Alaska Department of Environmental Conservation

Preliminary Draft

Residential Fuel Expenditure Assessment of a Transition to Ultra-Low Sulfur Heating Oil for the Fairbanks PM-2.5 Serious Nonattainment Area

March 22, 2018

Prepared by

The Alaska Department of Environmental Conservation Economist in collaboration with the University of Alaska Fairbanks Master of Science Program in Resource and Applied Economics.

Table of Contents

Executive Summary ……………………...……………………………………….…………..vi

Introduction ……………………...………………………………………………...……......1

Section 1:Fuel Costs……………...……………………………………….……...…...…1

1.1 Fuel Cost Overview.………………………...………………………………..………1

1.1.1 OPIS Fuel Price Data.………………………………………………………......4

1.2 Fuel Cost Trends and Differentials………………………………………………..….4

1.3 Fuel Differentials Summary……………………………………………………..…...13

1.4 Fuel Cost Conclusions………………………………………………………......…...14

Section 2: Household Expenditure Scenarios: Cost Analysis…………...……………………..…..15

2.1 Household Heating Oil Expenditure Changes from ULS…………….…………...15

2.1.1 Household Heating Oil Consumption…………………………………...…....15

2.1.2 Price Elasticity of Demand………………………………………………...17

2.1.3 Net Present Value and Discount Rates……………………...………......18

2.1.4 ULS and High Sulfur Cost Differentials……………………………..….....18

2.1.5 Appliance Efficiency and Maintenance cost with ULA………………..….19

2.2 Heating Cost Model………………………………..……………………….……….20

2.3 Summary of Household Impact……………………………………..………...…...22

Conclusion……………………………………..…………………………………;………...22

References……………………………………………………………………….……….....23

Appendix A…...…………………………………………………………………..………...24

Appendix B…...…………………………………………………………………..………...24

Appendix C…...…………………………………………………………………..………...25

List of Figures

Figure 1: Crude Oil & Refined Diesel Prices, Dollars per Gallon……………………………………..2

Figure 2: Alaska Fuel Price Comparison, Dollars per Gallon………………………...………..3

Figure 3: Anchorage Distillate Cost Comparison, Dollars per Gallon……………………………5

Figure 4: Anchorage Price Differential ULS No. 1 & HS No. 1, Dollars per Gallon…………....7

Figure 5: Fairbanks Distillate Cost Comparison, Dollars per Gallon…………………………....8

Figure 6: Fairbanks Price Differential ULS No. 1 & HS No. 1, Dollars per Gallon……….....…10

Figure 7: Fairbanks Price Differential ULS No. 1 & HS No. 2, Dollars per Gallon…………....12

Figure 8: Alaska ULS No. 1 Price Differentials, Dollars per Gallon……………………...….13

Figure 9: Buildup of Soot and Particulates on Heat Exchange Plates for Identical Boilers using Different Fuels…….……………………..…………………………...………………....19

List of Tables

Table 1: Anchorage Rack Pricing Differential per Gallon HS No. 1…………………………......6

Table 2: Fairbanks Rack Pricing Differential per Gallon HS No. 1………………………………9

Table 3: Fairbanks Rack Pricing Differential per Gallon HS No. 2…………………………......11

Table 4: Summary of Typical Annual Household Oil Only Use (gallons) by Appliance…………..………………………………………………………………16

Table 5: Summary of Typical Annual Central Oil - Wood Stove Appliance Household Consumption…………………………………………………………………………..16

Table 6: Summary of Heating Oil Cost Model Scenarios…………………………………….....21

Table 7: Estimated Expenditure Effects of ULS Fuel Transition on Typical FNSB Household……………………………………………………………….…………....21

Abbreviations

ADEC	Alaska Department of Environmental Conservation
BACM	Best Available Control Measure
BTU	British thermal unit
EIA	US Energy Information Agency
EPA	US Environmental Protection Agency
FSNB	Fairbanks North Star Borough
HS	High Sulfur
NPV	Net Present Value
OPIS	Oil Price Information Service
PSI	Petro Star, Inc.
PV	Present Value
SIP	State Implementation Plan
ULS	Ultra-low sulfur
US	United States

Executive Summary

In September 2017, the Alaska Department of Environmental Conservation (ADEC) Division of Air Quality requested the ADEC Economist to facilitate a research project regarding the evaluation of possible economic impacts of a potential PM-2.5 pollution control policy mandating a transition to ultra-low-sulfur (ULS) heating oil in the Fairbanks PM-2.5 Serious Nonattainment Area. The ADEC Economist worked on this research together with the University of Alaska, Fairbanks Master of Science Resource and Applied Economics Program Director and graduate students. This report is the outcome of the research conducted and provides an initial evaluation of the possible changes in home heating fuel expenditures for Fairbanks residents given a hypothetical requirement requiring a transition to ULS heating fuel.

Here we provide a summary of the key findings from each section of the analysis.

Section I: Fuel Costs

Important findings from the review of the incremental ULS price differentials, the additional cost to purchase ULS over high sulfur (HS), for both Anchorage and Fairbanks wholesale markets include:

- Since 2008-2010, the ULS price differential in Alaska has decreased significantly. Recent price data, however, indicate that the ULS price differential is increasing.
- From Oct. 2016 to Sep. 2017[1] the ULS No.1 to HS No.1 monthly price differentials for Anchorage range from 15-36 cents/gallon.
- The average ULS No.1 to HS No.1 price differential for Anchorage is 26.45 cents/gallon, a 14% price increase.
- Fairbanks ULS is more expensive than Anchorage, reflecting additional transport costs.
- The ULS No.1 to HS No.1 monthly price differentials for Fairbanks range from 22-44 cents/gallon over the last 12 months evaluated.
- The average ULS No.1 to HS No.1 price differential for Fairbanks is 33.64 cents/gallon, a 17% increase.
- In Fairbanks, there is a larger ULS price differential between ULS No.1 to HS No.2 than ULS No.1 to HS No.1, as HS No.2 tends to be cheaper relative HS No.1.
- The ULS No.1 to HS No.2 monthly price differentials for Fairbanks range from 31-53 cents/gallon over the last 12 months evaluated.
- The average ULS No.1 to HS No.2 price differential for Fairbanks is 42.74 cents/gallon, a 22% increase.

[1] This is the 12 month time frame evaluated. All 12 month average figures listed are calculated using OPIS price data from Oct. 2016 through Sep. 2017.

Section II: Fuel Costs

Important findings from the analysis of how fuel price differences found between fuel types potentially affect household heating expenditures for Fairbanks residential households include:

- Based on the survey data collected for the time period 2011-2015 approximately 40% of respondent households reported having a central oil fired in the household.
- Households using a central oil boiler with no other reported appliances reported using an average of 1,254 gallons of fuel oil.
- Price differentials of $0.34 and $0.43 cents/gallon were used to represent the difference between HS No.2 and ULS fuel prices.
- Assuming price differentials of $0.34 and $0.43 cents/gallon, an average annual fuel usage of 1,254 with a cross-price elasticity of -0.2[2], 50% of FNSB households would see an expenditure increase of $327.28 or $409.29, respectively for the first year.
- The focus of this analysis is on the short run effects of HS No.2 to ULS fuel transition, highlighting the price insensitivity of household heating for FNSB residents compared to long run effects.

[2] The assumed rate of -0.2% is drawn from a study of home heating fuel demand conducted by Hirst, Goeltz, & Carney (1982) and implies that a 1% increase in the price of home heating oil will decrease the quantity demanded by 0.2%.

Introduction

When EPA reclassified the Fairbanks PM-2.5 Nonattainment Area from a Moderate to a Serious Area, it triggered the requirement for ADEC to conduct a Best Available Control Measure (BACM) analysis. The BACM analysis looks at control measures implemented in State Implementation Plans to control PM-2.5. This analysis was conducted as a part of the BACM process. This report provides information on potential changes in residential home heating expenditures if there was a requirement to switch to ultra-low sulfur (ULS) heating oil in the Fairbanks PM-2.5 Nonattainment Area. *Section I* inspects the fuel cost differences between ULS and current heating fuels, high sulfur (HS) No.1 or No.2. *Section II* looks at how price differences found between fuels would affect household heating expenditures for the typical Fairbanks North Star Borough (FNSB) household.

This report presents a simple analysis on possible changes to household expenditures which may arise from a conversion to ULS heating oil. The analysis does not address any potential changes in household preferences and behaviors regarding home heating, nor does the assessment address other economic impacts which may arise from possible transition.

