ALASKA DEPARTMENT OF

ENVIRONMENTAL CONSERVATION

Peer Review Comments On:

The Need and Basis for More Stringent Wood-fired Heating Device Emission Standards in 18 AAC Air Quality Control, Peer Review Draft November 2013

http://dec.alaska.gov/air/anpms/comm/docs/justification_NOV13.pdf

December 13, 2013

Overview

Alaska Statue 46.14.010 requires that if the Department of Environmental Conservation (DEC) intends to adopt regulations establishing an emission standard more stringent than the Environmental Protection Agency (EPA) that a written finding must be peer reviewed. The written finding is required to show that meteorological conditions require the standard to protect human health, the standard is technologically feasible and economically feasible. In addition, Alaska Statute 46.14.015(d) specifically requires that persons that perform the peer review shall be selected on the basis of competitive sealed proposals. Furthermore, these statutes require at a minimum that three separate parties provide the review and that these parties shall not have significant financial interest or other significant interest that could bias the evaluation of the proposed regulation. Upon completion of their peer review, the comments of these reviewers are required to be released for public review.

To meet the requirements of these statutes, DEC first developed a written finding. Then DEC issued Informal Request for Proposal (IRFP) No. 18-9026-14 and 18-9026-14a which sought expertise in three different areas: 1) economics and cost analysis related to space heating fuels and devices, 2) solid fuel (wood/coal) residential heating device design, manufacture, operation and testing (e.g. wood stove/boiler manufacturer), 3) the impacts and effects of meteorology and wood heating emissions on monitored concentrations. As a result of the procurement and contracting process, there were three awards issued to the three different types of reviewers. Each reviewer was asked to focus their peer review on their area of expertise but that they could comment on the document as a whole should they choose to do so.

The three peer reviewers are:

Area 1 Economics and Cost Analysis- The Institute of Social and Economic Research (ISER) at the University of Alaska Anchorage. The reviewer assigned to the effort is Professor of Economics Steve Colt. Dr. Colt has a Ph.D. in economics from MIT with concentrations in empirical analysis ("econometrics") and also energy and environment. He has 29 years of Alaskan experience in performing economic analysis of energy issues, policies and markets. He also has the full intellectual resources of ISER available to draw upon. ISER is an organized research institute with more than 50 years of experience.

Area 2 Solid Fuel residential heating device design, manufacture, operations and testing. Dirigo Laboratories, Inc. Dirigo is accredited by the US EPA for Certification of Wood Heaters Pursuant to Subpart AAA of CFR Part 60, New Source Performance Standards for Residential Wood Heaters (certifications 9 and 9M). This includes EPA Methods 28, 28A 28WHH, 5G and 5H CSA B-415.1-10 and all associated ASTM test methods relating to both indoor and outdoor wood heater emissions.

Area 3 Air Quality expertise with respect to the impacts and effects of meteorology – Rincon Ranch Consulting. Robert Crawford, ScM. Physics. Mr Crawford is an independent consultant with 35 years of experience in environmental and energy matters. He provides support on statistical, data analysis, and modeling problems related to emissions from mobile and stationary emission sources and to ambient air quality data. Mr. Crawford is also familiar with Fairbanks meteorology and participated in the 2009, 2010 and 2012 Air Quality Symposiums in Fairbanks. He has worked indirectly for the State of Alaska and the Fairbanks North Star Borough as a subcontractor to Sierra Research.

Peer Review

of

“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”

Prepared for

Alaska Department of Environmental Conservation

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Introduction

This is a technical peer review of the DEC document titled *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*. This review focuses on Section 6 titled "Economic Feasibility of Establishing Wood-fired Heating Device Regulations." Some suggestions are also offered relating to the communication of material in other sections.

Criteria Employed

The *Findings* document is required by Alaska Statutes because "ADEC proposes more stringent emission standards for wood-fired heating devices than those currently adopted by EPA" (p. 10) It is the statutory requirements that underpin this peer review. The statutory requirement for economic analysis is that the *Findings* document must include "a written analysis of the economic feasibility of the proposal (AS 46.14.010(c)(3))." (p. 11). Thus, the task of this peer review is not to provide a "second opinion" about whether DEC's standards are good public policy. Rather, this review focuses on whether the economic analysis is sound.

The criteria that I have employed in determining the scientific validity of the Section 6 economic feasibility section are the following.

- Is the methodology appropriate (whether or not other appropriate methodologies might also exist)?
- Does the analysis rely squarely on data?
- Is the best available data used?
- Does the analysis clearly distinguish between data inputs and assumptions and clearly state the basis for those assumptions?
- Are the methods and data sources clearly explained in such a way that a similarly skilled researcher could attempt to replicate the analysis?
- Are the results of the analysis clearly stated along with limitations and uncertainties?
- Are the boundaries set by the available data and methods respected? In other words, are the conclusions and/or policy implications closely related to the analytical results?

