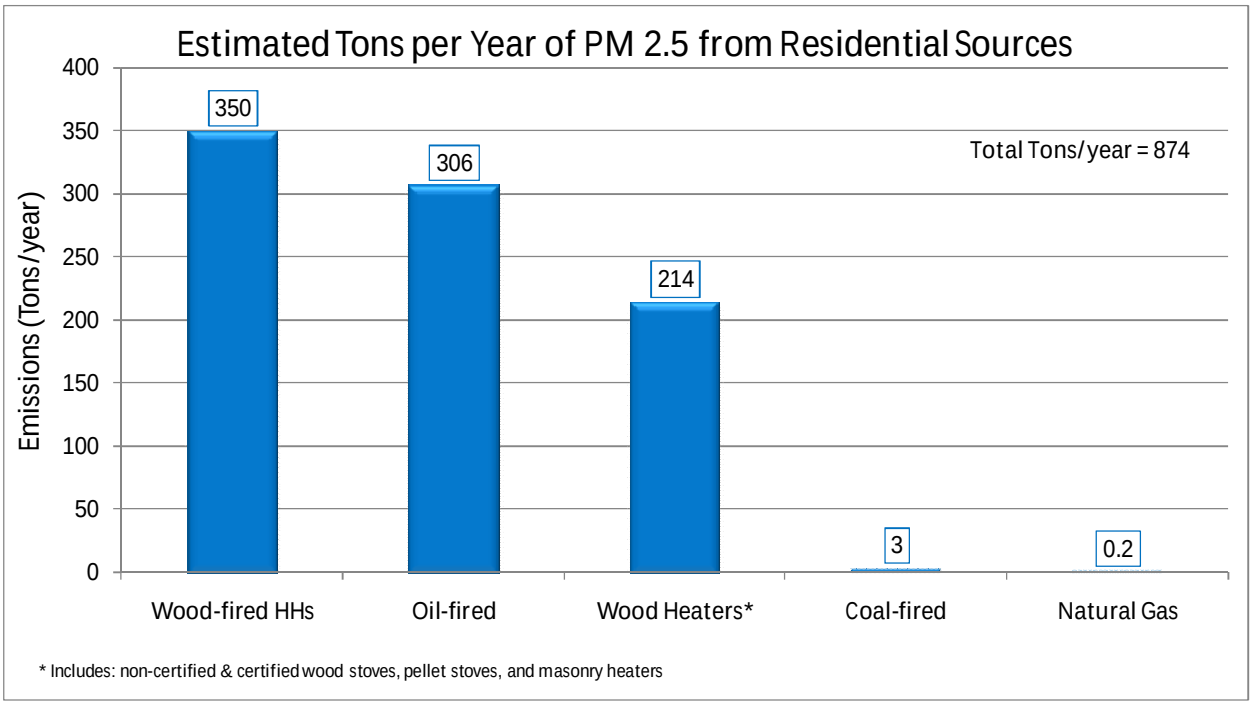
Observation #1 - Residential Heating is a Significant PM2.5 Emission Category:

PM2.5 from residential sources is significant in comparison to other sources of PM2.5 in the FNSB on the basis of total tons/year of PM2.5. To the extent that emissions from point sources do not enter the airshed, residential emissions become an even more significant contributor to concentrations.

Observation #2 - Wood Combustion is the Most Significant Source of PM2.5 Emissions in the Residential Heating Category on a Ton per Year Basis:

The highest emitter of PM2.5 by residential fuel type is wood at 564 tons of PM2.5 per year. Graph 3 displays the total tons of PM2.5 by fuel type.

Graph 3.



Observation #3 – Wood-fired Hydronic Heaters Emit More Annual Tons of PM2.5 than Any Other Residential Heating Category, and are on the Scale of Point Sources:

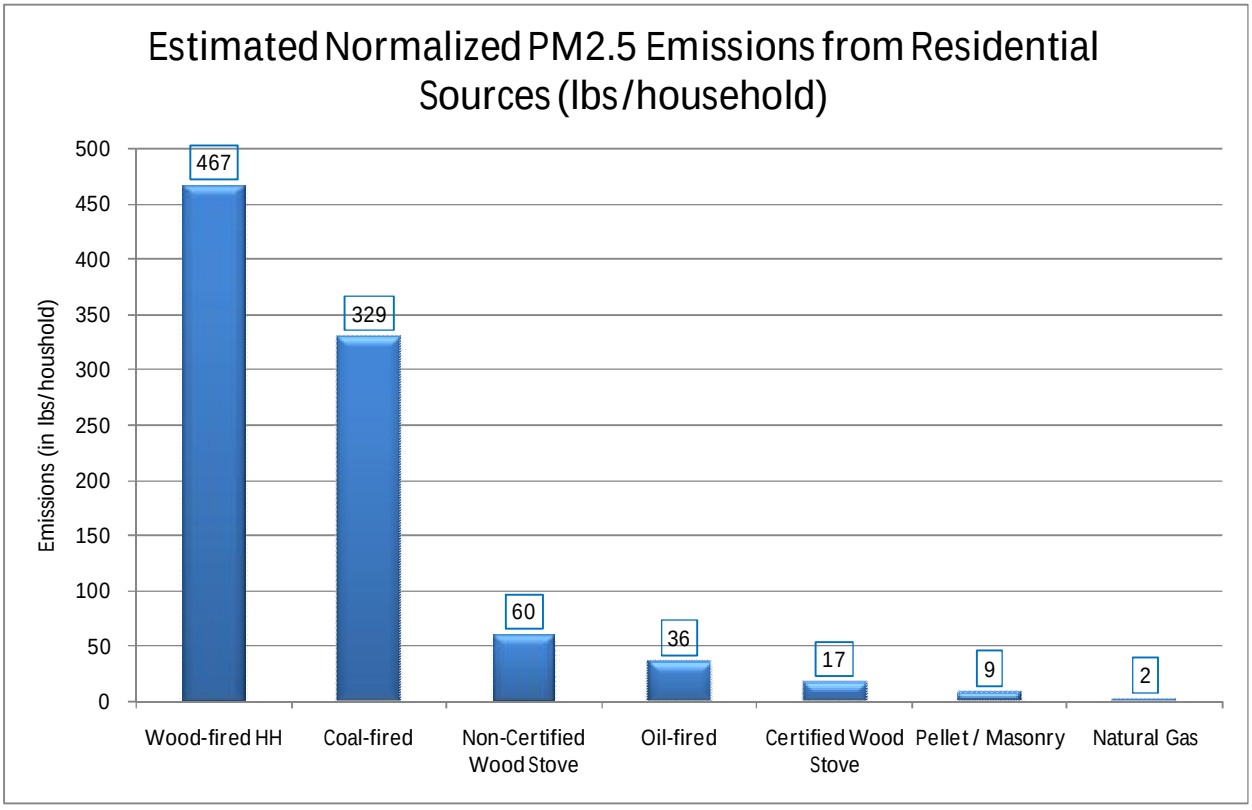
Wood-fired hydronic heaters emit more than any other residential source at 350 tons/year of PM2.5. The next highest emitter of PM2.5 from residential sources is heating oil at 306 tons/year, however, approximately 76% of the PM2.5 emissions from heating oil are estimated to be SO_X conversion to PM2.5, and as noted, the actual conversion rate in the FNSB is not known at this time.

Another measure of the significance of PM2.5 emissions from wood-fired hydronic heaters is direct comparison with point sources. Based on the estimated PM2.5 emissions from point sources (see Graph 6 on pg. 17), wood-fired hydronic heaters are significant sources of PM2.5 on an annualized basis.

Observation #4 – On a Household Basis Wood-fired Hydronic Heaters Emit the Most PM2.5 of All Residential Heating Sources.

Graph 4 displays the relative PM2.5 emissions from residential sources on a per household basis to rank which heating sources individually emit the most PM2.5. Wood-fired hydronic heaters emit the most per household at 467 pounds per year with coal ranked second at 329 pounds per year. The next closest residential source is a non-certified wood stove at 60 pounds per year.

Graph 4.



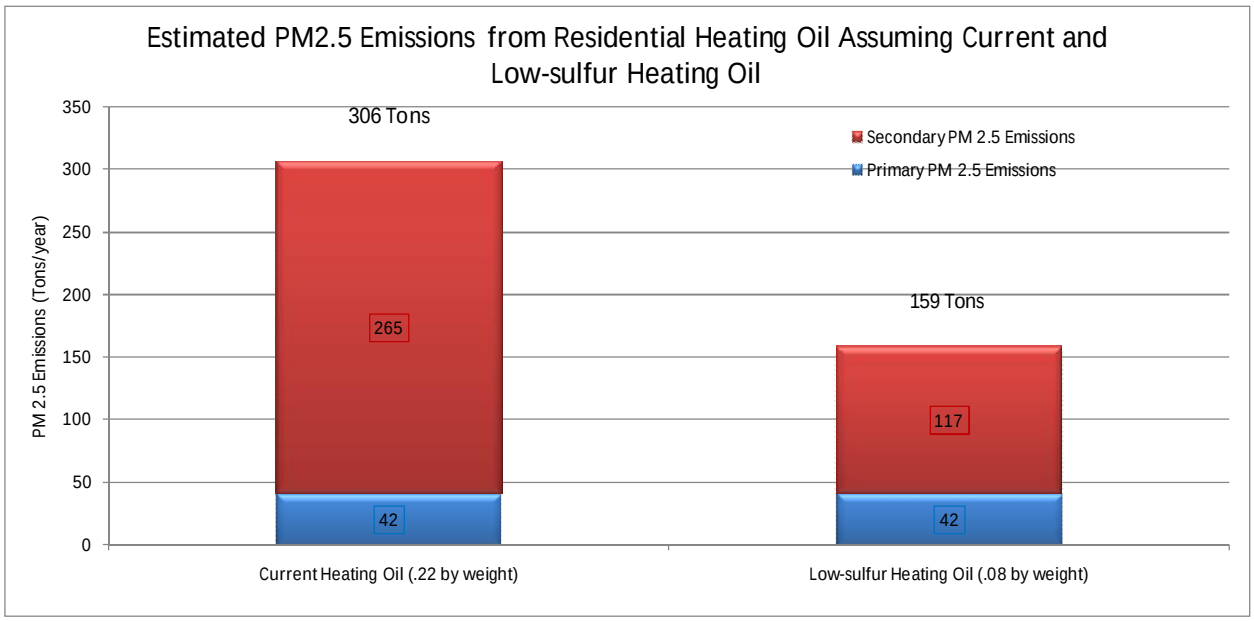
Observation #5 – Secondary Conversion of Sulfur in Residential Heating Oil to PM2.5 Needs to be Better Understood.

The sulfur in heating oil and other fossil fuels can convert to PM2.5 in the atmosphere after combustion. The extent to which this is happening in the FNSB is unknown, although atmospheric conditions are present during a Fairbanks winter that support conversion. It is extremely valuable for the FNSB to better understand what factors present in the FNSB are supporting sulfur conversion to PM2.5.

