# Benefits and Costs to Rural Alaska Households from a Carbon Fee and Dividend Program

Final Report

prepared by

Steve Colt
Professor of Economics
Institute of Social and Economic Research
University of Alaska Anchorage
sgcolt@uaa.alaska.edu

prepared for

Citizens' Climate Education Corporation
1330 Orange Ave, #300
Coronado, CA 92118

August 31, 2015

# Contents

Summary .......... 1
1. Introduction .......... 5
2. Dividends to households .......... 8
3. Carbon fees paid by households .......... 10
4. Discussion .......... 27
References .......... 29
Appendix A. Residential electricity use per household .......... 31

# Tables

Table 1. Study area baseline conditions .......... 6
Table 2. Carbon emission factors .......... 7
Table 3. Dividends per household and total dividends going to each region in 2016 .......... 9
Table 4. Kusilvak Population, households, and residential kWh, by household type .......... 14
Table 5. Estimated residential space and water heating fuel use by structure type .......... 15
Table 6. Kusilvak estimated residential heating fuel use by household type .......... 16
Table 7. Kusilvak electricity sales by customer class .......... 17
Table 8. Kusilvak allocation of nonresidential electricity consumption and carbon fees to household types .......... 18
Table 9. Kusilvak estimated nonresidential heating fuel use .......... 19
Table 10. Kusilvak nonresidential heating fuel allocation of consumption and carbon fees to household types .......... 19
Table 11. Kusilvak personal air transportation fuel use .......... 21
Table 12. Kusilvak estimated annual carbon fee per person due to air freight .......... 22
Table 13. Kusilvak summary of carbon fees paid per household for small and large households .......... 23
Table 14. Kusilvak results: initial year dividends and fees .......... 24
Table 15. Results summary: initial year dividends and fees for all regions .......... 26
Table 16. Nonresidential electrcity use per residential customer .......... 28

# Figures

Figure 1. Study area ........................................................................................................ 6
Figure 2. Distribution of households by household size ................................................................ 8
Figure 3. Growth in the annual dividend to a family of four ......................................................... 9
Figure 4. Growth of total dividends flowing to the study regions ............................................... 10
Figure 5. Variation in community average residential kWh across study area communities ..... 11
Figure 6. Variation in modeled heating fuel usage among 297 individual houses in the study area ................................................................................................................................ 12
Figure 7. Distribution of household income in Alaska and in Kusilvak ........................................ 13
Figure 8. Distribution of reported subsistence energy use among 405 households.................... 20
Figure 8. Distribution of median income by household size in each study region....................... 25
Figure 10. Summary of effects on large and small households ................................................... 27

**Acknowledgments**

The Alaska Department of Fish and Game, Division of Subsistence, provided data on household transportation energy consumption related to subsistence. Several reviewers provided helpful comments. The University of Alaska Foundation provided additional funding, originally donated by Alaska petroleum companies, that enabled additional data analysis to inform this study.

# Summary

This paper analyzes the benefits and costs of a carbon fee-and-dividend (CFD) policy to individual rural Alaska households. The three study area regions are the Bethel Census Area, the Kusilvak Census Area, and the Northwest Arctic Borough. These three regions have the state's highest fuel prices and very cold climates.

The CFD policy consists of two elements. The first is a fee of $15 per metric ton of $CO_2$ beginning in 2016 and increasing by $10 per ton in each subsequent year. The second is the complete return of all fees to households in the form of dividends, which are estimated to equal $300 for each adult plus $150 for each child (up to two). The annual dividends would increase in future years commensurate with the nationwide total amount of fees.

**Baseline conditions.** The study area has a total population of about 32,000 people, many of whom live in large households with low cash income. Fuel prices averaged $6.62 per gallon in January 2015.

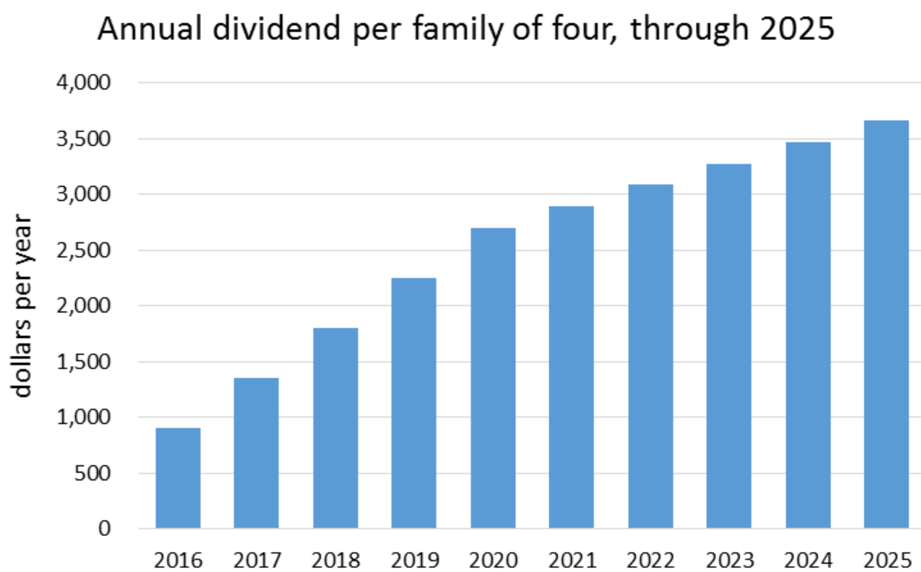
| | Bethel Census Area | Northwest Arctic Borough | Kusilvak Census Area | Overall Study Area |
|---|---|---|---|---|
| Baseline conditions: | | | | |
| Population | 17,013 | 7,523 | 7,459 | 31,995 |
| Households | 4,651 | 1,919 | 1,745 | 8,315 |
| Average household size | 3.7 | 3.9 | 4.3 | 3.8 |
| Median household income | 51,689 | 61,607 | 40,176 | [1] |
| Average fuel price, Jan 2015 | 6.68 | 6.59 | 6.51 | 6.62 |

note [1]: median income cannot be calculated for the overall study area.
sources: U.S. Census 2010 (population, households, income); *Alaska Fuel Price Report: Current Community Conditions January 2015*
http://commerce.state.ak.us/dnn/Portals/4/pub/Fuel_Price_Report_Jan-2015.pdf

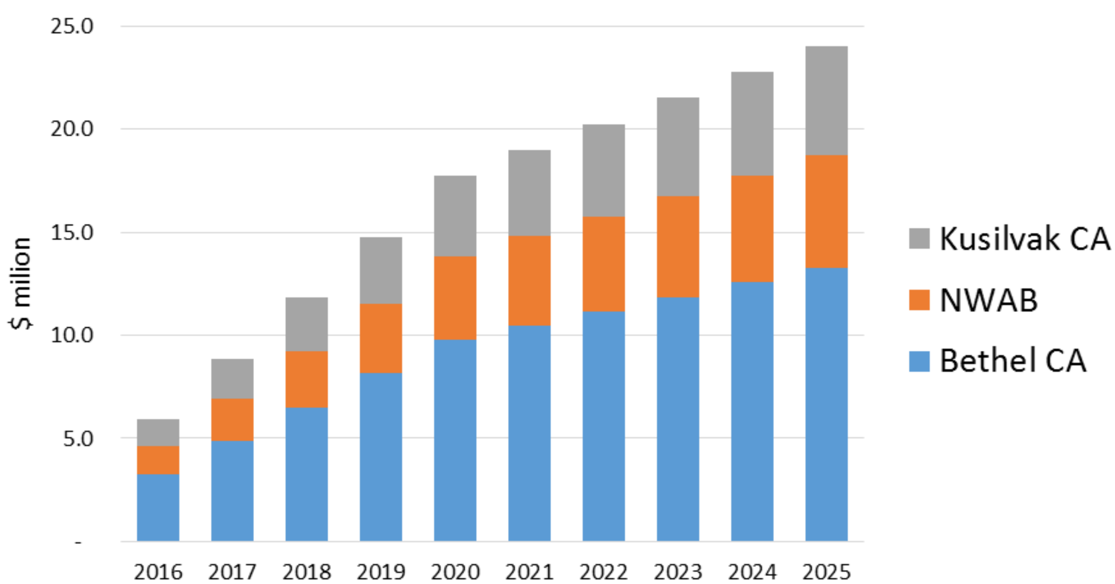
**Methodology.** Carbon fees paid by a household depend on the quantity of energy used, while dividends depend on household size. Both energy use and household size vary widely and more or less independently among individual households. It is critical to consider this variation when evaluating the CFD policy; the "average" outcome reveals very little about the distribution of dividends and fees. Existing household-level data are adequate to calculate dividends, but not fees. This analysis therefore uses community-level data to generate fee and dividend amounts for representative "small" (1-2 persons) and "large" (3+ persons) households in each region. Although this approach is admittedly imperfect, it represents a significant first step toward understanding the consequences of a CFD policy for individual rural Alaska households.

## Major findings

- A family of two adults and two or more children would receive a dividend of $900 in 2016, increasing to more than $3,600 by 2025.[1]

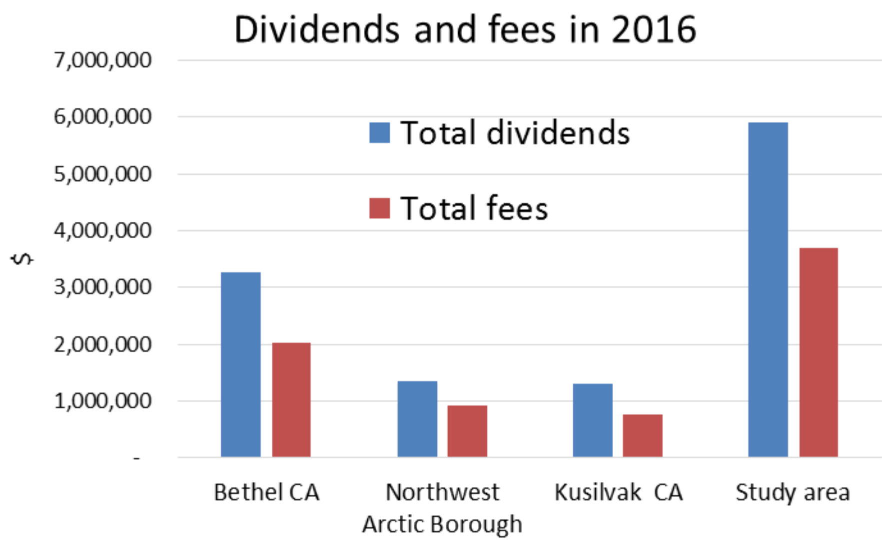



- A total of $5.9 million in dividend payments would flow to the three regions in 2016. Total dividends would increase to $24 million by 2025.

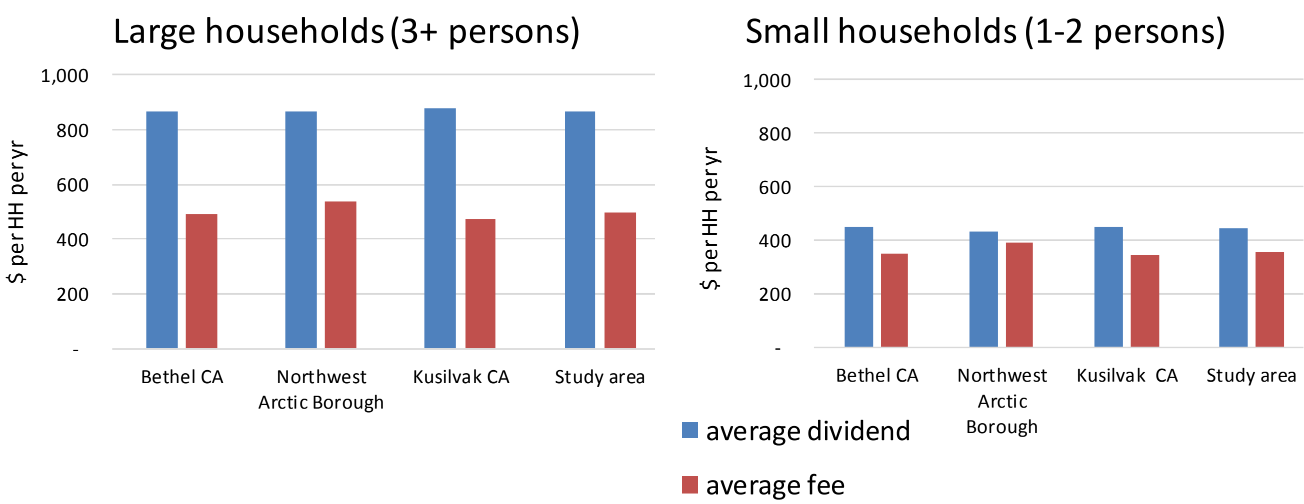



[1] All amounts are real dollars of year 2016 purchasing power.

