ALASKA DEPARTMENT OF

ENVIRONMENTAL CONSERVATION

Department Findings:

The Need and Basis for More Stringent Wood-fired Heating Device Emission Standards

In 18 AAC 50 Air Quality Control

Peer Review Draft

November 2013

Disclaimer

Mention or reference to the names of manufacturers, products, or appliance models taken from EPA certification listings or elsewhere and shown in this report is not intended and should not be construed as ADEC endorsement or recommendation of their suitability in any individual application.

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List of Acronyms & Abbreviations

AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
BTU	British Thermal Unit
CAA	Clean Air Act
CBJ	City and Borough of Juneau
CMAQ	Community Multiscale Air Quality Model (system)
CMB	Chemical Mass Balance
EPA	Environmental Protection Agency
FNSB	Fairbanks North Star Borough
g/hr	grams per hour
HPBA	Hearth, Patio and Barbecue Association
lbs/MMBTU	pounds per million BTU's of heat release
LMP	Limited Maintenance Plan
NAAQS	National Ambient Air Quality Standard
NSPS	New Source Performance Standard
PBL	Planetary Boundary Layer
$PM_{2.5}$	Fine Particulate Matter
PM_{10}	Coarse Particulate Matter
SIP	State Implementation Plan
ug/m^3	micrograms per cubic meter

1.0 Summary

The U.S. Environmental Protection Agency (EPA) has determined that a portion of the Fairbanks North Star Borough is in nonattainment of the health-based National Ambient Air Quality Standard (NAAQS) for fine particulate matter ($PM_{2.5}$). As a result, Alaska is required under the Federal Clean Air Act to develop and implement a State Implementation Plan (SIP) that commits to implement measures that will provide for timely attainment and maintenance of the air quality standard. Intensive measurement and modeling studies of Fairbanks have demonstrated that wood-burning heaters are the largest emissions category in the nonattainment area during exceedance periods and are the source of most of the area's $PM_{2.5}$ emissions and ambient $PM_{2.5}$ concentrations during such periods. Current emission reduction measures, including federal New Source Performance Standards (NSPS) adopted in 1988, have been inadequate to prevent these exceedances. Substantial additional reductions in emissions, including measures more stringent than the current NSPS and a contemplated federal update to it, will be needed to ensure attainment of the NAAQS. Therefore, the Alaska Department of Environmental Conservation (ADEC) proposes to implement particulate matter emission standards and other regulations for certain wood-fired heating devices pursuant to Alaska Administrative Code (AAC), Title 18 Environmental Conservation, Chapter 50 Air Quality Control that are more stringent than the current federal emission standards. ADEC proposes an emission limit of 2.5 g/hr for woodstoves, pellet stoves, and outdoor hydronic heaters. This report is intended to outline the necessity for adopting more stringent measures and to document conformance with specified requirements of Alaska Statute.

Following this Summary, Section 2 provides background on the $PM_{2.5}$ nonattainment problem in Fairbanks and on certain sections of the Alaska Statutes and Administrative Code that are pertinent to addressing the problem. Section 3 demonstrates that meteorological conditions contribute to the elevated $PM_{2.5}$ concentrations. Section 4 shows that the more stringent emission standards are necessary to protect human health. Section 5 demonstrates the technical feasibility of establishing wood-fired heating device regulations, and Section 6 documents their economic feasibility.

These written findings will be made available for peer and public review prior to the adoption of any final regulations to satisfy the requirements of AS 46.14.010 and AS 46.14.015.

2.0 Background – Need, ADEC Proposed Standards, Current Statutes and Regulations

The Federal Clean Air Act (CAA) designates Particulate Matter as a criteria pollutant due to its adverse effects on human health and its ability to reduce ambient visibility. More specifically, EPA has found the following[1]:

> *The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 micrometers in diameter pose the greatest problems, because they can get deep into your lungs, and some may even get into your bloodstream.*
>
> *Exposure to such particles can affect both your lungs and your heart. Small particles of concern include "inhalable coarse particles" (such as those found near roadways and dusty industries), which are larger than 2.5 micrometers and smaller than 10 micrometers in diameter; and "fine particles" (such as those found in smoke and haze), which are 2.5 micrometers in diameter and smaller.*
>
> *The Clean Air Act requires EPA to set air quality standards to protect both public health and the public welfare (e.g. visibility, crops and vegetation). Particle pollution affects both.*

In response to these findings, EPA has established NAAQS for coarse and fine particulate matter, PM_{10} and $PM_{2.5}$, respectively.[2] ADEC has the statutory authority to promulgate regulations for implementing and enforcing the Clean Air Act, including the development and implementation of Plans to comply with the NAAQS and other legislation. The current 24-hour maximum and annual arithmetic mean concentrations of $PM_{2.5}$, as specified by the primary[3] NAAQS, are 35 micrograms per cubic meter ($\mu g/m^3$) and 12 $\mu g/m^3$, respectively. The current 24-hour maximum allowable PM_{10} concentration is 150 $\mu g/m^3$.

ADEC conducts ambient air quality monitoring in cooperation with Alaska's major municipalities, including the Municipality of Anchorage (MOA), Fairbanks North Star Borough (FNSB), and the City and Borough of Juneau (CBJ), to determine whether air quality within these municipalities is meeting the NAAQS. ADEC also conducts monitoring in other areas of Alaska, such as Soldotna, the Matanuska-Susitna Valley, and in partnership with rural communities. Based on ambient air quality measurements collected in strict accordance with federal protocols using Federal Reference

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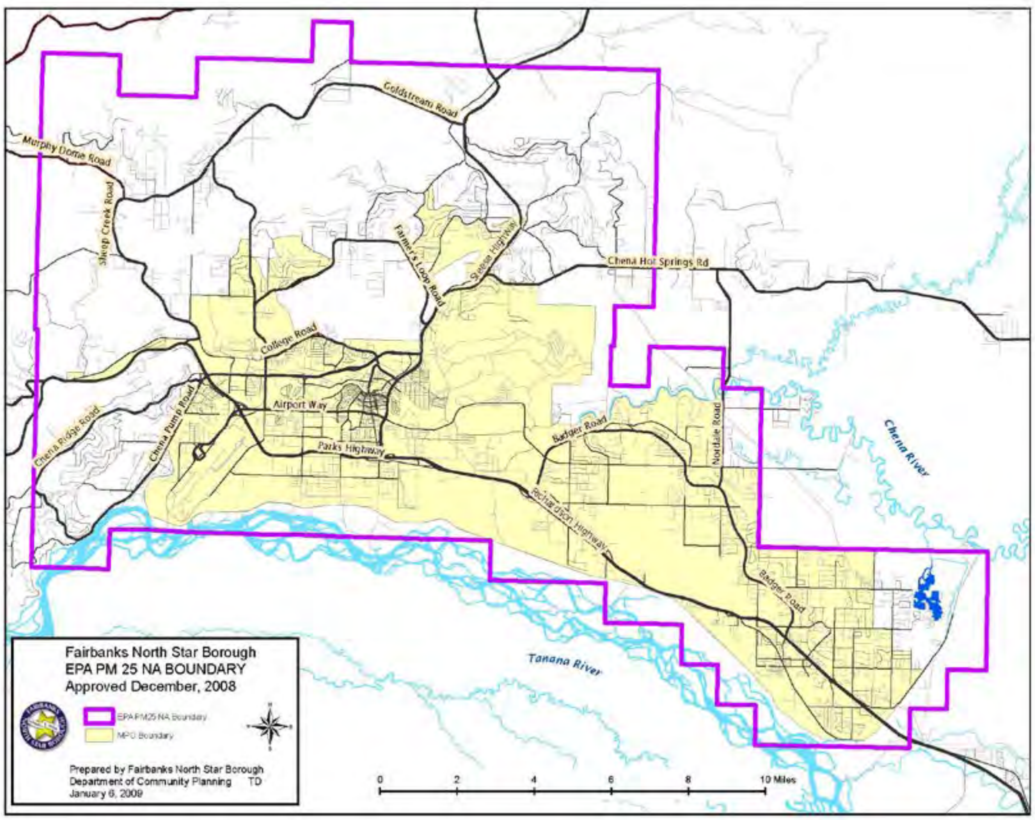
[1] *http://www.epa.gov/airquality/particlepollution/health.html* (accessed 7/14/13)

[2] "PM_{10}" and "$PM_{2.5}$" refer, respectively, to particles smaller than 10 microns and 2.5 microns in aerodynamic diameter. $PM_{2.5}$ (which is used here interchangeably with "fine particulate matter") typically includes particles formed by condensation and gas-to-particle conversion, including both particles formed as a result of combustion and secondary particles formed in the atmospheric from gaseous precursors. PM_{10} mass is typically formed by dust and abrasion processes, such as wind-blown soil and materials handling. PM_{10} ("coarse particulate matter") includes $PM_{2.5}$ plus larger particles that are typically associated with dust.