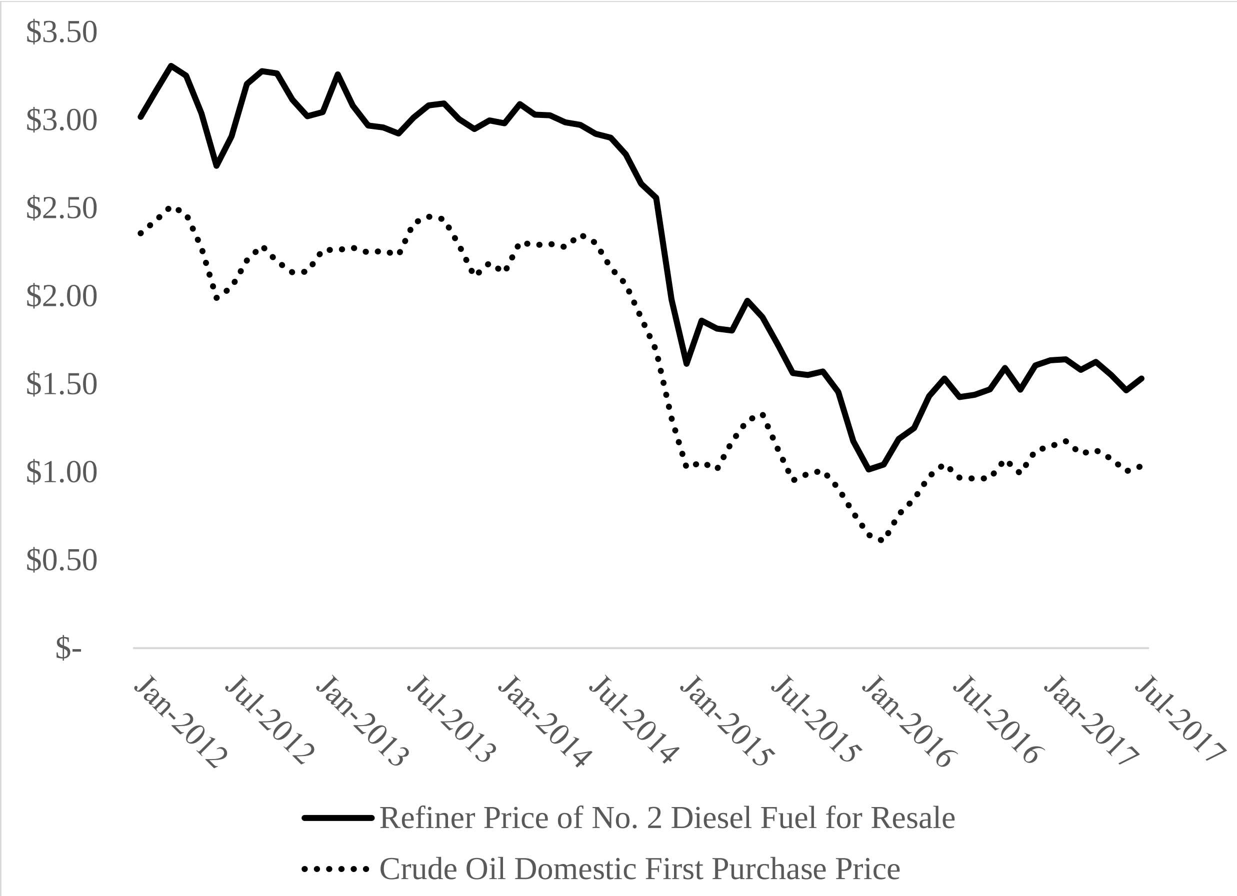
Section I: Fuel Costs

The purpose of this section is to estimate the cost effect of switching to ultra-low sulfur (ULS) heating oil in the Fairbanks PM-2.5 Nonattainment Area. We estimate the incremental price difference between the proposed ULS No.1 and heating fuel products currently used, high sulfur (HS) No.1 and No.2. This task is completed by analyzing the Oil Price Information Service (OPIS) data to determine fuel cost differentials.

1.1 Fuel Cost Overview

To fulfill our objective of developing a ULS fuel price estimate, it is beneficial to review current distillate fuel price structures. The price of refined distillate fuels generally follows the price of crude oil, which is driven by the global market, impacted by supply and demand, weather, transportation, geopolitical, and economic factors. In *Figure 1* we provide a comparison of Crude Oil and Retail Diesel No.2. This comparison depicts the price relationship between crude and refined fuels, as well as the overall decrease in the price of oil.

Figure 1: Crude Oil & Refined Diesel Prices, Dollars per Gallon



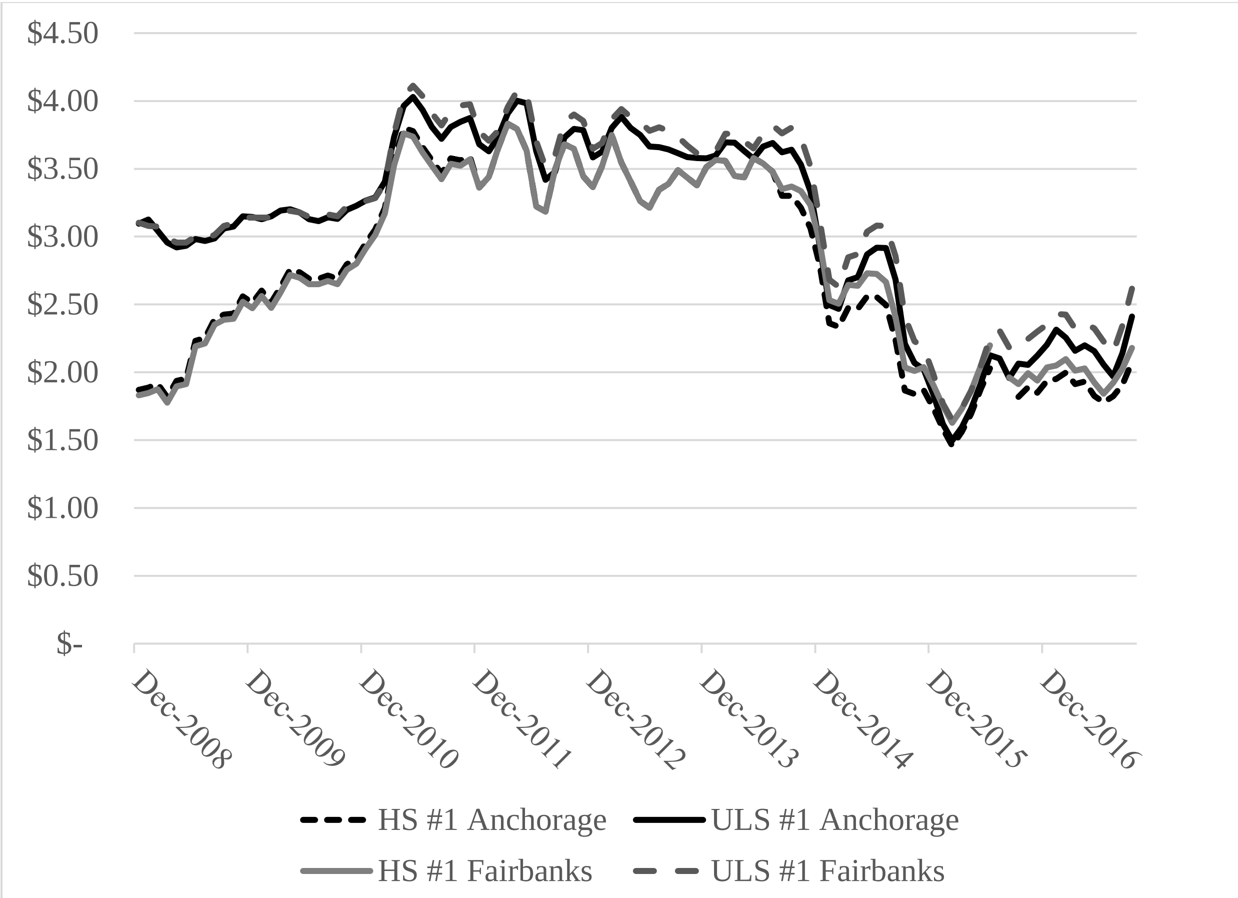
Source: Energy Information Administration (EIA), Energy Prices, October 2017[3]

In recent years, there has been a significant drop in crude oil prices. This can be viewed holistically as a change in the global market influenced by a large scale increase of US shale production (Institute for Energy Research (IER), 2016).

Alaska, compared to the continental US, is an isolated market with only five local refineries (two of which are located in Prudhoe Bay and supply fuel for crude oil drilling operations). Even as prices for refined distillate fuels and heating fuels have fallen, in Alaska these prices hover above the national average. In addition, fuel prices are higher in Fairbanks than in Anchorage as fuel needs additional shipping to get to its final destination (Northern Economics, 2007. p.15).

[3] https://www.eia.gov/totalenergy/data/monthly/#prices 9.1 Crude Oil Prices "Crude Oil Domestic First Purchase Price"…9.6 Refiner Prices of Petroleum Products for Resale "Refiner Price of No. 2 Diesel Fuel for Resale"

Figure 2: Alaska Fuel Price Comparison, Dollars per Gallon



Source: Alaska Department of Environmental Conservation, OPIS

Figure 2 above shows the price of HS No.1 in Anchorage, HS No.1 in Fairbanks, ULS No.1 in Anchorage, and ULS No. 1 in Fairbanks. These prices follow national market trends and reflect the price of crude oil. As a result, fuel prices in recent years are significantly lower than the 2011-2014 timeframe.

One notable exception in Alaska is that the ULS Price Differential, the additional premium to purchase ULS over HS, decreased significantly since 2008-2010. It is likely that, this can be attributed to increased ULS capacity, as new ULS capacity came online from Alaskan refineries. Beginning in 2008, Petro Star Inc. (PSI) invested $200 million to produce ULS at their Valdez refinery. In 2007, Andeavor (formerly known as Tesoro) invested $63 million and from 2010-2014 an additional $189 million to manufacture ULS fuel (Econ One Research, Inc., 2015. p.3). Recently, the ULS price differential has been increasing again.

In Fairbanks, ULS tends to be more expensive than Anchorage, which likely reflects the additional costs to transport fuel to this region. In section 1.2 and 1.3 we will explore the actual observed price differences in Fairbanks rack fuel prices over time and product type.

1.1.1 OPIS Fuel Price Data

The data reviewed consists of monthly non-weighted calendar day averages gathered by the Oil Price Information Service (OPIS). OPIS is the only provider of U.S. spot, rack, and retail prices. OPIS is known for having a defined methodology for the collection of fuel price data. Rack price data used represents market wholesale terminal prices ("*Our Spot Market Pricing Methodology*" , 2018).