- Total dividends initially exceed total fees in all three regions, resulting in a net cash benefit of $2.2 million flowing into the study area in 2016.




- Both small and large households in every region would receive average dividends exceeding average fees in 2016. While there are undoubtedly financial winners and losers within each household group, it is reasonable to conclude that the vast majority of people in the study area stand to initially gain more in dividends than they would pay in fees.



- Large households (3+ people) would receive average initial dividends that exceed fees by more than $325 per year, with the largest net cash benefit of $400 per household going to the Kusilvak Census Area. Large households represent 86% of the study area population.

- For small households (1-2 people) average initial dividends would also exceed fees, but by smaller amounts – ranging from $45 per year in Northwest Arctic Borough to $106 per year in Kusilvak CA. Small households represent 10% of the borough population.

- These net benefits would likely increase over time, but future outomes will also very likely depend on further progress within the study area regions to increase energy efficiency and to displace diesel with low-carbon sources such as natural gas, propane, or renewables.

**Summary of results for 2016**

| | Bethel Census Area | Northwest Arctic Borough | Kusilvak Census Area | Overall Study Area |
|---|---|---|---|---|
| Initial year dividends and fees | | | | |
| Total dividends | 3,257,550 | 1,346,550 | 1,306,500 | 5,910,600 |
| Total fees | 2,020,942 | 921,644 | 760,442 | 3,703,028 |
| Net cash benefit to region | 1,236,608 | 424,906 | 546,058 | 2,207,572 |
| Small households (1-2 people) | | | | |
| Average dividend per HH | 447 | 434 | 448 | 444 |
| Average fee per HH | 351 | 388 | 341 | 358 |
| **Average net cash benefit per HH** | **96** | **45** | **106** | **86** |
| Number of households | 1,846 | 727 | 518 | 3,091 |
| Share of region population | 16% | 15% | 10% | 14% |
| Large households (3+ persons) | | | | |
| Average dividend per HH | 867 | 865 | 876 | 869 |
| Average fee per HH | 490 | 536 | 476 | 497 |
| **Average net cash benefit per HH** | **377** | **329** | **400** | **372** |
| Number of households | 2,805 | 1,192 | 1,227 | 5,224 |
| Share of region population | 84% | 85% | 90% | 86% |

# 1. Introduction

This paper uses the best available data to estimate the benefits and costs to rural Alaska households of a Carbon Fee and Dividend (CFD) policy. Policymakers have legitimate concerns about the effects of any measure that would add to the burden of high energy costs in rural Alaska, where heating fuel prices consistently exceed $6.00 per gallon in several regions and very cold temperatures contribute to high heating fuel consumption.

Under the CFD policy the fees are based on the quantities of electricity and fossil fuel consumed while the dividends to a household depend on household size. It is important to keep in mind that the CFD policy would add a fixed *dollar amount* per gallon to the price of fuel, rather than a fixed *percentage*. What matters most for how a household fares under the plan is the quantity of fuel used, not the price. Because they have been living with high prices, cold winters, and low cash incomes for a long time, many rural Alaska households use relatively low amounts of electricity and heating fuel. A large household using small quantities might come out well ahead, with dividends exceeding fees by a significant amount.

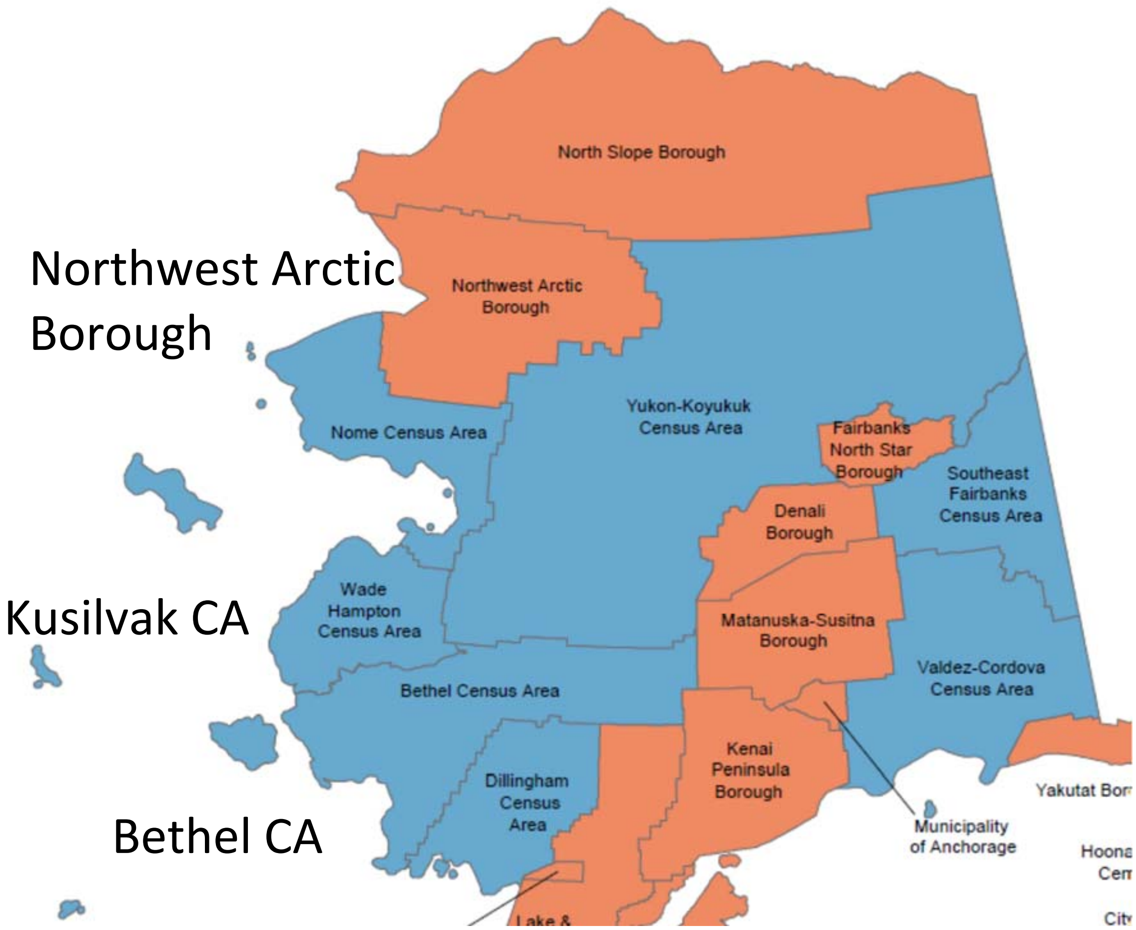
Two features of the analysis are noteworthy. First, following the general approach of "consumption-based emissions accounting" (Kummel 2014), I consider both direct household energy consumption and also indirect consumption where the cost is initially paid by other parties but then passed through – at least partly – to local residents. Second, the analysis attempts to get beyond regional averages to explore effects on individual households. Due to a lack of household-level data, I use community-level data to generate fee and dividend amounts for representative "small" (1-2 persons) and "large" (3+ persons) households in three different regions. Although this approach is admittedly imperfect, it represents a significant first step toward understanding the consequences of a CFD policy for actual rural Alaska households.

## Conceptual approach

The study area consists of the Bethel Census Area, the Kusilvak Census Area,[2] and the Northwest Arctic Borough (Figure 1). These three regions have the state's highest fuel prices, low median incomes, and very cold climates (Table 1). Each region is analyzed separately. By using these three regions as case studies, the analysis helps to show how people throughout rural Alaska might fare under the CFD policy.

[2] formerly known as the Wade Hampton Census Area.

**Figure 1. Study area**




Map source: Alaska Department of Labor and Workforce Developmenr

**Table 1. Study area baseline conditions**

| | Bethel Census Area | Northwest Arctic Borough | Kusilvak Census Area | Overall Study Area |
|---|---|---|---|---|
| Baseline conditions: | | | | |
| Population | 17,013 | 7,523 | 7,459 | 31,995 |
| Households | 4,651 | 1,919 | 1,745 | 8,315 |
| Average household size | 3.7 | 3.9 | 4.3 | 3.8 |
| Median household income | 51,689 | 61,607 | 40,176 | [1] |
| Average fuel price, Jan 2015 | 6.68 | 6.59 | 6.51 | 6.62 |

note [1]: median income cannot be calculated for the overall study area.
sources: U.S. Census 2010 (population, households, income); *Alaska Fuel Price Report January 2015*
http://commerce.state.ak.us/dnn/Portals/4/pub/Fuel_Price_Report_Jan-2015.pdf

The Carbon Fee & Dividend policy has the following key elements:

- The initial fee is $15 per metric ton CO2, increasing by $10 per ton (in real dollars) in each subsequent year.
- The initial dividend is estimated to be $300 per adult plus $150 per child for up to two children per household.[3]
- The carbon dividend amounts increase annually consistent with growth in the national total of fees received.[4]
- The carbon emission factors and the resulting initial fees per gallon are as shown in Table 2.[5]

**Table 2. Carbon emission factors**

| | kg CO2 / mmbtu | mmbtu / gal | kg CO2/gal | fee $/ton | fee $/gal |
|---|---|---|---|---|---|
| diesel for electricity | 73.15 | 0.134 | 9.80 | 15.00 | 0.147 |
| heating fuel | 73.15 | 0.134 | 9.80 | 15.00 | 0.147 |
| gasoline | | | 8.91 | 15.00 | 0.134 |
| jet fuel | | | 9.57 | 15.00 | 0.144 |
| avgas | | | 8.32 | 15.00 | 0.125 |
| aviation fuel average | | | 9.00 | 15.00 | 0.135 |

The analysis uses direct data where possible. I also use or develop best estimates of key assumptions derived from statewide data or other published sources. As noted above, the general approach is to consider both direct payments and indirect payments by households for energy. Direct payments are out-of-pocket payments for residential electricity, residential heating fuel, and personal transportation fuel. Indirect payments are caused by items such as commercial electricity or heating fuel for the school. While these costs are initially paid by other entities such as local businesses, the school district, or state or federal government, they are ultimately paid *in part* by local residents in the forms of higher retail prices, taxes, or fees.[6] Indirect payments also arise from energy costs embodied in the prices of goods and services, notably air transportation and air freight.

This report proceeds as follows. Section 2 analyzes the amounts of money that households would receive as dividends. Section 3 estimates the carbon fees that households in each region would pay and compares fees to dividends. Section 4 concludes with discussion.

[3] initial dividend amounts are estimated from current CO2 emissions.
[4] I used projections of future dividend amounts per household from REMI (2014), figure 3.18.
[5] Carbon emission factors from http://www.eia.gov/oiaf/1605/excel/Fuel_Emission_Factors.xls . Aviation fuel average is professional judgment based on factors for avgas and jet fuel.
[6] The question of “who ultimately pays” is the age-old problem known in economics as *tax incidence*.

## 2. Dividends to households

Census data on the number of households of varying sizes allows for a precise calculation of how much money individual households would receive as dividends in each study region.

Figure 1 shows how numbers of households vary by size in each region. Table 3 summarizes the way that household sizes translate into dividends per household, and how the number of households of each size then determines total amount of cash dividends that would come into the region. A total of almost $6 million would flow into the study area in the first year. The assumption that all large households have no more than two adults is for simplicity; in reality many households of 3+ people might have 3 (or more) adults and receive annual dividends exceeding $900.