Appraisal

The economic feasibility assessment is thorough, honest, and based squarely on available data. An important point to keep in mind is that the proposal for more stringent standards applies to new devices and does not require the change-out or scrapping of existing devices. This is a critical feature of the proposal that simplifies the feasibility analysis.

Methodology. Because the proposed standards apply to purchases of new equipment, the methodology used -- a comparison of the cost of different new devices -- is appropriate. The essential cost comparison is between devices that do and do not meet the standard of 2.5 grams per hour. The analysis appropriately focuses on this comparison.

Data. Two data sources are used. The first is an existing analysis prepared by EPA in 2009. This analysis suggests that there is no systematic difference in cost between woodstoves with higher vs. lower emissions. The second data source is a compilation of actual woodstove prices, sizes, and emissions rates for stoves currently sold in Fairbanks. This source qualifies as the best currently available data since it avoids speculation about stoves that are not currently available for purchase. However, it is perhaps important to remember that other models would likely become available for sale in Fairbanks if new emissions standards were implemented. Currently, low emissions are likely not a strong selling point and catalytic stoves are likely being sold on the basis of their higher combustion efficiency. The point of this short discussion about data is that the data set employed is likely to **overstate** any potential tradeoff between lower emissions and higher prices.

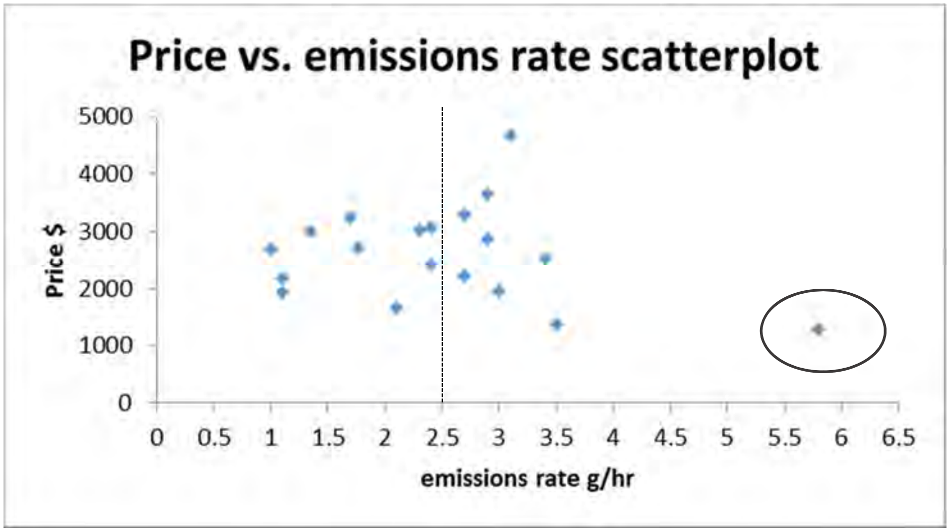
Assumptions vs. data. The analysis presents the data used, in Table 2. Table 2 is well footnoted to document the numbers contained. Because the raw data are provided, I was able to conduct a validation analysis of my own (see below).

Results. The text provides a straightforward discussion of the data to support the overall conclusion that woodstoves meeting the proposed 2.5 grams per hour standard can be purchased at prices no higher than the price of stoves with higher emissions. The discussion candidly includes one example where the low-emission catalytic model costs twice as much as the higher-emission non-catalytic model. Also mentioned is a compelling example of a low-emission stove that costs less than a similar higher-emission stove.

The key finding of the analysis is stated as follows:

> "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." (p. 20)

I conducted my own analysis of the data to verify this general conclusion. First, I prepared this scatterplot of stove price vs. emissions rate using the 19 data points presented in Table 2.



Data source: *Findings* Table 2.

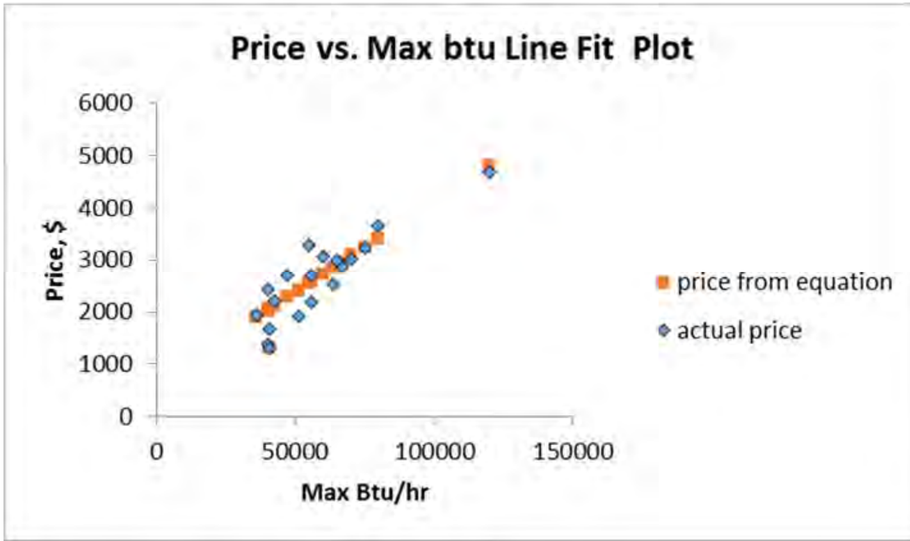
This plot suggests that 1) There is no obvious relationship between emissions and price; and 2) The stove with emissions rate 5.8 (circled) could reasonably be considered to be an outlier.