[3] The annual average "primary" (i.e., health-based) standard is 12 ug/m^3, and the annual average secondary (welfare-based) standard is 15 ug/m^3; since the primary standard is the more stringent, it is the controlling standard.

Methods (FRMs) and equipment, ADEC has determined that certain areas in Alaska do not meet the NAAQS for $PM_{2.5}$, i.e., they are in "nonattainment" (18 AAC 50.015) of the NAAQS. In December 2009, EPA formalized the nonattainment designation for $PM_{2.5}$ for a portion of the FNSB, including the cities of Fairbanks and North Pole, as depicted in Figure 1.[4] As a result, ADEC, in conjunction with the FNSB, is required by 40 C.F.R. Part 51.1007 to adopt and submit a State Implementation Plan (SIP) to achieve and maintain the NAAQS in accordance with a statutory time schedule.

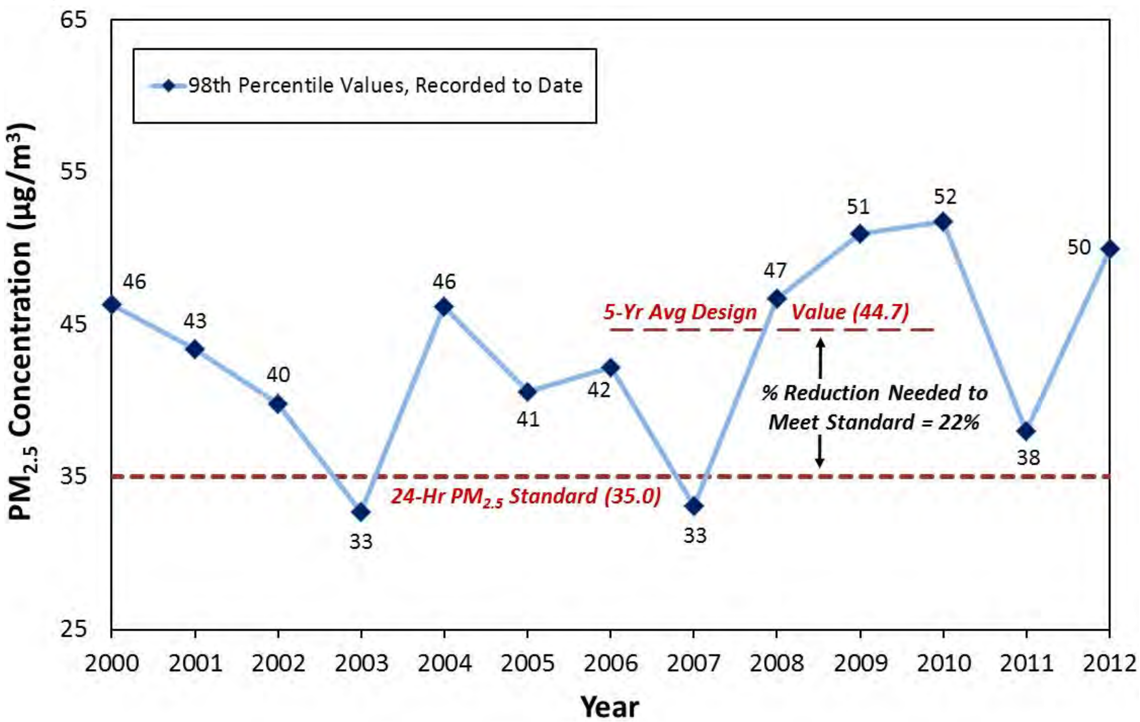
Figure 1 - Fairbanks $PM_{2.5}$ Nonattainment Boundary Established by EPA, December 2009



[4] For a more complete description and a map of the FNSB $PM_{2.5}$ nonattainment area, see ADEC's and EPA's designation letters and supplemental information provided on ADEC's website: *http://dec.alaska.gov/air/PM2-5_AK.htm*

The severity and trend of the $PM_{2.5}$ problem in Fairbanks are reflected in Figure 2, which shows the annual 98th percentile values of the 24-hour average $PM_{2.5}$ concentrations measured at the State Office Building in downtown Fairbanks using a Federal Reference Method (FRM) air monitor. The figure shows that for the five-year period ending in 2010, the $PM_{2.5}$ "design value" concentration, which is the statistic prescribed by EPA to quantify the magnitude of exceedance of a NAAQS, was 44.7 ug/m^3. Starting from this design value, attainment of the 24-hour average NAAQS target of 35 ug/m^3 will require a reduction in the ambient design value concentration of 22%. The data in the figure also show that the annual 98th percentile value in the Fairbanks nonattainment area has exceeded the concentration level of the standard in 11 of the last 13 years and appears to be trending upwards.

Figure 2 - Trend in 98th Percentile $PM_{2.5}$ Concentrations in Downtown Fairbanks



Source: Sierra Research

ADEC and others have, over a period of years, sponsored extensive supplemental monitoring and research to better quantify the emissions sources that contribute to exceedances of the NAAQS for $PM_{2.5}$ in Fairbanks. Results from several of these investigations have been provided in a series of status updates to the FNSB Assembly[5] prepared by Sierra Research under ADEC sponsorship. Results from these studies have also been presented in a series of public and scientific workshops and meetings, beginning with FNSB's Air Quality Symposium in 2009.[6] Most recently, a portion of the results from Sierra's and ADEC's emissions inventory and photochemical modeling studies of the Fairbanks $PM_{2.5}$ Nonattainment problem[7] were presented to the 2013 Western Air Quality Modeling Workshop. These and other studies have consistently shown that space-heating by wood-fired devices is the largest single category of $PM_{2.5}$ emissions in the study area during the period of wintertime $PM_{2.5}$ exceedances.[8] The most current estimate as of this writing shows that wood-fired space heating devices are responsible for approximately 3.18 tons of $PM_{2.5}$ emissions per day as compared to the modeling area total emissions from all sources of 5.65 tons per day. Thus, wood-burning for space heat represents 56% of total emissions during winter episodes of high $PM_{2.5}$ concentration. Furthermore, during the episode periods, wood burning is responsible for 97% of the $PM_{2.5}$ emissions from space heating. In addition to the downtown State Office Building monitor, another FRM air monitor was placed in North Pole at the fire station and has recorded official AQS (EPA's Air Quality System database) 24-hr average $PM_{2.5}$ concentrations during the winter (Figure 3). North Pole is not the attainment demonstration monitor, but the area is important as a large "hot spot" of high wood burning emissions, leading to some of the highest recorded 24-hr average $PM_{2.5}$ concentrations during the winter in the Fairbanks area.