This analysis focuses on Fairbanks rack fuel prices. Unless otherwise noted, we are referring to Fairbanks wholesale fuel price data. The way data are used in this analysis is static. We look at the realm of where market prices have been in order to develop an estimate of the incremental cost difference between fuel types.

All prices are listed in nominal terms and have not been adjusted for inflation. This price data does not include taxes or the final transportation cost that occurs when the fuel is shipped from the wholesale terminal to the end user. Months for which there are missing values have been dropped. In cases where there are missing values, this is likely due to the product not being sold in that market within the given time frame.

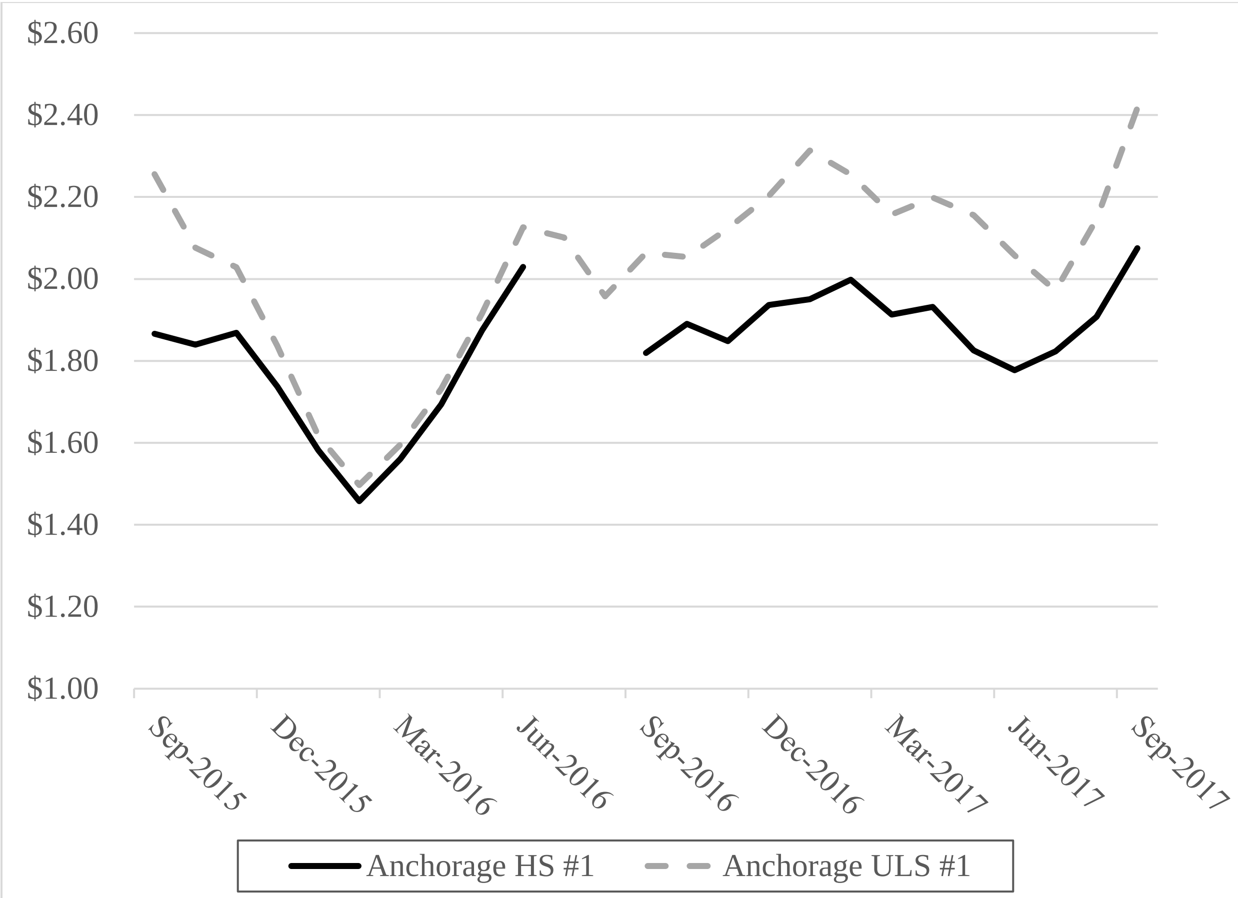
A critical benefit of using OPIS data is that it represents the market price. Market price in economics is the price at which an asset is bought or sold. This type of data is of value as it reflects the actual prices in the given market. Use of market price adds credibility to our price differential estimates.

1.2 Fuel Cost Trends

To develop estimates of the price difference between ULS and HS fuel we conducted a review of current pricing. We focus on a comparison of HS to ULS fuel prices, as the prospective policy scenario evaluated here, would require a transition to ULS to fulfill EPA's sulfur content requirements for a PM-2.5 control measure. The aim of this exercise is to understand the cost difference between fuel types and gauge fiscal impact on Fairbanks' households under this scenario. We review Anchorage prices to provide background information should the purchase of Anchorage fuel and rail transport to Fairbanks be necessary.

We reviewed the price data by taking the non-weighted monthly average prices for Anchorage and Fairbanks and calculated the price differentials between ULS and HS for each location. We first detail the fuel price differential between ULS No.1 and HS No.1 for Anchorage (*Table 1*) and then cover Fairbanks. For Fairbanks, we compute the price differential between both ULS No.1 and HS No.1 (*Table 2*) as well as ULS No.1 and HS No.2 (*Table 3*).

Figure 3: Anchorage Distillate Cost Comparison, Dollars per Gallon



Source: Alaska Department of Environmental Conservation, OPIS

Figure 3 provides a visual representation of wholesale rack fuel prices in Anchorage over the past 16 months. As expected, there is a premium for ULS fuel. ULS production in Alaska is limited and requires additional resources to produce (Econ One Research, Inc., 2015).

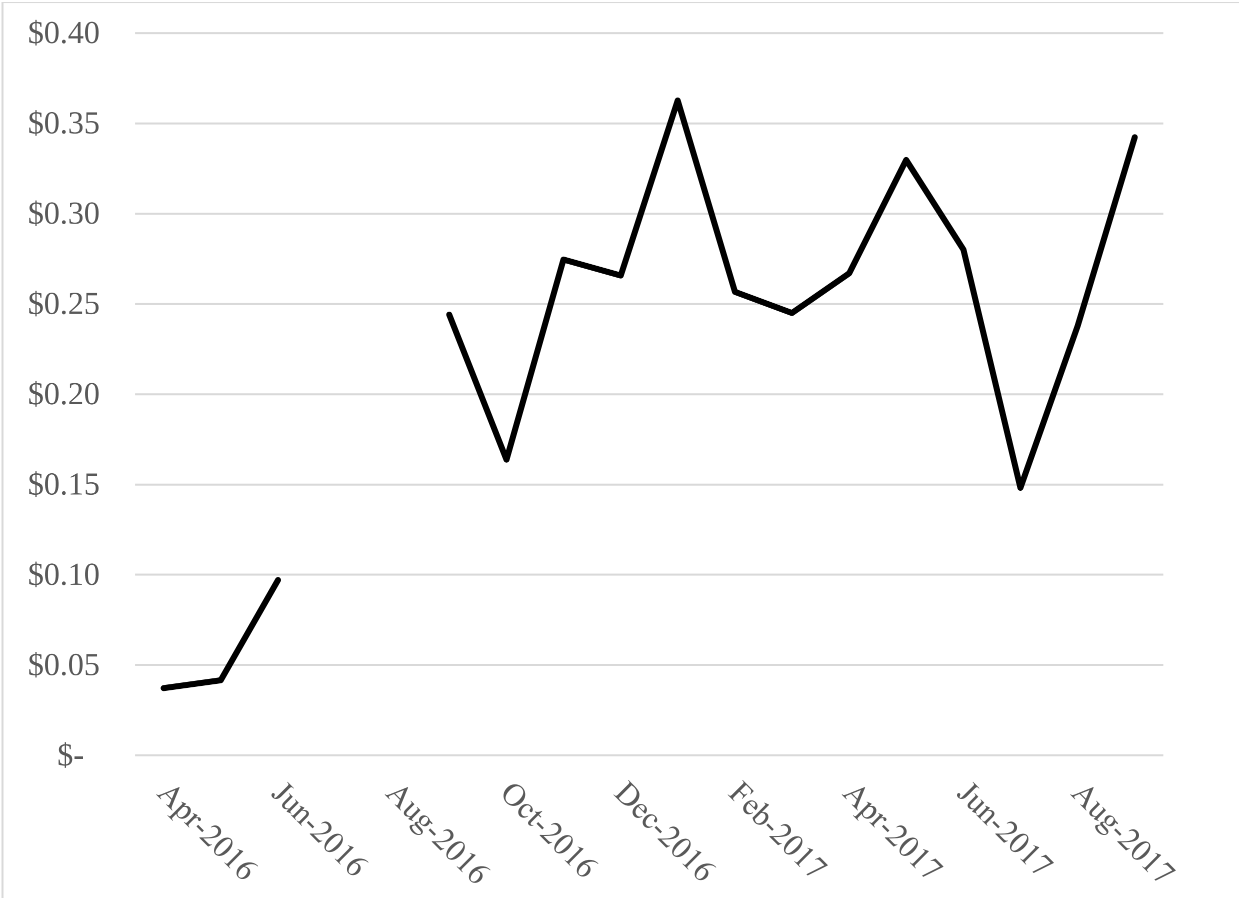
Table 1: Anchorage Rack Pricing Differential per Gallon HS No. 1