**Figure 2. Distribution of households by household size**

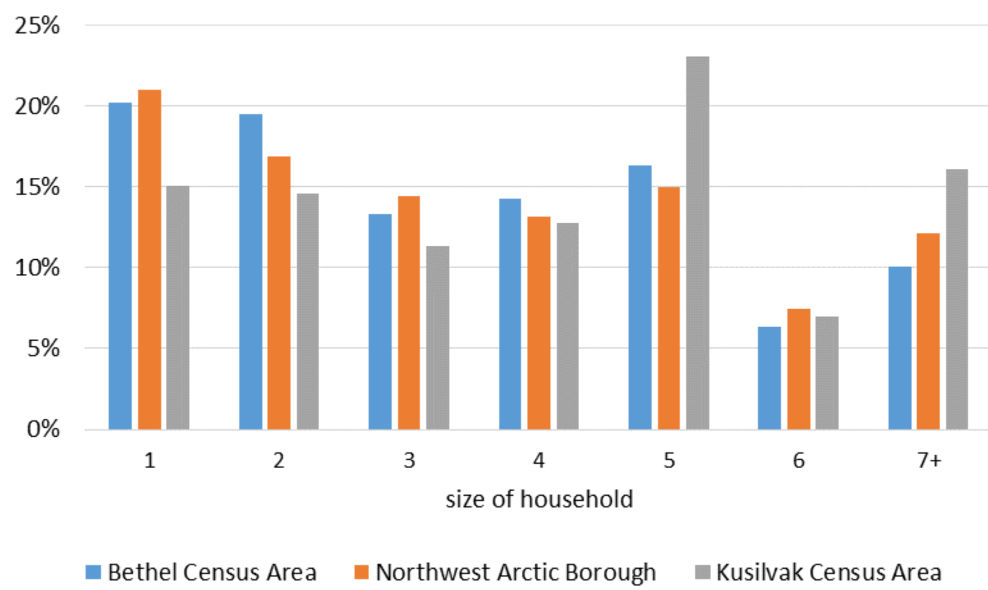


**Table 3. Dividends per household and total dividends going to each region in 2016**

| | Household size | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7+ | Overall |
| dividend per HH: | $ 300 | $ 600 | $ 750 | $ 900 | $ 900 | $ 900 | $ 900 | |
| Bethel Census Area | | | | | | | | |
| # households | 939 | 907 | 619 | 665 | 759 | 295 | 467 | 4,651 |
| median income | 21,181 | 65,650 | 42,500 | 51,442 | 64,338 | 52,614 | 61,964 | |
| total dividends | 281,700 | 544,200 | 464,250 | 598,500 | 683,100 | 265,500 | 420,300 | 3,257,550 |
| Northwest Arctic Borough | | | | | | | | |
| # households | 403 | 324 | 277 | 253 | 287 | 143 | 232 | 1,919 |
| median income | 34,028 | 58,977 | 83,125 | 66,667 | 61,667 | 66,500 | 69,063 | |
| total dividends | 120,900 | 194,400 | 207,750 | 227,700 | 258,300 | 128,700 | 208,800 | 1,346,550 |
| Kusilvak Census Area | | | | | | | | |
| # households | 263 | 255 | 198 | 223 | 403 | 122 | 281 | 1,745 |
| median income | 16,131 | 34,063 | 37,656 | 40,833 | 39,563 | 47,500 | 57,857 | |
| total dividends | 78,900 | 153,000 | 148,500 | 200,700 | 362,700 | 109,800 | 252,900 | 1,306,500 |

For a household of two adults and two children, the annual dividend would start at $900 in 2016 and grow to more than $3,600 by 2025 (Figure 3). This projection is based on national studies of how the total dividend pool would grow due to the increased fee per ton (REMI 2014). The growth of dividends is less than the growth in the fee per ton since total carbon emissions decrease over time in response to the fee.

**Figure 3. Growth in the annual dividend to a family of four**

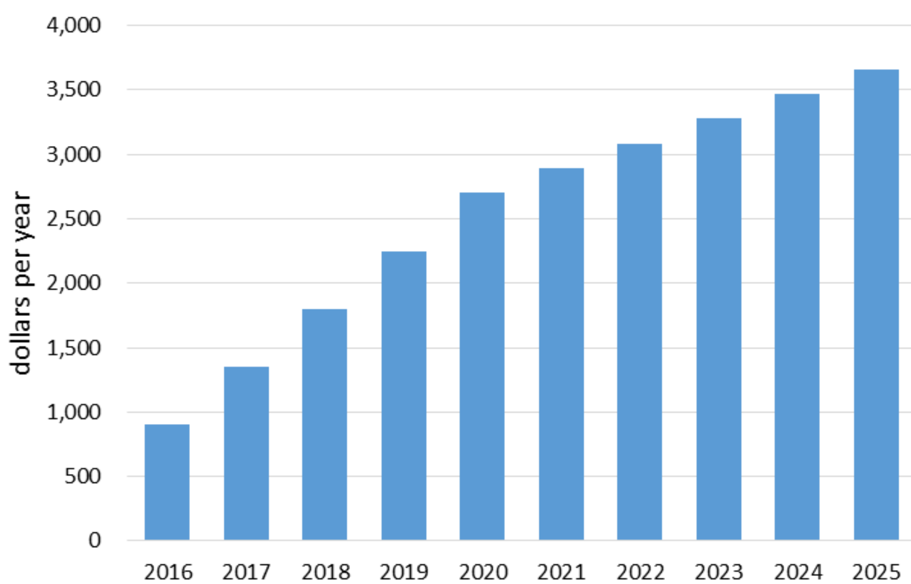
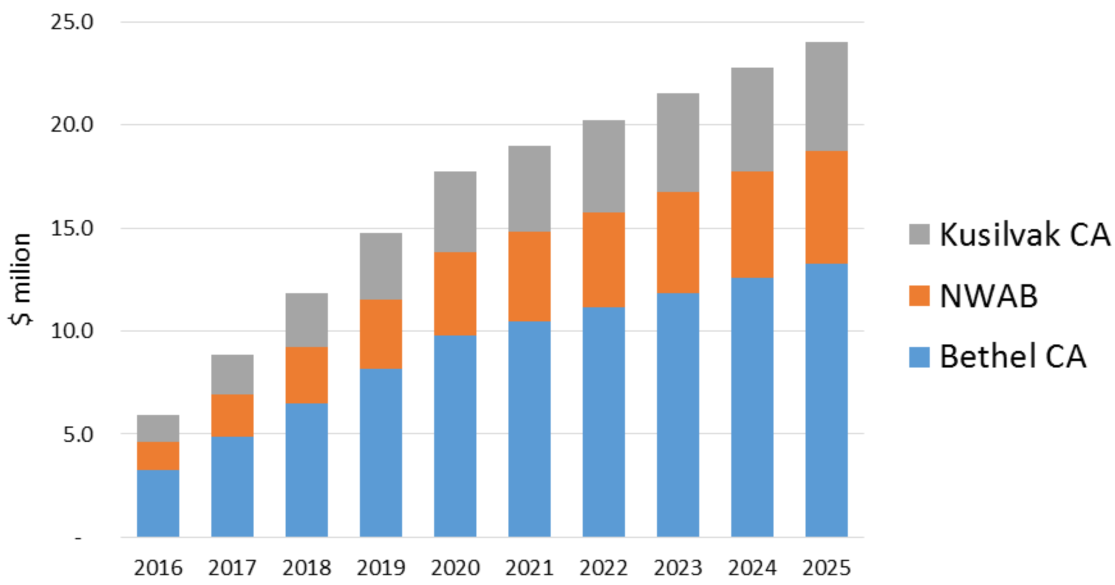


Figure 4 shows how total annual dividends to study area households would grow to almost $25 million by 2025.

**Figure 4. Growth of total dividends flowing to the study regions**




# 3. Carbon fees paid by households

## Fees and dividends paid by the “average” household

It is straightforward to calculate the direct fees paid and the dividends received by the “average” household in a region. For example, using the data and methods described below, the total use of diesel fuel and gasoline in the Bethel Census Area for all electricity (residential, commercial, community, government), for all space heating (residential, commercial, community, government) and for personal land and water transportation equates to about 968 gallons per person per year. The average household size is 3.6 persons. Therefore in the first year the average household would pay about $515 in fees and receive about $849 in dividends. For this average household dividends would exceed fees by $334.

## Variation among households

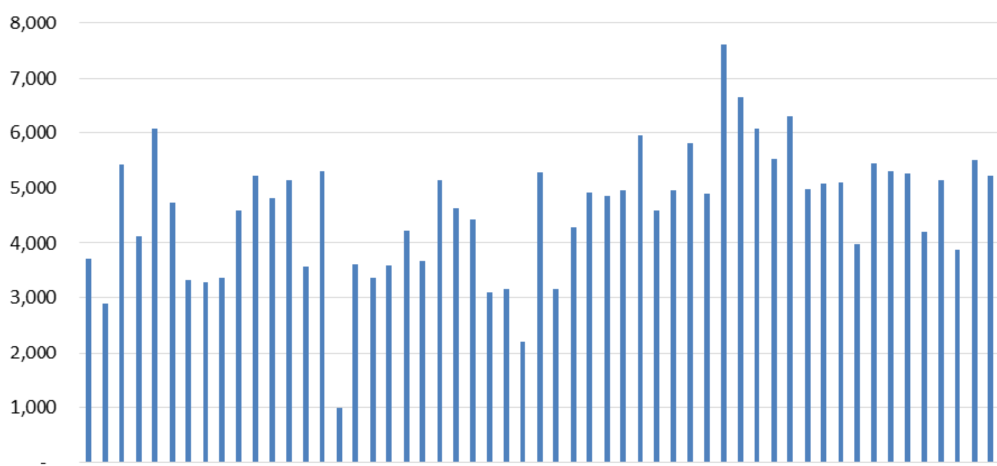
There are two main problems with this simple calculation using averages. The first problem is that it fails to add the additional energy embodied in good and services (like air freight) and fails to subtract the portion of nonresidential electricity and heating fuel that is likely not paid for by residents. This problem can be addressed through a more thorough analysis of these uses and payments.

The second, and far more serious, problem is that the "average household" is a statistical fiction that represents few, if any, actual households. There is tremendous variation in energy use, household size, and income among the 8,315 households in the study area. The main factor affecting the fee amount is household energy use and the main factor affecting the dividend amount is household size – both the number of adults and the number of children. Household income and spending are also important to the outcomes realized by particular households.

The following figures give some sense of these variations. Figure 2, above, showed the distribution of household sizes within the study area. The distribution is noteworthy for its "flat" shape – *not* like a bell curve with most households near the average. Too, the distribution itself seems to be noticeably different in different regions.

Figure 5 shows how the *community average* residential kWh per customer varies by a factor of 8 across study area communities.[7] The variation across individual households is likely to be at least as high as this variation in community averages.

**Figure 5. Variation in community average residential kWh across study area communities**

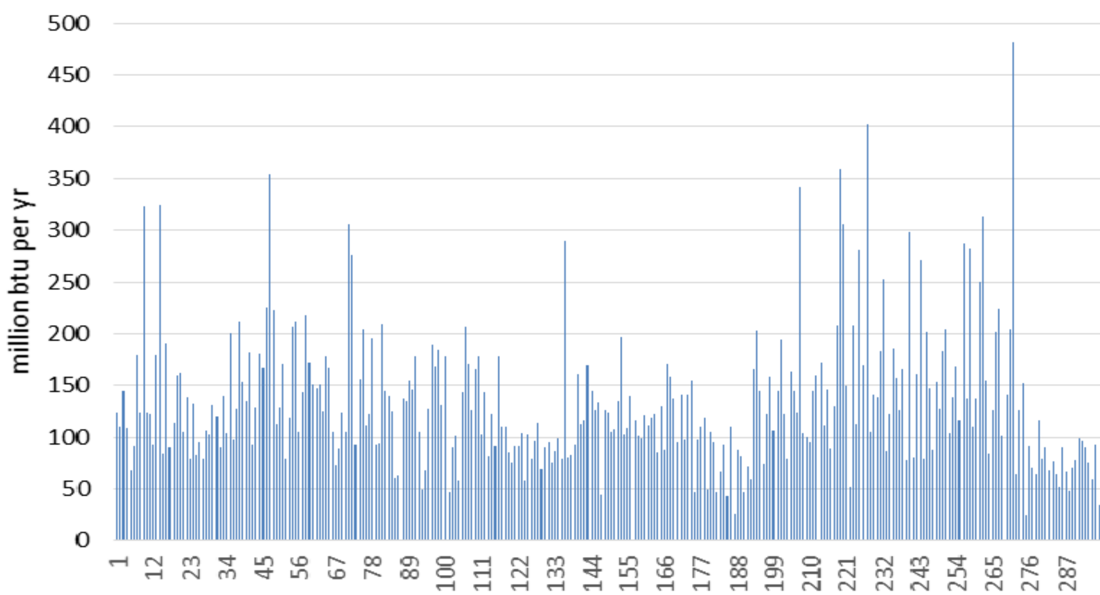



source: Alaska Energy Authority, Power Cost Equalization Program

[7] The raw data are from the Power Cost Equalization Program (PCE) statistical databases provided directly by the Alaska Energy Authority.