Based on the assumptions in the CCHRC model, SO_X derived PM2.5 from residential heating oil is estimated to be 232 tons/year, or approximately 76% of the total 306 tons of PM2.5 emissions from residential heating oil. Primary PM2.5 and NO_X derived PM2.5 are the sources of the remaining PM2.5 from residential heating oil at 42 and 33 tons/year, respectively.

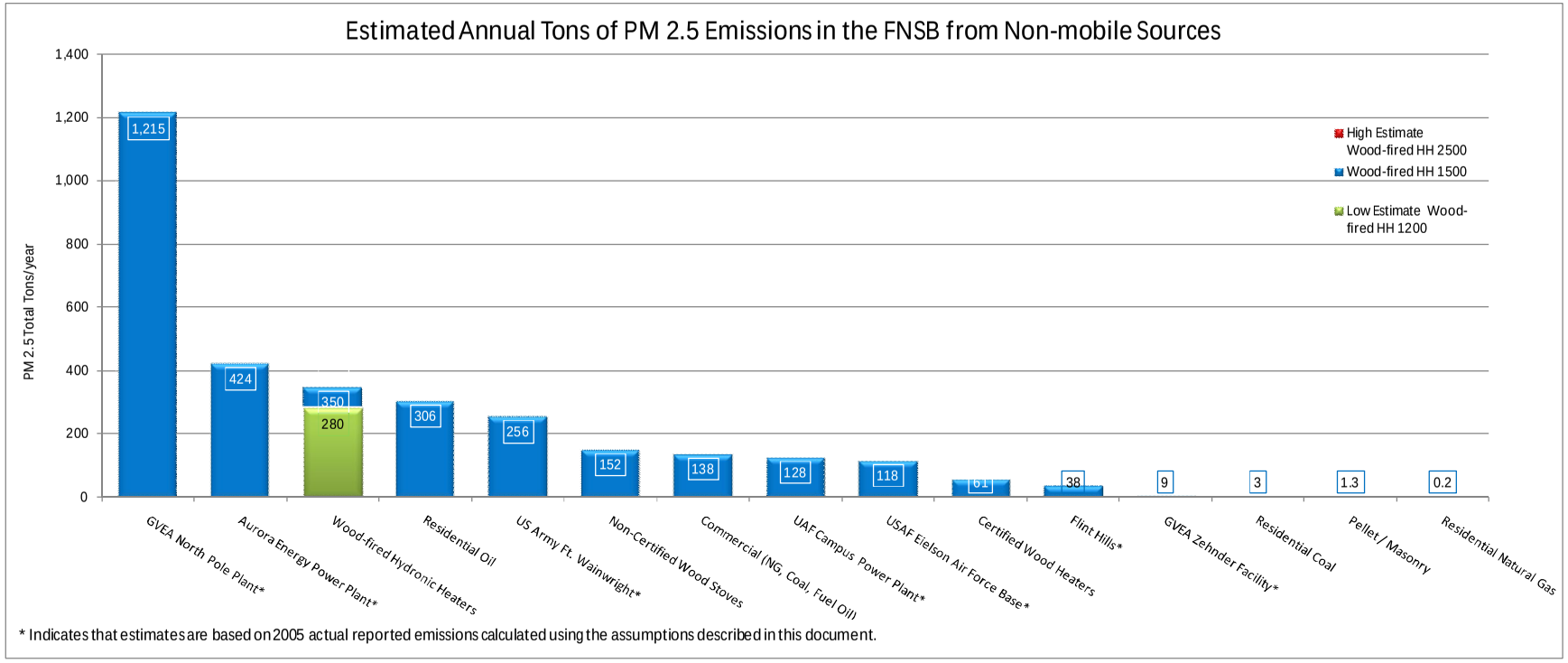
If the current heating oil at 0.22 weight percent sulfur were switched to low-sulfur heating oil at 0.08 weight percent, the estimated annual tons of PM2.5 from residential heating oil would decrease by 146 tons/year as displayed in Graph 5.

Graph 5.



It is premature at this time to consider a policy to reduce sulfur in heating oil, because of the uncertainty in the sulfur conversion rate, and the probably very large cost associated with that policy. Wood burning devices emit almost exclusively primary PM2.5 emissions, while PM2.5 emissions from residential heating oil can be significant, when considering secondary conversions of SO_X and NO_X. Because of this, reducing PM2.5 from wood burning devices is more certain and quantifiable.

Graph 6.



* Indicates that estimates are based on 2005 actual reported emissions calculated using the assumptions described in this document.

Order of Magnitude PM2.5 Concentrations and Localized PM2.5 Issues

Although it is not within the CCHRC's scope of work it is important to consider the emissions of PM2.5 (tons/year) from residential sources in the context of concentration levels. CCHRC applied two general techniques to determine the potential magnitude of PM2.5 concentrations from residential heating sources. The first technique applies an envelope model which divides a quantity of PM2.5 by a set volume. The second technique evaluates a range of potential localized exposures to wood-fired hydronic heater emissions.

Envelope Model of PM2.5 Concentration in Defined Volumes

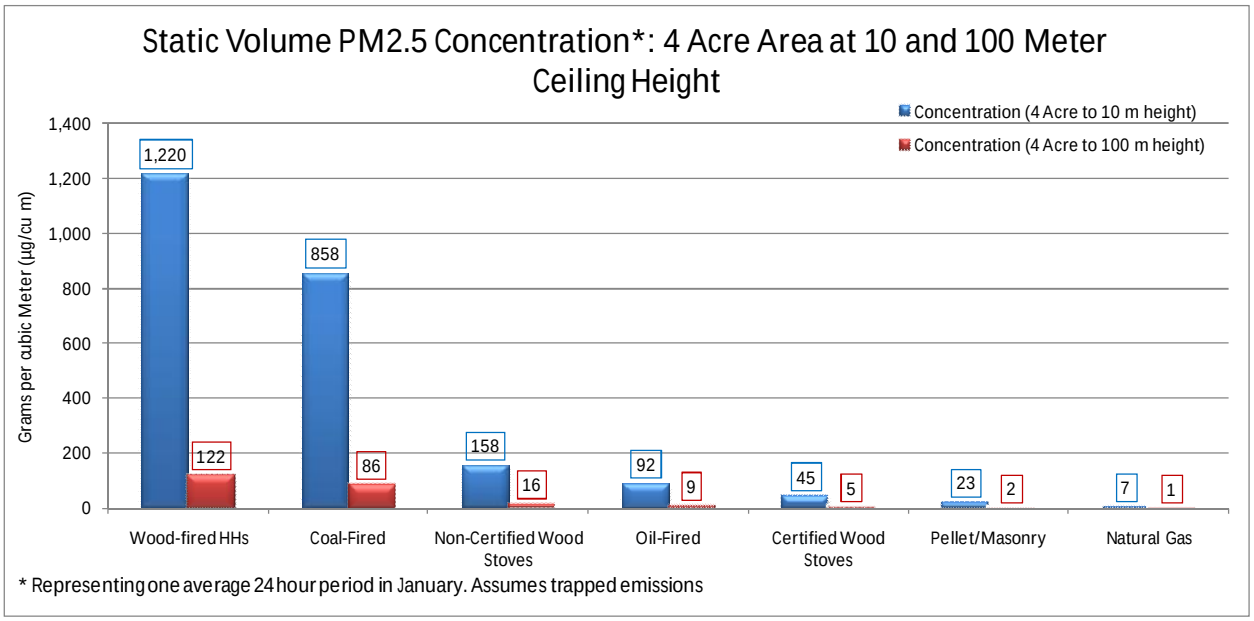
We used two sets of static volumes to establish the magnitude of PM2.5 concentrations estimated to be produced from residential heating sources. One set of calculations assumes a 4 acre plot with 10 and 100 meter ceiling heights and the other set assumes a volume representing the total FNSB non-attainment area at 10 and 100 meter ceiling heights.

Seven static volume concentration calculations were performed for the 4 acre plot to represent the operation of one unit of the following for one hour: wood-fired hydronic heater, non-certified wood stove, certified wood stove, pellet stove, coal device, heating oil device, and natural gas device.

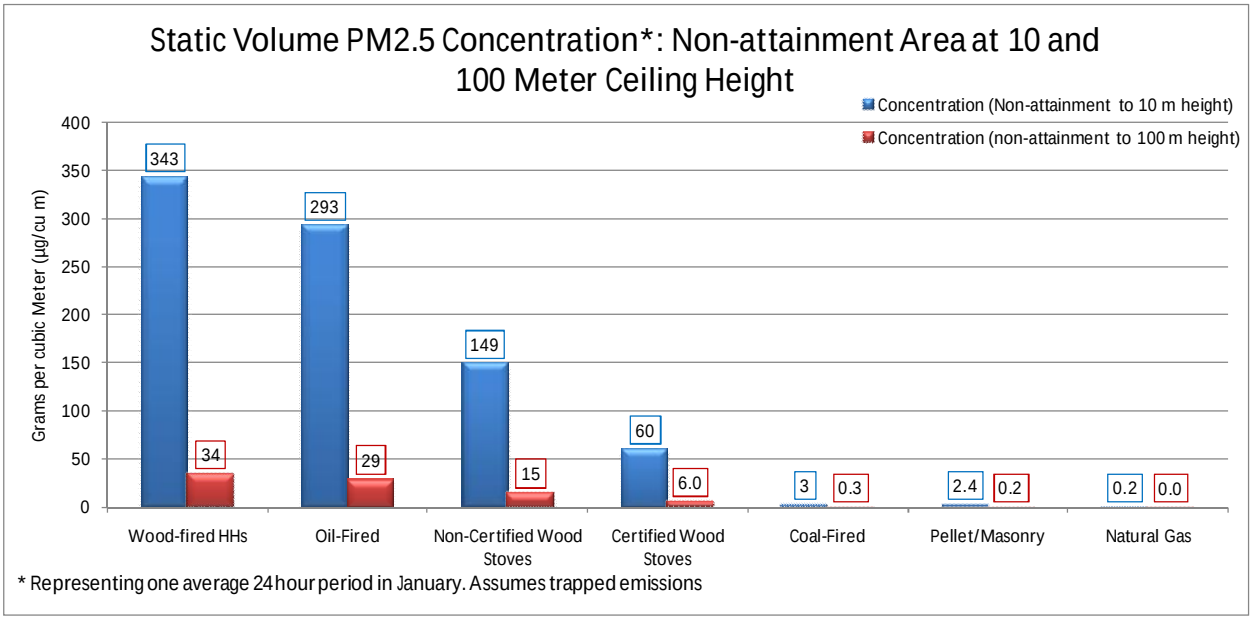
The calculation of concentration for the static volume representing the FNSB non-attainment area airshed assumes a 24-hour contribution from all seven residential source categories.