Month	ULS No. 1	HS No. 1	Price Spread ($)	Price Increase (%)
Apr 2016	1.7310	1.6938	0.0372	2.20
May 2016	1.9161	1.8746	0.0415	2.21
Jun 2016	2.1259	2.0289	0.0970	4.78
Jul 2016	2.1008			
Aug 2016	1.9574			
Sep 2016	2.0635	1.8195	0.2440	13.41
Oct 2016	2.0538	1.8900	0.1638	8.67
Nov 2016	2.1227	1.8481	0.2746	14.86
Dec 2016	2.2024	1.9367	0.2657	13.72
Jan 2017	2.3131	1.9504	0.3627	18.60
Feb 2017	2.2546	1.9979	0.2567	12.85
Mar 2017	2.1576	1.9126	0.2450	12.81
Apr 2017	2.1990	1.9320	0.2670	13.82
May 2017	2.1557	1.8259	0.3298	18.06
Jun 2017	2.0573	1.7773	0.2800	15.75
Jul 2017	1.9715	1.8233	0.1482	8.13
Aug 2017	2.1452	1.9074	0.2378	12.47
Sep 2017	2.4173	2.0750	0.3423	16.50
12 Month Average	**2.1709**	**1.9064**	**0.2645**	**13.85**

Source: Alaska Department of Environmental Conservation, OPIS

Table 1 provides Anchorage price differentials by month for ULS No.1 in comparison to HS No.1. From Oct. 2016 to Sep. 2017, the 12 month average fuel price differential is 26.45 cents/gallon. This represents an average price differential of 13.85%. The average monthly ULS No.1 price differential for during this annual time frame ranges from 15-34 cents/gallon.

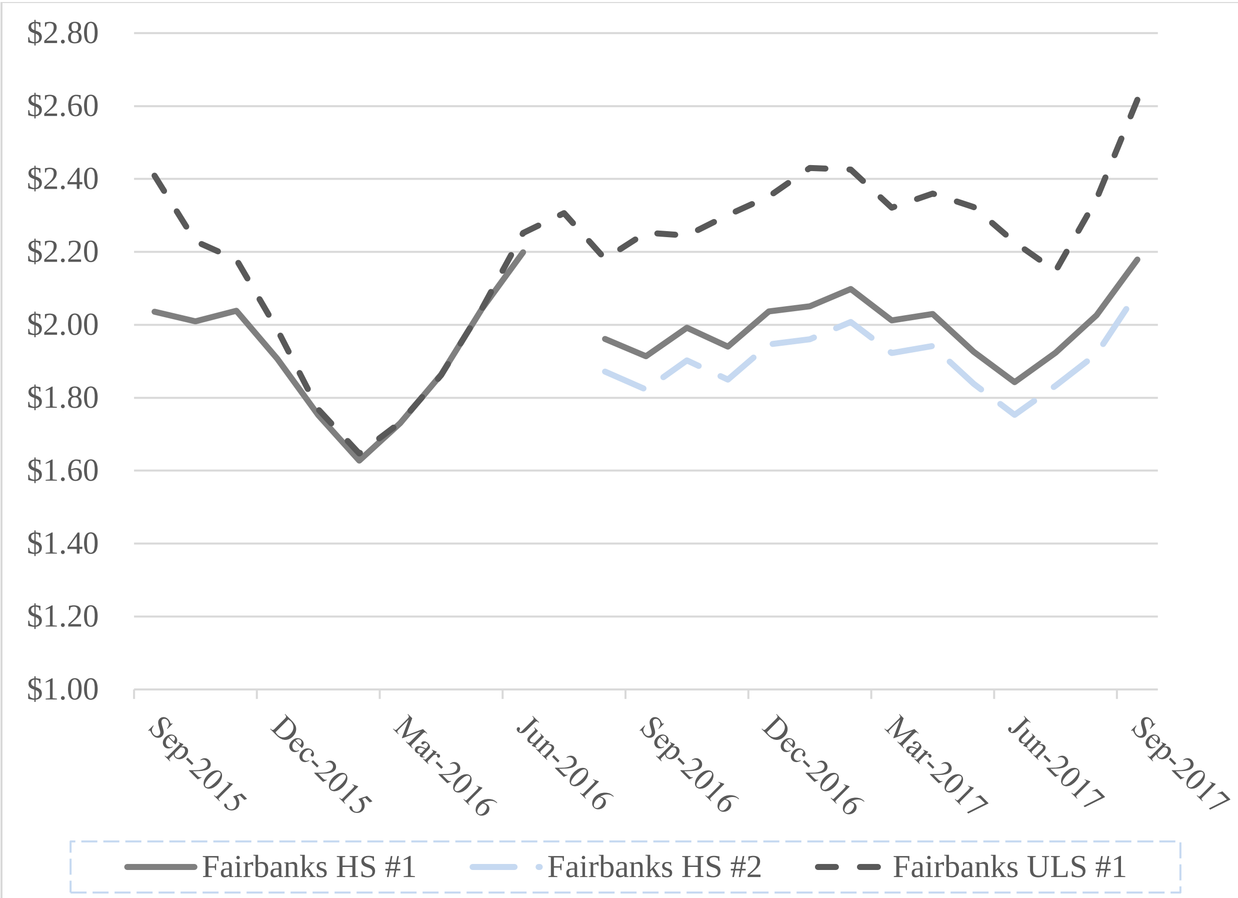
Figure 4: Anchorage Price Differential ULS No. 1 & HS No. 1, Dollars per Gallon



Source: Alaska Department of Environmental Conservation, OPIS

Figure 4 graphically depicts the fuel price differential (detailed in *Table 1*) for the Anchorage wholesale market. Price differences range from a low of 4.15 cents/gallon to a high of 36.27 cents/gallon with a 16 month average differential of 22.46 cents/gallon. In late 2016 a considerable increase in the price spread between ULS No.1 and HS No.1 occurred. The following set of *Figures* and *Tables* will explore the fuel price differential for the Fairbanks wholesale market.

Figure 5: Fairbanks Distillate Cost Comparison, Dollars per Gallon



Source: Alaska Department of Environmental Conservation, OPIS

Figure 5 provides a visual representation of wholesale rack fuel prices in Fairbanks over the past 25 months. As expected, there is a premium for ULS fuel. It is notable that this differential between ULS No.1 and other fuel types has risen sharply since the summer of 2016. Since the price difference between HS No.1 and HS No.2 is significant we take this into account through further analysis of each fuel type and develop specific scenarios that take into account HS No.1 and HS No.2 fuel usage.

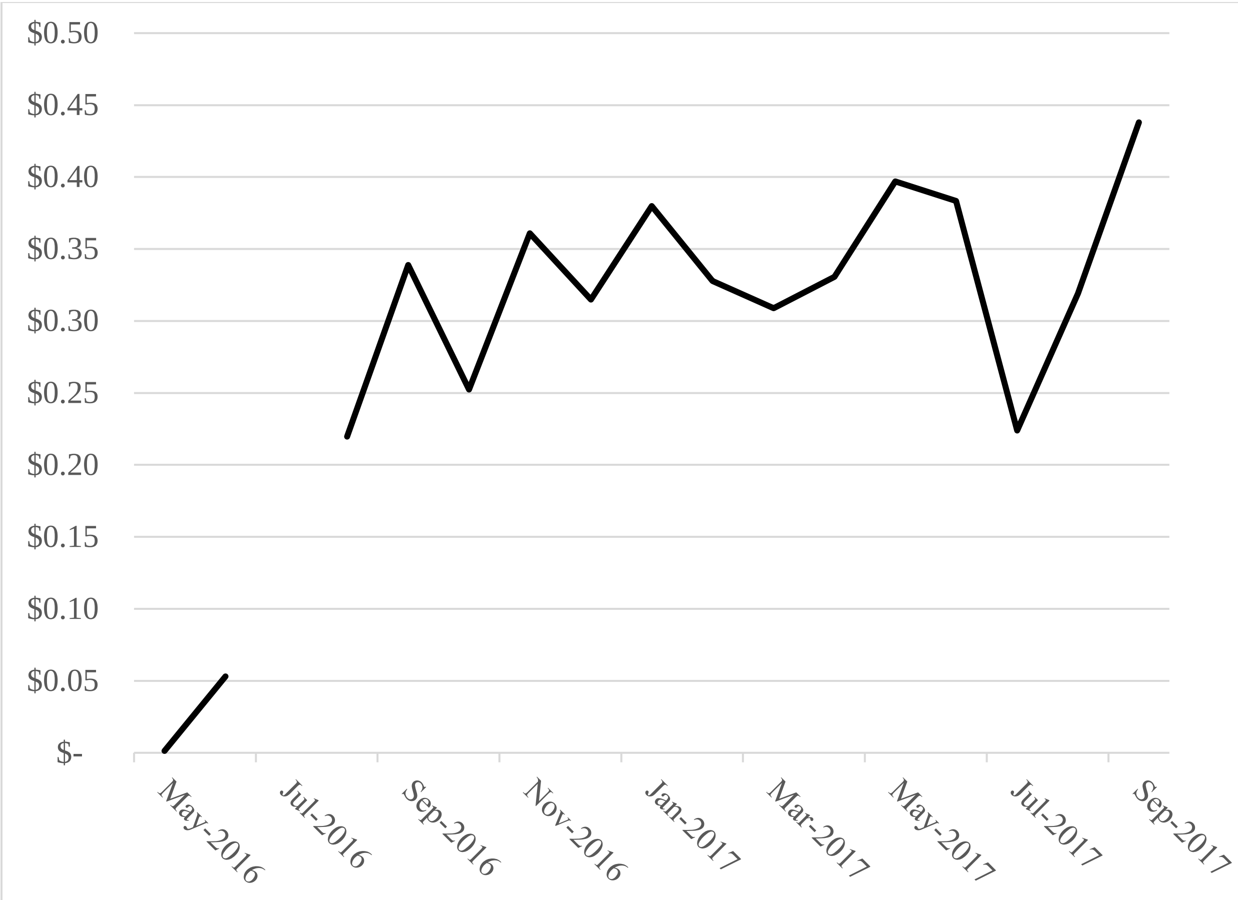
Table 2: Fairbanks Rack Pricing Differential per Gallon HS No. 1