I then conducted a multiple regression to control for the effect of stove heating capacity on price. In this regression I included a “dummy variable” to statistically control for the outlier point. The resulting regression equation is:

Sales price = 638 + 0.035 x (*Max btu/hr*) – 2.32 x (*emissions g/hr*) – 752 x (*dummy*)

Adjusted R-squared = .78
N = 19

The “t-statistic” associated with the coefficient (=.035) on stove capacity is 7.3. This t-value indicates a highly significant statistical correlation between price and capacity. The magnitude of this coefficient is high – indicating that a stove with 10,000 btu/hr additional capacity costs an additional $350.00. This result is shown graphically in the following plot of the predicted and actual relationship between price and capacity.



Data source: *Findings* Table 2. Regression equation from text, above.

Conversely, the "t-statistic" associated with the coefficient (= -2.32) on emissions rate is 0.02. This t-value indicates that price and emissions are completely uncorrelated. (The magnitude of this coefficient is also very low – indicating that a stove with emissions lower by a full 1.0 gram per hour would cost only an additional $2.32 – but the coefficient is statistically not different from zero, so its magnitude is not relevant.)

My regression analysis therefore strongly confirms the stated result from the *Findings* that there is no statistical correlation between stove price and emissions rates after controlling for stove capacity.

Limitations and uncertainty. Notwithstanding the above results, the feasibility analysis is careful to acknowledge that it is a broad statistical conclusion. The document states: "for some manufacturers it appears that there may be an increased cost for woodstoves having lower emissions rates" (p. 20).

Specific Strengths

The analysis is strong because it relies on local data collected for actual stoves currently available and because it makes the raw data available to readers so that they can judge for themselves whether the conclusions are supported.

Suggestions for Improvement

1. In Table 2, the data source for emissions rates – presumably the EPA's certified stove list:

http://www.epa.gov/Compliance/resources/publications/monitoring/caa/woodstoves/certifiedwood.pdf

-- could be more clearly stated on the same page as the table, so that the table can be self-contained with complete source referencing.

2. Footnote 24 is important and could be included as a sentence in the main text.

3. The health benefits of improved air quality are not calculated as an offset to any possible increased equipment cost. The document could mention this point in the text to reinforce the limited nature of the feasibility assessment – limited to the individual consumer's out of pocket cost perspective.

Conclusion

The economic feasibility analysis included as Section 6 in the DEC *Findings* document is scientifically valid. It is well-supported by local primary data and the data are included in the document. Uncertainty is appropriately acknowledged along with the main result of no correlation between woodstove price and emissions rates.

Alaska Department of Environmental Conservation Peer Review

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

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Subject Area 2: Solid Fuel Wood Space Heating Appliances and Operation.

5.0 Technologic Feasibility of Establishing Wood-fired Heating Device Regulations

General:

The ADEC's proposed adoption of the 2.5 g/hr. $PM_{2.5}$ emission standard for residential heating appliances is a technologically feasible goal as it applies to EPA Method 28 for wood and pellet stoves. Technological issues begin to arise with Hydronic Heaters and Indoor wood-fired furnaces with the ADEC new proposed emission standard.

Test Methods:

With the adoption of the stricter Washington state emission standards for wood stoves and the requiring of only EPA qualified hydronic heaters to be sold, many states have been successful at reducing $PM_{2.5}$ emissions. It is hard to argue the success of these more stringent standards in the reduction of $PM_{2.5}$. While Method 28 and 28WHH represent a proven method of determining emissions, it is important to understand their limitations.

EPA Method 28 and 28WHH are adequate for comparing emissions of similar types and sizes of residential wood fired appliances to one another. The results achieved from these test methods do not reflect actual performance in the field. In other words, just because the label says "2.5 g/hr" does not mean your unit will perform at 2.5 g/hr. There are many reasons that would affect the emissions rate of a wood-fired heater. Wet wood, poor draft, over sizing, etc. For the purpose of our area of expertise, we will focus on the laboratory issues and the actual test methods.