In both cases, the PM2.5 levels were assumed to occur on an average day in January to represent a day in which an exceedance might occur. The results of these calculations are contained in Graphs 7 and 8.

Graph 7.



Graph 8.



The results indicate that the potential exists for residential source categories to create PM2.5 concentrations in the order of magnitude of the EPA limit. Additionally, in the case of the 4 acre plot both wood-fired hydronic heaters and coal exhibit relatively high PM2.5 emissions exceeding the order of magnitude of the EPA concentration limit. In the case based on the volume of air in the FNSB non-attainment area, wood-fired hydronic heaters, oil-fired devices, and non-certified wood stoves exhibit potential to create significant PM2.5 concentration levels.

Localized PM2.5 Concentration Issues

Another way of considering volumetric concentrations of PM2.5 from a wood-fired hydronic heater is to estimate the area of effect based on the distance emissions from a wood-fired hydronic heater can travel while maintaining high PM2.5 concentration levels.

Two different studies on wood-fired hydronic heaters suggest that their emissions can create high concentration levels up to 1,000 feet away. (NESCAUM, 2006; Liebl, 2007) Figure 1 displays a more conservative distance of 200 meters (656 feet) on a GIS rendered map of downtown Fairbanks as a way of showing a potential reach of emissions.

The emission plume will likely disperse based on wind and terrain features and not necessarily in all directions simultaneously or consistently. This means that some neighbors will be affected more than others, and some neighbors may not be affected at all even if they are near a wood-fired hydronic heater. Additionally note that the figure does not imply a particular concentration level.

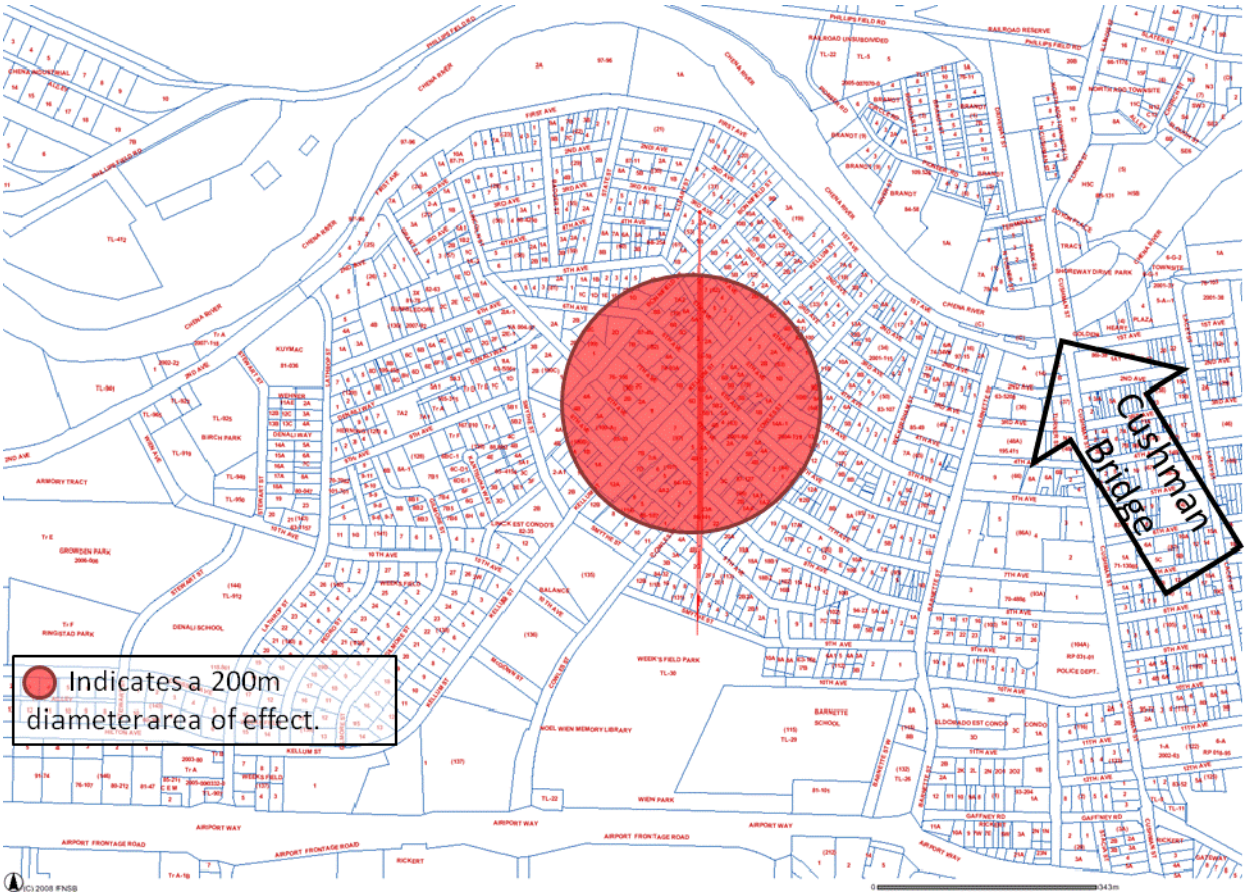
Table 3 displays a potential number of residents exposed to wood-fired hydronic heater emissions based on an estimated range of wood-fired hydronic heater of 1,200 to 2,500 and an estimated potential range of exposure of 2 to 10 neighbors per device.

Table 3.

Estimated Potential Range of the Number of Neighbors Exposed to Wood-fired HH Emissions			
Avg. # of Neighbors Exposured per Device	Estimated Number of HHs		
	1,200	1,500	2,500
2	2,400	3,000	5,000
4	4,800	6,000	10,000
6	7,200	9,000	15,000
8	9,600	12,000	20,000
10	12,000	15,000	25,000

The range of potential exposure to wood-fired hydronic heater emissions, and the potential for those emissions to be high, gives cause to consider a nuisance based ordinance to resolve localized emission issues.

Figure 1. Potential Area of Effect of Emissions from a Wood-fired Hydronic Heater



Policy Recommendations

Based on observations from the baseline model, and the reductions estimated for various policy options, CCHRC is recommending the following (these options are further elaborated below):

- Establish a Uniform PM2.5 Emission Limit of 7.5 grams/hour for all Prospective Sales and Existing Solid Fuel Devices.
- Establish a Changeout Program to Help Residents Adapt to the New Uniform Emission Limit.
- Require Decommissioning of Solid Fuel Burning Devices that do not Meet the Uniform PM2.5 Emission Limit of 7.5 grams/hour at the Time of Real Estate Sale.
- Develop a Method of Forecasting Exceedance Conditions that can be Used to Trigger Episodic Solid Fuel Burning Restrictions.
- Establish a Sustained Educational Program Regarding Heating with Wood.
- Establish and Enforce a Standard that Addresses Nuisance Emissions.

This set of policy recommendations is an amalgamation of policy elements that are combined to create a comprehensive and effective approach to reducing PM2.5 from residential heating. The combined effect of these policy options reduces PM2.5 from residential heating sources by an estimated 452 tons/year, or approximately 52%. Additional reductions will be achieved through the burn restriction at times when exceedances are forecasted.

Recommendation to Significantly Reduce PM2.5 from Residential Heating Sources

After modeling PM2.5 emissions from residential heating sources and evaluating the data and policy options specific to residential heating, CCHRC concludes that combining the following policy components is an effective, enforceable, and affordable way to reduce PM2.5 emissions from residential heating sources.

Establish a Uniform PM2.5 Emission Limit of 7.5 grams/hour for All Prospective Sales and Existing Solid Fuel Devices

Establishing a PM2.5 emission limit of 7.5 grams/hour that applies to both prospective sales and existing devices will reduce the estimated PM2.5 emissions from residential heating by an estimated 447 tons, or 51% of PM2.5 from residential heating. The reduction estimates assume complete compliance, and that all those switching devices switch to a wood-fired device emitting 7.5 grams/hour or less. Additional PM2.5 reductions will be realized if those switching devices switch to heating oil or natural gas.

CCHRC compared the effect of establishing a 7.5 grams/hour limit to a 4.5 grams/hour limit. The 4.5 gram/hr limit reduces PM2.5 by an additional 16 tons/year, or a 51% reduction of PM2.5 from residential space heating to 53%. Because a 4.5 grams/hour limit creates a marginally improved reduction and will require adopting a standard more stringent than the EPA emission limit, CCHRC is recommending the limit be set at 7.5 grams/hour.

It is important for the FNSB to consider the existing set of regulations guiding the EPA wood stove emission limit of 7.5 gram/hr. The EPA has specifically exempted masonry heaters and cook stoves, and CCHRC recommends the FNSB do the same. EPA exempts masonry heaters because they are considered to be a mature technology that produces extremely low emissions that are considerably lower than EPA limits. Cook stoves are exempt because they are considered to be used in limited capacity and the EPA definition of cook stove effectively restricts cook stove use for space heating.

In 2010 EPA will require wood-fired hydronic heaters to be certified at a rate of 0.32 pounds of PM2.5 per 1 million BTU of input, which is approximately 14.5 grams/hour per 100,000 BTU of input to the device. CCHRC recommends extending the 7.5 grams/hour limit to this class of device, regardless of the EPA limit and mandatory certification timeframe. There are several reasons for this.