Month	**ULS No. 1**	**HS No. 1**	**Price Spread ($)**	**Price Increase (%)**
May 2016	2.0459	2.0446	0.0013	0.06
Jun 2016	2.2519	2.1989	0.0530	2.41
Jul 2016	2.3065			
Aug 2016	2.1810	1.9614	0.2196	11.20
Sep 2016	2.2529	1.9140	0.3389	17.71
Oct 2016	2.2446	1.9923	0.2523	12.66
Nov 2016	2.3010	1.9400	0.3610	18.61
Dec 2016	2.3516	2.0367	0.3149	15.46
Jan 2017	2.4303	2.0504	0.3799	18.53
Feb 2017	2.4256	2.0979	0.3277	15.62
Mar 2017	2.3215	2.0126	0.3089	15.35
Apr 2017	2.3602	2.0296	0.3306	16.29
May 2017	2.3228	1.9259	0.3969	20.61
Jun 2017	2.2266	1.8431	0.3835	20.81
Jul 2017	2.1473	1.9233	0.2240	11.65
Aug 2017	2.3454	2.0263	0.3191	15.75
Sep 2017	2.6172	2.1792	0.4380	20.10
12 Month Average	**2.3412**	**2.0048**	**0.3364**	**16.79**

Source: Alaska Department of Environmental Conservation, OPIS

Table 2 provides Fairbanks price differentials by month for ULS No.1 in comparison to HS No.1. From Oct. 2016 to Sep. 2017, the 12 month average fuel price differential is 33.64 cents/gallon, which represents an average premium of 16.79% for ULS No.1 over HS No.1. The average monthly ULS No.1 price differential is during this time frame is consistently in the 30-39 cents/gallon range. However, there is a noticeable increase in the fall of 2017.

Figure 6: Fairbanks Price Differential ULS No. 1 & HS No. 1, Dollars per Gallon



Source: Alaska Department of Environmental Conservation, OPIS

Figure 5 graphically depicts the price differential of ULS No.1 to HS No.1 (detailed in *Table 2*) for the Fairbanks wholesale market. Price differences range from a low of 0.13 cents/gallon to a high of 44.8 cents/gallon with an average difference of 29.1 cents/gallon.

Table 3: Fairbanks Rack Pricing Differential per Gallon HS No. 2

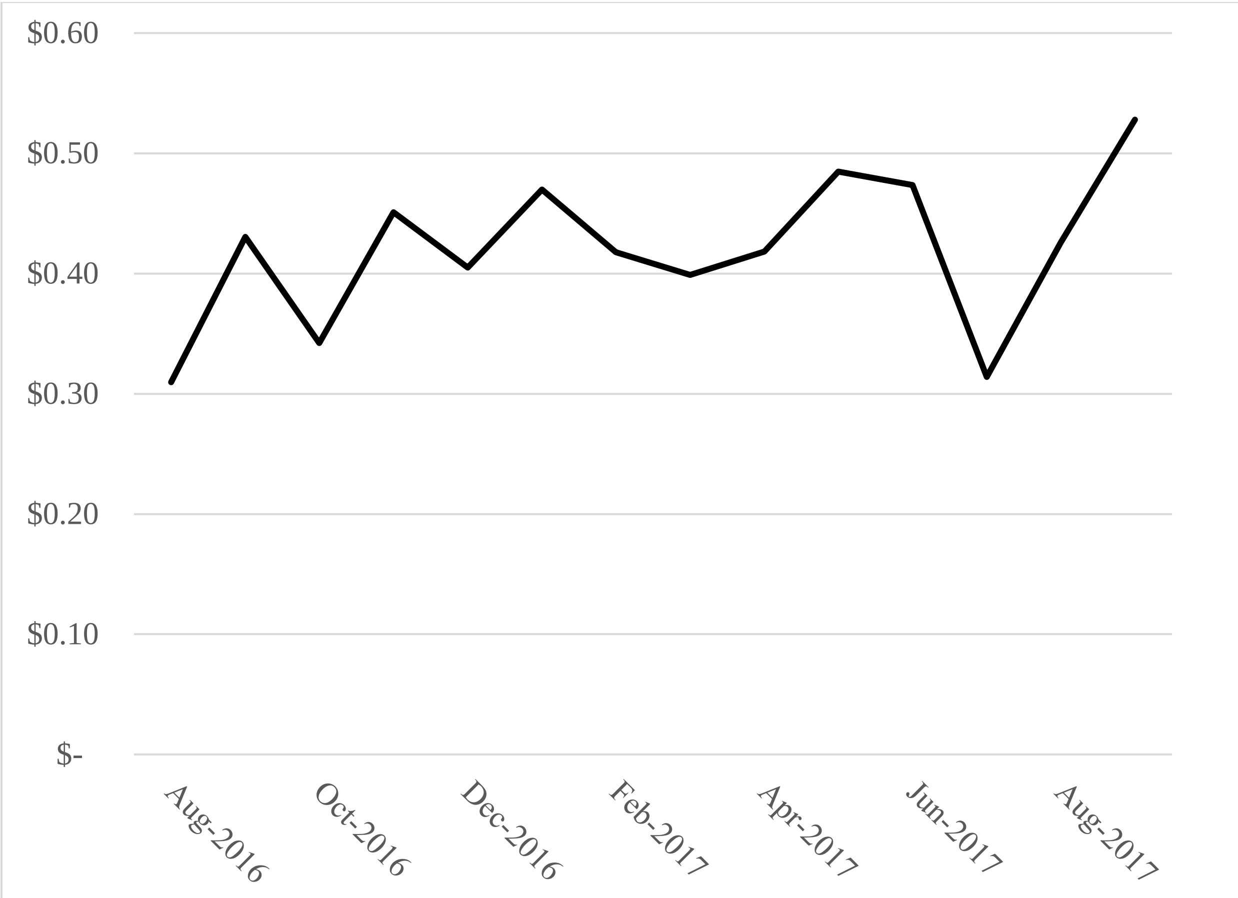
Month	ULS No. 1	HS No. 2	Price Spread ($)	Price Increase (%)
May 2016	2.0459			
Jun 2016	2.2519			
Jul 2016	2.3065			
Aug 2016	2.1810	1.8714	0.3096	16.54
Sep 2016	2.2529	1.8225	0.4304	23.62
Oct 2016	2.2446	1.9023	0.3423	17.99
Nov 2016	2.3010	1.8500	0.4510	24.38
Dec 2016	2.3516	1.9467	0.4049	20.80
Jan 2017	2.4303	1.9604	0.4699	23.97
Feb 2017	2.4256	2.0079	0.4177	20.80
Mar 2017	2.3215	1.9226	0.3989	20.75
Apr 2017	2.3602	1.9420	0.4182	21.53
May 2017	2.3228	1.8381	0.4847	26.37
Jun 2017	2.2266	1.7531	0.4735	27.01
Jul 2017	2.1473	1.8333	0.3140	17.13
Aug 2017	2.3454	1.9196	0.4258	22.18
Sep 2017	2.6172	2.0892	0.5280	25.27
12 Month Average	**2.3412**	**1.9138**	**0.4274**	**22.35**

Source: Alaska Department of Environmental Conservation, OPIS

Table 3 provides Fairbanks price differentials by month for ULS No.1 in comparison to HS No.2. HS No.2 is also used for residential heating oil in Fairbanks; due to its lower price it has the largest price differential evaluated.

The fuel price differentials, from Oct. 2016 through Sep. 2017, period ranges from 31.40 to 52.8 cents/gallon. This results in a 12 month average price differential for ULS No.1 in comparison to HS No.2 in Fairbanks is 42.74 cents/gallon. This represents an average price differential of 22.35%.