The test methods have very specific parameters that must be adhered to. Even within these parameters, slight changes, such as in wood moisture content or fuel load weight could have dramatic effects on test results. These slight changes affect the precision of the test methods. As we begin lowering the g/hr. limits, the precision of the test methods decreases even more. You begin reaching the limits of the test methods margin of error and the g/hr. numbers become less relevant. Some studies have shown that the margin of error can be anywhere from 2.5 g/hr to 6.5 g/hr. between laboratories. (Kurkeet, 2010) While we believe lowering the standard to 2.5 g/hr is technologically feasible, we have less faith in the actual numbers that are being represented. Also, because these numbers are achieved under laboratory conditions, the correlation between how a unit performs in the field with cordwood versus in the lab with cribs is loose at best. This lack of correlation between certification values in in-home emissions has been confirmed by a number of studies funded by the US EPA, US DOE, Environment Canada, Oregon DEQ, NYSERDA, and the Hearth, Patio and Barbecue Association.

Since the inception of the NSPS - consumers, manufacturers and laboratories have wanted to develop a cordwood test method that would provide the real world performance with repeatable results. This has proven to be problematic over the years but most all agree that if a repeatable, cordwood test method could be developed, it would be in everyone's best interest. It should be emphasized that if a cordwood test method is to ever be promulgated, the g/hr results would be completely different than from the current test method and that there will be little to no correlation to current emission limits. You could have the situation where you actually get better correlation of laboratory to real world results but the g/hr would be reported as higher, confusing the public even more.

Technological Issues:

Wood Stoves:

It is also important to recognize which wood fired residential heating appliances can reach the 2.5g/hr standard. The ADEC 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." A chart showing the size and BTU range of these 13% would be helpful to understand the current range of appliances that would be available to consumers.

Hydronic Heaters:

In reference to hydronic heaters, it was stated "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". Upon checking the web site, it was found that there were 8 pellet units and 6 cordwood appliances (14) that met the 2.5g/hr. proposed standard. Four (3 pellet and 1 stick) of those appliances could be used indoor or outdoor while the remaining were outdoor only. The max BTU for these pellet appliances was 179,458 BTU and the max BTU on these cordwood units was 200,645. Method 28WHH covers appliances that range up to 350,000 BTU. Adopting the 2.5 g/hr. standard could be problematic for the larger appliances until current technology can catch up. It should be noted that anything above 350,000 BTU is not covered under Method 28WHH as EPA considers these commercial and not residential appliances.

Indoor wood fired furnaces:

While it is not entirely clear if ADEC intends to include these appliances within the proposed standard, currently, indoor wood fired furnaces are exempt under the NSPS. It is widely believed that EPA will be requiring the certification of these units with the adoption of the NSPS currently under review. These appliances can be a significant source of $PM_{2.5}$ and there could be significant technological barriers to meeting the proposed ADEC standard. It will undoubtedly take manufacturers some time to have the technology catch up with the proposed ADEC standard that is significantly stricter than the proposed federal standard.

Conclusion:

We commend the ADEC for adopting lower emission standards in its efforts comply with $PM_{2.5}$. The g/hr. achieved in the laboratory make for a good comparison and starting point but is limited as to what can actually be said about how an appliance performs in the field.

Because of the number and variety wood stoves available, adopting the 2.5g/hr emission rate may be easier for wood and pellet stoves than hydronic heaters and wood-fired furnaces. Hydronic heaters having a limit of 200,000 BTU may be problematic for consumers. The technological barriers for developing cleaner burning hydronic heaters that cover the range of BTU output from 200,000 BTU to 350,000 BTU could be significant. It will more than likely take a few years for technology to catch up with the proposed 2.5 g/hr. standard for those larger units. Should ADEC also include indoor wood-fired furnaces then there will almost certainly be issues regarding the technological feasibility of these appliances to perform at the ADEC proposed limit of 2.5 g/hr. Additional time will be required by manufacturers to engineer cleaner burning appliances.

PEER REVIEW OF EMISSIONS STANDARDS FOR SPACE HEATING DEVICES IN ALASKA

December 2013

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PEER REVIEW OF EMISSIONS STANDARDS FOR SPACE HEATING DEVICES IN ALASKA

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1. INTRODUCTION

In December 2009, the U.S. Environmental Protection Agency (EPA) designated portions of the Fairbanks and North Star Borough (FNSB) as a non-attainment area for $PM_{2.5}$. $PM_{2.5}$ refers to fine particulates less than 2.5 microns in diameter that are produced as byproducts of fuel combustion and are breathed deeply into the lungs. Health effects studies have shown that exposure to fine particulates increases the risk of heart and lung disease and causes premature death. National ambient air quality standards for $PM_{2.5}$ were established to safeguard human health.

Under federal statutes, the Alaska Department of Environmental Conservation (ADEC) is required to adopt and submit a State Implementation Plan (SIP) to bring the Fairbanks area into attainment for $PM_{2.5}$ in accordance with a statutory time schedule. To support development of the SIP, ADEC and others have sponsored extensive monitoring and research to better quantify the emission sources and meteorological circumstances that contribute to exceedances of the 24-hour $PM_{2.5}$ standard. Multiple control measures will be needed to reach attainment.