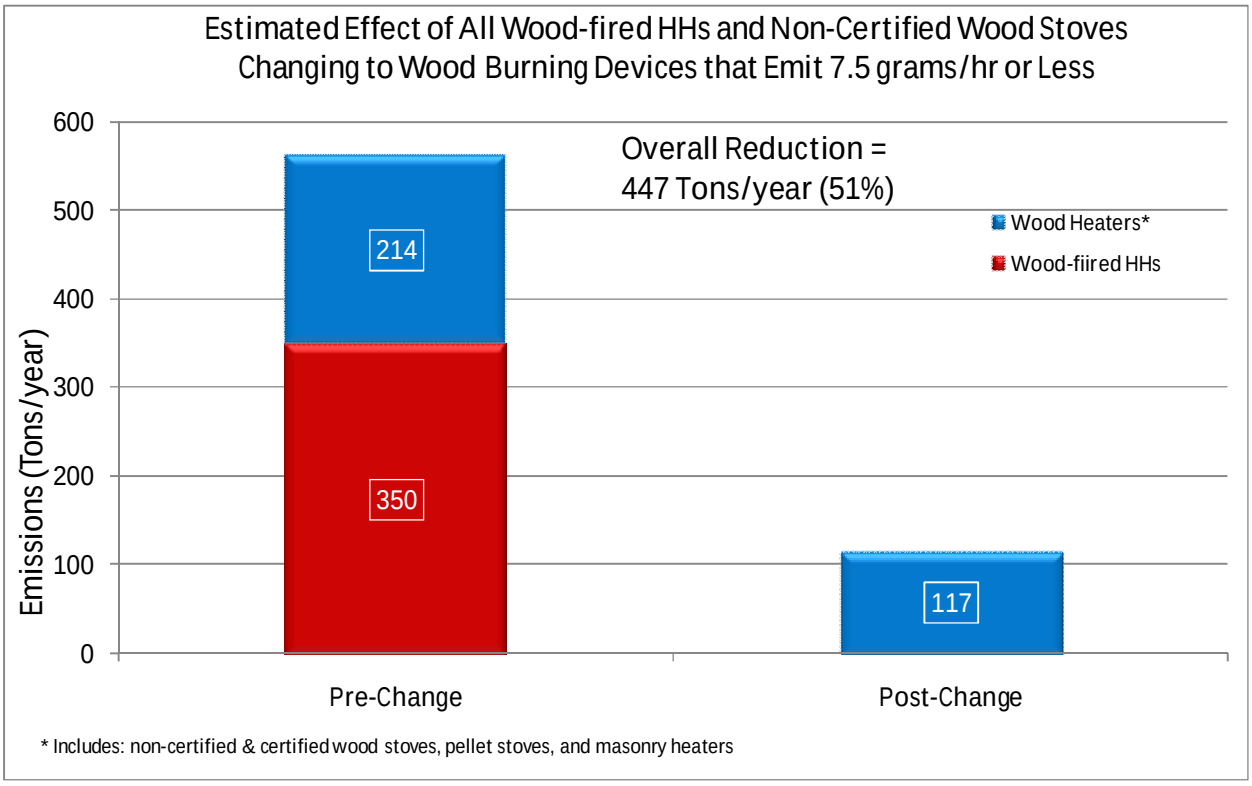
1. The EPA limit is established to encourage the development of cleaner burning devices, but is not specifically established to bring any municipality into compliance with PM2.5 concentrations limits.
2. The EPA emission testing procedure likely underestimates the emission potential of a device in Fairbanks in two ways:
    a. The devices are tested indoors, which creates a more efficient and clean combustion environment.
    b. The devices are tested at full operation, which does not account for the dampering of devices when less heat is required.

3. Currently half of the wood-fired hydronic heaters on the voluntary certification list emit 7.5 grams/hour or less.

The summary result of establishing a uniform emission limit of 7.5 grams/hour as recommended is to allow residents to continue to use and purchase clean wood burning devices. There are currently over 700 wood burning devices on EPA's certified wood stove list, and seven out of fifteen of the wood-fired hydronic heaters on EPA's voluntary list will meet a 7.5 grams/hour limit.

Even with this level of consumer flexibility, this policy will reduce PM2.5 emissions by 447 tons, or 51% of all residential heating. Graph 9 displays the estimated reduction.

Graph 9.



Additionally, by establishing the uniform emission limit prospectively, the FNSB will buffer itself from the potential of the existing inventory of non-complying, wood-fired hydronic heaters being dumped in the Fairbanks market prior to EPA's effective date for mandatory certification.

A final major consideration is to establish the effective date in a way that applies the limit to prospective sales in the near term, and allows residents with non-complying devices time to adapt.

Establish a Changeout Program to Help Residents Adapt to the New Uniform Emission Limit

Establishing a changeout program as soon as possible will provide residents with the time and financial incentives necessary to comply with the new uniform emission limit.

Devices that qualify for decommissioning should include wood fired hydronic heaters, non-certified wood stoves, and devices exempt by EPA except for masonry heaters and cook stoves. Allowable new devices that qualify for incentives should include wood burning devices certified at PM2.5 emissions of 7.5 grams/hour or lower, masonry heaters, heating oil fired devices, and natural gas fired devices.

A market survey is optional but can be used to establish an effective incentive rate and to determine responsiveness to a rebate and a tax incentive.

Some communities have implemented a tiered incentive structure that encourages residents to switch from wood to heating oil or natural gas to increase the amount of PM2.5 emission reduction per device changed. The FNSB will need to consider this in the context of all its policies including those related to greenhouse gas emissions.

The EPA has developed a guide for establishing a wood stove change out program (http://www.epa.gov/woodstoves/process.html), and also a guide for incorporating a wood stove changeout program in a SIP (http://epa.gov/ttn/oarpg/t1/memoranda/guidance_quantfying_jan.pdf). Between the two documents, the policy considerations of implementing a changeout program adequately address Fairbanks based issues. Some of the key considerations are:

- Require professional installation of new devices.
- Establish a method to document that the device being replaced was decommissioned and replaced with a qualifying appliance.
- Establish a priority ranking system for distributing money based on factors important to the intent of the program such as location of the household and overall estimated emission improvement.

Table 4 shows just the rebate or tax incentive cost for a changeout program assuming varying levels of rebate/incentive, and participation.

Table 4.

	Estimated Incentive Cost of a Non-Certified Wood Stove and Wood-fired Hydronic Heaters Changeout Program			
	100% Participation		10% Participation	
Incentive	Non-Certified Wood Stoves (5,042 Devices)	Hydronic Heaters (1,500 Devices)	Non-Certified Wood Stoves (504 Devices)	Hydronic Heaters (150 Devices)
$ 100.00	$ 504,200.00	$ 150,000.00	$ 50,400.00	$ 15,000.00
$ 200.00	$ 1,008,400.00	$ 300,000.00	$ 100,800.00	$ 30,000.00
$ 300.00	$ 1,512,600.00	$ 450,000.00	$ 151,200.00	$ 45,000.00
$ 400.00	$ 2,016,800.00	$ 600,000.00	$ 201,600.00	$ 60,000.00
$ 500.00	$ 2,521,000.00	$ 750,000.00	$ 252,000.00	$ 75,000.00
$ 600.00	$ 3,025,200.00	$ 900,000.00	$ 302,400.00	$ 90,000.00
$ 700.00	$ 3,529,400.00	$ 1,050,000.00	$ 352,800.00	$ 105,000.00
$ 800.00	$ 4,033,600.00	$ 1,200,000.00	$ 403,200.00	$ 120,000.00
$ 900.00	$ 4,537,800.00	$ 1,350,000.00	$ 453,600.00	$ 135,000.00
$ 1,000.00	$ 5,042,000.00	$ 1,500,000.00	$ 504,000.00	$ 150,000.00

Require Decommissioning of Solid Fuel Burning Devices that do not Meet the Uniform PM2.5 Emission Limit of 7.5 grams/hour at the Time of Real Estate Sale

Requiring devices that do not meet the uniform PM2.5 emission limit of 7.5 grams/hour to be decommissioned at the time real estate is sold will improve compliance with the limit in the long-term. The effective date of this policy can coincide with the effective date of the uniform emission limit.

Effectively implementing this policy will require engaging professionals involved in real estate transactions. Similar to considerations relating to the implementation of a change out program, documentation will be required to verify that non-complying devices are decommissioned and approved devices are installed.

Develop and Implement a Method to Forecast Exceedance Conditions that can be Used to Trigger an Episodic Solid Fuel Burning Restriction

The FNSB can effectuate targeted PM2.5 reductions at times when exceedances are expected by forecasting exceedance conditions and using the forecast to implement solid fuel burning restrictions. The restrictions can be multi-staged and structured to impose greater restrictions as the forecasted concentration approaches 35 $\mu g/m^3$.

There are several examples of this type of anticipatory burn restriction system, including the *Spare the Air campaign* in Sacramento County (www.sparetheair.com). Additionally, the City of Juneau issues air quality alerts and enforces an episodic burn ban (http://www.juneau.org/lands/woodsmoke.php).

The effectiveness of this policy will depend in part on how well the program is communicated to the public. A few methods for outreach include:

1. A website that clearly indicates the restriction level and the instructions for that level of restriction, plus a forecast of restriction on future days.
2. PSA announcements using television, radio, and newspaper. Ideally, agreements would be reached to communicate the restriction level and forecast in the same place and way the weather forecast is communicated.
3. Media interviews when forecast is dismal.
4. Automated emails to those who have signed up for alerts.
5. Partnerships with those who sell solid fuel and solid fuel appliances.
6. Partnerships with major employers to communicate restriction levels.

Establish and enforce a clear schedule of fines to improve the effectiveness of the restriction.

While this policy alone is not enough to bring the FNSB into compliance with EPA's PM2.5 emission limit, it is complimentary to the other policy recommendations and provides a focused tool to provide additional mitigation of PM2.5 emissions at the times it is needed most.

The FNSB will have to consider to whom the restriction applies, particularly if the restriction will apply to those who rely on wood burning for heat and do not have an alternative. Another related consideration is whether to create an income based exemption to allow those with low income to continue to use wood to heat.

Establish a Sustained Educational Program Regarding Heating with Wood

CCHRC recommends establishing a sustained effort to educate the public on clean burning practices, and the details of the changeout program, uniform emission limit, and solid fuel burning restrictions. Even if the FNSB does not implement any other policies designed to reduce PM2.5 from residential heating sources, CCHRC recommends establishing a standalone educational effort focused on clean burning practices.

According to the EPA, an effective educational program can cause 5%-10% reduction in the amount of PM2.5 emitted from solid fuel burning.

There are several good solid fuel burning educational materials to emulate, most of which have the same characteristics. A few states with educational materials include Washington, Colorado, California, and Wyoming. Additionally, CCHRC is developing educational material based on its wood burning device testing program. Some considerations of an effective educational program are:

- Establish a "brand" (logo, theme, and core message).
- Create digital and paper content for internet, TV, radio, newspaper, and brochures.
- Establish partnerships including Division of Forestry, Bureau of Land Management, DEC, those who sell solid fuel and solid fuel devices, Cooperative Extension Service, GVEA, PORTAL, etc.
- In some cases those who sell solid fuel and solid fuel burning devices are required to convey material to customers.

Establish a Standard to Address Nuisance Emissions

Establishing a nuisance emission standard will create an enforcement mechanism for the FNSB to respond to complaints about high and/or harmful emissions from residential heating sources, and ultimately give the FNSB actionable grounds to restrict the use of nuisance emissions from devices on a case by case basis.

This type of policy is recommended on its own merit regardless of the total effect it may have on PM2.5 concentration levels due to the potentially large number of people affected by nuisance emissions.