Figure 6 shows the variation in modeled heating fuel use by 297 single-family houses in the study area.[8] Each house was given an energy audit and the house characteristics were fed into the same modeling software. Therefore, this figure provides a reasonable gauge of the variation across individual households. The variation is once again about 10-fold.

**Figure 6. Variation in modeled heating fuel usage among 297 individual houses in the study area**

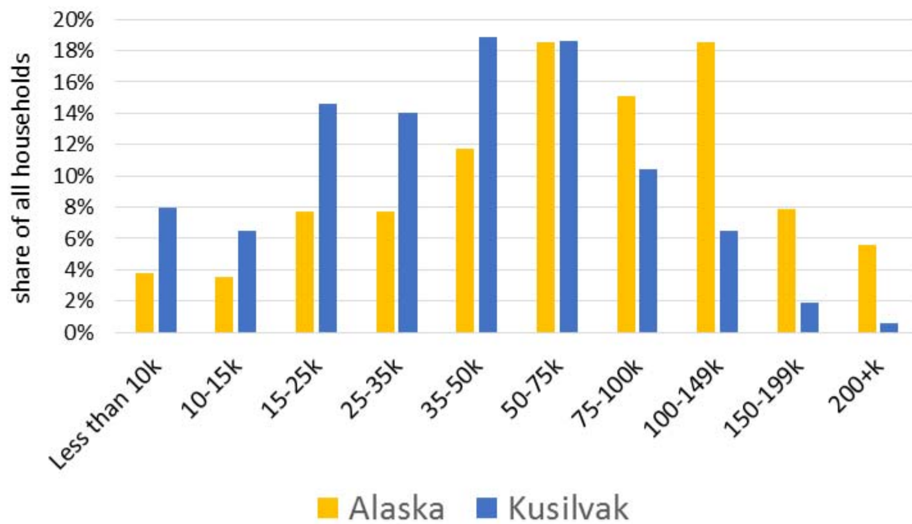



source: Alaska Retrofiit Information System; Alaska Energy Authority & WH Pacific, Alaska End Use Study (2012)

Finally, Figure 7 shows the distribution of household income for one of the three study regions – the Kusilvak Census Area. Household incomes in the study area are more concentrated among lower income levels than they are for the state as a whole.

[8] These data are from the Alaska Retrofit Information System (ARIS), provided by the Alaska Housing Finance Corporation. This sample of 297 single family houses was extracted for analysis as part of the Alaska End Use Energy Study. http://www.akenergyauthority.org/Efficiency/EndUse

**Figure 7. Distribution of household income in Alaska and in Kusilvak**




source: American Community Survey, 2013 5-yr estimates

## Using two household types to capture variation

The ideal way to deal with all of this variation would be to conduct a household survey that measured energy use, household size, and spending patterns. The resulting household-level data could be used to estimate the fee and dividend amounts for each household in the study area population. However, no such household-level data are available.[9]

This analysis therefore proceeds by constructing two different representative household types, denoted as “small” and “large.” I define “small” households to be those with 1 or 2 persons and “large” households to be those with 3 or more persons. For each type I estimate electricity, space heating, and transportation energy use, as well as household size, in such a way that the estimates are consistent with all available community and regional data for both types added together. I use two household types, rather than 3 or 4, in an attempt to capture significant variation among households while remaining solidly grounded in data and using a minimum number of *ad hoc* assumptions.

This methodology is described and applied in the following section, using the Kusilvak Census Area as an example. Results are then given for the Bethel Census Area and the Northwest Arctic Borough.

[9] The American Community Survey Public Use Microdata Sample (PUMS) provides some household-level data, but it falls far short of what is needed. I discuss use of the PUMS data in Section 4, below.

## Carbon fee analysis for Kusilvak Census Area

### Residential Electricity

The foundation of the entire analysis is the community-level electricity consumption data reported through the Alaska Power Cost Equalization (PCE) program. I used these data from years 2010 and 2011 to estimate a regression equation that shows how residential electricity consumption within the study area varies by household size. The regression shows that households of 3+ members use an additional 4,000 kWh per year than households of size 1 or 2.[10] This result is highly statistically significant and provides a good empirical basis for creating two distinct household types to analyze.

The 2010 decennial Census provides data on the number of households by size and hence the number of small and large households. I then calculated the residential electricity consumption of each type that is consistent with the regression equation discussed above and also yields the actual total consumption -- by all residential households -- of 8,789,315 kWh, which is a known data point. The resulting allocation is shown in Table 4. This example illustrates the general approach of allocating known total amounts among the two household types.

To determine the gallons of diesel fuel needed to generate this electricity, I used data from the PCE program on total kWh sold per gallon of diesel fuel consumed. These data are for the 36 months between July 2011 and June 2013. (It was not possible to use similarly updated data for consumption because the consumption amounts must be tied to other household data from the 2010 Census.) I used more recent data for these ratios of kWh per gallon because the ratios have improved since 2010, indicating recent progress toward reduced diesel consumption.

**Table 4. Kusilvak Population, households, and residential kWh, by household type**

| | Small HH (1-2 members) | Large HH (3+ members) | All HH |
|---|---|---|---|
| Population | 703 | 6,221 | 6,924 |
| % of total population | 10% | 90% | 100% |
| Households | 471 | 1,115 | 1,586 |
| % of total HH | 30% | 70% | 100% |
| Average household size | 1.5 | 5.6 | 4.4 |
| Residential kWh per HH | 2,763 | 6,715 | 5,542 |
| Total residential kWh: | 1,300,734 | 7,488,580 | 8,789,315 |
| kWh sold per gal diesel | 13.36 | 13.36 | 13.36 |
| Gal of diesel to generate: | 97,360 | 560,522 | 657,883 |

[10] This result is obtained by hedonic regression using the fraction of households with 3+ members in each community as an independent variable to explain average residential consumption in that community. Again, no household-level consumption data are available. For more discussion of the regression, see Appendix A.

**Residential Space Heat**

There is no data set with actual, measured, residential heating fuel consumption by rural Alaska households. However, fuel use for residential space heat has been studied and modeled as a function of house size and heating degree days (Colt 2013, Alaska Energy Authority & WH Pacific 2012). The entire study area is in Alaska Climate Zone 8, as defined by the Alaska Building Energy Efficiency Standards. These standards define Climate Zone 8 by reference to heating degree days in the range from 12,600 to 16,800.[11]

To estimate heating fuel use by housing type -- single-family, multi-family, and mobile home -- I used a sample of 318 houses that were audited and modeled as part of the Alaska Home Energy Rebate Program. These houses are all in Alaska climate zones 7, 8 and 9 and are known as the "ARIS Sample." I also obtained a separate sample of audited and modeled houses from the Alaska End Use Energy Study (Alaska Energy Authority and WH Pacific 2012). These houses are known as the "EUS Sample." As Table 5 shows, the resulting estimates of heating fuel use per house from these two samples agree well with each other and also with the estimates of 850 and 903 gallons per house given in the *Northwest Arctic Strategic Energy Plan*.[12]

**Table 5. Estimated residential space and water heating fuel use by structure type**

| | ARIS rural sample (318 houses) | EUS Sample (328 houses) | Average of both samples | | | compare to NANA SEP |
|---|---|---|---|---|---|---|
| | million btu/yr | million btu/yr | million btu/yr | million btu/gal | gallons/yr | gallons/yr |
| Single-family | 121 | 133 | 127 | 0.134 | 948 | 903 |
| Multi-family | 105 | 119 | 112 | 0.134 | 836 | |
| Mobile Home | 185 | 216 | 201 | 0.134 | 1,496 | |

The next step toward determining residential heating fuel use by household types is to associate each type – small and large -- with a mix of single-family, multifamily, and mobile home structures. The Census provides data on the total numbers of these structures for Kusilvak. I allocated these total numbers of structures to households of each type using professional judgment. The purpose of this allocation is to implement the idea that small households are more likely to live in multifamily housing or mobile homes.[13] With this

[11] See Alaska Housing Finance Corporation (2014).

[12] Northwest Arctic Leadership Team, no date (approx. 2009). The NWASEP uses both a "rough order of magnitude estimate" of 850 gallons per single-family house (p. 4) and an estimate of 129 gallons per house per month (p. 11) times 7 full months of heating season = 903 gallons per household per year.

[13] It would, of course, be more direct to use actual data on heating fuel use by households of different sizes. However, the data sets with audited houses do not include the number of people living in the structure. So this

allocation made, I calculated residential heating fuel use for each household type. This calculation is summarized in Table 6. Estimated use per household is slightly higher for small households than for large. This is partly because small households are assumed to be more likely to live in mobile homes, which have very high modeled fuel consumption in the data samples used here.

**Table 6. Kusilvak estimated residential heating fuel use by household type**

| | **Number of houses by HH type:** | | | |
|---|---|---|---|---|
| | **Small HH (1-2 members)** | **Large HH (3+ members)** | **All HH** | **Fuel per house (gal/yr)** |
| Single family | 421 | 1,060 | 1,481 | 948 |
| Multi family | 28 | 34 | 63 | 836 |
| Mobile Home | 21 | 21 | 42 | 1,500 |
| Total houses | 471 | 1,115 | 1,586 | |
| Total fuel use (gal/yr) | 454,668 | 1,064,832 | 1,519,500 | |
| Average fuel use (gal/HH) | 966 | 955 | 958 | |

## Nonresidential electricity

Nonresidential customers use 61% of total Kusilvak electricity, as shown in Table 7. Data are reported for sales to "commercial," "community facilities," and "government facilities" customers. However, these terms are in quotation marks because they may not include what one would expect. For example, both the Yukon-Kuskokwim Health Corporation (YKHC) headquarters offices and the YKHC regional hospital are classified as "commercial" customers, while schools are typically classified as government facilities.[14]

allocation attempts to use measured variation in heating fuel by structure type to generate some variation in heating fuel use by household type – small and large.

[14] Cady Lister, Alaska Energy Authority program manager, personal communication 12 June 2015.

**Table 7. Kusilvak electricity sales by customer class**

| Customer type | kWh | % of total kWh | generation efficiency kWh/gal | Diesel gal/yr | carbon fee $/yr |
|---|---|---|---|---|---|
| residential | 8,789,315 | 39% | 13.36 | 657,883 | 96,729 |
| commercial | 4,180,937 | 18% | 13.36 | 312,944 | 46,013 |
| community facilities | 3,835,725 | 17% | 13.36 | 287,105 | 42,214 |
| government facilities | 5,828,823 | 26% | 13.36 | 436,289 | 64,148 |
| unbilled | 8,769 | 0% | 13.36 | 656 | 97 |
| Total kWh sold | 22,643,568 | | 13.36 | 1,694,878 | 249,200 |
| nonresidential subtotal | 13,854,253 | 61% | | 1,036,995 | 152,471 |

There are two important allocations required in order to estimate how much of the carbon fees associated with nonresidental electricity are paid by each household type. The first allocation is called *local incidence*. The local incidence fraction is the proportion of the total carbon fees ultimately paid by local residents. For example, if all commercial electricity were consumed by small businesses that are owned and operated by local households, then the local incidence of carbon fees for commercial electricity would reasonably be 100%. Conversely, if all commercial electricity were consumed by a Seattle-based fish processing company that does not sell locally, then the local incidence of the resulting fees would be essentially zero.[15]

I assume that the local incidence of reported "commercial" electricity costs in Kusilvak CA is 50%. This is simply a best estimate recognizing that the following entities would not pass the fees through to local people: Regional health corporations; businesses serving tourists; businesses (such as a fish processor) exporting to nonlocal customers; or nonlocal business owners who cannot pass all of the fees through to local customers.[16] The assumed local incidence of "community facilities" electricity costs is 100% and the assumed local incidence of "government facilities" electricity costs is 0%. These assumptions are, of course, simplifications of a more complex reality.