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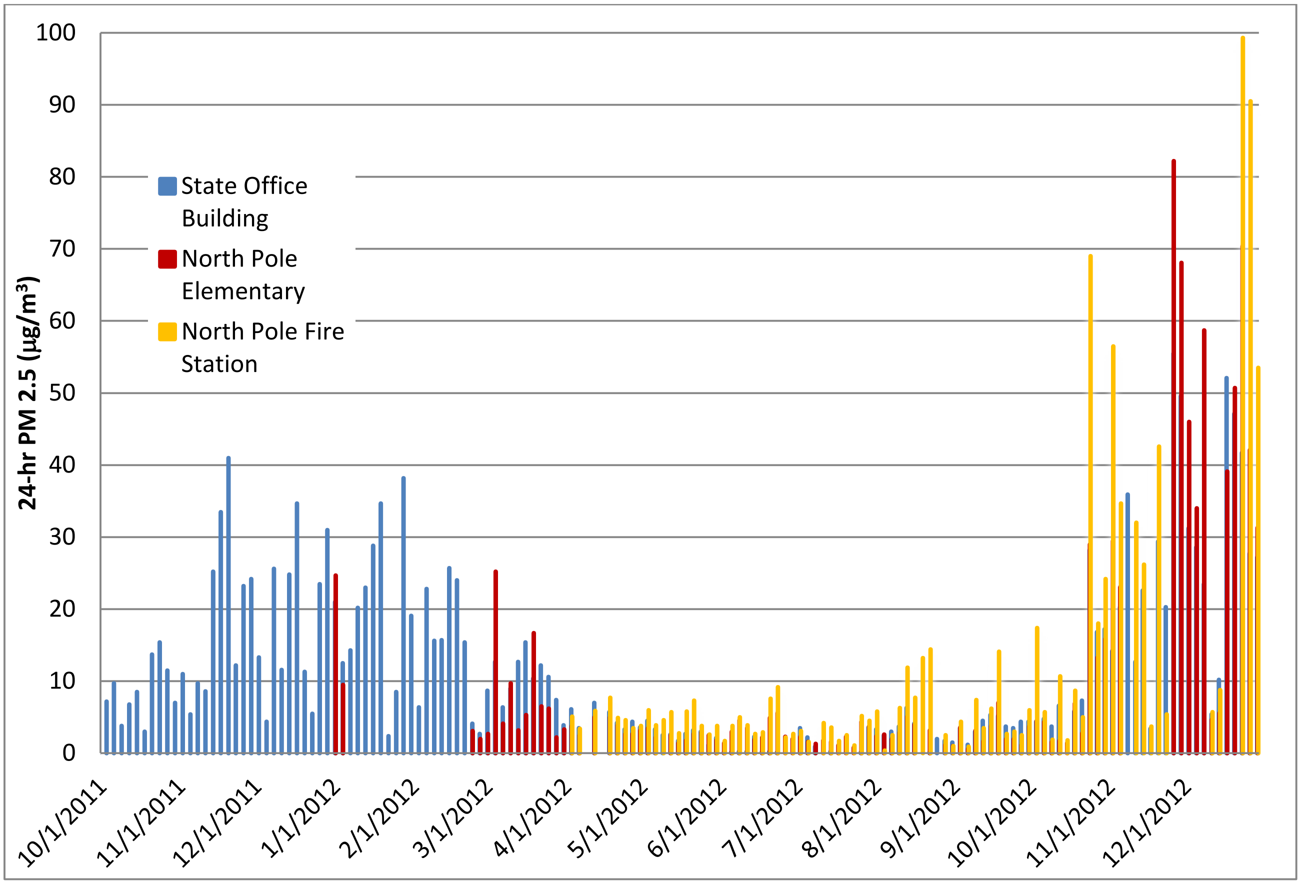
[5] See, for example, "Fairbanks $PM_{2.5}$ Planning, 4th in a Series: Control Measures," March 15, 2012; "Fairbanks $PM_{2.5}$ Planning: 5th in a Series: Plan Development & Control Measure Implementation," August 16, 2012; and "Status of FNSB $PM_{2.5}$ Air Quality Plan," March 21, 2013. All were prepared for ADEC and presented to the FNSB Assembly by Sierra Research.

[6] A summary of the Fairbanks Air Quality Symposium, July 15-17, 2009, Fairbanks, Alaska, may be found here: *ftp://ftp.co.fairbanks.ak.us/AQ-Symposium/Symposium_Summary.pdf*

[7] Deanna Huff and Mark Hixson, "SIP Modeling for Fairbanks $PM_{2.5}$ Nonattainment," presented at the 2013 Western Air Quality Modeling Workshop, July 10, 2013.

[8] Summer wildfires caused by lightning and other natural causes generally cannot be prevented; these are considered "exceptional events" and are excluded by EPA when determining compliance with the NAAQS.

Figure 3 – Fairbanks/North Pole Fine Particulate Matter ($PM_{2.5}$) Monitoring Data: State Office Building, North Pole Fire Station and North Pole Elementary School October 2011 – December 2012



Source: Deanna Huff, Alaska Department of Environmental Conservation

As a part of its research into emissions sources and trends, ADEC has, for nearly a decade, sponsored annual residential telephone surveys of space heater types and fuel burning amounts in FNSB. Reviews of the annual survey data prepared for ADEC by Sierra Research indicate that the fraction of households burning wood and the amount of wood burned have trended upwards over much of the last decade and nearly doubled since 2006,[9] which appears to be the result of consumer response to increases in the price of fuel oil and the lack of low-cost, clean-burning alternative fuels.

[9] See, for example: Memorandum (draft) to Cindy Heil, ADEC, from Frank Di Genova et al, Sierra Research, 6/26/13.

Further insight into the dominant impact of wood burning upon $PM_{2.5}$ air quality can be gained by reviewing the two maps shown in Figure 4. Both figures correspond to the two extended winter $PM_{2.5}$ episode periods selected for study in 2008.[10] Figure 4a (top) is a gridded map showing the results from a computer-calculated spatial distribution of $PM_{2.5}$ emissions from space heating[11] in the Fairbanks nonattainment region. Cells with the greatest emissions (shown in red and orange) tend to be residential areas with the greatest housing density, and thus the greatest density of home heating appliances; green-colored cells have fewer emissions and white cells have no such emissions. Figure 4b (bottom) shows the output from a computer-simulation of ambient concentrations of $PM_{2.5}$ resulting <u>from all sources</u> and averaged over all the modeled episode days.[12] Cells with the highest average concentration (more than 50 ug/m^3) are shown in red and those with lowest concentration (less than 15 ug/m^3) are shown in green, with color gradations in-between. The computer simulation model used here was CMAQ—a state of the art, open source, photochemical air quality model approved by EPA for SIP analysis—which was run in this case with all known emission sources, and accounting for the effects of meteorology, dispersion, chemical reactivity, deposition, etc.

Comparing the two gridded maps in Figure 4, it is evident that there is a close association between the locations of predicted high average $PM_{2.5}$ concentrations ("hot spots") in the nonattainment area and the locations where the most emissions are produced from space heating (almost entirely from wood-burning); this, along with other studies (discussed later), tends to affirm the major contribution of wood-burning space heating to high $PM_{2.5}$ concentrations and the need for further emission reductions from wood burners used in space heating.

These and related photochemical modeling results in Fairbanks for the base year 2008 have been subjected to exhaustive review as a part of Alaska's SIP development, and the model has been shown, using EPA modeling evaluation criteria, to reliably simulate most of the high $PM_{2.5}$ days in the two multi-day episode periods of the 2008 base year, as reflected in Figure 5.

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[10] These two $PM_{2.5}$ episodes (1/23/08 – 2/10/08 and 11/2/08 – 11/17/08) were selected in an effort to represent a bounding range of meteorological conditions that can cause exceedances. The first was characterized by extreme cold and extreme stagnation, while the second was a milder winter condition that still had high, exceedance-level concentrations.

[11] Because of the high (97%) fraction of space heating $PM_{2.5}$ emissions caused by wood-burning, the distribution of $PM_{2.5}$ emissions from space heating shown in Figure 4a is virtually synonymous with $PM_{2.5}$ emissions from wood-burning for space heating.

[12] Note that these episode-averaged modeled concentration levels cannot strictly be compared the NAAQS which is statistically-based on multiple years of data.

Figure 4a – Home Heating Emissions (1/23/08 – 2/10/08 & 11/2/08 – 11/17/08)