Figure 7: Fairbanks Price Differential ULS No. 1 & HS No. 2, Dollars per Gallon



Source: Alaska Department of Environmental Conservation, OPIS

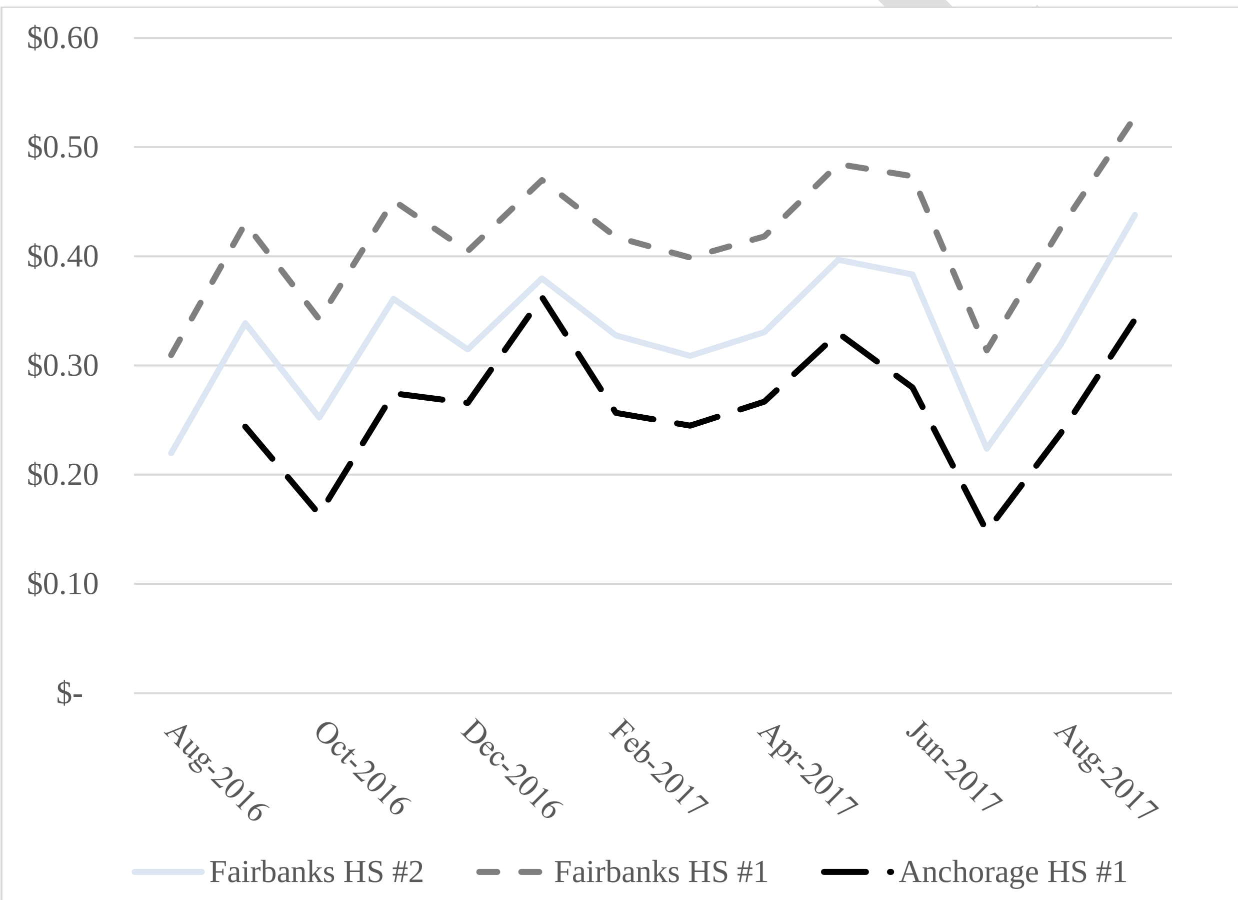
Figure 7 graphically depicts the ULS No.1 over HS No.2 fuel price differential (from *Table 3*) for the Fairbanks wholesale market. The monthly price differentials range from a low of 30.96 cents/gallon to a high of 52.8 cents/gallon, with an average difference of 42.74 cents/gallon. This analysis is static and looks at the average of recent months, in terms of looking into the future, it is important to note that the most recently analyzed month of data Sep. 2017 has the highest fuel price differential.

1.3 Fuel Differentials Summary

The incremental cost difference between HS and ULS heating fuel is important to review. A potential change in fuel demand may induce further economic impacts and present additional costs to households. In the previous section we reviewed the price differential for shifting from HS products to ULS No.1 for individual rack fuels. In this section, we examine these differentials holistically and provide a summary of our review of fuel price differentials.

These differentials are important as they indicate one of the cost impacts that the hypothetical ULS heating fuel requirement could have on Fairbanks, Alaska. In *Figure 8* we graphed each of the fuel price differentials together.[4]

Figure 8: Alaska ULS No. 1 Price Differentials, Dollars per Gallon



Source: Alaska Department of Environmental Conservation, OPIS

[4] We did not evaluate Anacortes fuel prices here as we do in *Figure 2*, as there is no data to compute a ULS/HS differential (our current OPIS dataset indicates that Anacortes does not supply HS fuel). Northern Economics, found in previous work that reviewed 2006 and 2007 OPIS data from indicated that the Northwest area had a very small ULS price differential of about 1.5%. (Northern, 2007. p.57)

The data in *Figure 8* indicate that the price differential between HS and ULS No.1 ranges from 8% to 26% during the assessed time period. Price differences range from a low of 14.82 cents/gallon in Anchorage during July 2017 to a high of 52.6 cents/gallon in Fairbanks during Sep 2017.

The price differential between HS and ULS No.1 fuel is significantly higher for Fairbanks than Anchorage. A clear explanation for this phenomena was provided by Northern Economics in their 2007 report a "Cost Assessment for Diesel Fuel Transition in Western and Northern Alaska Communities, which states a key driver as, "all ULS products are shipped by rail from Anchorage to Fairbanks, while the HS product is obtained from local refiners. The end result is an average pricing premium…" (p. 56).

Fuel transportation logistics do indeed result in a higher price premium in the Fairbanks wholesale market. From Anchorage fuel can be stored at Ship Creek where it then goes up the Alaska Railroad to Fairbanks. The latest publicly available information on the cost to ship fuel to Anchorage, from the Andeavor refinery in Kenai, is approximately $0.02 per gallon while the rail costs between Anchorage and Fairbanks is approximately $0.16 per gallon (Econ One Research, Inc., 2015, p.10). This study also estimated the cost of transport for ULS fuel from PSI's Valdez refinery to Fairbanks at approximately $0.20 per gallon (Econ One Research, Inc., 2015, p.25). Granted, the fuel price differentials we reviewed here do not account for any added capital costs regarding shipping additional quantities of ULS to Fairbanks. Also, we do not evaluate the effect of economies of scale with increased ULS demand or the potential for third party fuel distributors to enter the market to ship imported ULS to Fairbanks and undercut competitors' prices. These factors are important to recognize in regards to analyzing the costs of shifting to ULS heating fuel in Fairbanks, but are beyond the scope of this study, which aims at reviewing the direct cost impacts to Fairbanks households.

1.4 Fuel Cost Conclusions

Our findings show, through review of HS No.1 and HS No.2 Fairbanks price data from October 2016 to September 2017, there was an annual average 33.64 cents/gallon for ULS over HS No.1 and an annual average 42.74 cents/gallon premium for ULS over HS No.2. Respectively, a shift from HS No.1 to ULS No.1 would result in a price increase of approximately 17%. While a shift from HS No.2 to ULS No.1 would result in a price increase of approximately 26%. These price increases would directly affect household heating expenditures for fuel oil and are used in *Section II* to support the cost analysis.

Section II: Household Expenditure Scenarios: Cost Analysis

This section provides information on a cost model to explain potential changes in residential home heating expenditures assuming a switch to ultra-low sulfur (ULS) heating fuel in the Fairbanks PM-2.5 Nonattainment Area. This assessment does not address the economic impact of a switch to ULS nor does it address the relative costs and benefits associated with conversion. Additional costs might include those associated with changes in fuel storage and distribution, whereas additional benefits would include those associated with improvement in air quality and reduced boiler maintenance. A switch to ULS may also produce behavioral responses by households which impact heating fuel demand in both the short and long run. It is important to note that our models do not take these issues into account and therefore our results are only estimates based on the best information available at the time of publication.

2.1 Household Heating Oil Expenditure Changes from ULS

A potential transition from high sulfur (HS) No.2 home heating oil to ULS fuel would result in changes to household expenditures on fuel oil. Contributing factors include: fuel price differentials, heating efficiency changes, boiler maintenance cost reduction, and changes in the quantity of fuel used due to consumer price sensitivity.

To assess how a potential transition from HS No. 2 home heating oil to ULS fuel might change household expenditures the analysis makes a number of assumptions about key contributing factors likely to influence spending. First, expenditure estimates draw on the 12-month price differentials of $0.34 and $0.43 presented in *Section I*. The differential adjusted prices are multiplied by the quantity of fuel consumed by a typical household using only a central oil fired boiler. Existing estimates of household fuel usage were adjusted to account for an average price sensitivity factor of -0.2%. Evidence in the literature suggests that reducing sulfur and heat content in boiler fuel have a zero net change effect on fuel consumption. Additional detail about the fundamental components of the estimates as well as supporting documentation is presented in the following discussion. It should also be noted that while the expenditure calculations do not include potential changes in maintenance costs that may occur, information about the potential savings have also been included.

2.1.1 Household Heating Oil Consumption

The cost scenarios are based on an assumed level of annual household heating oil demand. The estimated home heating oil usage is based on the Fairbanks Home Heating Telephone Survey conducted by Sierra Research Inc. Our estimate utilized data[5] from 2011-2015, of the 2,304 households surveyed, 1,910 reported fuel quantities for at least one oil burning appliance. Homes

[5] A description of the data set is included in *Appendix A*.

that are heated only by a central oil burner are the most common heating configuration, representing about 40% of homes in the data set. On average, central oil burner FNSB homes consumed 1,254 gallons of heating fuel oil per year as shown in *Table 4*. Homes with a central oil burner and a wood stove are also common in the data set, representing about 20% of households. *Table 5* contains the oil and wood consumption quantities for homes with a central oil burner/wood stove appliance combination. We do not account for cross price effects of oil on other energy sources, such as firewood. Respondents were asked to estimate their annual fuel consumption (in gallons and in cost) over the phone. Fuel consumption estimates are heavily influenced by home size, heating degree days[6], and regional climate factors. These dynamics contribute to variability in responses resulting in a large standard deviations for the estimates.