For the SIP, ADEC proposes to adopt emission standards for wood stoves, pellet stoves, and outdoor hydronic heaters to limit emissions of fine particulates to 2.5 g/hr, which is more stringent than the current federal emission standard. ADEC has the authority under AS 46.14.010 (Emission Control Regulations) to establish emission standards that are more stringent than the corresponding federal standards, but before adopting a regulation it must:

(1) 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;

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

(3) prepare a written analysis of the economic feasibility of the proposal.

ADEC must also follow the procedure in AS 46.14.015 (Special Procedure For More Stringent Regulations) that requires the department to submit the findings to a peer review by independent parties and to make the written findings available to the public at locations around the State.

I was selected as an independent party to review the written finding with respect to the <u>impacts and effects of meteorology and wood smoke from space heating</u>. I have examined the Peer Review Draft* of the written finding entitled: Department Findings: The Need and Basis for More Stringent Wood-fired Heating Device Emissions Standards to determine whether ADEC has met the requirements of AS 46.14.010 (c)(1) and (d) with regard to the meteorological conditions that contribute to elevated $PM_{2.5}$ concentrations and exceedances.

This report provides my written comments and opinion on the Finding. Section 2 presents the peer review of the Finding with respect to meteorology. Section 3 presents a summary and my opinion, which is that ADEC has met its obligations under the Alaska statutes by demonstrating that meteorological conditions in the Fairbanks area reasonably require the proposed $PM_{2.5}$ emission limitation on wood-fired heating devices.

2. PEER REVIEW OF ADEC FINDING WITH RESPECT TO METEOROLOGY

The ADEC Finding addresses the need and basis for more stringent emission standards in four areas: (1) how meteorological conditions contribute to elevated $PM_{2.5}$ concentrations; (2) the necessity to protect human health; (3) technological feasibility; and (4) economic feasibility. The following review examines the first of these areas. It is presented in the form of six key questions and my answers.

1. Has ADEC correctly identified the meteorological factors that lead to high $PM_{2.5}$ concentrations in Fairbanks?

Yes. Fairbanks frequently experiences <u>strong surface inversions,</u> <u>calm winds,</u> and <u>very cold temperatures</u> that combine to produce high concentrations of $PM_{2.5}$ in the air. Cold surface temperatures lead to high rates of fuel consumption (mostly fuel oil and wood) to heat homes and businesses causing high emission rates for fine particulates. With a strong surface inversion (which prevents vertical dispersion of pollutants) and the near-absence of surface wind (which prevents horizontal dispersion), $PM_{2.5}$ concentrations can climb rapidly.

It has long been known that Fairbanks experiences some of the most severe meteorology of any major city due to its location in the Arctic. Dr. Carl S. Benson – now Faculty Emeritus at the Geophysical Institute (University of Alaska Fairbanks) – conducted some of the early research on climatic and meteorological factors causing Arctic air pollution. In one paper, he describes the meteorological challenge in Fairbanks as follows:

> "… the two requirements for air pollution are: 1) the availability of pollutants, and 2) a restriction in the volume of air which dissolve these pollutants. Conditions controlling the latter requirement vary widely from place to place

* Hereinafter referred to as the Finding.

because they depend on meteorologic and topographic factors. The most stable atmospheric conditions occur under and within inversion layers.

"… temperature inversions form at ground level when there is a net loss of heat from the earth's surface by outgoing longwave radiation.* The radiative balance between the surface and the air aloft causes this cooling to proceed upward in the air as described in detail by Wexler (1936). These inversions become especially well developed at night over snow surfaces and are common both day and night in parts of the Arctic and Antarctic. Unfortunately, they are also common in Fairbanks.

"The rate of change of temperature within the inversion layer, i.e., the 'steepness,' or 'strength,' of the inversion, is also important because the stability of the air increases with it. The steepness of radiative inversions increases as topographic features restrict low level air motion. Thus, the strongest inversion measured at the South Pole was 9.65°C/100 m at 2315 GMT on 21 April 1958; this is a strong inversion, but the inversions measured during cold spells at Fairbanks are among the steepest in the world with values of 10 to 30°C/100 m common in the first 50 to 100 m. These different ranges of values can be attributed to topography. The South Pole area is essentially a flat plateau; Fairbanks is surrounded by hills on three sides which permits stagnant air to form at low levels similar to the situation in the Los Angeles Basin." (Benson 1970, p. 9)

Fairbanks experiences frequent surface inversions – among the strongest in the world including the South Pole – during cold spells in the winter as a result of its Arctic location and the local topography. When a surface inversion sets up in clear, cold weather, it creates a "meteorological dome" over the city which impedes the dispersal of pollutants. And this often occurs when emission rates are highest. These are the meteorological reasons why Fairbanks experiences high $PM_{2.5}$ concentrations during the winter.