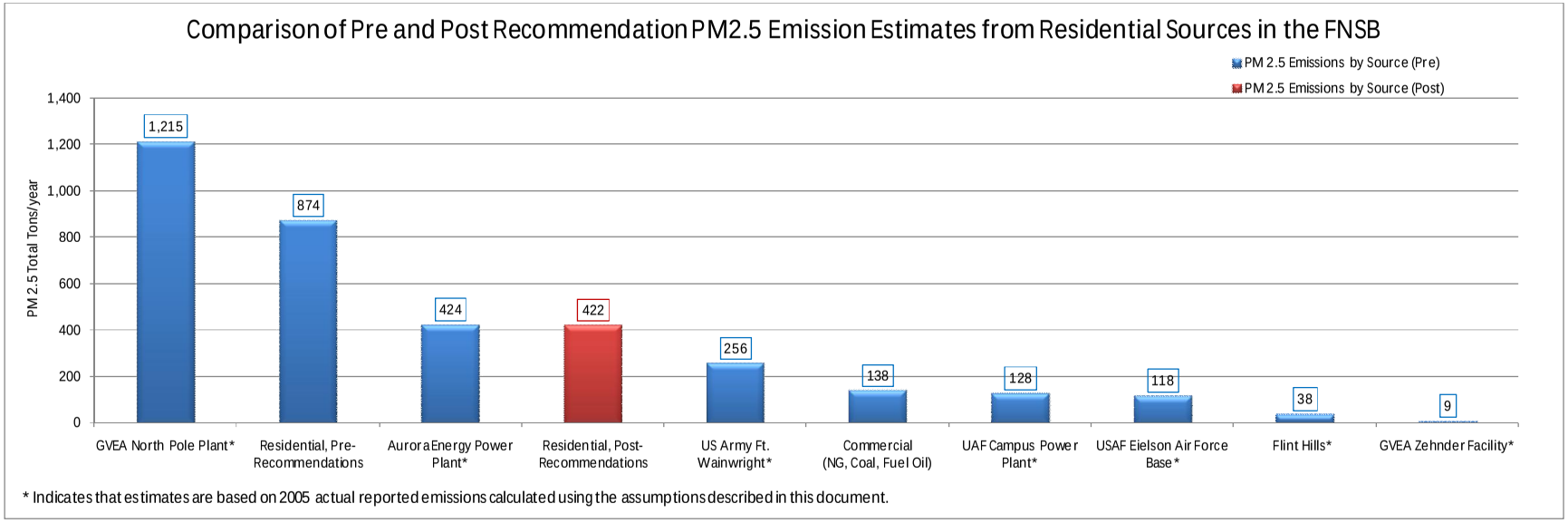
Total Estimated Effect of Policy Recommendation

The combined effect of implementing the recommended policies reduces PM2.5 from residential heating sources from an estimated 874 tons/year to 422 tons/year. Graph 10 displays the PM2.5 from residential heating source before and after the policy recommendations.

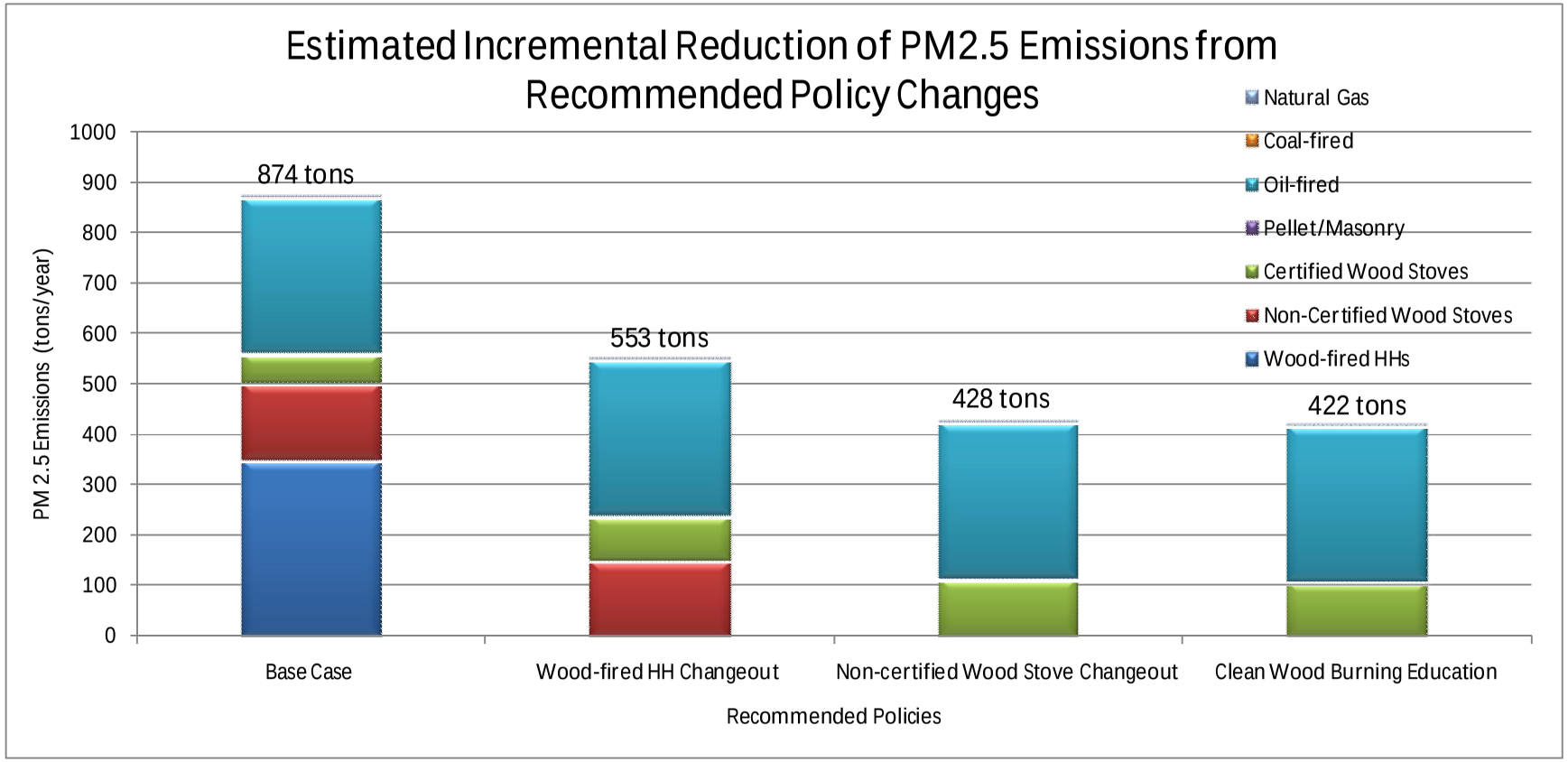
The same reduction is expressed differently in Graph 11, which displays the cumulative reduction on a per policy basis. The left most gradient bar indicates the total estimated emissions of PM2.5 from residential heating sources. The second bar from the left assumes that all existing wood-fired hydronic heaters are replaced with wood burning devices emitting 7.5 grams/hour or less. The second bar from the right assumes that all existing non-certified wood stoves are replaced with wood burning devices emitting 7.5 grams/hour or less. The right most bar assumes that all policies have taken effect and a clean burning educational effort results in an additional 5% reduction in PM2.5 emission.

The effect of a burn restriction tied to exceedance forecast triggers is not estimated, and therefore not part of the estimated total reduction.

Graph 10.


Comparison of Pre and Post Recommendation PM2.5 Emission Estimates from Residential Sources in the FNSB
PM 2.5 Emissions by Source (Pre)
PM 2.5 Emissions by Source (Post)
PM 2.5 Total Tons/year
1,400
1,200
1,000
800
600
400
200
0
1,215
874
424
422
256
138
128
118
38
9
GVEA North Pole Plant*
Residential, Pre-Recommendations
Aurora Energy Power Plant*
Residential, Post-Recommendations
US Army Ft. Wainwright*
Commercial (NG, Coal, Fuel Oil)
UAF Campus Power Plant*
USAF Eielson Air Force Base*
Flint Hills*
GVEA Zehnder Facility*
* Indicates that estimates are based on 2005 actual reported emissions calculated using the assumptions described in this document.

Graph 11.


Estimated Incremental Reduction of PM2.5 Emissions from Recommended Policy Changes
PM 2.5 Emissions (tons/year)
1000
900
800
700
600
500
400
300
200
100
0
874 tons
553 tons
428 tons
422 tons
Natural Gas
Coal-fired
Oil-fired
Pellet/Masonry
Certified Wood Stoves
Non-Certified Wood Stoves
Wood-fired HHs
Base Case
Wood-fired HH Changeout
Non-certified Wood Stove Changeout
Clean Wood Burning Education
Recommended Policies

Digest of Policy Options

The Digest of Policy Options is a listing of distinct policy components presented and described individually to isolate considerations. This is done to enable the reader to consider issues with individual policy options outside the context of the recommendation.

The digest includes summaries of the following policy options:

- Ban on the Use of Wood-fired Hydronic Heaters
- Moratorium on the Sale of Wood-fired Hydronic Heaters
- Restrict the Installation of Wood-fired Hydronic Heaters as a Primary Source of Heat
- Restrict the Installation and Use of Wood-fired Hydronic Heaters in New Construction and Significantly Remodeled Homes
- Require the Decommissioning of Wood-fired Hydronic Heaters at the Time of Sale of a Home or Structure
- Restrict the Use of Wood-fired Hydronic Heaters based on Parcel Size, Zone Designation, or Setback Requirement
- Ban the Use of Non-certified Wood Stoves
- Require the Decommissioning of Non-certified Wood Stove at the Time of Sale of a Home or Structure
- Changeout Programs
- Episodic Restriction on the Burning of Solid Fuel
- Establish and Enforce a Nuisance Emission Standards
- Establish Emission Rates Equal to or More Strict than the EPA
- Establish a Sustained Educational Program Aimed at Reducing PM2.5 from Solid Fuel Burning
- Other Policy Considerations

Ban on the Use of Wood-fired Hydronic Heaters

Type of Appliance(s) Effected: Wood-fired Hydronic Heaters

Estimated Number of Existing Appliances: 1,500

Estimated Emission Range per Appliance: 7.5 – 152 grams/hour

Estimated Existing Tons/Year PM2.5 Emissions: 350 tons/year

Summary:

A ban on the use of wood-fired hydronic heaters will substantially reduce the amount of PM2.5 currently emitted from residential heating sources. This mitigation action would necessarily be coupled with a policy to address the prospective addition of wood-fired hydronic heaters.

This mitigation action requires careful consideration of the user group and the investment that has been made by device owners. Mitigation actions that involve the banning of appliances or types of fuel can set effective dates in the future to allow the owner to plan to heat their home with a different appliance or fuel.

An enforcement mechanism is required to ensure that the prohibition is effective. Methods to improve compliance include establishing a conspicuous complaint contact, an incentive schedule for early compliance, and a fine schedule for non-compliance.

CCHRC is not recommending any device specific ban.

Moratorium on the Sale of Wood-fired Hydronic Heaters

Type of Appliance(s) Effected: Wood-fired Hydronic Heaters

Estimated Number of Existing Appliances: 1,500

Estimated Emission Range per Appliance: 7.5 – 152 grams/hour

Estimated Existing Tons/Year PM2.5 Emissions: 350 tons/year

Summary:

A moratorium on the sale of wood-fired hydronic heaters would significantly limit the number of new units entering the FNSB market. The moratorium would probably not result in zero new devices entering the market because consumers who wanted to ignore the law could purchase a device from outside the FNSB and install it within the FNSB.

Some wood-fired hydronic heaters emit significant amounts of PM2.5, and while improvements in technology are being achieved, there is still a wide range of emission rates from wood-fired hydronic heaters. Part of the reason for improved technology is that EPA is requiring mandatory certification of wood-fired hydronic heaters similar to the required certification of wood stoves.