Table 4: Summary of Typical Annual Central Oil Only Appliance Household Consumption

	Mean	**Median**	**Standard Deviation**	**Observations**
Oil Usage (gal)	1254	1100	719	787
Home Size (sq ft)	1895	1842	827	787

Source: Sierra Research Inc., Fairbanks Home Heating Telephone Survey, 2011-2015

Table 5: Summary of Typical Annual Central Oil - Wood Stove Appliance Household Consumption[7]

	Mean	**Median**	**Standard Deviation**	**Observations**
Oil Usage (gal)	880	800	535	403
Wood Usage (cord)	3.6	3	2.3	403
Home Size (sq ft)	1935	1855	709	403

Source: Sierra Research Inc., Fairbanks Home Heating Telephone Survey, 2011-2015

[6] Heating degree days are a common metric used to compare space heating loads or demand across locations or by month/season within a specific area and represent the number of degrees that at day's average temperature is below a base or reference number, typically 65° F.

[7] We are unable to calculate estimates of the additional fuel cost expenditures to these homes at this time. Additional work is being conducted to understand cross-price elasticity for households in this category.

2.1.2 Price Elasticity of Demand

The price elasticity of demand measures how sensitive the quantity demanded of a good or service is to a change in price.[8] How sensitive the quantity of heating oil consumed by a household is to changes in price depends on a number of factors, including: temperature preferences, heating appliance(s) type, heating appliance(s) age, home age, and the overall energy efficiency of the home. Price elasticity of demand figures are presented in absolute terms, as they typically consist of negative values, due to the inverse relationship between price and the quantity demanded of a good or service. Demand is said to be "inelastic" when the percentage change in quantity is less than the percentage change in price. Demand is said to be "elastic" when the percentage change in quantity is greater than the percentage change in price. Cost scenarios are evaluated using an assumed oil price elasticity of -0.2%. Using an assumed elasticity of 0 would imply that home heating oil demand is perfectly inelastic and that any change in the price of heating oil will not alter the quantity of heating oil demanded by households.

We also assume a constant elasticity of demand[9] for all levels of home heating oil demand. The assumed rate of -0.2% is drawn from a study of home heating fuel demand conducted by Hirst, Goeltz, & Carney (1982) and implies that a 1% increase in the price of home heating oil will decrease the quantity demanded by 0.2%. This estimate is for the short run effects of the transition to ULS fuel. Long run effects are not taken into consideration in this analysis but would have lower costs compared to the short run.

Given a price increase to heating fuel, households will pursue activities to control heating expenditures. Immediate improvements such as caulking and weather stripping can reduce home heating expenditures in the average US household by 2.5% (Gardner, 2008). A less immediate action, such as improving insulation and eliminating drafts within a home attic space can reduce home heating expenditures by up to 7% in the typical US household. Most simply, homeowners will turn down their thermostat. As the typical FNSB household spends more on home heating than the typical US household, these numbers are likely to underestimate the cost savings associated with caulking, weather stripping, and attic insulation within the FNSB. If a home is able to complete these home improvements it would decrease their price sensitivity to heating fuel.

---

[8] Examples of how the price elasticity of demand is calculated are explained in *Appendix B*.

[9] See *Appendix C*

2.1.3 Net Present Value and Discount Rates

Net present value (NPV) represents the time value of money and is used to compare the discounted value of cash flows across different time horizons. Cost scenarios were evaluated using a 25 year time horizon starting in 2018 under an assumed discount rate of 5%. The discount rate used in this analysis is the same as that used in a recent cost assessment of converting to low sulfur diesel in Western Alaska (Northern Economics, 2007). In addition, a set of current value cost calculations assuming a discount rate of 0% were also developed. A formula for present value is included as *equation 1*.

$$PV = CashFlow/r^{t} \qquad (1)$$

Cash Flow is the additional expenditure associated with the use of ULS fuel in a household which consumes 1,254 gallons of fuel per year over the given time horizon, and *r* is the discount rate applied to the cash flow.

The discount rate may be thought of as the rate of return received on these cash flows if they had not been spent on fuel, and instead had been invested. The NPV calculated for our scenarios therefore represent the amount of cash that would need to be given to the average household and invested at the given discount rate in order to pay for the additional expenditures associated with ULS and for the household to experience no change in their financial situation over 25 years.

2.1.4 ULS and High Sulfur Cost Differentials

Drawing on *Section I*, the cost scenarios incorporate heating fuel price differentials based on 12 months (Oct. 2016 through Sep. 2017) of OPIS data for Fairbanks. We make no assumptions as to whether these price differentials will increase or decrease over time, and so all of our models employ constant price differentials. As mentioned in *Section 1.5*, the average price differential for ULS and HS No.1 and ULS and HS No.2, are $0.34 and $0.43 respectively. These differentials and historical pricing data may be seen in *Table 2* and *Table 3*.

We use both of these price differentials in their own scenarios, referred to as Scenario 1 for the lower price differential of $0.34, and Scenario 2 for the higher price differential of $0.43. We do not make assumptions as to the current fuel usage mix used by the typical FNSB household, therefore the estimate of $0.34 will result in a lower predicted cost to the typical household than in actuality, and the estimate of $0.43 will result in a higher predicted cost to the typical households than in actuality.

2.1.5 Appliance Efficiency and Maintenance cost with ULS

Heat content differences in HS No. 2 fuel and ULS fuel mean that more ULS fuel will need to be burned to maintain the same indoor temperatures. Approximately 1% more ULS fuel by volume would be required to compensate for the loss in heat content over HS No. 2 fuel oil (EIA, 2018). However, boilers burning ULS fuels operate at a higher level of efficiency. We assume that the balance of these effects results in no change to fuel quantity consumption. The analysis presented in this paper accounts only for changes in fuel consumption, but a brief discussion of potential maintenance and repair costs is included. An explanation of our assumptions and a relevant synopsis of two Brookhaven National Laboratory Reports (Batey & McDonald, 2007 and Batey & McDonald, 2015) are included here.

A switch from HS No. 2 fuel to ULS fuel has a significant effect on boiler efficiency. Batey and McDonald, 2015 compared the rates of 'boiler fouling' in systems using conventional heating oil and ULS fuel. Decreases in boiler efficiency are caused by buildup of soot on heat exchange surfaces. As shown in *Figure 9,* soot buildup is directly related to sulfur content of the burned fuel.

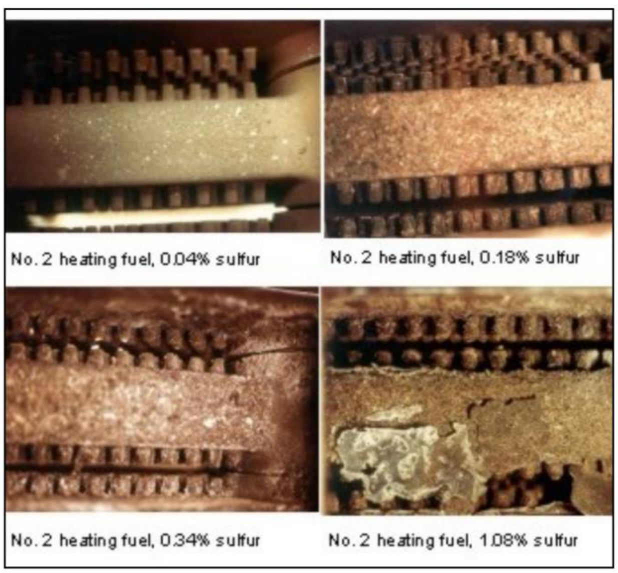


Figure 9: Buildup of Soot and Particulates on Heat Exchange Plates for Identical Boilers using Different Fuels

Source: Batey and McDonald, 2015, p. 14

The amount of buildup also increases with time and causes the boiler to consume more fuel to compensate for lost energy during heat transfer. Batey and McDonald, 2007 conducted a cost-benefit analysis of a potential transition from conventional fuel oil (0.2-0.25% sulfur by weight) to low sulfur fuel (0.05% sulfur by weight) in New York State. This earlier report estimates that boilers burning conventional fuel oil experience a decrease in efficiency of 2% per year due to fouling. We assume a zero net change in fuel quantity, which is conservative given the availability of information. Estimates of household heating expenditures can easily be adjusted to account for different efficiency levels. A procedure for adjustments is presented in *Section 2.2*.

The rate of boiler fouling may also impact household expenditures on maintenance calls and routine boiler cleaning. Batey and McDonald, 2015 used a Boiler Fouling Scale to compare the relative rate of buildup for residential fuel oil compared to ULS fuels. After approximately one year of operation, the conventional fuel oil group scored 2.15 and the ULS group scored 0.47. The ratio of boiler fouling is then 2.15/0.47 = 4.6. This means that boiler fouling occurs in conventional fuel oil boilers at a rate that is 4.6 times greater than ULS boilers. As boilers are typically cleaned every 1.5 to 2 years, a boiler using ULS fuel would only need to be cleaned approximately every 6.9 years. The Batey and McDonald, 2007 analysis assumed an average boiler cleaning service call would require 1.1 hours of labor. They also assumed service call costs ranging from $44 - $104 per hour. Based on the reduction in maintenance from the fuel switch, they estimated average annual household savings of $16 - $40. These savings are presented in 2007 dollars for New York State residents. Potential maintenance savings to FNSB residents are most likely larger than the Batey and McDonald, 2007 estimates due to a higher cost of living. These maintenance considerations are not included in the cost scenarios.

Batey and McDonald, 2015 also found that a switch from conventional fuel oil to ULS could pose some risk to boiler systems with particular lip seals present in some oil burner pumps. 85% of existing residential oil burning systems use black nitrile seals, which were unaffected by the change in sulfur content. However, a smaller proportion of brown 'Viton' type seals are highly susceptible to degradation from ULS fuels. These seals were used for a brief period in the early 2000's, but were observed to have a much higher rate of failure than their nitrile substitutes. This may indicate a further increase in boiler repair costs for some households. With the proportion of the vulnerable seals so low, this affect is not included in the cost scenarios.