2. Are meteorological circumstances in Fairbanks more severe than in the Lower 48?

Yes. In fact, they are much more severe. To compare Fairbanks with locations in the Lower-48 States, three other wintertime $PM_{2.5}$ non-attainment areas were selected:

- Salt Lake City, UT. Salt Lake City and nearby communities form a cluster of $PM_{2.5}$ non-attainment areas in the northwestern portion of Utah. These locations, at higher elevations in the arid West, are analogous to Fairbanks in

* Dry air is highly transparent to infrared ("longwave") radiation and Arctic atmospheres are often very dry. In radiative cooling, infrared radiation is emitted by the Earth's surface and carries heat out to the deep-cold of outer space.

that they can experience surface temperature inversions due to radiative cooling.

- Pittsburg, PA. Pittsburg and nearby cities form a cluster of $PM_{2.5}$ non-attainment areas in the western portion of the State. Terrain is a prominent factor here; the Pennsylvania air agency notes that the tall ridges and deep river valleys characteristic of this area are effective in trapping emissions within the valleys.
- Seattle-Tacoma, WA. Pierce County is classified as a $PM_{2.5}$ non-attainment area based on monitor readings in South Tacoma. The Seattle-Tacoma metropolitan area has a marine climate and experiences a different type of inversion, in which warm, moist marine air flows over colder air at the surface.

For surface temperature, it is no surprise that Fairbanks is much colder than any of the other cities (see Exhibit 1). While both Salt Lake City and Pittsburgh can experience cold temperatures, their record minimum temperatures are much less severe than in Fairbanks and their average minimum winter temperatures are much milder. In fact, the temperatures that count as record cold in these cities are common occurrences in Fairbanks during winter. Fairbanks also experiences many more days below freezing (more than one-half of the year) than either Salt Lake City or Pittsburgh. Seattle-Tacoma enjoys a mild climate in comparison to all of the other cities.

Exhibit 1. Comparison of Temperatures in Fairbanks and Three Winter Non-Attainment Areas in the Lower-48 United States

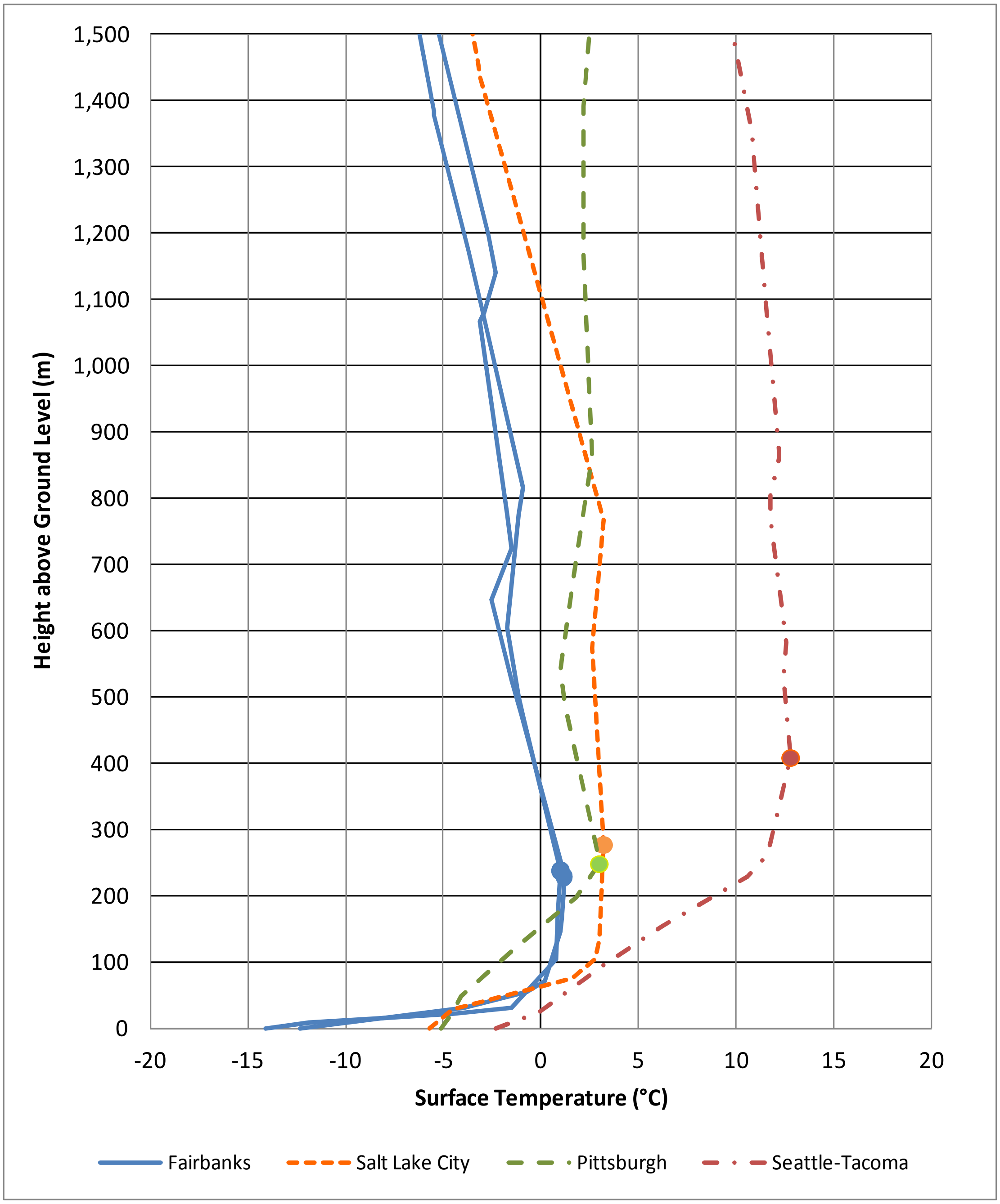
	Fairbanks, AK	Salt Lake City, UT	Pittsburgh, PA	Seattle-Tacoma, WA
Record Minimum Temperature	-62°F	-30°F	-22°F	0°F
Coldest Minimum Monthly - Average Temperature in Winter	-17°F	22°F	22°F	36°F
Average Number of Days below Freezing (Annual)	222	121	120	29