This creates good and bad potential in the FNSB. The good potential is for wood-fired hydronic heaters to become cleaner over time. The bad potential is that the standing inventory of wood-fired hydronic heaters in the country will be sold in markets with high demand over the next few years, regardless of EPA's new mandatory certification.

CCHRC is not recommending a device based moratorium, but rather an emission limit that is applied to both existing and prospectively sold devices.

Restrict the Installation of Wood-fired Hydronic Heaters as a Primary Source of Heat

Type of Appliance(s) Effected: Wood-fired Hydronic Heaters

Estimated Number of Existing Appliances: 1,500

Estimated Emission Range per Appliance: 7.5 – 152 grams/hour

Estimated Tons/Year PM2.5 Emissions: 350 tons/year

Summary:

Restricting the installation of wood-fired hydronic heaters as a primary source of heat will cause no direct reduction of the amount of PM2.5 currently emitted by residential heating sources, and will still allow for marginal growth prospectively. In order to reduce PM2.5 emission from existing wood-fired hydronic heaters the policy would need to be enforced on existing units.

Similarly themed policies have been implemented in other areas, although the restriction was on installing wood appliances as a primary source of heat in new construction. The primary issue with this type of policy from a PM2.5 reduction standpoint is that it does not address current PM2.5 exceedances.

Additionally, it will be extremely difficult to identify and enforce the primary source of heat standard.

CCHRC is not recommending this policy approach.

Restrict the Installation and Use of Wood-fired Hydronic Heaters in New Construction or Significantly Remodeled Homes

Type of Appliance(s) Effected: Wood-fired Hydronic Heaters

Estimated Number of Existing Appliances: 1,500

Estimated Emission Range per Appliance: 7.5 – 152 grams/hour

Estimated Tons/Year PM2.5 Emissions: 350 tons/year

Summary:
Restricting the use of wood-fired hydronic heaters in new construction or significantly remodeled homes will have a minor effect on the existing PM2.5 emissions from residential heating sources and therefore have no significant effect on existing PM2.5 concentration levels. The ability to enforce this policy is challenged due to the need to monitor and have enforcement capability in each case of new construction or significant remodel. This is dubious given the existing building code structure within the FNSB.

CCHRC is not recommending this policy.

Require the Decommissioning of Wood-fired Hydronic Heaters at the Time of Sale of a Home or Structure

Type of Appliance(s) Effected: Wood-fired Hydronic Heaters

Estimated Number of Existing Appliances: 1,500

Estimated Emission Range per Appliance: 7.5 – 152 grams/hour

Estimated Tons/Year PM2.5 Emissions: 350 tons/year

Summary:

Requiring wood-fired hydronic heaters to be decommissioned when a home or structure is sold will cause a slow but methodical reduction in PM2.5 emissions from existing wood-fired hydronic heaters by reducing the number of appliances over time. The decommissioning rate will be a function of turnover in the real estate market in homes with wood-fired hydronic heaters and rate of compliance.

Implementing this policy will require establishing a responsible party for identifying and decommissioning targeted devices, although both responsibilities need not be assumed by the same party.

This policy is complimentary to policies restricting wood-fired hydronic heaters, but is not an effective strategy to reduce PM2.5 emissions in the short-term on a standalone basis.

CCHRC is recommending this policy if implemented in the context of the policies contained in the recommendation section.

Restrict the Use of Wood-fired Hydronic Heaters Based on Parcel Size, Zone Designation, or Setback Requirement

Type of Appliance(s) Effected: Wood-fired Hydronic Heaters

Estimated Number of Existing Appliances: 1,500

Estimated Emission Range per Appliance: 7.5 – 152 grams/hour

Estimated Tons/Year PM2.5 Emissions: 350 tons/year

Summary:

Restricting the use of wood-fired hydronic heaters based on parcel size, zone designation, or set back requirement is designed to mitigate emission exposure to both the device owner and nearby residents. This policy option can be complimentary to a nuisance emission policy by preempting emissions from traversing lot lines.

Restricting use of wood-fired hydronic heaters to parcels of a certain size will limit the number of surrounding lots exposed due to the size of the owner parcel, but leaves the possibility of a device legally operating on a parcel surrounded by densely populated areas. This circumstance can create outcomes divergent from the intent.

Restricting the use of wood-fired hydronic heaters based on setback requirements can in effect require a certain lot size and mitigate effects on surrounding residents depending on the set back distance.

Restricting the use of wood-fired hydronic heaters based on zone designation can address both the owner parcel and surrounding parcels.

None of these three approaches address PM2.5 concentration levels directly, although depending on the parcel size, zone, or setback established can effectively prohibit the use of wood-fired hydronic heaters on the vast majority of land in the city limits and in densely populated areas. Another consideration of this policy is whether it will apply to existing and/or prospective wood-fired hydronic heaters. The enforcement mechanism and required effort is different for addressing existing and prospectively sold wood-fired hydronic heaters.

CCHRC is not recommending this approach to address nuisance emissions; however, CCHRC is recommending a nuisance regulation as discussed elsewhere.

Ban the Use of Non-Certified Wood Stoves

Type of Appliance(s) Effected: Non-Certified Wood Stoves

Estimated Number of Existing Appliances: 5,042

Estimated Emission Range per Appliance: 7.5 – 30 grams/hour

Estimated Tons/Year PM2.5 Emission: 152 tons/year

Summary:

Banning the use of non-certified wood stoves will significantly reduce the amount of PM2.5 generated from residential sources.

This mitigation action requires careful consideration of the user group including the need to give the user time to provide an alternate source of heat. Because of this, bans on appliance types are typically implemented with an effective date set in the future.

Additionally, an incentive such as a wood stove changeout program and a disincentive such as a fine for non-compliance improve the effectiveness of the policy. A ban can also be combined with the required decommissioning of non-certified wood stoves at the time of home sale to improve long-term effectiveness.

Banning the use of non-certified wood stoves requires a diligent enforcement mechanism on a scale larger than that of a ban of wood-fired hydronic heaters due to non-certified wood stoves being more numerous and less conspicuous.

Regardless of the structure of a ban on non-certified wood stoves, there will likely be residents who do not comply.

CCHRC does not recommend a direct ban on non-certified wood stoves.

Require the Decommissioning of Non-Certified Wood Stoves at the Time of Sale of a Home or Structure

Type of Appliance(s) Effected: Non-Certified Wood Stoves

Estimated Number of Existing Appliances: 5,042

Estimated Emission Range per Appliance: 7.5 – 30 grams/hour

Estimated Tons/Year PM2.5 Emissions: 152 tons/year

Summary:

Requiring non-certified wood stoves to be decommissioned when a home or structure is sold will have a slow but methodical effect on reducing the amount of PM2.5 emitted from non-certified wood stoves. The decommissioning rate will be a function of turnover in the real estate market in homes with non-certified wood stoves and the rate of compliance.

Implementing this policy will require establishing a responsible party for identifying and decommissioning targeted devices, although both responsibilities need not be assumed by the same party.

This policy is complimentary to policies that restrict the use of non-certified wood stoves and changeout programs.

CCHRC is recommending this policy if implemented in the context of the policies contained in the recommendation section.

Changeout Programs

Type of Appliance(s) Effected: Wood-fired Hydronic Heaters and Non-Certified Wood Stoves

Estimated Number of Existing Appliances: Non-Certified Wood Stoves – 5,042

Wood-fired Hydronic Heaters – 1,500

Estimated Emission Range per Appliance: Non-Certified Wood Stoves 7.5 – 30 grams/hour

Wood-fired Hydronic Heaters – 7.5-152 grams/hour

Estimated Tons/Year PM2.5 Emissions: 502 tons/year

Summary:

A common action taken to mitigate PM2.5 emissions is to establish a changeout program in which incentives are offered to those who volunteer to replace a high-emission appliance with a low-emission appliance.

Changeout programs use rebates or tax incentives to encourage the owner of a targeted device to change it out for a qualifying device. The rebate and tax incentive level can either be flat or tiered, with tiered incentives designed to motivate greater emission improvements.

Rebate dollars can originate from a variety of sources including the EPA; state air quality authority; local government; the Hearth, Patio, and Barbeque Association; appliance manufacturers; and local energy companies.

A possible source of tax incentive in the FNSB is to offer a property tax credit.

The effectiveness of changeout programs depends on the number of appliances replaced and the difference in emission rate between the old appliance and the new appliance.

Additionally, some changeout programs have provided for higher rebate levels to those who qualify as low-income.

There are several key components of an effective changeout program:

1. Define which devices are preferred to be decommissioned and which devices will qualify as replacements. Some programs change out non-certified or old wood stoves to certified wood stoves. Others change out non-certified or old wood stoves to certified wood stoves, heating oil devices, or natural gas-fired devices.
2. Establish an incentive structure: either rebate, tax incentive, or both; and either flat or tiered incentive.

3. Establish an incentive level that encourages people to switch devices. It is common for wood stove changeout programs to offer rebates ranging between $200 and $600, and in some special cases the entire amount of the new device is covered. Tax incentives can also be used to encourage people to switch devices. In the case of the FNSB, a property tax incentive can be made available.
4. Establish a mechanism to ensure that the targeted device is decommissioned and the new device is installed. Typically certificates and forms are used in addition to other proof such as pictures of the installation and decommissioning.

The EPA has prepared an internet based resource for implementing a wood stove changeout program titled "Process for Implementing a Wood Stove Changeout Program" (http://www.epa.gov/woodstoves/process.html).

Beyond the functional considerations of the program is the consideration of how a wood stove changeout program factors into a SIP. EPA has prepared a guide for incorporating a wood stove changeout program in a SIP titled "Guidance for Quantifying and Using Emission Reductions from Voluntary Woodstove Changeout Programs in State Implementation Plans" (http://epa.gov/ttn/oarpg/t1/memoranda/guidance_quantfying_jan.pdf).

A changeout program is recommended as part of CCHRC's comprehensive set of policy recommendations.

Episodic Restriction on the Burning of Solid Fuel

Type of Appliance(s) Effected: Wood Burning Devices

Estimated Number of Existing Appliances: Approximately 13,829

Estimated Emission Range per Appliance: 0.8 – 152 grams/hour

Estimated Tons/Year PM2.5: 564 tons/year

Summary:

An episodic restriction on the burning of solid fuel can be effective in moderately reducing PM2.5 emissions at times when exceedances are predicted, although this is considered to be complimentary to other efforts to reduce PM2.5 and should not be relied on alone to prevent the FNSB from exceeding the EPA limit.

Episodic based programs can be implemented either after the exceedance in an attempt to improve the air quality, or in anticipation of an exceedance. Taking action after an exceedance is merited to improve air quality, but ineffective in terms of preventing exceedances. Therefore, a system based on anticipating atmospheric conditions as a way of triggering burn restrictions is warranted.