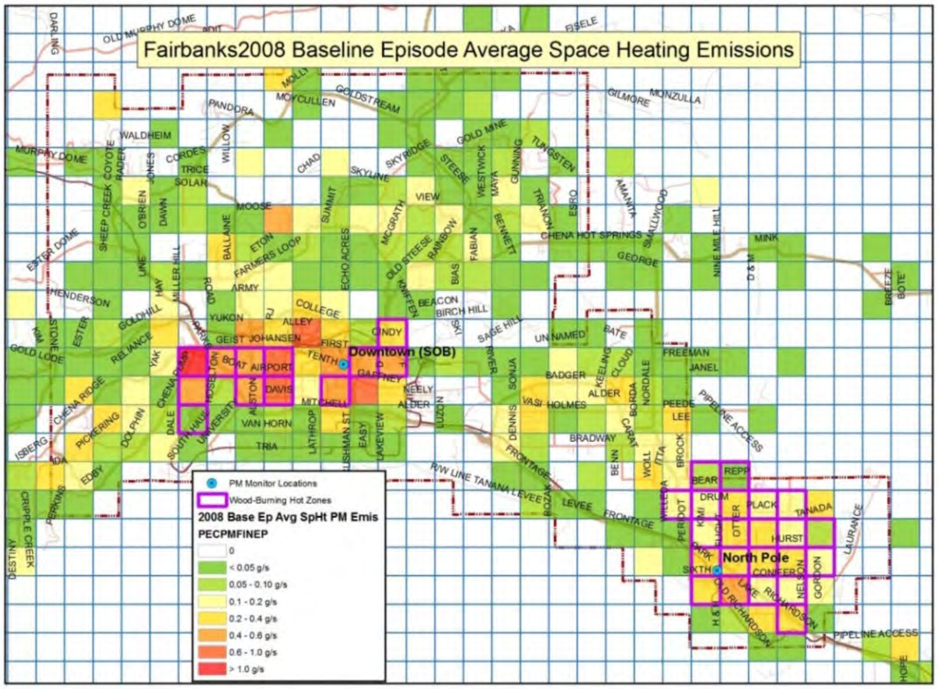
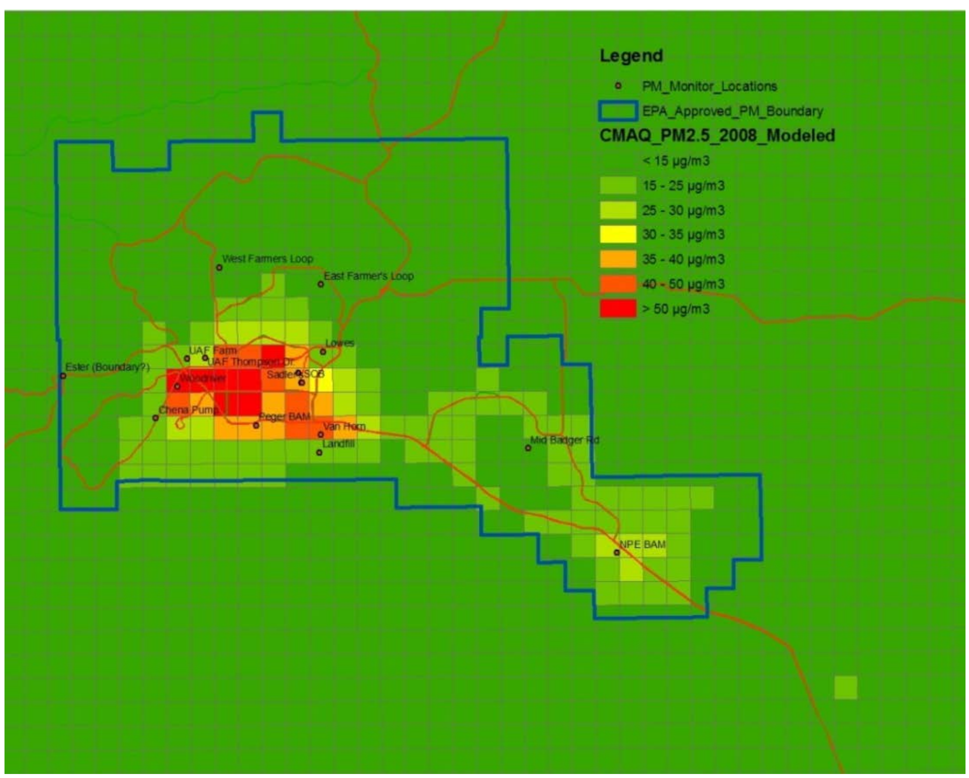
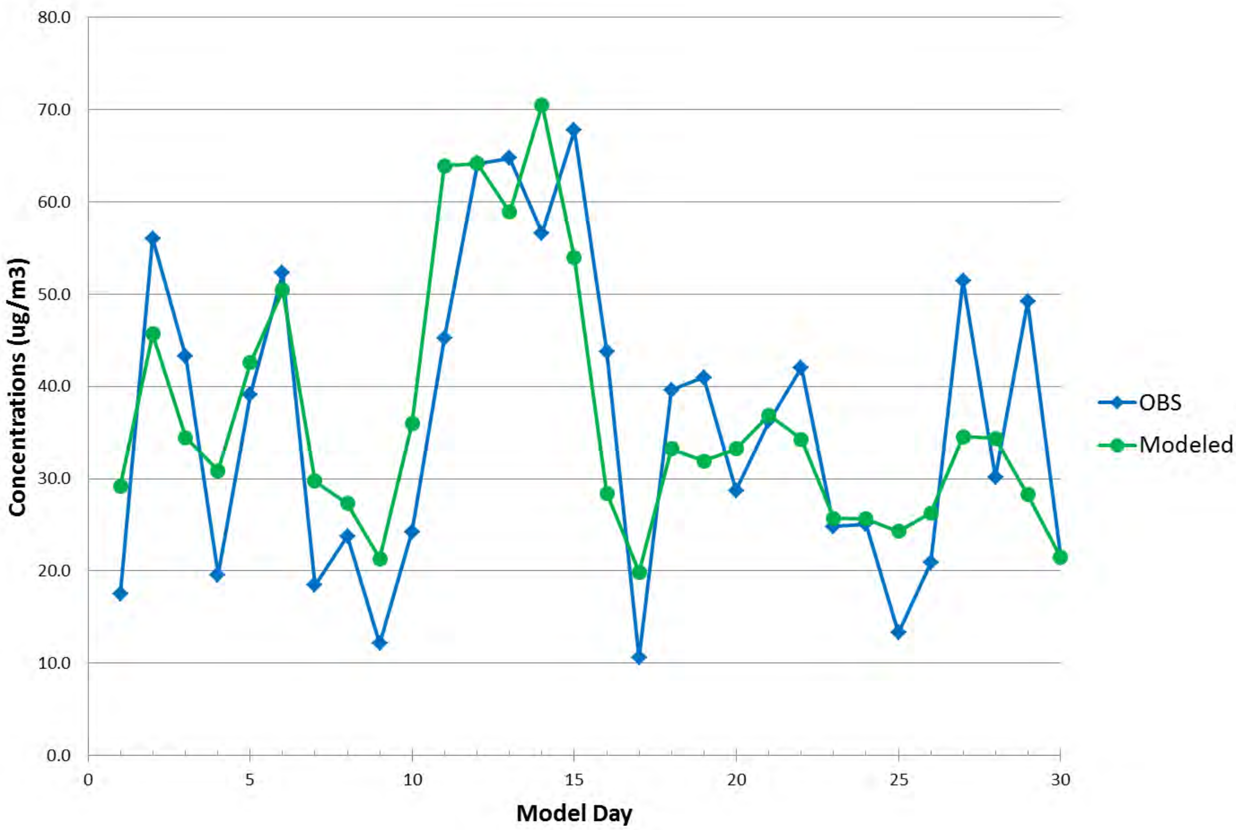


Figure 4b – Modeled Ambient PM2.5 Concentration (1/23/08 – 2/10/08 & 11/2/08 – 11/17/08)



Source: Deanna Huff and Mark Hixson, "SIP Modeling for Fairbanks $PM_{2.5}$ Nonattainment," presented at the 2013 Western Air Quality Modeling Workshop, July 10, 2013.

Figure 5 – 2008 Total $PM_{2.5}$ Modeled and Observed Comparison



Source: Deanna Huff and Mark Hixson, "SIP Modeling for Fairbanks $PM_{2.5}$ Nonattainment," presented at the 2013 Western Air Quality Modeling Workshop, July 10, 2013.

To promote attainment and maintenance of NAAQS throughout the country, EPA regulates the emissions of particulate matter and other air pollutants from certain sources through the establishment of New Source Performance Standards (NSPS). These standards specify emission limits that manufacturers of applicable devices must meet. The current particulate matter NSPS limits, which were established by EPA in 1988, for catalytic[13] and non-catalytic woodstoves are 4.1 grams per hour (g/hr) and 7.5 g/hr, respectively. Recent survey data from Fairbanks on the year of installation of existing wood-burning appliance[14] indicate that 87% of existing woodstoves were installed in the 25-year period following EPA's imposition of the NSPS. To date, EPA has

[13] A catalytic wood-burning stove routes smoke through a ceramic honeycomb catalytic burner, coated with a metal such as platinum or palladium. Smoke gases and particles pass through the combustor and ignite at a much lower temperature (250 degrees C) than they would without the combustor (500 degrees C). The result is harmful substances are more completely burned. The fuel produces more heat through an extended clean burn.

[14] 2013 Wood Tag Survey, summary of survey responses concerning the year of wood stove installation.

not adopted a particulate matter NSPS for wood-fired hydronic heaters (sometimes called "outdoor wood boilers").

EPA has recently proposed to revise its NSPS for wood-fired heating devices (see 2009 preliminary rule summary in Appendix A). On December 30, 2009, EPA informally released a preliminary particulate matter NSPS (2009) for stakeholder review and feedback. EPA sought feedback on a standard for new catalytic woodstoves of 2.5 g/hr and for new non-catalytic woodstoves of 4.5 g/hr. EPA also sought feedback on a preliminary particulate matter NSPS for both outdoor and indoor new hydronic heaters of 0.32 pounds per million British Thermal Units (lbs/mmBTU), which is the current level of the agency's voluntary, Phase II qualification program for these devices. Compliance target dates would be 2014 and 2015. EPA has since conducted stakeholder meetings with industry and states in an effort to obtain a consensus for establishing the wood-fired heating device NSPS particulate matter emission limits. The draft proposed NSPS for wood-fired heating devices may become available in 2013, with final rules following in 2014. At the time of this writing, it is not known with certainty what the new or revised NSPS levels will be for any of the device types mentioned. However, based on information available from EPA and detailed computer modeling calculations of the degree of emission reductions needed from wood burning, the emission standards being contemplated by EPA at this time will not provide sufficient emission reductions to ensure attainment of the NAAQS in Fairbanks.