Once the local incidence has been determined, the second important allocation is to allocate the total local payments among the two household types. I do this by first estimating the fraction of total regional household income accruing to each household type. The calculations are based on Census data that provides median income by household size. Several adjustments are needed to convert this distribution of median incomes into the desired total income

[15] To be completely precise, some small portion of fees might get passed through to locals if the fish processor aggressively cut its use and shifted some of the fixed cost of the utility onto other customers.

[16] The full amount of the fee must be shared between customers and owners, so if both groups are local, the local incidence of such fees is 100%. (This assertion ignores passing costs "backwards" to upstream suppliers.)

amounts accruing to small and large household types.[17] The resulting shares are 19% of total income to small households and 81% to large households.

I used the total income shares to allocate the locally-paid share of commercial electricity cost and carbon fees to small and large households. For community facilities electricity I allocated the locally-paid share on an equal amount per household basis. I allocated government facilities electricity using total income shares, but the allocation is irrelevant because the assumed local incidence is zero. Table 8 summarizes the nonresidential electricity carbon fee allocations.

**Table 8. Kusilvak allocation of nonresidential electricity consumption and carbon fees to household types**

| | Total gal/yr | Total fee $/yr | Assumed local incidence | Total fees paid by all HH | Allocation method to HH types | Total fees paid by small HH | Total fees paid by large HH |
|---|---|---|---|---|---|---|---|
| commercial | 312,944 | 46,013 | 0.50 | 23,006 | income | 4,407 | 18,599 |
| community facilities | 287,105 | 42,214 | 1.00 | 42,214 | equal per HH | 12,531 | 29,683 |
| government facilities | 436,289 | 64,148 | 0.00 | 0 | income | 0 | 0 |
| Subtotal | 1,036,339 | 152,374 | | 65,220 | | 16,938 | 48,281 |
| Unbilled | 656 | 97 | 0.43 | 41 | pro-rated | 11 | 31 |
| Total nonres electricity | 1,036,995 | 152,471 | | 65,261 | | 16,949 | 48,312 |

## Nonresidential heating fuel

There is no systematic data on measured heating fuel use in nonresidential buildings in the study area. I therefore used parameters from the Alaska Village Energy Model (Colt 2013) to estimate nonresidential heating fuel as a linear function of nonresidential kWh.[18] The statistical parameter is 0.112 gallons heating fuel per nonresidential kWh. The resulting estimate of total nonresidential heating fuel is shown in Table 9.

[17] The census data does not include mean income by household size. Hence, the key step is to estimate mean income by household size based on median income data. I did this using a constant adjustment factor that did not vary across household sizes. I used trial and error (Excel goal-seek) to find the adjustment factor such that the calculated grand total income amount for all households matched the known grand total amount of income earned by all households in the census area.

[18] The coefficients were determined using a data set of 312 nonresidential buildings for which both measured electricity consumption and measured heating fuel consumption (from bills) was included in the data.

**Table 9. Kusilvak estimated nonresidential heating fuel use**

| | nonres electricity kWh/yr | parameter: gal heatfuel per kWh electricity | Heating fuel gal/yr |
|---|---|---|---|
| commercial | 4,180,937 | 0.112 | 469,734 |
| community facilities | 3,835,725 | 0.112 | 430,949 |
| government facilities | 5,828,823 | 0.112 | 654,877 |
| Total nonresidential heating fuel | | | 1,555,561 |

To allocate the total nonresidential heating fuel gallons and fees I used the same fractions for local incidence and the same allocation methods to household types as were used for nonresidential electricity. Table 10 shows the resulting allocation of carbon fees.

**Table 10. Kusilvak nonresidential heating fuel allocation of consumption and carbon fees to household types**

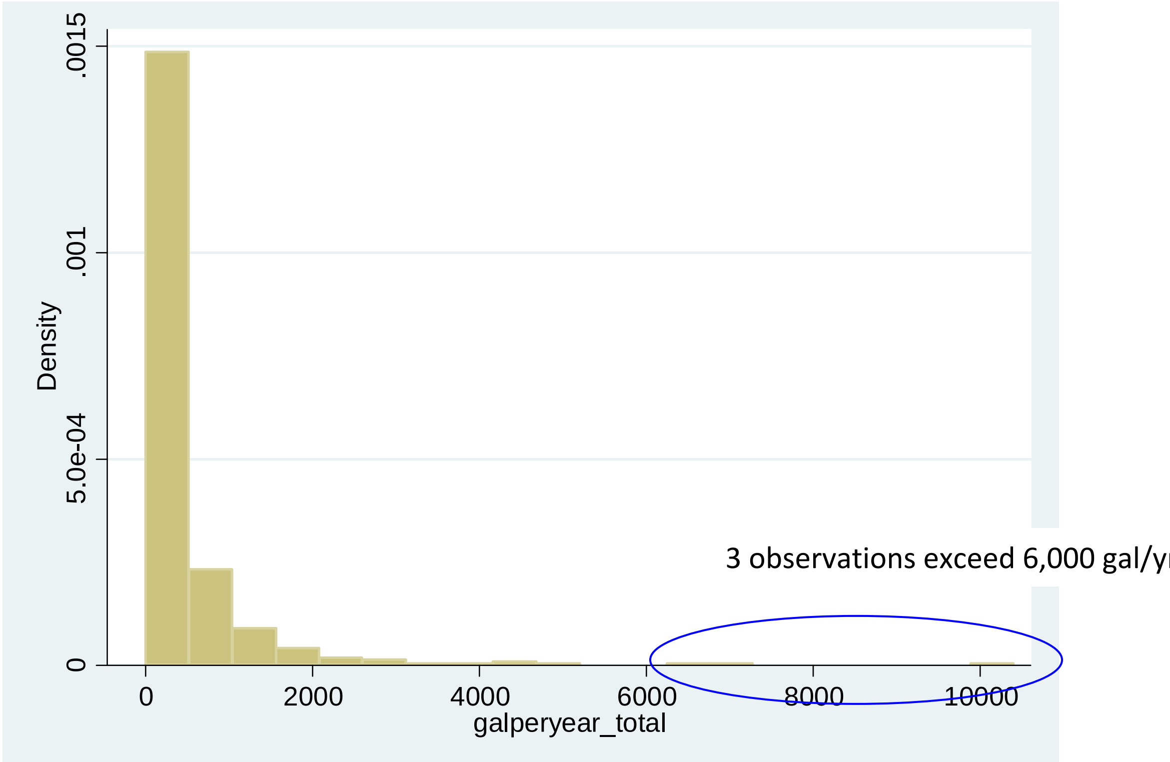
| | Total gal/yr | Total fee $/yr | Assumed local incidence | Total fees paid by all HH | Allocation method to HH groups | Total fees paid by small HH | Total fees paid by large HH |
|---|---|---|---|---|---|---|---|
| commercial | 469,734 | 69,066 | 0.50 | 34,533 | income | 6,615 | 27,917 |
| community facilities | 430,949 | 63,363 | 1.00 | 63,363 | equal per HH | 18,809 | 44,554 |
| government facilities | 654,877 | 96,288 | 0.00 | - | income | 0 | 0 |
| Total nonres heat | 1,555,561 | 228,716 | | 97,896 | | 25,425 | 72,471 |

**Personal land and water transportation**

Personal land and water transportation includes all-terrain vehicles (ATVs), boats, trucks & cars, and snowmachines. I combined two household survey data sets to estimate these uses. The first is a survey of 54 households in coastal northwest Alaska (Schwoerer 2013) that was used in the Alaska Village Energy Model (Colt 2013). The second data set is from 351 household subsistence surveys conducted in 12 interior (meaning non-coastal) communities by the Alaska Department of Fish and Game Division of Subsistence.

I eliminated 3 observations from the combined subsistence energy use data set as probable outliers – the cutoff was 6,000 gallons per household per year. I determined the cutoff using the histogram shown in Figure 8.

**Figure 8. Distribution of reported subsistence energy use among 405 households**




Using these data the mean consumption for subsistence is 243 gallons per year for small households and 514 gallons per year for large households.

The coastal Alaska dataset also contains data on fuel used for visiting and shopping. The average reported amounts are 51 gallons per year for small households and 81 gallons per year for large households.

Adding these two amounts together, estimated fuel used for personal land and water transportion equals 294 gallons per year for small households and 595 gallons per year for large households.

**Personal air transportation**

Personal air transportation is that which is paid for by local households. I estimate this consumption using the expenditure method (Kummel 2014). The Alaska IMPLAN economic model provides an "absorption coefficient" which says that for every dollar's worth of air transportion that is produced and sold, 31 cents worth of refined petroleum product must be purchased. In essence, every dollar's worth of air travel includes 31 cents worth of fuel.[19]

[19] M. Guettabi, Instiute of Social and Economic Research, University of Alaska, personal communication. April 15, 2015.

Assuming an average aviation fuel price of $3.00 per gallon (for a mix of jet and avgas),[20] the 31 cents per dollar equates to 0.1 gallons per dollar. This number agrees reasonably well with the figure of 0.15 gallons per dollar reported by Kummel (2014) based on data from the MIT Airline Data Project.[21]

To complete the calculation I use data from the coastal northwest Alaska household surveys (Schwoerer 2013). Respondents reported the numbers of air tickets used for regional, in-state, and U.S. travel. I assume unit prices of $125, $250, and $1,000 respectively. Table 11 documents the resulting estimates of total fuel use by each household type. Large households have slightly lower estimated expenditures because they reported fewer trips outside Alaska. It is also important to note that the reported numbers of tickets include trips paid for by others, such as health care providers or employers.[22] Therefore, the expenditure amounts in Table 11 are likely to overestimate true household spending.

**Table 11. Kusilvak personal air transportation fuel use**

| | Small HH | Large HH | All HH | price per trip ($) |
|---|---|---|---|---|
| Trips per household per yr | | | | |
| Regional | 6.0 | 5.6 | | 125 |
| State | 2.6 | 3.8 | | 250 |
| U.S. | 0.6 | 0.2 | | 1000 |
| expenditures per household | 1,963 | 1,814 | | |
| gallons fuel per $ | 0.10 | 0.10 | | |
| gallons per household | 196.3 | 181.4 | 185.8 | |
| total gallons per hh per yr | 92,418 | 202,297 | 294,715 | |

**Embodied carbon fees in goods and services**

For rural Alaska two special features of the economy are important to the analysis of fuel costs and carbon fees embodied in goods and services. First, any local purchases of energy by commercial enterprises, such as food stores, service providers, and restaurants, are accounted for in the above analysis of nonresidential electricity use and nonresidential heating fuel use. Locally-produced heat and light becomes part of the output of the food store itself – a warm,

[20] The use of $3.00 is a "round number" assumption based on consideration of averaging over jet fuel and avgas, and averaging the prices paid mostly in Anchorage but also in outlying communities, especially regional hubs.
[21] http://web.mit.edu/airlinedata/www/default.html
[22] There is no way to determine how many tickets fall into this category.

lighted place to shop and a properly refrigerated space to store the jugs of milk. The isolated nature of rural Alaska communities allows for a relatively clear picture of these costs.

The second special feature is that the cost of many goods reflects the extensive use of energy-intensive air freight. Fay et al. (2013) cite an analysis by Northern Economics (2009) indicating that air freight shipments to off-road Alaska communities averaged 1,096 pounds per capita in 2007.