2.2 Heating Oil Cost Scenarios

A cost model was developed using data from 2011-2015 to estimate the impact on households' fuel expenditures in the project area. Project scenarios were developed using five key assumptions, and are listed below:

Scenario 1: Annual household heating oil use of 1,254 gallons, an own-price elasticity of demand of -0.2, no net change to efficiency and energy loss, 5% rate of discount, and a price differential of $0.34/gallon for ULS.

Scenario 2: Annual household heating oil use of 1,254 gallons, an own-price elasticity of demand of -0.2, no net change due to efficiency and energy loss, a 5% rate of discount, and a price differential of $0.43/gallon for ULS.

Table 6: Summary of Heating Oil Cost Model Scenarios

Scenario	**Gallons of Prior Fuel Usage**	**Price Differential**	**Own-Price Elasticity**
1	1,254	$0.34	-0.2
2	1,254	$0.43	-0.2

All scenarios assume oil usage only and use an estimate of 1,254 gallons of prior fuel usage, and all models assume a 5% discount rate. *Table 6* above presents the concise differences between the scenarios in the cost model. *Table 7* shows results from the scenarios indicating approximate impact of household heating expenditure.

Table 7: Estimated Expenditure Effects of ULS Fuel Transition on Typical FNSB Household

Scenario	**Annual Increase in Oil Expenditure**	**NPV over 25 years-discounted**	**NPV over 25 years- no discount**	**NPV - Perpetuity**
1	$327.28	$4,612.70	$8,182.05	$6,545.64
2	$409.29	$5,768.56	$10,232.34	$8,185.87

For Scenario 1 we use a $0.34 price differential, consumption equal to 1,254 gallons per year, and a price elasticity -0.2. Scenario 1 results in additional heating fuel expenditures of $327 per year and discounted a net-present value of $8,182. For Scenario 2 we use a $0.43 price differential, consumption equal to 1,254 gallons per year, and a price elasticity -0.2. Scenario 2 results in additional heating fuel expenditures of $409 per year and a discounted net-present value of $10,232.

Adjustments can be made to the household expenditure estimates to account for different levels of efficiency and fuel heat content. Each additional percentage point of efficiency loss or heat content loss translates to approximately $30 more in household expenditure. At a price differential of $0.34 a 1% decrease in efficiency would cost $29.61. At a price differential of $0.43 a 1% decrease in efficiency would cost $30.43.

2.3 Summary of Household Impact

Naturally, these estimates vary considerably depending on the assumed household sensitivity to price changes and the price differential used. These estimates do not include the change in maintenance costs associated with changing to ULS, the potential switch to alternate fuels (for example wood or natural gas), or behavioral responses which reflect a change in home heating practices.

We estimate the cost of the potential transition to the average FNSB household would be between $327 and $409 in the first year, with models accounting for consumer sensitivity to prices and the lower price differential of $0.34 resulting in the lower estimates. The discounted net-present value of the increased cost from implementation to 25 years varies between $8,182 and $10,232, with the higher estimates being associated with the $0.43 price differential assumptions and inelastic demand.

Conclusion

A prospective switch to ultra-low sulfur (ULS) heating oil will increase residential heating expenditures for the typical Fairbanks North Star Borough (FNSB) household. This does not take into consideration any potential benefits of the change, such as savings in boiler maintenance, decreased costs associated with improved air quality, and other factors. The cost analysis provided in *Section II* (using the price differentials from *Section I*) represents the likely range of estimates given the available information and scope of the analysis, between $327 and $409 in the first year. Larger economic impacts are not taken into consideration, but should be discussed before a policy change is considered. We do not account for cross-price effects on alternative energy sources like firewood, even though a substantial portion of FNSB homes contain more than one heating appliance. Future research should examine household expenditures and determine whether the reduction in particulates and improvement in air quality are acceptable given the cost to consumers in the FNSB.

References

Batey, J. E., & McDonald, R. (2015). *Ultra Low Sulfur Home Heating Oil Demonstration Project* (pp. 1-120, Rep.).

Batey, J. E., & McDonald, R. (2007). *Low Sulfur Home Heating Oil Demonstration Project Summary Report* (pp. 1-57, Rep.).

Farris, P. & Pfeifer, P. (2010). *Pricing II: Constant Elasticity* [PowerPoint Slides] Retrieved from http://www.management-by-the-numbers.com/concepts/pricingconstantelasticity/pricingconstantelasticity.html

U.S. Energy Information Administration, EIA. (2018). *Energy Units and Calculations*. Retrieved February 26, 2018, from https://www.eia.gov/energyexplained/index.cfm?page=about_energy_units

Econ One Research, Inc. (2015). *The State of Alaska's Refining Industry* (pp. 1-64, Rep.).

Gardner, G. T., & Stern, P. C. (2008). The short list: the most effective actions U.S. households can take to curb climate change. Environment, (5), 12.

Hirst, E., Goeltz, R., & Carney, J. (1982). Residential energy use: Analysis of disaggregate data. *Energy Economics*, *4*(2), 74-82. Retrieved from https://doi.org/10.1016/0140-9883(82)90024-X.

How the Oil Price War Made U.S. Producers Even Stronger. (2016, December 28). Retrieved January 12, 2018, from https://instituteforenergyresearch.org/analysis/oil-price-war-made-u-s-producers-even-stronger/

Monthly Energy Review [Advertisement]. (2017, December 22). Retrieved January 12, 2018, from https://www.eia.gov/totalenergy/data/monthly/#prices

Northern Economics. (2007). *Cost Assessment for Diesel Fuel Transition in Western and Northern Alaska Communities.* Prepared for the Alaska Department of Environmental Conservation.

OPIS. Our Spot Market Pricing Methodology. (2018). Retrieved January 12, 2018, from https://www.opisnet.com/about/methodology/

Sierra Research Inc. Fairbanks Home Heating Telephone Survey Data 2006-2015 - Unified Format.

Appendix A

We estimate the typical FNSB household fuel oil usage to be 1,254 gallons per year. This assumption is based on the Fairbanks Home Heating Telephone Survey Data 2006-2015, collected and prepared by Sierra Research Inc. Our analysis was limited to the continuous time period from 2011-2015. The survey collected information on household characteristics, appliance types, and fuel consumption for home heating. The survey focused on heating oil, firewood, natural gas, and coal as the primary heating fuels, and asked respondents to estimate their fuel consumption in terms of annual quantity and expenditures. Our estimate of household oil consumption isolated households that burned only oil in a central boiler. For households with a central oil burner and reported oil consumption > 0, the average FNSB home uses 1,254 gallons of conventional heating oil per year. All calculations were performed using the statistical analysis software, STATA.

Appendix B

Price elasticity of demand measures the responsiveness of the quantity demanded of a good to a change in its price. It is calculated by the percentage change in quantity demanded divided by the percentage change in price.

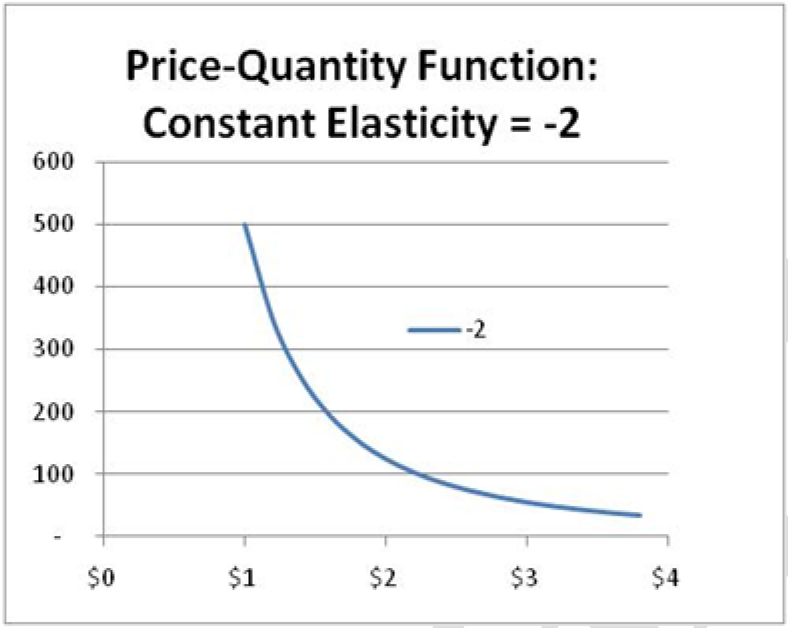
$$E_d = \frac{\%\Delta Q}{\%\Delta P} \quad (3)$$

$$E_d = \frac{(Q_1 - Q)/Q}{(P_1 - p)/P} \quad (4)$$

These equations are all different ways to calculate the price elasticity of demand, with *equation 4* a more explicitly written version of *equation 3*. To find this value with calculus *equation 5* could be used. This uses the partial derivative of the quantity demanded with respect to the price of the good multiplied by the specific price of the good divided by the specific quantity demanded associated with that price.

$$E_d = \frac{\partial Q}{\partial P} \times \frac{P_0}{Q_0} \quad (5)$$

Appendix C



Source: Farris & Pfeifer 2010

A constant elasticity demand function means the elasticity of demand is the same at every point along the demand curve, but the slope is different at every point. This is represented in *equation 6* where ε is the price elasticity of demand and k is a constant.

$$Q = kP^{\varepsilon} \tag{6}$$

Instead of a linear demand function, a constant elasticity demand function is assumed for this analysis because of the numerous assumptions made about heating fuel demand for the Fairbanks area. The post-transition level of heating oil demand is not known, so we assume fixed elasticity demand values across a range of fuel quantities.