To support attainment of the NAAQS for $PM_{2.5}$ as required under the federal Clean Air Act, and in accordance with the requirements of AAC Title 18 Environmental Conservation Chapter 50, ADEC proposes to adopt and implement particulate matter emission standards and other regulations for wood-fired heating devices limiting emissions to 2.5 g/hr. This proposed limitation which is for woodstoves, pellet stoves and outdoor hydronic heaters, is more stringent than the current federal emission standards. ADEC's proposed regulations apply to any manufacturer, supplier, distributor, or person intending to sell, lease, distribute, market or convey a wood-fired heating device in Fairbanks North Star Borough and to any person who owns or operates a wood-fired heating device located within the Fairbanks North Star Borough.

ADEC proposes more stringent emission standards for wood-fired heating devices than those currently adopted by EPA because the existing federal emission standards have been and continue to be inadequate to prevent deterioration of air quality in Alaska and exceedances of NAAQS. This proposed tighter standard will allow for the continued use of wood fuel, which ADEC views in Fairbanks and many other communities as a necessary means of addressing high energy costs until long-term, cleaner-burning heating options become available.

Alaska statute (AS 46.14.010(b)(2)) gives ADEC the authority to establish air emission control regulations that are more stringent than the corresponding federal standard provided ADEC follows procedures for establishing more stringent regulations as specified in AS 46.14.015 "Special procedures for more stringent regulations."

AS 14.046.015(b) requires the Department to prepare written findings for peer and public review that must include a discussion of the following:

- find in writing that exposure profiles and either meteorological conditions or emissions unit characteristics in the state or in an area of the state reasonably require the ambient air quality standard, or emission standard to protect human health and welfare or the environment; this paragraph does not apply to a regulation under (b)(3) of this section (AS 46.14.010(c)(1));

- find in writing that the proposed standard or emission limitation is technologically feasible (AS 46.14.010 (c)(2)); and

- prepare a written analysis of the economic feasibility of the proposal (AS 46.14.010(c)(3)).

The remaining three sections of this report address, in turn, each of the above points.

3.0 Meteorological Conditions Contribute to Elevated $PM_{2.5}$ Concentrations

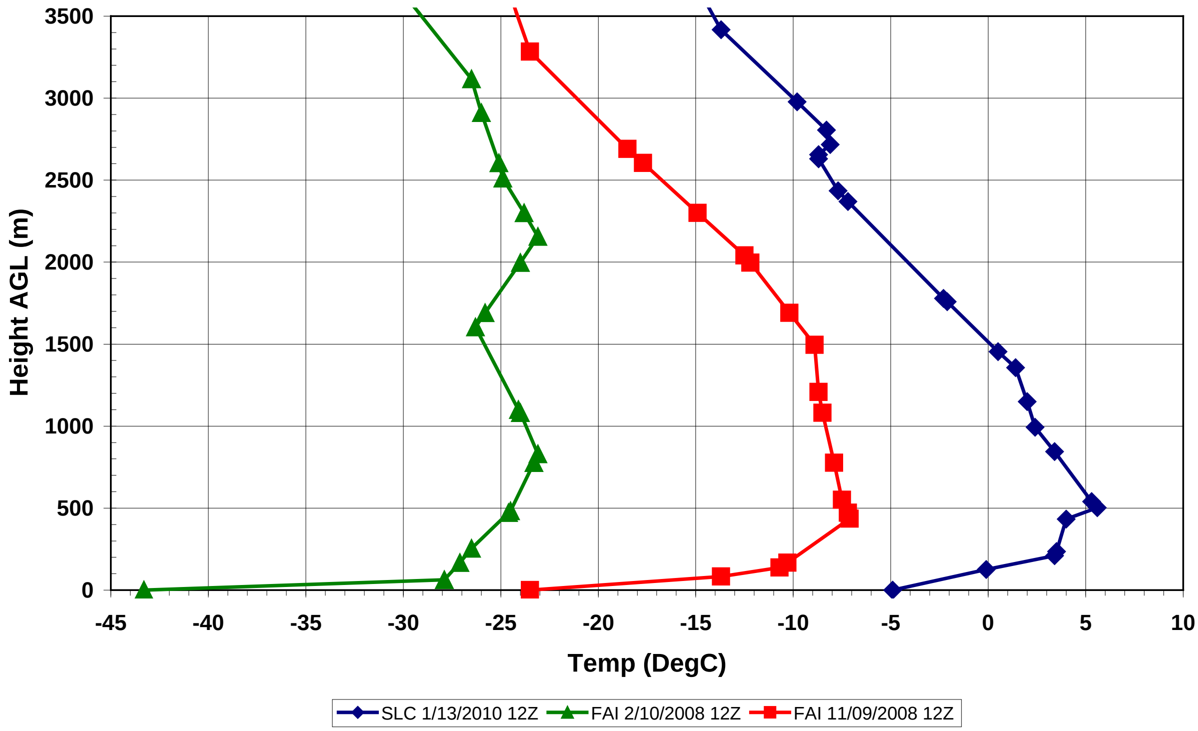
Due to a number of geographical and meteorological factors, patterns of cold, stable air dominate Fairbanks winters, greatly reducing atmospheric mixing and dispersion.[15]

Fairbanks frequently experiences inversions of considerable strength (Γ = 40°/100 meters) as surface temperatures cool faster than the air above. As a result, as parcels of warm air released into the environment rise under subadiabatic[16] environmental conditions, and particularly under the extreme subadiabatic condition of temperature inversion, they expand and cool at a rate which is greater than the temperature lapse rate of the surrounding air, and quickly become more dense than the surrounding air, which forces them back down, thus inhibiting vertical air movement and vertical dispersion. These intense surface-based inversion layers are often topped by weaker inversion zones such that the layer of inverted temperatures may range as high as 1-2 kilometers. Due in part to the low rate of surface heating associated with the low solar elevation in its subarctic winters, low ambient temperatures, low level of absolute humidity, frequent calm wind conditions, and other factors, surface based inversions in Fairbanks are among the strongest in the United States. For example, Figure 6 compares a strong lapse rate in Utah (another wintertime $PM_{2.5}$ non-attainment area) of 4°C/100 meters and typical winter lapse rate in Fairbanks of 25°C/100 meter. Under these conditions, (and with all other factors held constant) identical ground-level emissions in both locations would result in markedly higher concentrations in Fairbanks due to the greatly inhibited vertical mixing of the emissions. When other factors are also considered, such as the increased heating demand (and associated emissions increase) at low temperatures and the typically low-speed or calm winds in Fairbanks, the concentration differences can be much greater.

During the months of December and January, a surface-based inversion that hinders mixing of the surface-based emissions, including $PM_{2.5}$ emissions from wood-burning space heaters, is present 80% of the time in Fairbanks[17]. When this condition coincides with clear skies, little or no wind and cold to very cold surface temperatures, Fairbanks can experience extremely high $PM_{2.5}$ concentrations, well-above the NAAQS for days at a time. While high $PM_{2.5}$ concentrations are observed at less extreme temperatures, the most extreme $PM_{2.5}$ concentrations tend to occur under the classic case of strong lapse rates, low surface temperatures, which describes winter cold snaps in Fairbanks[17,17a].

[15] See, for example, Brian Hartmann et al, "Climatology of the Winter Surface Temperature Inversion in Fairbanks, Alaska," Geophysical Institute, University of Alaska, Fairbanks, JP2.26.
[16] John Seinfeld, Air Pollution Physical and Chemical Fundamentals, 1975.
[17] Brader et al, "Meteorology of Winter Air Pollution in Fairbanks", Jim Brader, NWS forecaster, presented at Air Quality Symposium, 2009.
[17a] Alaska Department of Environmental Conservation, observational calibrated BAM concentration and temperature data, winter 2012-2013.

Figure 6 – Example Inversions from Fairbanks and Salt Lake City



Source: Alaska Department of Environmental Conservation

4.0 Emissions Standard is Necessary to Protect Human Health

One of ADEC's primary objectives is the protection of human health and welfare via the safeguarding of air quality. At the same time, DEC recognizes that citizens of Alaska face extreme winter temperatures and high energy costs. The $PM_{2.5}$ and PM_{10} NAAQS are health-based standards, and the health effects due to inhalation of particulate matter are well documented.[18] Particles smaller than 2.5 microns in aerodynamic diameter tend to diffuse across the alveoli of the lung. This diffusion allows for systemic distribution of the particles and their contents throughout the body via the circulatory system. In addition to asthma and lung-related irritation, research indicates that exposure to $PM_{2.5}$ can cause premature death in individuals with heart and lung diseases and it can increase the risk of nonfatal heart attacks, irregular heartbeat, and decreased lung function. Children, older adults, and those with heart and lung issues are affected more commonly than healthy adults. $PM_{2.5}$ monitoring data collected during the 2008-2009, 2009-2010, and 2010-2011 winters in the FNSB suggest that the 24-hour $PM_{2.5}$ NAAQS is being exceeded about 25% of the days during the winter months.