Source: Comparative Climate Data – United States. Golden Gate Weather Services http://ggweather.com/ccd/

For inversion strength, ADEC presents data that illustrate the much stronger surface lapse rates in Fairbanks compared to Salt Lake City (Finding, p. 12-13). To extend this comparison, upper air soundings for the past winter, taken by the National Weather Service (NWS) at airports located in or near each city, were reviewed to identify specific examples that are representative of the strongest inversions typically experienced. Exhibit 2 plots the air temperature profiles for the selected soundings.

Exhibit 2. Comparison of Inversion Strength in Fairbanks and Three Winter Non-Attainment Areas in the Lower-48 United States.

Representative strong inversions were selected from NWS upper air soundings during the period October 2012 through March 2013. Air temperature profiles are plotted versus height above ground to allow direct comparison across areas. The top of the surface inversion is marked with a filled circle.



In the plot of air temperature profiles, a surface inversion is noted by the rightward slope of the temperature line from the surface to the top of the inversion (marked by filled circles). The more horizontal the line, the more quickly the air warms above the surface and the stronger is the inversion. While air temperatures at the top of the inversion (200-300m above the ground) are similar for Fairbanks, Salt Lake City and Pittsburgh, the surface temperature is much colder in Fairbanks and the temperature profile near the surface is nearly horizontal. The temperature profiles for the other cities rise more vertically.

This is the characteristic difference between inversions in Fairbanks and Lower-48 locations. The nearly-complete absence of sunshine in mid-winter coupled with clear skies and bone-dry Arctic air permit rapid radiative cooling of the surface, pulling surface temperatures well below that of the air above. Pollutants emitted from homes and businesses are trapped very close to the surface and concentrations can rise to high levels.

Exhibit 3 presents supporting data for the plot of temperature profiles and additional information regarding inversion strength and frequency of occurrence. The average lapse rate is computed from the temperature difference between the surface and the top of the inversion. On this measure, the Fairbanks inversions are about twice as strong as those in the other cities. The surface lapse rate is computed between the surface and a height of 20-30 m. Here, the difference among the cities is dramatic. The surface lapse rate in Fairbanks exceeds 25°C/100 m in both soundings, while it is below 10°C/100 m for all of the other cities.

Exhibit 3. Supporting Data for Soundings Selected From Winter 2012-2013

	Fairbanks, AK		Salt Lake City, UT	Pittsburg, PA	Seattle-Tacoma, WA
Date	03 Feb 2013	04 Feb 2013	8 Feb 2013	8 Jan 2013	19 Jan 2013
Sounding					
Time (GMT)	12Z	00Z	12Z	12Z	12Z
Location (IATA code)	FAI	FAI	SLC	PIT	UIL
Inversion Height (m)	283	324	278	247	405
Average Lapse Rate (°C per 100m)	6.3	5.9	3.2	3.3	3.7
Surface Lapse Rate (°C per 100m)	27.5	27.1	4.4	2.5	9.6
Winter 2012-2013 Statistics					
Frequency of Inversion (% of days during winter)	64%		40%	38%	24%
Longest Inversion Period (consecutive days)	11		2	7	1

Inversions are also more frequent in Fairbanks, being present nearly two-thirds of the time during the past winter (see Winter 2012-2013 Statistics in Exhibit 3). Further, inversion conditions can persist for extended periods in Fairbanks, the longest during the past winter being 11 days. Of the other cities, only Pittsburgh comes close with a longest episode of 7 days, while Salt Lake City and Seattle-Tacoma had longest episodes of 2 and 1 days. The latter is more typical in the Lower-48 States, where inversions can set up overnight but will usually breakdown the next day when sunshine heats the ground. Inversions that set up in Fairbanks during mid-winter often persist for many days.