My estimate of fuel use due to air freight is based on a direct comparison of air freight fuel costs, fuel use, and tons of freight delivered. The data were developed by Fay et al. (2013),[23] from Department of Transportation flight segment statistics.[24] The analysis is summarized in Table 12 and the bottom line is that rural Alaska residents such as those in the study area annually use about 65 gallons of fuel per person – both jet fuel and aviation gasoline – for air freight. A local incidence of 1.00 is assumed. Clearly some air freight costs would not be paid by local residents, but using the high value of 1.00 accounts for some other transportation costs, such as barges, that are not explicitly calculated. Allocating the total payments on an equal per-person basis, each person would pay about $9.00 in carbon fees in 2016 due to higher fuel costs for air freight.[25]

**Table 12. Kusilvak estimated annual carbon fee per person due to air freight**

| | units | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| Average price aviation fuel | 2011$ | 2.46 | 2.60 | 3.30 | 2.03 | 2.51 |
| Cargo delivered by cargo-only flights | tons | 60,524 | 64,613 | 63,674 | 54,787 | 57,504 |
| Fuel used | gallons | 8,009,018 | 7,419,954 | 7,568,123 | 6,524,065 | 6,505,137 |
| | gallons per ton | 132 | 115 | 119 | 119 | 113 |
| Air freght pounds per person | | | | 1,096 | | |
| Air freight tons per person | | | | 0.55 | | |
| Gallons per person | | 73 | 63 | 65 | 65 | 62 |
| Total gallons for region | | | | 450,987 | | |
| Total carbon fee to be allocated | | | | 60,274 | | |
| Local resident incidence | | | | 1.00 | | |
| Carbon fee per person | | | | $ 8.71 | | |

[23] See esp. pages 22,24

[24] Raw data comes generally from the Bureau of Transportation Statistics, available at www.transtats.bts.gov . See Fay et al (2013), pp. 19-20 and Table C-1 at p. 34 for discussion.

[25] Another potentially useful data set is the U.S. Department of Agriculture's "Cost of Food at Home" series which covers some rural communities over several years. Comparison of annual changes in food costs with annual changes in fuel costs could potentially yield a useful estimate of the degree to which higher fuel prices are actually passed through to the cost of goods in rural Alaska.

## Carbon fee calculations

With all of the electricity and fuel consumption quantities estimated, it is straightforward to calculate carbon fees for each household type.[26] Table 13 shows this tally. Small households would pay an average of $341 while large households would pay an average of $476.

**Table 13. Kusilvak summary of carbon fees paid per household for small and large households**

| | Total gal/yr | Total fee $/yr | Local inci - dence | Total fees paid by all HH | Total fees paid by small HH | Total fees paid by large HH | Fee per HH paid by small HH | Fee per HH paid by large HH |
|---|---|---|---|---|---|---|---|---|
| Electricity | | | | | | | | |
| residential | 657,883 | 96,729 | 1.00 | 96,729 | 14,315 | 82,414 | 30 | 74 |
| commercial | 312,944 | 46,013 | 0.50 | 23,006 | 4,407 | 18,599 | 9 | 17 |
| community facilities | 287,105 | 42,214 | 1.00 | 42,214 | 12,531 | 29,683 | 27 | 27 |
| government facilities | 436,289 | 64,148 | 0.00 | 0 | 0 | 0 | 0 | 0 |
| unbilled | 656 | 97 | 0.43 | 41 | 11 | 31 | 0 | 0 |
| Space & water heat | | | | | | | | |
| residential | 1,519,500 | 223,414 | 1.00 | 223,414 | 66,851 | 156,564 | 142 | 140 |
| commercial | 469,734 | 69,066 | 0.50 | 34,533 | 6,615 | 27,917 | 14 | 25 |
| community facilities | 430,949 | 63,363 | 1.00 | 63,363 | 18,809 | 44,554 | 40 | 40 |
| government facilities | 654,877 | 96,288 | 0.00 | 0 | 0 | 0 | 0 | 0 |
| Pers. land/water transport | 801,959 | 107,182 | 1.00 | 107,182 | 18,499 | 88,683 | 39 | 80 |
| Personal air transport | 294,715 | 39,787 | 1.00 | 39,787 | 12,476 | 27,310 | 27 | 24 |
| Fuel used for airfreight | 450,987 | 60,883 | 1.00 | 60,883 | 6,178 | 54,705 | 13 | 49 |
| Total | 6,317,600 | 909,183 | | 691,153 | 160,693 | 530,460 | 341 | 476 |

A final adjustment to the calculated carbon fees is necessary before comparing total fees to total dividends. The PCE data that underlies the above analysis does not cover all communities in the region. The calculated total fee amounts must therefore be adjusted upward to reflect the count of all households from the 2010 Census. For example, in Kusilvak the community of St. Mary's (population 507 in 2010) is not included in the PCE data, so that data covers only 1,586 households and must be adjusted up to reflect the census count of 1,745 total households within Kusilvak.

[26] In doing so, I make no further adjustment for the effects of the Alaska Power Cost Equalization program (PCE) subsidy. Although according to the PCE program formula a large fraction of the carbon fee on residential electricity would be paid for by the program, in fact total PCE payments are limited by available funding; payments are pro-rated down when total funds are insufficient to cover total calculated payments. In recent years th Alaska Legislature has made annual appropriations to add money to the amounts drawn from the PCE Endowment Fund. It is extremely unlikely that these appropriations wil continue, let alone increase.

**Results for Kusilvak**

In Kusilvak, small households would receive $106 more in dividends ($448) than they pay out in fees ($341), while large households would collect an average of $876 in annual dividends while paying an average of $476 in fees.[27] Overall, people in the region would receive net cash benefits totaling $546,058 in 2016 (Table 14).

**Table 14. Kusilvak results: initial year dividends and fees**

| | All HH | smal HH | large HH |
|---|---|---|---|
| Total Dividends | 1,306,500 | 231,900 | 1,074,600 |
| Total Fees | 760,442 | 176,803 | 583,640 |
| Total net cash to region | 546,058 | 55,097 | 490,960 |
| | | | |
| Average dividend per HH | 749 | 448 | 876 |
| Average fee per HH | 436 | 341 | 476 |
| Average net cash benefit | 313 | 106 | 400 |

Both small and large households in Kusilvak get initial net cash benefits under the CFD policy, equal to $106 per year for small households and $400 per year for large households. The net benefits would likely increase over time, but future outomes will also likely depend on increases in energy efficiency and further displacement of diesel with low-carbon energy sources such as natural gas, propane, or renewables.

It is important to acknowledge that there will likely be some households – especially smaller ones -- for which fees exceed dividends. That's because this analysis does not capture the complete range of variation in energy use. To take one possible example, single-person households who engage in significant personal transportation could easily pay more in fees than the $300 dividend they would receive. Without household-level data that specifies the energy consumption behavior of individual households, it is not possible to estimate precisely how many people or households households might fall into this category.

## Assumptions and results for other regions

**Bethel Census Area**

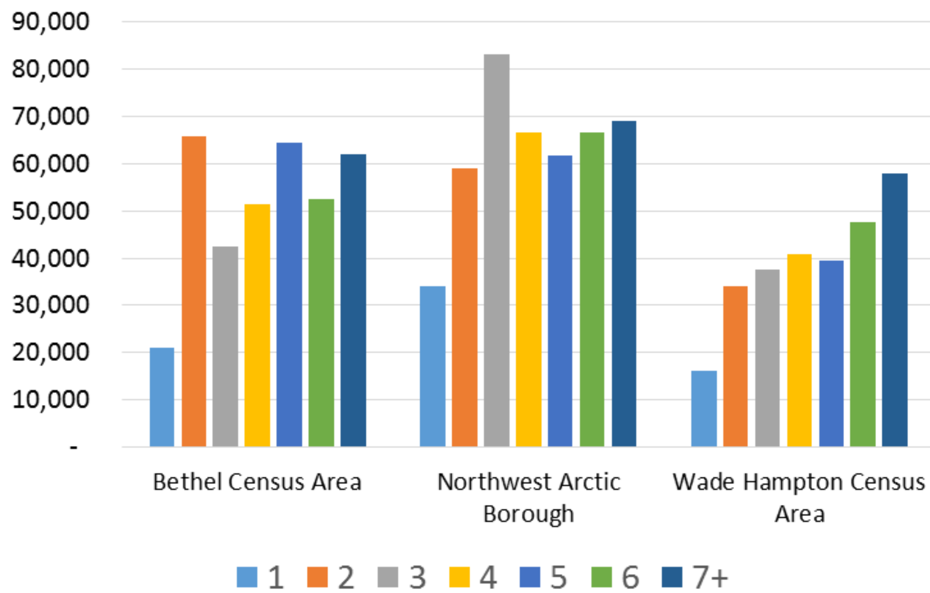
Bethel Census Area includes the regional hub of Bethel itself, and has a total poulation of about 18,000 -- more than 3 times as many people as Kusilvak. There is significant "commercial" electricity consumption, much of which might be associated with Alaska Native Nonprofit organizations such as Y-K Health Corporation. There is higher income, which is reflected in

[27] Numbers may not appear to add exactly due to rounding for display purposes.

higher residential electricity use. Figure 9 documents this difference, showing how the entire distribution of median income across household sizes is higher in the Bethel Census Area than in Kusilvak.

The results for the Bethel Census Area are that large households would initially receive average dividends that exceed average fees by $377, while for small households average dividends exceed average fees by $96 per household.

**Figure 9. Distribution of median income by household size in each study region**




**Northwest Arctic Borough**

The Northwest Arctic Borough has significantly higher electricity consumption per person than either of the other two regions. On a per-household basis, it is 20% higher than in Bethel Census Area and almost 40% higher than in Kusilvak. This difference, which may reflect colder weather, drives the calculations toward higher estimated fuel use. As a result, Northwest Arctic Borough households in the small household group receive a relatively low initial net cash benefit -- dividends exceed fees by $45 per year.  For large households, average dividends exceed average fees by $329 per household.

**Study area summary**

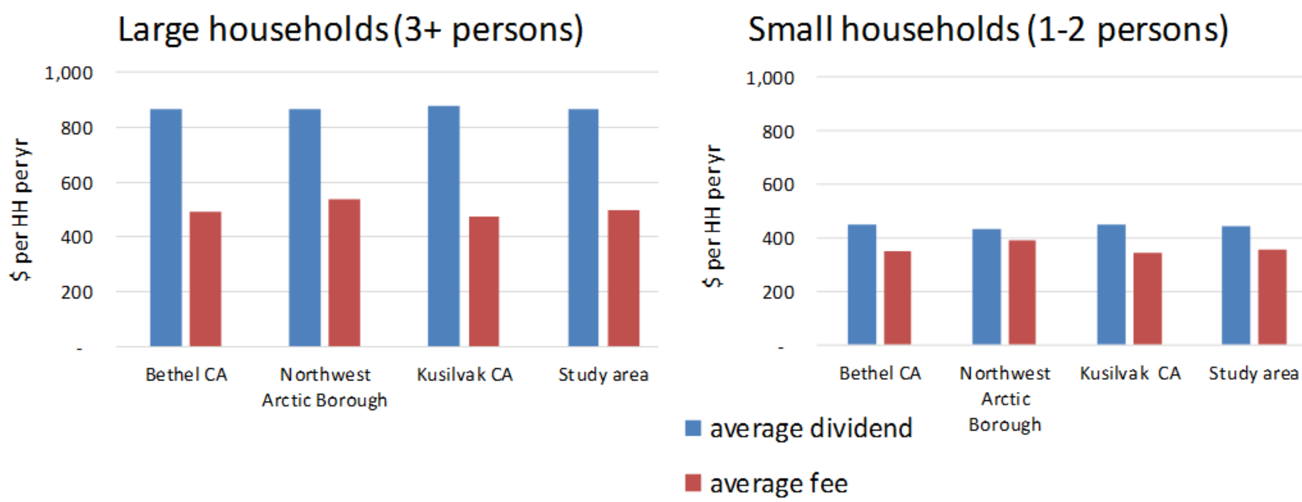
Table 15 and Figure 10 summarize the analysis of this section. They show the initial year outcomes for all three regions. Both small and large households in every region receive a net cash benefit because their average dividends exceed their average fees. Net cash benefits to small households range from $45 per year in Northwest Arctic Borough up to $106 per year in Kusilvak Census Area.

Considering the study area as a whole, total dividends exceed total fees by more than $2.2 million. While there are undoubtedly some financial losers within each household group, it is reasonable to conclude that the vast majority of people in the study area stand to initially gain more in dividends than they would pay in fees.