The following are key elements of an anticipatory episodic restriction on wood burning:

1. Establish the forecast triggers will be used to change the restriction level, e.g. cold, low wind, inversion, etc.
2. Establish the levels of restriction. Levels of restriction can be designated by device type, gram/hour ranges, fuel type, etc. The number of levels can be tailored to the severity of the forecast. Typical levels include:
    a. No burning of solid fuel
    b. No burning except for those who are exempt
    c. Voluntary burn restriction
    d. Ok to burn.
3. Define exemptions from the burn restriction. Exemptions can include allowing people using solid fuel as a primary source of heat and allowing cleaner appliances such as pellet appliances and masonry heaters. Exemptions can be hard to enforce, and given the number of people using solid fuel as a source of heat, may dilute the effectiveness of an episodic solid fuel restriction.
4. A clear, comprehensive, and conspicuous outreach effort is needed to make residents aware of the changing restriction levels. This can be accomplished using typical methods including:
    a. A website that clearly indicates the restriction level and the instructions for that level of restriction, plus a forecast of restriction on future days.

b. PSA announcements using television, radio, and newspaper. Ideally, agreements would be reached to communicate the restriction level and forecast in the same place and way the weather forecast is communicated.
c. Media interviews when forecast is dismal.
d. Automated emails to those who have signed up for alerts.
e. Partnerships with sellers of solid fuel and solid fuel appliances.
f. Partnerships with major employers to communicate restriction levels.

5. Establish and enforce a schedule of fines.

A great example of an anticipatory episodic restriction program is the Spare the Air program operated by Sacramento County (http://www.sparetheair.com/burncheck.cfm)

Consider the implementation of an episodic burn restriction in the context of the overall effort to reduce PM2.5 concentration, especially given the amount of time concentrations are near or above the EPA limit. If the FNSB does not effectively mitigate PM2.5 concentrations it is conceivable that the episodic restriction would be in place over a substantial number of winter days, in essence banning solid fuel burning.

CCHRC is recommending this policy as part of the comprehensive set of policy recommendations.

Establish and Enforce a Nuisance Emission Standard

Type of Appliance(s) Effected: All

Estimated Number of Existing Appliances: Indeterminate

Estimated Emission Range per Appliance: Indeterminate

Estimated Tons/Year PM2.5 Emission: Indeterminate

Summary:

Adopting a nuisance emission ordinance will enable the FNSB to respond to complaints of high or harmful emissions from residential heating sources, and ultimately give the FNSB actionable grounds to restrict nuisance emissions from devices on a case by case basis.

Nuisance policies are designed to mitigate harmful emissions caused by device operation, while giving the device operator an opportunity to remedy the cause. If effectively enforced on a large enough scale, a nuisance policy could be effective at moving toward compliance with the EPA PM2.5 concentration limit. However, the focus of a nuisance policy is to address the individual complaints, and not FNSB wide concentration.

Additionally, nuisance regulations typically do not address appliance type but rather a qualitative condition such as the creation of dense smoke.

A nuisance policy merits thoughtful consideration given the number of recent complaints raised about emissions from solid fuel burning devices.

CCHRC is recommending this policy as part of the comprehensive set of policy recommendations.

Establish PM2.5 Emission Rates Equal to or More Strict than EPA

Type of Appliance(s) Effected: Wood Burning Devices

Estimated Number of Existing Appliances: Approximately 13,829

Estimated Emission Range per Appliance: 0.8-152 grams/hour

Estimated Tons/Year PM2.5 Emission: 564 tons/year

Summary:

Establishing a local PM2.5 emission limit will allow the FNSB to limit the growth of PM2.5 emissions on prospective sales of residential heating appliances, and if applied to existing appliances, will result in a reduction of existing PM2.5 emissions.

Washington State has established emission standards more strict than EPA to improve air quality. The following italicized language is taken directly from the Washington State Air Quality website (http://www.ecy.wa.gov/programs/air/OUTDOOR_WOODSMOKE/wood_smoke_page.htm#Washingtons_wood_stove_requirements):

Type of Device	*Washington Limit*	*EPA Limit*
Catalytic wood burning device	*2.5 grams per hour*	*4.1 grams per hour*
Non-catalytic wood burning devices	*4.5 grams per hour*	*7.5 grams per hour*
Factory-built fireplaces and masonry heaters	*7.3 grams per kilogram*	*Currently no limit*

Any new wood burning device sold, offered for sale, or given away to Washington residents must meet Washington's standards. Even devices that are exempt from EPA certification must meet Washington standards. Wood burning devices include:

- *wood stoves*
- *pellet stoves*
- *wood furnaces*
- *manufactured fireplaces*

An emission limit applied to both prospective sales and existing devices has distinct advantages over an device ban and moratorium combination. The primary advantage is that it applies a standard based on desired emission levels and not by device class, the latter of which can result in clean devices being unduly restricted.

Any consideration of an emission limit will require consideration of devices that EPA does not currently require to meet certified emission limits such as masonry heaters and cook stoves. The EPA refers to these devices as "unaffected facilities" and has exempted them from complying with certified emission limits. These devices are exempt because the EPA considers masonry heaters mature technologies that have extremely low emission profiles and considers cook stoves to be used a small number of hours throughout the year.

CCHRC is recommending a similar policy based on EPA's existing 7.5 gram/hr limit as part of the comprehensive set of policy recommendations.

Establish a Sustained Educational Program Aimed at Reducing PM2.5 from Solid Fuel Burning

Type of Appliance(s) Effected: Wood Burning Devices

Estimated Number of Existing Appliances: Approximately 13,829

Estimated Emission Range per Appliance: 0.8 – 152 grams/hour

Estimated Tons/Year PM2.5 Emission: 564 tons/year

Summary:

Efforts to educate the public about clean burning practices, clean burning devices, burn restrictions, and other PM2.5 related mitigation laws are moderately effective on a standalone basis, and can enhance the effectiveness of other policy options including changeout programs, bans, and burn restrictions.

According to the EPA, wood burning educational efforts can result in a 5%-10% decrease in the amount of PM2.5 generated from wood burning. Elements of an effective educational program are:

1. Simple instructions on how to burn wood cleanly including device operation and optimal wood conditioning.
2. Clear explanation of laws affecting wood burning such as episodic burn restrictions.
3. Clear explanation of changeout program details.
4. Listing of high efficiency wood burning devices.

An educational program is a cornerstone of a comprehensive policy designed to reduce PM2.5 emissions from residential solid fuel burning.

CCHRC is recommending this policy as part of the comprehensive set of policy recommendations.

Other Policy Considerations

Energy Efficiency:

Improving the energy efficiency of a home or device will reduce the amount of fuel required to provide heat. The FNSB should encourage policies and activities that improve energy efficiency not only for economic reasons, but also because the reduction in fuel use will reduce PM2.5 and other regulated and harmful air pollutants.

Wood-fired Hydronic Heater Retrofit:

It is possible to retrofit a wood-fired hydronic heater to improve the efficiency and reduce PM2.5 emissions. One retrofit option involves modifying the internal features of the device and the other involves installing an external thermal storage device that enables the wood-fired hydronic heater to operate in its most efficient mode. Further study of these options is required to determine their effectiveness and cost.

Emission Control Devices:

There are a handful of emission control devices that exist to address PM2.5 and PM2.5 precursors. The effectiveness and practicality of applying these devices to significantly reduce PM2.5 is indeterminate.

Methodology

CCHRC developed a spreadsheet model to estimate the total emissions of PM2.5 (tons/year) generated from four primary types of fuel used in residential heating: wood, heating oil, natural gas, and coal. The model does not address spatial, temporal or atmospheric issues and does not estimate concentration levels. Many of these issues are being addressed by other entities.

The following describes the basic approach of the two methods used to estimate PM2.5 emissions from the four categories of residential fuel. One method was developed for estimating emissions from wood burning, and another method was used to estimate emissions from heating oil, natural gas, and coal.

Wood:

The model calculates emissions of PM2.5 (tons/year) from wood burning by estimating the number of various wood burning devices, the emission rate (grams/hour) for each of the various wood burning devices, and the number of hours of operation for each device in a year.

Estimates of the number of devices in the FNSB were developed for certified wood stoves, non-certified wood stoves, pellet stoves, masonry heaters, and wood-fired hydronic heaters.

The number of hours of operation is estimated based on survey responses wherein those who indicated they heated with a wood stove also indicated which of seven use categories they identified with: evening, day and weekend, evening only, day only, weekend only, evening and weekend, occasional use, or no use. Based on this information, a usage factor was developed to define the number of hours a week the wood-fired device was in operation. The usage factor was then weighted by heating degree days to establish a year-round usage profile that established hours of operation that could be applied to the average rate (grams/hour) of emissions from the wood-fired device in each category.

For wood-fired hydronic heaters and pellet stoves a final assumption was incorporated that weighted use toward the evening, day, and weekend category to better reflect the way in which those devices are used.

Heating oil, natural gas, and coal:

Calculations of the emissions of PM2.5 (tons/year) from burning heating oil, natural gas, and coal, were all based on emission rates (tons of PM2.5 per unit of fuel) from AP 42, Fifth Edition. The amounts of heating oil, natural gas, and coal used for residential heating were taken from the *Fairbanks North Star Borough Baseline Greenhouse Gas Emission Inventory, Base Year 2007* (Holdman and Murphy, 2008). Heating degree days were used to weight fuel usage.

The PM2.5 estimate for these fuels involved two other assumptions. One, the amount of sulfur in residential heating oil and coal used in Fairbanks is 0.22% and 0.25% weight by volume, respectively. Two, the conversion of SO_X and NO_X to PM2.5 is 30% and 7.4%, respectively.

The model was used to establish a baseline estimate of the amount of PM2.5 emissions from certified wood stoves, non-certified wood stoves, pellet stoves, masonry heaters, wood-fired hydronic heaters, heating oil, natural gas, and coal devices.

Total Number of Households:

We used 35,685, which is the number of households in the FNSB property tax database (does not include households on Fort Wainwright and Eielson).

Estimate the Number of Certified and Non-certified Wood Stoves in the FNSB:

We referred to a Sierra Research survey for the winter of 2005/2006 (Dulla et. al, January 2008) to establish the number of certified and non-certified wood stoves in the FNSB. The total number of wood stoves (10,420), was calculated by multiplying the percentage of people in the survey who responded they had a wood stove (29.2%) by the total number of households in the FNSB. Next, the number of certified vs. non-certified was established based on the number of respondents who indicated that they possessed a wood stove that was pre-1988 (the year EPA established certification). The survey data indicated that 48.4% of wood heaters were pre-1988 units, which equates to 5,042 pre-1988 wood stoves and 5,378 post 1988 wood stoves. All post 1988 wood stoves were assumed to be certified.