3. Does ADEC correctly describe how cold temperatures combine with strong surface inversions to create high $PM_{2.5}$ concentrations?

Yes. The presence of a strong surface inversion will first slow and then halt the natural tendency of pollutants emitted near ground level to rise and disperse into the atmosphere. The tendency to rise is driven by the buoyancy of the warm exhaust emitted from chimneys, flues, and other sources. Its warmth (and low density) causes it to rise, which causes it to expand and cool. When an inversion is present, the air parcel will continue to rise and cool until its density becomes greater than that of the warmer air aloft, at which point it will stagnate. When the atmosphere warms rapidly with increasing height, the point of stagnation will be close to the surface. The presence of a strong inversion also calms surface winds.

As a result, the temperature inversion impedes the dispersion of air pollutants vertically and horizontally. When the surface air temperature is also very cold, emission rates from sources are highest as fuel oil, wood and other fuels are burned at increased rates for space heating. Recurring weather systems lead to the combination of cold temperatures and strong surface inversions, causing $PM_{2.5}$ conditions to rise to high levels many times during the winter.

4. Is the $PM_{2.5}$ problem in Fairbanks really as simple as the combination of cold temperatures, low winds and strong surface inversions?

Not entirely, because meteorology is complex, as are the processes of pollutant generation and transport. But the combination of cold temperatures, low winds and strong inversions is far and away the largest meteorological contributor. Because the problem is complex, ADEC's attainment planning has relied extensively on the Community Multiscale Air Quality Model (CMAQ) – a state-of-the-art photochemical air quality model approved by EPA for SIP analysis – to simulate how all of the relevant factors come together to determine $PM_{2.5}$ concentration levels.

One example of the meteorological complexity is the potential for a capping inversion, where warmer air moves into the area to create a warm air layer above a colder air mass at the surface. Before this happens, the surface temperature can be relatively mild and the surface inversion may have only a modest strength. However, the strengthening of the inversion at the boundary between the air masses increases the effective trapping and causes $PM_{2.5}$ concentrations to increase. In Fairbanks, a capping inversion can be created by a southerly "Chinook flow" that strengthens the inversion and causes the mixing height to lower. (Brader 2009)

5. Is the meteorology of the recent period unusual – i.e., could a return to more normal conditions in the future improve the $PM_{2.5}$ problem?

No. The recent period has had relatively normal meteorology. As ADEC shows (Finding, p. 4), there are some years where favorable meteorology leads to a lower design value (a standardized measure of the severity of $PM_{2.5}$ problem), but this is not a common occurrence and not one that can be counted on. In other years, more typical or even adverse meteorology leads to a higher design value. Barring a dramatic change in climate over the next century, Fairbanks will continue to experience severely cold surface temperatures and strong surface inversions because of its inland location in the Arctic and the local topography.

6. Why does the severe meteorology experienced in Fairbanks imply the need for the State to set more stringent emission standards for wood-fired heating devices?

Wood-fired space heating devices – predominantly wood/pellet stoves and hydronic heaters – are used by a growing number of Fairbank residents to heat homes and businesses. As ADEC notes, "… 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, 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." (Finding, p. 6) Research has shown that wood smoke is "… 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." (Ward 2012, abstract)

Analysis conducted for the SIP demonstrates that the change-out of wood-fired equipment to EPA-approved devices will not solve the problem, even when EPA's new and more stringent proposed emission standards are considered. (Finding, p. 10) Because of the need to retain wood as a backup for cold temperatures, natural gas is not a solution on its own. (ADEC 2013, p. 13) Therefore, it is necessary to go beyond the EPA standards to reduce emissions from wood-burning devices and bring Fairbanks into attainment with the 24-hour $PM_{2.5}$ standard.

3. SUMMARY AND OPINION

The climate and topography of Fairbanks create recurring periods each winter when a "meteorological dome" is placed over the area. The combination of <u>very cold temperatures</u>, <u>strong surface inversions,</u> and <u>calm winds</u> causes fine particulates to accumulate in the air near the surface. Cold surface temperatures lead to high rates of fuel consumption and emissions of fine particulates, with wood-burning space heating devices being the single largest source. Strong surface inversions prevent vertical dispersion of pollutants, while calm winds prevent horizontal dispersion. In these conditions, $PM_{2.5}$ concentrations climb rapidly and can easily exceed the 24-hour standard.

ADEC has correctly described the meteorological conditions experienced in the Fairbanks area in the Finding. In fact, Fairbanks experiences some of the most severe meteorology of any major city due to its inland Arctic location and the local topography.

In my opinion, ADEC has demonstrated that meteorological conditions in the Fairbanks area reasonably require the proposed $PM_{2.5}$ emission limitation on wood-fired heating devices. Therefore, ADEC has met its obligations under AS 46.14.010 (c)(1) and (d).

4. REFERENCES

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