**Table 15. Results summary: initial year dividends and fees for all regions**

| | Bethel Census Area | Northwest Arctic Borough | Kusilvak Census Area | Overall Study Area |
|---|---|---|---|---|
| Initial year dividends and fees | | | | |
| Total dividends | 3,257,550 | 1,346,550 | 1,306,500 | 5,910,600 |
| Total fees | 2,020,942 | 921,644 | 760,442 | 3,703,028 |
| Net cash benefit to region | 1,236,608 | 424,906 | 546,058 | 2,207,572 |
| Small households (1-2 people) | | | | |
| Average dividend per HH | 447 | 434 | 448 | 444 |
| Average fee per HH | 351 | 388 | 341 | 358 |
| **Average net cash benefit per HH** | **96** | **45** | **106** | **86** |
| Number of households | 1,846 | 727 | 518 | 3,091 |
| Share of region population | 16% | 15% | 10% | 14% |
| Large households (3+ persons) | | | | |
| Average dividend per HH | 867 | 865 | 876 | 869 |
| Average fee per HH | 490 | 536 | 476 | 497 |
| **Average net cash benefit per HH** | **377** | **329** | **400** | **372** |
| Number of households | 2,805 | 1,192 | 1,227 | 5,224 |
| Share of region population | 84% | 85% | 90% | 86% |

**Figure 10. Summary of effects on large and small households**




## 4. Discussion

This paper has attempted to estimate the differing amounts of carbon fees and dividends that might be paid and received by individual households in different regions of remote rural Alaska. While dividend amounts can be calculated with precision, at least for the first several years, there is simply not enough data to make strong conclusions about the fees that individual households would pay. By considering two distinct types of households, this analysis has shown that larger households are likely to see significant net cash benefits while smaller households in all study area regions would still receive positive, but smaller, net cash benefits. In the study area 86% of the population lives in a household with 3 or more members. In Kusilvak, that fraction is 90%, and energy use is relatively low. The carbon fee and dividend concept appears to be relatively well-suited for areas like the three regions analyzed here. It favors larger households with relatively low energy use, and could initially deliver millions of dollars of net cash benefits to rural Alaska.

This analysis has necessarily focused on initial year numbers. Both future dividends and future fees are uncertain. Future dividends will increase as the fee per ton goes up, but the total amount available for distribution also depends on aggregate *national* $CO_2$ emissions, which would likely decline under the influence of increasing carbon fees. Future fees, on the other hand, can be moderated, or even eliminated, if rural Alaska communities can continue to increase energy efficiency and reduce dependence on diesel fuel.

### The importance of nonresidential local energy use

The category of "commercial" electricity use looms large in the analysis, because it is a large amount and because the portion of the associated carbon fees paid by local residents is likely significant, but unknown. Furthermore, it is important to remember that in this analysis nonresidential heat fuel use is estimated a simple linear function of nonresidential electricity, which amplifies the importance of nonresidential electricity. Table 16 shows the variation among the study regions in "commercial" and other categories of nonresidential electricity use, all expressed in terms of kWh per residential customer. The table also shows the dramatic effect of removing the hub communities of Bethel and Kotzebue from the calculations.

**Table 16. Nonresidential electrcity use per residential customer**

| | commercial | comm facil | govt facil | Total |
|---|---|---|---|---|
| Total Study Area | 5,848 | 1,421 | 2,155 | 14,859 |
| Bethel Census Area | 6,910 | 810 | 1,724 | 14,537 |
| Northwest Arctic Borough | 6,571 | 2,156 | 2,117 | 17,502 |
| Wade Hampton Census Area | 2,360 | 2,165 | 3,289 | 12,779 |
| Bethel CA excluding hub | 2,255 | 977 | 1,497 | 9,247 |
| NWAB excluding hub | 3,268 | 2,551 | 3,149 | 14,658 |

Further research could profitably look more carefully at these electricity consumption categories, perhaps by using individual customer billing data.

## Use of Public Use Microdata (PUMS) to check results

The Public Use Microdata Sample (PUMS) from the American Community Survey year 2013, 5-yr estimates data set provides a potentially powerful tool for household-level analysis of carbon fees and dividends. The main drawback of PUMS data is that all of rural Alaska, plus some large communities like Kodiak and Sitka, are lumped together as one geographic area known as PUMA 400. It is not possible to tell whether a household in the data set is from Ketchikan or from Kusilvak. A single large area would not be a problem if the data set contained estimates of electricity and fuel consumption for each household. However, it does not. What the PUMS does contain are self-reported *expenditures* on electricity and heating fuel. But the variation in fuel *prices* within the PUMA is so great that it must affect the reported expenditures by at least as much as variations in quantities of fuel used.[28]

Despite these drawbacks, the Alaska PUMS sample for rural areas, known as the "Subsistence Alaska PUMA" and numbered PUMA 400, can still provide useful evidence about potential dividends and fees. I used the PUMS sample with several auxiliary assumptions and side calculations to estimate carbon fees due to residential energy use and to compare the fee for each household in the sample to its dividend (which can be easily calculated from the household size).

[28] This problem would be solved if the ACS asked about and reported the prices associated with the expenditure data. There is no such data.

The results of this exploratory analysis generally corroborate the conclusions reported above. For example, more than 99% of households in the PUMS sample would receive sufficient dividends to defray the fees associated with their own estimated household residential electricity and fuel use. About 86% would receive enough dividends to cover twice that amount. The analysis in Section 3 suggests that total carbon fees -- for both direct and indirect purchases of energy -- are about 1.9 times the fees due to residential heating fuel and electricity. Therefore, one tentative conclusion from the PUMS household-level data is that more than 86% of all households in the geographic area known as the "Subsistence Alaska PUMA" would receive enough dividends to cover all of the fees considered in Section 3 (residential and nonresidential heat and electricity, personal land, water, and air transportation, and fuel for air freight). Due to the great limitations of the PUMS data, this result can only be considered as a "weak" or very broad corroboration of the main analysis using household types.

## References


Alaska Energy Authority and W.H. Pacific. 2012. Alaska end Use Study. http://www.akenergyauthority.org/Efficiency/EndUse

Alaska Housing Finance Corporation (AHFC). 2014. Alaska Housing Finance Corporation Alaska-Specific Amendments to IECC 2012. June 18, 2014. http://www.ahfc.us/index.php/download_file/view/2927/292/

Colt, S. 2013. "The Alaska Village Energy Model: An Integrated Community Energy Planning Tool." USAEE/IAEE North American Conference. Anchorage. July 2013. Notes available at http://www.iser.uaa.alaska.edu/Publications/2013-07_Village_energy_model_notes.pdf . Model available at http://www.iser.uaa.alaska.edu/Publications/2013-07_AVEM3.xlsx

Colt, S.; Goldsmith, S.; Larsen, P. 2007. Analysis of National Greenhouse Gas Control Legislation on Alaska Energy Prices and Consumer Costs. July 2007. http://www.iser.uaa.alaska.edu/Publications/presentations/Bingaman_update_V2.pdf

Colt, S., Scott Goldsmith, and Amy Wiita. 2003. Sustainable Utilities in Rural Alaska. Final report. Prepared for USDA Rural Development and Alaska Science and Technology Foundation. http://www.iser.uaa.alaska.edu/Publications/sustainB.pdf

Fay, G.; Schwoerer, T.; Guettabi, M. Armagost, J. 2013. Analysis of Alaska Transportation Sectors to Assess Energy Use and Impacts of Price Shocks and Climate Change Legislation. April. http://www.iser.uaa.alaska.edu/Publications/2013_04-nalysisAKTransportationSectorsAssessEnergyUse.pdf

Kummel, B. 2014. Who Pollutes? A Household-Level Database of America's Greenhouse Gas Footprint. Center for Global Development Working Paper 381. October.

http://www.cgdev.org/publication/who-pollutes-household-level-database-americas-greenhouse-gas-footprint-working-paper

Mori, Keibun. 2011 Washington State Carbon Tax Fiscal and Environmental Impacts Evans School of Public Affairs, University of Washington.

Northern Economics, Inc., 2009. The Economic Contribution of the Aviation Industry to the Economy of Alaska, Prepared for Alaska Department of Transportation and Public Facilities as part of the Alaska Aviation System Plan.

Regional Economic Modeling, Inc. (REMI) and Synapse Energy Economics, Inc. 2014. The Economic, Climate, Fiscal, Power, and Demographic Impact of a National Fee-and-Dividend Carbon Tax. Prepared for Citizens' Climate Lobby. June.

Schwoerer, T. 2013. "Personal Transportation in Rural Alaska". Presentation given at 2013 Alaska Rural Energy Conference in Anchorage, AK on May 1st, 2013 http://www.iser.uaa.alaska.edu/Publications/presentations/2013_05_01-SchwoererRuralTransportationEnergyUse.pdf

# Appendix A. Residential electricity use per household

This appendix discusses the regression equation used in Section 3 to determine differences in residential electricity use per household (hh).

**Goal**
The goal of the exercise is to estimate two quantities that do actually exist:

*use_small* = average residential electricity use per small hh across the study area
*use_large* = average residential electricity use per large hh across the study area

These are population averages, which fit into the overall approach used in this study, which is to develop average energy use for small hh and for large hh. There is no need to worry about whether individual households each have identical or nearly identical use.

If we had household level data for electricity consumption by each hh, we would just calculate these population (or sample) averages. But all we have is community level data for total use in that community.

**Model**
The starting point is a hypothetical model of residential electricity use under which every small household uses the same amount and every large household use a different (but identical for each large hh) amount. For example, the following table shows an example where each small hh uses 8 and each large hh uses 12 (the units are irrelevant). The example also assumes that in this particular community there are 80 small hh and 20 large hh. Total community use is therefore easily calculated as (80x8) + (20x12) = 880.

**Table A1. Hypothetical residential use by Community A**

| | | | smal hh | large hh | total |
|---|---|---|---|---|---|
| use per HH | | | 8 | 12 | |
| # HH | | | 80 | 20 | 100 |
| Fraction of HH | | | 0.8 | 0.2 | 1 |
| Total use | | | 640 | 240 | 880 |

The situation faced in this analysis is that we have data only for numbers of hh and for total consumption: the data say that 80 small hh and 20 large hh together somehow use 880 total in Community A. But suppose we also know that in Community B the hh amounts are 50 small and 50 large and the total use is 1000.

If we thus had the following data:

| | A | B |
|---|---|---|
| small hh | 80 | 50 |
| large hh | 20 | 50 |
| use | 880 | 1000 |

Then we would have two equations in two unknowns:

**80** x *use_small* + **20** x *use_large* = **880** = **use_total**
**50** x *use_small* + **50** x *use_large* = **1000**

Boldface indicates data, while italics indicate parameters to be determined, which are the unknowns to be solved for in this two-equation systm.

This system can be solved to get

*use_small* = 8
*use_large*= 12

We have now determined, using two data points, a possible linear model for total use in community *k:*

8 *x* **num_small**(k) + 12 x **num_large**(k) = **use_total**(k)

where num_small(k) is the number of small hh in community k and num_large(k) is the number of large hh in community k.

**Using community-level data**

We have data for num_small(k), num_large(k), and use_total(k). Again, this is community-level data. The data do not line up perfectly along a line because of random factors other than the **mix** of small and large houses determining total use in community *k.* These random factors could be "individual" (many hh in community k have electric water heaters) or "community" (colder climate). The crucial assumption to get unbiased estimates of the population means that we seek – *use_small* and *use_large* – is that these errors are uncorrelated with the **relative** numbers – the mix -- of small and large hh. This seems like a reasonable assumption, but I cannot prove it.

Assuming the assumption is reasonable, we can proceed. It helps to transform the data into amounts per hh. This transformation helps control for heteroskedasticity (larger random errors in larger communities).

The equation to be estimated is therefore:

**use_average**(k) = *use_small* x **frac_small**(k) + *use_large* x **frac_large**(k) + **error**(k)

where bold-faced data are:
**use_average**(k) = average use in community k
**frac_small**(k) = share of total hh that are small
**frac_large**(k) = share of total hh that are large

A further simplification is that since **frac_small**(k) + **frac_large**(k) = 1.00, we can substitute (1-**frac_large**(k)) for **frac_small**(k) and rearrange terms to get:

**use_average**(k) = *use_small* + *(use_large – use_small)* x **frac_large**(k) + error(k)

This equation works better for estimation because it has a constant term. The results are easy to interpret. The estimated constant is average use per small hh and the coefficient is the additional amount used by a large hh.