In an effort to better discern and document the sources of $PM_{2.5}$ in the FNSB nonattainment area, ADEC sponsored research at the University of Montana to conduct source apportionment by means of Chemical Mass Balance (CMB) modeling at four locations in the nonattainment area. The monitoring locations were the State Office Building in downtown Fairbanks, North Pole, a mobile site RAMS (Relocatable Air Monitoring System) trailer site, and Peger Road. Measurement data were collected and analyzed over a three-winter period (2008-09, 2009-10, and 2010-11).[19] At each of the four sites, measured $PM_{2.5}$ concentrations averaged between 22.5±12.0 micrograms per cubic meter ($\mu g/m^3$) and 26.5±18.9 $\mu g/m^3$ over the three-winter period, exceeding the 24-hour $PM_{2.5}$ NAAQS approximately 25% of the time. Using source profiles developed by EPA and local profiles, CMB modeling revealed that wood smoke (likely residential wood combustion) was the major source of $PM_{2.5}$ throughout the winter months in Fairbanks, contributing between 60% and nearly 80% of the measured $PM_{2.5}$ at the four sites.

ADEC also sponsored chemical analyses to confirm the results of the CMB modeling. Carbon 14 (C^{14}) isotopic ratios, taken from a subset of the air monitoring filter samples from each of the four sites, revealed that approximately 32% to 66% of the measured ambient $PM_{2.5}$ originated from a contemporary carbon source, such as wood smoke. ADEC-sponsored researchers also measured elevated concentrations of Levoglucosan, an organic "tracer" compound found in the atmosphere only as a result of wood combustion emissions, throughout the winter of 2008/2009 at three of the four monitoring sites. In summary, CMB modeling results, coupled with the C^{14} and Levoglucosan

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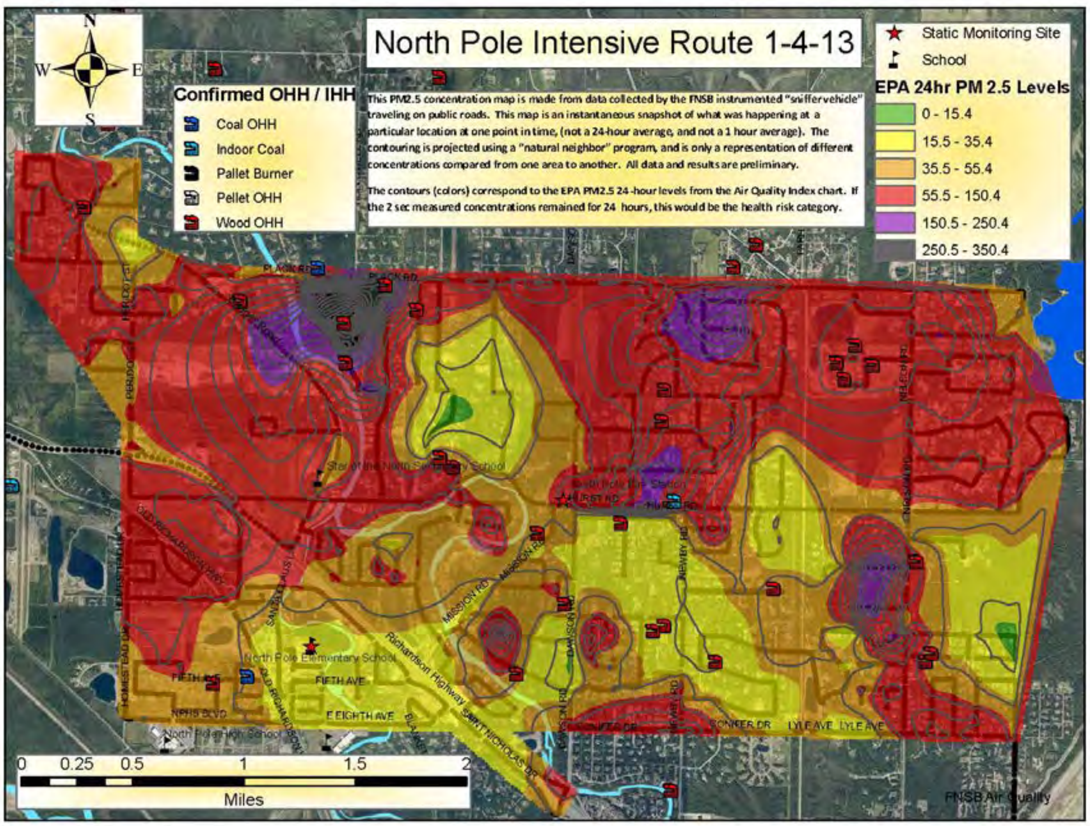
18 EPA's Health Effects of Particulate Matter: *http://www.epa.gov/airquality/particlepollution/health.html*

19 "The Fairbanks, Alaska PM-2.5 Source Apportionment Research Study," Final Report, July 23, 2012, by Tony J. Ward, Ph.D., Center for Environmental Health Sciences, University of Montana, Missoula, MT.

results, established wood smoke as the major contributor to the ambient $PM_{2.5}$ in the Fairbanks airshed during the winter months.

FNSB and ADEC have also supported a series of instrumented "sniffer vehicle" studies. While not performing 24-hour average measurements and not using FRM measurement methods (neither of which is intended or suited for operation in a moving vehicle), the sniffer vehicle was able to drive on the road and measure $PM_{2.5}$ concentrations over a much broader area and obtain concentration measurements at a much finer spatial scale than is practical with fixed site monitoring[20]. Figure 7 shows an example of the monitoring results from one such drive, which was conducted on January 4, 2013.

Figure 7 - North Pole 24-hr $PM_{2.5}$ Concentrations Measured by Sniffer Vehicle



Source: "Status of FNSB PM2.5 Air Quality Plan," presented to FNSB Assembly by Sierra Research, March 21, 2013; monitoring data provided by ADEC and FNSB.

The capability for fine spatial resolution monitoring has permitted FNSB to investigate, document, and better respond to the high $PM_{2.5}$ concentrations by targeting these "hot spot" neighborhoods

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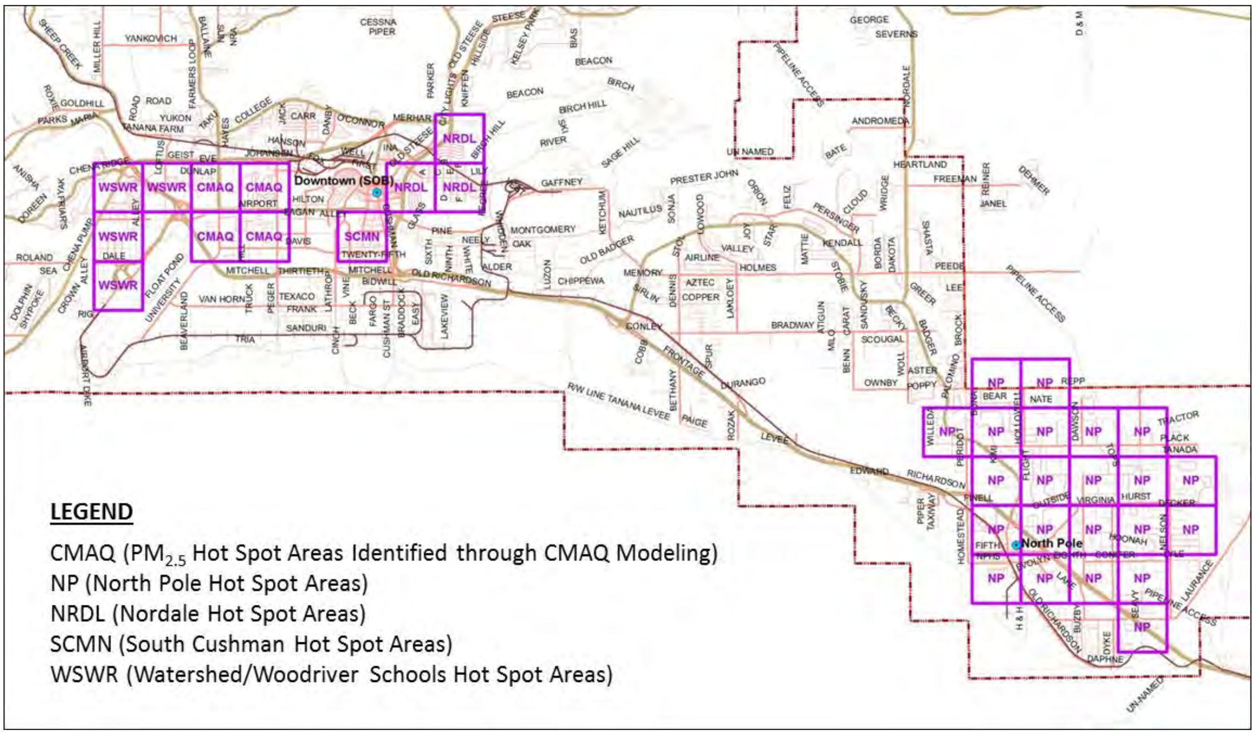
[20] See, for example, Frank Di Genova et al, "Mobile PM2.5 Measurements in the Winter of 2008-09," presented at the Fairbanks Air Quality Symposium, July 15-17, 2009, by Sierra Research.