Next, the Sierra Research survey from the winter of 2006/2007 (Dulla et. al, January 2008) was used to establish the increase in the number of certified wood stoves, based on the percentage increase in the number of respondents using a wood stove. We assumed that all the new wood stoves were certified. These data modified to the heating season of 2006/2007 are used in the baseline model.

We compared our baseline data to data contained in a Sierra Research survey conducted during the winter of 2007/2008 (Dulla and Di Genova, March 2008). There were a number of problems with interpreting the survey data, but our best projection is that wood stove use increased from 33.5 to about 34 percent of households. Since the potential change in emissions is relatively small and uncertain we decided to maintain the baseline model using data up to the 2006/2007 heating season.

Estimate of the Number of Wood-fired Hydronic Heaters:

The number of existing wood-fired hydronic heaters is estimated to be between 1,200 and 2,500. During the summer of 2008, Dr. Jim Conner, FNSB Division of Air Quality, conducted a survey of those selling wood-fired hydronic heaters. The survey led Dr. Conner to conclude that there were between 1,000 and 2,000 wood-fired hydronic heaters sold during the summer of 2008. Our high estimate assumed that 2,000 wood-fired hydronic heaters were sold in the summer of 2008, and that 500 existed previously; our low estimate assumed 1,000 were sold in the summer of 2008, and that 200 existed previously.

Our baseline model assumed an estimate of 1,500 wood-fired hydronic heaters. We evaluated the effect of the low and high estimates in Graph 6, which showed that emissions for wood-fired hydronic heaters ranged from a low of 280 to a high of 467 tons/year. The baseline model yields 350 tons/year.

Estimate of the Number of Pellet Stoves:
The Sierra Research survey conducted during the winter of 2007/2008 (Dulla and Di Genova, March 2008) indicated that over the prior several years the number of households using pellet stoves equaled 2.2% of households that use wood burning devices. Therefore, our baseline model assumes 345 pellet stoves were in operations for the 2007/2008 heating season.

Estimate of the Number of Masonry Heaters:
In the baseline model we estimated that there are 30 masonry heaters operating in the FNSB. This estimate is based on personal communication with Dave Misiuk, who is CCHRC's Wood Energy Specialist, and voting member of the Masonry Heater Association of North America.

Estimate the Number of Hours Wood Heating Devices Operated in the FNSB:
The Sierra Research survey conducted over winter 2006/2007 (Dulla et. al, January 2008) included questions designed to indicate the usage patterns of those with wood stoves. The usage categories were: all days and evenings, evening only, day only, weekend only, evening and weekend only, occasional use, and no current use. To use these categories mathematically in our modeling we divided each day into three eight hour periods. We then assigned a usage for each category as displayed in Table 5:

Table 5.

Usage Category	Equals
All Days and Evenings	16 hours/day, every day
Evenings & Weekends	8 hours/day, Monday – Friday
	16 hours/day, Saturday & Sunday
Evenings Only	8 hours/day, every day
Daytime Only	8 hours/day, every day
Weekend Only	16 hours/day, Saturday & Sunday
No use	No use
Occasional use	two 8 hour periods/week

The usage factor was modified by weighting the use by heating degree days per Table 6 below. This accounts for increased use when temperatures are cold and decreased use when temperatures are warm.

Table 6.

Heating Degree Days Fairbanks, Alaska (30 year averages, 1971 – 2000)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2315	1926	1670	999	504	179	121	283	615	1287	1882	2199	13980

The HDD weight was based on establishing the coldest month of the year as a factor of 1. All other months were assigned a factor based on their number of heating degree days divided by the number of heating degree days in January. Table 7 indicates the actual number of hours used in the model for each usage category.

Table 7.

USE	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days and Evenings	496	358.9	360.2	207.8	107.1	35.17	22.31	53.55	120	255	364.8	478.8
Evenings & Weekends	319	230.7	231.7	133.8	68.88	22.62	14.35	34.44	77.26	164	234.8	307.9
Evenings	248	179.4	180.1	103.9	53.55	17.58	11.16	26.78	60	127.5	182.4	239.4
Daytime	248	179.4	180.1	103.9	53.55	17.58	11.16	26.78	60	127.5	182.4	239.4
Weekends	142	102.5	103.1	59.3	30.66	10.07	6.388	15.33	34.25	73.01	104.1	137.1
No Use	0	0	0	0	0	0	0	0	0	0	0	0
Occasional Use	71	51.27	51.56	29.87	15.33	5.034	3.194	7.666	17.25	36.5	52.44	68.54

Distribution of Wood Heating Devices Over Usage and Emissions Categories (not including Wood-fired Hydronic Heaters):

Table 8 shows actual distribution of 12,374 heating devices assigned within the baseline model to each use and emissions category. A similar table distributes 1,500 wood-fired hydronic heaters over similar categories.

Table 8.

USE	15 - 30 g/hr	7.5 - 15 g/hr	4.5-7.5 g/hr	1.5-4.5 g/hr	Pellet Stoves	Masonry Heaters
Days and Evenings	985	985	1605	1605	230	30
Evenings &	300	300	360	359	58	

Weekends						
Evenings	200	200	218	218	58	
Daytime	120	120	120	120		
Weekends	59	59	59	59		
No Use	329	329	389	389		
Occasional Use	528	528	728	728		

Emission Rate for Wood-burning Devices (not including wood-fired hydronic heaters):

For certified wood stoves the emissions rates (grams/hour) were derived from the EPA certified wood stove list, which has an upper limit of 7.5 grams/hour. Two emission averages were established, one at 3 grams/hour and one at 6 grams/hour. The number of certified wood stoves was distributed evenly between these two averages.

For non-certified wood stoves, the emissions rates (grams/hour) were based on an upper limit of 30 grams/hour and a lower limit of 7.5 grams/hour (EPA, October 7th, 2008). The two emission averages were 11.5 grams/hour and 22.5 grams/hour. The number of non-certified wood stoves was distributed evenly between the two emission averages.

For pellet stoves an average of 1.5 grams/hour was used in the baseline model, based on a review of the EPA list of certified wood stoves.

For masonry heaters and average of 0.8 grams/hour was used in the baseline model. This value is based on test results from an EPA accredited lab (personal communication, Myren Test Lab, April 2008) that represent the majority of masonry heaters operating in FNSB.

Emission Rate for Wood-fired Hydronic Heaters

For wood-fired hydronic heaters in the baseline model, eight emission averages were developed using an upper limit emission range of 152 grams/hour and a low limit of 7.5 grams/hour. The eight emission range averages are: 139 g/hr, 111 g/hr, 83.5 g/hr, 55 g/hr, 50 g/hr, 40 g/hr, 25 g/hr, 11.25 g/hr. The average and extent of this range approximates the average and extent of the emission rates cited in the NESCAUM report (NESCAUM 2006).

Estimate of the Amount of Heating Oil, Natural Gas, and Coal:

Units of fuel for heating oil, natural gas, and coal were derived from the *Fairbanks North Star Borough Baseline Greenhouse Gas Emission Inventory, Base Year 2007*, (Holdmann and Murphy, 2008).

Emission Weighting for Heating Oil, Natural Gas, and Coal:

The total tons/year of PM2.5 emissions from heating oil, natural gas, and coal were distributed based on the heating degree days as displayed in Table 9. This accounts for increased fuel use when temperatures are cold, and decreased use when temperatures are warm.

Estimating Secondary Conversion of SO_X and NO_X to PM2.5:

We used the secondary conversion factor contained in the report, "Air Emissions from Residential Heating: The Wood Option Put into Environmental Perspective" (Houck et. al, 1998), which estimates a SO_x and NO_x conversion factor of 30% and 7.4%, respectively.

Estimation of PM2.5 from Point Sources in the FNSB:

The actual reported emissions during the last reporting period (2005) (Hartig, October 2008) for point sources in the FNSB were used to determine PM10, SO_x, and NO_X. PM2.5 was not reported.

SO_X and NO_X were converted to PM2.5 at rates of 30% and 7.4% respectively based on the report "Air Emissions from Residential Heating: The Wood Option Put into Environmental Perspective" (Houck et. al, 1998).

The same report indicates that 65% – 90% of all PM 10 particulate in combustion is actually PM2.5. PM10 is assumed to be 85.8% of PM2.5. This value was obtained by comparing the ratios of PM2.5 to PM10 in forest fires in the FNSB.

Moisture Content of Wood:

We used 20% as the average moisture content for wood, which represents the moisture content used by AP 42 for testing dry wood. According to a NESCAUM study (NESCAUM, 2006), for every 10 percentage point increase in the moisture content of wood the PM2.5 emissions increase by 166%.

Calculation of the average heat load of a home in Fairbanks

We calculated the heating load requirement of an average home in Fairbanks using design load values contained in the Aurora Energy District Heat Capacity Study (PDC, 2008). The design load values were presented in BTUs per hour at the design temperature of minus 47 degrees (F) with an indoor temperature of 68 degrees (F). To calculate the heating load for the entire year we divided the design load BTU requirement by the number of degrees between 68 (F) and minus 47 (F) to establish a BTU per hour per degree. We multiplied the BTU per hour per degree by the number of hours in each month, multiplied by the number of heating degree days in the month, and divided the product by 24 because heating degree days are measured in days, and our BTU per hour per degree value is in hours.

The PDC report contained four value sets representing the average design load in four residential areas of Fairbanks. We calculated the BTU requirement for each of the four areas. The average heating load requirement is 306,000,000 BTU per year. We used 300,000,000 as the estimated annual heating load requirement of a home in Fairbanks.

Calculation of the pounds of PM2.5 per household

We divided the annual emissions for each source category by the estimated number of homes in each source category to estimate the average annual pounds of PM2.5 per household.

The numbers of homes in the wood categories are the number of estimated devices in each wood category. To estimate the number of households using heating oil, coal, and natural gas, the total heating value (BTU) of fuel consumed in the FNSB in each category was divided by the average heating load requirement of a home.

Estimate of the Envelope PM2.5 Concentration:

To establish the relative magnitude of the PM2.5 emissions estimated to be produced from residential heating sources on a concentration ($\mu g/m^3$) basis, a series of calculations were performed using two sets of static volumes.

The first set is comprised of volumes equal to 4 acre (4046.86 m^2) area with a ceiling height of 10 and 100 meters, respectively. The average emission per hour during January from each device category was divided by each static volume.

The second set is comprised of volumes equal to the estimated footprint of the FNSB non-attainment area (approximately 200 square miles) with ceiling heights of 10 and 100 meters, respectively. The 24 hour average emission during January from the entire residential heating sector was divided by each static volume.

Estimating the PM2.5 Emission Reduction from a Uniform Emission Limit and Changeout Program

All wood-fired hydronic heaters and non-certified wood stoves were eliminated and redistributed equally in the wood stove emission categories 7.5 grams/hour or lower.

BTUs per Unit of Fuel:

The following BTU values were used in the calculation of pounds of PM2.5 per household.

Heating oil – 138,000 btu/gallon

Natural gas – 1,000 btu/scf

Coal – 7,800 btu/lbs

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