for increased outreach and participation in the Borough's voluntary wood stove changeout program[21]. Furthermore, merging of the sniffer vehicle measurements with the modeling results cited earlier, has improved understanding of the locations and causes of $PM_{2.5}$ hot spots within the nonattainment area. Together, the mobile measurements and modeling have provided a basis for the Borough to maximize the air quality benefits of its voluntary woodstove changeout program in the nonattainment areas's $PM_{2.5}$ hot spot areas (see Figure 8).

Figure 8 - Map of Enhanced Solid Fuel Burning Area Hot Spot Cell Locations



Source: "Status of FNSB $PM_{2.5}$ Air Quality Plan," presented to FNSB Assembly by Sierra Research, March 21, 2013; monitoring data provided by ADEC and FNSB (legend has been added to the original version).

More stringent emission standards for woodstoves and new standards for hydronic heaters will reduce emissions and ambient $PM_{2.5}$ concentrations in the FNSB nonattainment area with every new installation. Lowering allowable emission rates from new wood-burning appliances will help balance the need for cleaner air with the need to use wood as a viable, sustainable, and economical energy source. Given the large population in Fairbanks and the need to protect human health, tighter emission standards can help to ensure air quality improvements through the use of cleaner burning devices.

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[21] It should be noted that FNSB's wood stove changeout program, while very effective and a model program in many respects, is highly subsidized and is therefore focused, necessarily, on replacing only uncertified (higher emitting) stoves. It would be prohibitively expensive to replace all woodstoves in the nonattainment area under the program. Furthermore, because it is a voluntary program, the SIP emission credits which may be claimed for it are limited by EPA regulation to a nominal percentage.

5.0 Technological Feasibility of Establishing Wood-fired Heating Device Regulations

The increased burning of wood has already resulted in new installations of wood stoves and hydronic heaters, and this trend is projected to continue in the future. Fortunately, lower emission rate appliances are technologically feasible and already available for sale.

There are no significant technological barriers preventing the adoption of the 2.5 g/hr $PM_{2.5}$ emission standard. A review of EPA's certified woodstove list shows that 142 certified wood stoves meet the NSPS of 2.5 g/hr that is currently being contemplated by EPA (i.e. their emissions are equal to or below 2.5 g/hr). Of the 69 pellet stove models from EPA's list of certified pellet stoves, 52 models produced by 24 manufacturers meet the 2.5 g/hr limit. Only 17 models produced by 5 manufacturers would not meet the limit. A review of the EPA Phase II Qualified list of cleaner hydronic heaters available on the EPA website reveals 11 models that meet a 2.5 g/hr emission standard.

ADEC also sponsored an investigation of the particulate matter emission rates for wood stoves currently being sold in Alaska. The analysis determined that 13% (30 of 181) of the wood-stove models currently being sold in Alaska meet Alaska's proposed particulate matter standard of 2.5 g/hr. It further determined approximately 60% (18 of 30) of the catalytic wood-stove models and 15% (22 of 151) of the non-catalytic woodstove models currently being sold in Alaska meet the the proposed Alaska particulate matter standard (2.5 g/hr). . Of the 11 EPA Phase II qualified hydronic heaters meeting the 2.5 g/hr average, five (45% are available in Alaska, all in Fairbanks

ADEC also compared the models currently being sold in Alaska to the models listed on EPA's current, certified wood stove list.[22] ADEC found that most models (>95%) currently being sold in Alaska are listed on EPA's certified wood stove list, and therefore meet the current particulate matter NSPS emission limitations ADEC then complared the manufacturers with home heating devices available for sale in Fairbanks with the EPA certified stove list or Phase II qualified list with a 2.5 g/hr or less emission level (see Table 1, below) Retailers also indicated they are able to order most models within the brands they sell based on a customer's need; the smaller number of models in retail showrooms does not accurately reflect the total number of models available to consumers.

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[22] EPA's "List of EPA Certified Wood Stoves," September 12, 2012, at *http://www.epa.gov/burnwise/woodstoves.html*

Table 1 - Availability of Wood and Pellet Stoves/Insert Models Meeting the 2.5 g/hr Emission Level and Models Sold in Fairbanks

Wood and Pellet Stoves/Inserts*		Outdoor Wood Hydronic Heaters**	
EPA List (<=2.5g/hr)	Sold/available to be special ordered in Fairbanks	EPA List	Sold/available to be special ordered in Fairbanks
258	72	15	5

Notes:
* Numbers are based on EPA's certification list dated March 15, 2013 and testing method for woodstoves; DEC survey found 30 woodstove models are sold in Fairbanks.
** It is possible there are many more pellet stoves that would have emission levels meeting the prposed Alaska standard, but since pellet stoves are currently exempt from the NSPS, they have not needed to be tested.
***Hydronic Heater Numbers are based on EPA's qualified list and testing method for "Phase 2" OWHH dated May 20, 2013; DEC survey found 6 pellet, 2 wood, and 3 coal/wood models sold in Fairbanks.

6.0 Economic Feasibility of Establishing Wood-fired Heating Device Regulations

There are direct economic costs associated with implementing more stringent emission standards. EPA conducted a cost analysis[23] for developing new wood-fired heating devices based on the 2009 preliminary NSPS, and estimated the additional manufacturing costs per unit based on appliance type, as summarized below.

- Wood Stoves - Certified wood stoves and pellet stoves represent a well-developed technology, and EPA could not identify price differences between models with lower emission levels compared to models with higher emission levels. Therefore, EPA assumed no additional manufacturing costs.
- Hydronic heaters - EPA has seen a range of estimates for additional costs to the manufacturer for producing a hydronic heater capable of meeting the emission standards associated with the EPA voluntary program, with an average being approximately $3,000. EPA assumes that the additional costs to manufacture an NSPS-certified furnace will be comparable, i.e., $3,000 (exclusive of recovering R&D cost).
- Single-Rate Burn Stoves - One manufacturer estimated that it will cost an average of $100 more to manufacture a lower-emitting, single burn rate product (exclusive of recovering R&D cost).

ADEC compared the retail cost of a subsample of the large, medium, and small woodstove models currently being sold in Alaska (Table 2). Woodstove prices tend to be based in part on the rated maximum thermal output (BTUs/hr), the presence of catalytic vs. non-catalytic technology, and whether they are free standing or an insert. Shipping costs to Alaska are included in the prices.

Catalytic woodstove models are generally more expensive than non-catalytic models, and for some manufacturers it appears that there may be an increased cost for woodstoves having lower emissions rates. For example, the catalytic Blaze King Princess model emits less than half the the amount of $PM_{2.5}$ (2.4 vs. 5.8 g/hr) as the similarly heat rated non-catalytic Blaze King Guardian model, but it costs nearly twice as much ($2,433 vs. $1,293). Conversely, the Hearthstone Clydesdale, a non-catalytic model, which has an emission rate of 3.1gr/hr, tends to cost more than the Vermont Castings Defiant, a catalytic model that has approximately the same thermal output and a lower emission rate (1.1-2.3 g/hr). Based on these limited data, it is possible that there will

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[23] EPA Internal Memorandum, unpublished data, "Unit Cost Estimates of Residential Wood Heating Appliances," dated December 8, 2011.

be additional direct economic costs[24] that will be borne by residents of Alaska using woodstoves and hydronic heaters if these regulations are adopted.

Further analysis of wood stove prices in Fairbanks and the corresponding emission rates for the models sold did not show a correlation between $PM_{2.5}$ emission rates and wood heating device costs. There are both high- and low-emitting wood heating units in the lower end of the cost range. This suggests that a lower emission standard does not consistently result in a higher device cost for the consumer. Customers should find economical choices available for lower-emitting stoves.

[24] Some of these costs may be offset by the fuel savings associated with more efficient heating appliances.

Table 2 - Retail Price Comparison of Woodstoves Being Sold in Alaska

Manufacturer	Model	Catalytic/ Non-Catalytic	Maximum Energy Output** (BTU/hr)	EPA SEP12 Woodstove list Max BTU/hr*** (BTU/hr)	Emission Rate (g/hr)	Retail Cost Juneau ($)	Retail Cost Anchorage ($)	Retail Cost Fairbanks ($)
Blaze King	Briarwood II	non-catalytic	40,000	36,000	3.5	$1,528	$1,850	$1,373 base*
Blaze King	Guardian	non-catalytic	40,741	39,800	5.8	$1,158	$2,257-$2,615	$1,293 base *
Blaze King	King	catalytic	47,000	39,800	1.76	$2,508-$3,075	$3,300	$2,711 base *
Blaze King	Princess	catalytic	40,000	35,600	2.4	$2,258-$2,609	$2,494-$2,761	$2,433 base *
Hearthstone	Clydesdale (not Q-F)	non-catalytic	75,000	33,100	3.1	$3,759-$4,259	$3,575-$4,215	(not sold)
Hearthstone	Equinox	non-catalytic	120,000	37,900	3.1	$4,709	$4,366-$4,979	$4685 base *
Hearthstone	Heritage	non-catalytic	55,000	32,800	2.7	$3,359-$3,819	$3,149-$3,695	$3,300 base *
Hearthstone	Homestead	non-catalytic	50,000	33,600	1.9	$3,029-$3,459	$2,985-$3,350	(not sold)
Hearthstone	Mansfield (NHC, Inc.)	non-catalytic	80,000	45,300	2.9	$3,689-$4,259	$3,495	$3,660 base *
Hearthstone	Phoenix	non-catalytic	60,000	41,500	2.4	$3,209-$3,609	$3,115-$3,595	$3,080 base *
Hearthstone	Tribute	non-catalytic	36,000	28,300	3	$2,149-$2,599	$1,889	$1,950 base *
Quadra-Fire	2100 Millennium	non-catalytic	40,800	37,200	2.1	$1,749-$1,812	$1,660-$1795	$1673 base *
Quadra-Fire	3100 Step Top	non-catalytic	51,000	43,200	1.1	$2,467-$2,907	$1,815-$2,068	$1921 base *
Quadra-Fire	4300 Millennium	non-catalytic	56,000	58,500	1.1	$2,149-$2,212	$2,100-$2,250	$2180 base *
Quadra-Fire	4300 Step Top	non-catalytic	56,000	38,305	1	$2,667-$3,107	$3,025	$2698 base *
Quadra-Fire	5700 Step Top	non-catalytic	70,300	40,359	2.3	$2,957-$3,387	$2,900-$3,350	$3017 base *
Quadra-Fire	Cumberland Gap	non-catalytic	63,900	44,300	3.4	$2,549-$3,099	$2,440-$3,015	$2539 base *
Quadra-Fire	Isle Royale	non-catalytic	66,700	46,800	2.9	$2,849-$3,499	$2,760-$3,430	$2863 base *
Quadra-Fire	Yosemite	non-catalytic	42,500	28,600	2.7	$2,249-$2,699	$1,615	$2211 base *
Vermont Castings	Defiant Flexburn ****	cat / non-cat	75,000	34,000	1.1-2.3	$3,159-$3,979	$3,611	$3,179 - $3,300
Vermont Castings	Encore Flexburn ****	cat / non-cat	65,000		1.2-1.5	$2,849-$3,509	$3,239	$3,000 base *

Note: Retail sales prices for Juneau were obtained from Alaska Hearth Products located in Juneau, AK, October 2012; retail sales prices for the Anchorage area were obtained from Northeast Hearth and Home (Anchorage), Wholesales Distributors of Alaska (Anchorage) and A Fireplace Store (Kenai); retail sales prices for Fairbanks were obtained from The Woodway, Cold Country Hearth and Patio, and Wholesale Distributors of Alaska in Fairbanks. Retailer in Fairbanks (Arctic Tech Services) is no longer actively selling woodstoves, selling out of what they have.

* Add up to $500 for upgrades from base model (black cast iron); upgrades include nickel or brass doors/hardware, fan, etc.

** Maximum BTUs listed appear to be from the manufacturer's webpage.

*** Several of the stoves had more than one test or more than one model of the stove and the BTU value of the emission rate shown was listed.

**** Vermont Castings brochure. (*http://literature.mhsc.com/vermont_castings/brochures/ MHSC_11420_VC_Flexburn_Brochure_111312_Spread.pdf*). The BTU value listed for the Encore Flexburn is from the brochure/ website, as are the emission rates shown. On 1/3/13, J. Hardesty called a local dealer who reported that he had the VC Defiant Flexburn on the floor and he read the EPA certification data to Hardesty. The maximum BTU reported is shown above. EPA verified both woodstoves are on their certified list, just not published yet (1/15/13 update on EPA website).

Appendix A- Summary of EPA's December 2009 Discussion Draft on Preliminary NSPS for Wood-Fired Heating Devices

APPLIANCE TYPE	KEY ASPECTS OF DRAFT (ALL EMISSION LIMITS BELOW ARE FOR PM UNLESS OTHERWISE SPECIFIED)	COMPLIANCE DEADLINES (PRELIMINARY)	KEY ISSUES AND OTHER SIGNIFICANT POTENTIAL OPTIONS
Wood stoves	Tightens existing NSPS limits to match WA limits, i.e., 4.5 g/hr of PM (non-catalytic), 2.5 g/hr (catalytic). Adds efficiency requirement of 70% to reduce CO.	"2014" i.e., one year after expected effective date	Current NSPS limits are 7.5 g/hr (non-catalytic stoves) and 4.1 g/hr (catalytic stoves), however >85% of existing EPA-certified stoves currently meet WA limits. EPA is proposing test method improvements. EPA has requested comments and data to support other options for promulgation, e.g., establishing one limit of 2.5 g/hr for both non-catalytic and catalytic stoves. Cost-effectiveness of 2.5 g/hr option is estimated at $28,000/T, with annualized cost-to-sales ratio of 5.9%.
Hydronic heaters	**Level 1**: 0.32 lb/mmBTU heat output with cap of 18 g/hr (matches Phase 2 of EPA voluntary program and NESCAUM model rule). Adds efficiency requirement of 75% to reduce CO. **Level 2**: 0.15 lb/mmBTU heat output with cap of 7.5 g/hr and efficiency of 80%.	**Option 1**: "2014" for outdoor and "2015" for indoor at Level 1 plus "2017" for Level 2 for both **Option 2**: **Level 2** **"immediately**"	Strong industry, state, public support for including HH in revised NSPS. Proposing test method revisions. EPA expects to request comments and data to support either of the co-proposed options or additional options for promulgation. Option 2 would achieve an additional emission reduction of 338 tons/year over the period of 2013-2015. The cumulative annualized costs would decrease by $300,000 for 2012-2014 because there would be a reduced number of models available for certification in those years,
Single-burn-rate stoves	3.0 g/hr and 70% efficiency.	"2015" (Level 1)	Largest exemption for wood stoves in existing NSPS in terms of number of units sold (>40,000 units/year). EPA expects to request comments and data to support additional options for promulgation, e.g., 2.5 g/hr.
Forced-air furnaces	0.93 lb/mmBTU heat output (equivalent to Canadian level).	"2015"	Emissions more significant than previously thought. Manufacturers want more time to develop improved best demonstrated systems of emission reduction (BSER).

APPLIANCE TYPE	KEY ASPECTS OF DRAFT (ALL EMISSION LIMITS BELOW ARE FOR PM UNLESS OTHERWISE SPECIFIED)	COMPLIANCE DEADLINES (PRELIMINARY)	KEY ISSUES AND OTHER SIGNIFICANT POTENTIAL OPTIONS
			EPA expects to request data and comments to support additional options for promulgation, e.g., same levels as hydronic heaters to avoid competitive imbalance.
Pellet stoves	4.5 g/hr (non-catalytic), 2.5 g/hr (catalytic) and 70% efficiency. Specifically include in NSPS; i.e., do not allow current exemption for appliances with >35:1 air-to-fuel ratio.	"2014"	Typically cleaner than wood stoves. Inclusion in NSPS reduces competitive imbalance versus wood stoves. Manufacturers generally want to be included in the NSPS. EPA expects to request data and comments to support additional options for promulgation, e.g., tighten the level in "2015" to 2.5 g/hr. Estimated cost-effectiveness of $60,000/T and cost-to-sales ratio of 0.97% (potential Level 2).