**Simulation using made-up data**

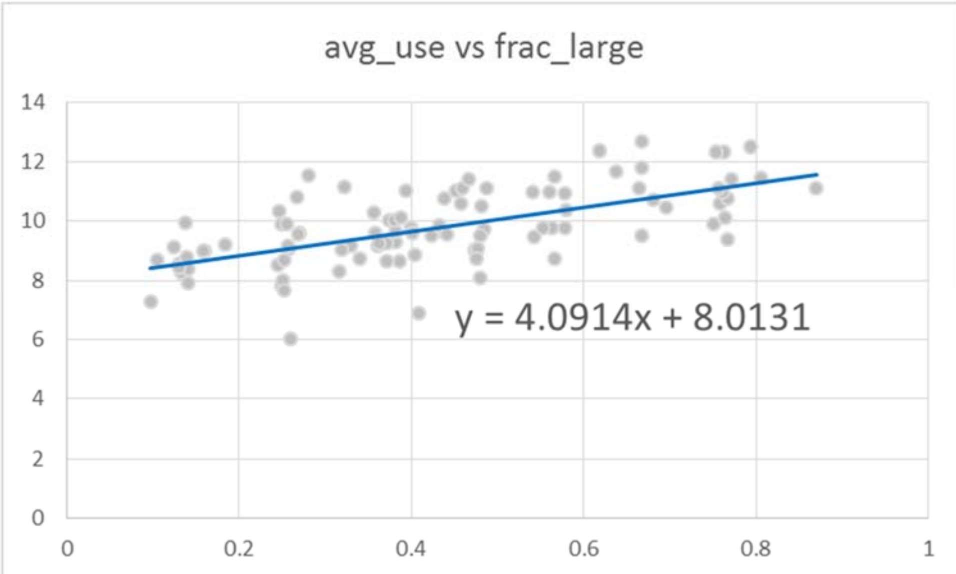
I created a made-up data set of 100 values for numbers of large and small hh in 100 communities. I then assumed that average consumption per small hh (= *use_small*) =8 and average consumption per large hh (= *use_large*) = 12. I further generated total community use "data" as:

**use_total** = 8 x **number of small hh** + 12 x **number of large hh** + [random error]

where [random error] is a random draw from a standard normal distribution.

The following table shows the resulting made-up data set and the figure that precedes it shows the resulting regression line. The estimated value for differential use -- 4.019 -- is remarkably close to the true value of 4 – the value that generated the data.

**Regression line generated by made-up data:**




The following pages show the made-up data that resulted in this regression line.

| | | | use per HH | | | | Regression data | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 8 | 12 | | | | | |
| communit | N(0,1) | error | smallHH | largeHH | totalHH | total_use | | frac_large | avg_use |
| 1 | 1.995719 | 1.995719 | 20 | 40 | 60 | 640 | | 0.666667 | 12.66239 |
| 2 | 0.639706 | 0.639706 | 30 | 41 | 71 | 732 | | 0.577465 | 10.94957 |
| 3 | 1.147834 | 1.147834 | 40 | 38 | 78 | 776 | | 0.487179 | 11.09655 |
| 4 | 1.027239 | 1.027239 | 50 | 39 | 89 | 868 | | 0.438202 | 10.78005 |
| 5 | 0.169904 | 0.169904 | 60 | 40 | 100 | 960 | | 0.4 | 9.769904 |
| 6 | 0.184937 | 0.184937 | 70 | 39 | 109 | 1028 | | 0.357798 | 9.61613 |
| 7 | -0.96549 | -0.96549 | 80 | 37 | 117 | 1084 | | 0.316239 | 8.299464 |
| 8 | 2.420039 | 2.420039 | 90 | 35 | 125 | 1140 | | 0.28 | 11.54004 |
| 9 | 0.542289 | 0.542289 | 100 | 60 | 160 | 1520 | | 0.375 | 10.04229 |
| 10 | -0.29248 | -0.29248 | 110 | 62 | 172 | 1624 | | 0.360465 | 9.149382 |
| 11 | -0.6402 | -0.6402 | 120 | 62 | 182 | 1704 | | 0.340659 | 8.722434 |
| 12 | 1.853247 | 1.853247 | 130 | 62 | 192 | 1784 | | 0.322917 | 11.14491 |
| 13 | -0.09387 | -0.09387 | 80 | 62 | 142 | 1384 | | 0.43662 | 9.652613 |
| 14 | -0.75451 | -0.75451 | 90 | 61 | 151 | 1452 | | 0.403974 | 8.861389 |
| 15 | -0.90453 | -0.90453 | 100 | 63 | 163 | 1556 | | 0.386503 | 8.641478 |
| 16 | 0.858666 | 0.858666 | 110 | 61 | 171 | 1612 | | 0.356725 | 10.28557 |
| 17 | -0.17079 | -0.17079 | 120 | 59 | 179 | 1668 | | 0.329609 | 9.14765 |
| 18 | -0.22825 | -0.22825 | 130 | 61 | 191 | 1772 | | 0.319372 | 9.049233 |
| 19 | -1.07934 | -1.07934 | 20 | 60 | 80 | 880 | | 0.75 | 9.920659 |
| 20 | 0.21586 | 0.21586 | 15 | 62 | 77 | 864 | | 0.805195 | 11.43664 |
| 21 | -0.01849 | -0.01849 | 30 | 64 | 94 | 1008 | | 0.680851 | 10.70491 |
| 22 | -0.35727 | -0.35727 | 10 | 67 | 77 | 884 | | 0.87013 | 11.12325 |
| 23 | -0.94477 | -0.94477 | 20 | 65 | 85 | 940 | | 0.764706 | 10.11405 |
| 24 | 0.002632 | 0.002632 | 100 | 67 | 167 | 1604 | | 0.401198 | 9.607422 |
| 25 | -0.2508 | -0.2508 | 110 | 68 | 178 | 1696 | | 0.382022 | 9.277289 |
| 26 | -0.21492 | -0.21492 | 120 | 71 | 191 | 1812 | | 0.371728 | 9.271995 |
| 27 | -0.19704 | -0.19704 | 130 | 74 | 204 | 1928 | | 0.362745 | 9.253936 |
| 28 | -0.84932 | -0.84932 | 80 | 72 | 152 | 1504 | | 0.473684 | 9.045417 |
| 29 | 1.238875 | 1.238875 | 90 | 74 | 164 | 1608 | | 0.45122 | 11.04375 |
| 30 | 0.112122 | 0.112122 | 100 | 76 | 176 | 1712 | | 0.431818 | 9.839394 |
| 31 | -2.74903 | -2.74903 | 110 | 76 | 186 | 1792 | | 0.408602 | 6.885376 |
| 32 | 0.129048 | 0.129048 | 120 | 74 | 194 | 1848 | | 0.381443 | 9.654821 |
| 33 | 0.517655 | 0.517655 | 130 | 80 | 210 | 2000 | | 0.380952 | 10.04146 |
| 34 | -0.20829 | -0.20829 | 100 | 79 | 179 | 1748 | | 0.441341 | 9.557071 |
| 35 | -0.19124 | -0.19124 | 110 | 81 | 191 | 1852 | | 0.424084 | 9.505094 |
| 36 | 1.463047 | 1.463047 | 120 | 78 | 198 | 1896 | | 0.393939 | 11.0388 |
| 37 | -0.83375 | -0.83375 | 130 | 77 | 207 | 1964 | | 0.371981 | 8.654176 |
| 38 | 1.306252 | 1.306252 | 20 | 77 | 97 | 1084 | | 0.793814 | 12.48151 |
| 39 | -0.33246 | -0.33246 | 35 | 80 | 115 | 1240 | | 0.695652 | 10.45014 |
| 40 | 1.149894 | 1.149894 | 40 | 80 | 120 | 1280 | | 0.666667 | 11.81656 |
| 41 | 1.898643 | 1.898643 | 50 | 81 | 131 | 1372 | | 0.618321 | 12.37193 |
| 42 | -0.51991 | -0.51991 | 60 | 82 | 142 | 1464 | | 0.577465 | 9.789953 |
| 43 | 0.446211 | 0.446211 | 40 | 79 | 119 | 1268 | | 0.663866 | 11.10167 |
| 44 | -0.25165 | -0.25165 | 130 | 20 | 150 | 1280 | | 0.133333 | 8.281688 |
| 45 | -0.89733 | -0.89733 | 20 | 18 | 38 | 376 | | 0.473684 | 8.997406 |
| 46 | 0.54918 | 0.54918 | 30 | 19 | 49 | 468 | | 0.387755 | 10.1002 |
| 47 | -1.13721 | -1.13721 | 10 | 20 | 30 | 320 | | 0.666667 | 9.529454 |
| 48 | 1.252685 | 1.252685 | 20 | 17 | 37 | 364 | | 0.459459 | 11.09052 |
| 49 | 0.353054 | 0.353054 | 100 | 19 | 119 | 1028 | | 0.159664 | 8.99171 |
| 50 | -0.64205 | -0.64205 | 110 | 18 | 128 | 1096 | | 0.140625 | 7.920451 |

continues

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 51 | 0.048948 | 0.048948 | 120 | 18 | 138 | 1176 | | 0.130435 | 8.570687 |
| 52 | 0.221166 | 0.221166 | 130 | 21 | 151 | 1292 | | 0.139073 | 8.777458 |
| 53 | 0.469339 | 0.469339 | 80 | 18 | 98 | 856 | | 0.183673 | 9.204033 |
| 54 | 0.340107 | 0.340107 | 90 | 17 | 107 | 924 | | 0.158879 | 8.975621 |
| 55 | 1.372035 | 1.372035 | 100 | 16 | 116 | 992 | | 0.137931 | 9.923759 |
| 56 | -0.18948 | -0.18948 | 110 | 18 | 128 | 1096 | | 0.140625 | 8.373023 |
| 57 | 0.60926 | 0.60926 | 120 | 17 | 137 | 1164 | | 0.124088 | 9.10561 |
| 58 | -1.10548 | -1.10548 | 130 | 14 | 144 | 1208 | | 0.097222 | 7.283405 |
| 59 | -0.07229 | -0.07229 | 100 | 15 | 115 | 980 | | 0.130435 | 8.449445 |
| 60 | 0.285093 | 0.285093 | 110 | 13 | 123 | 1036 | | 0.105691 | 8.707858 |
| 61 | 0.900226 | 0.900226 | 120 | 40 | 160 | 1440 | | 0.25 | 9.900226 |
| 62 | 1.351013 | 1.351013 | 122 | 40 | 162 | 1456 | | 0.246914 | 10.33867 |
| 63 | -1.1643 | -1.1643 | 123 | 41 | 164 | 1476 | | 0.25 | 7.835698 |
| 64 | -0.47539 | -0.47539 | 123 | 40 | 163 | 1464 | | 0.245399 | 8.506208 |
| 65 | -1.01507 | -1.01507 | 125 | 42 | 167 | 1504 | | 0.251497 | 7.990919 |
| 66 | -0.33947 | -0.33947 | 127 | 43 | 170 | 1532 | | 0.252941 | 8.672298 |
| 67 | -3.02385 | -3.02385 | 128 | 45 | 173 | 1564 | | 0.260116 | 6.016612 |
| 68 | 0.041497 | 0.041497 | 129 | 45 | 174 | 1572 | | 0.258621 | 9.07598 |
| 69 | 0.15636 | 0.15636 | 130 | 45 | 175 | 1580 | | 0.257143 | 9.184931 |
| 70 | 0.500481 | 0.500481 | 130 | 48 | 178 | 1616 | | 0.269663 | 9.579133 |
| 71 | 0.491587 | 0.491587 | 131 | 48 | 179 | 1624 | | 0.268156 | 9.564213 |
| 72 | 1.759793 | 1.759793 | 132 | 48 | 180 | 1632 | | 0.266667 | 10.82646 |
| 73 | -1.34197 | -1.34197 | 133 | 45 | 178 | 1604 | | 0.252809 | 7.669262 |
| 74 | 0.868224 | 0.868224 | 131 | 45 | 176 | 1588 | | 0.255682 | 9.890951 |
| 75 | 0.806725 | 0.806725 | 40 | 47 | 87 | 884 | | 0.54023 | 10.96764 |
| 76 | -0.46072 | -0.46072 | 38 | 49 | 87 | 892 | | 0.563218 | 9.792152 |
| 77 | 1.234111 | 1.234111 | 36 | 47 | 83 | 852 | | 0.566265 | 11.49917 |
| 78 | 0.733505 | 0.733505 | 36 | 46 | 82 | 840 | | 0.560976 | 10.97741 |
| 79 | 0.034917 | 0.034917 | 34 | 47 | 81 | 836 | | 0.580247 | 10.3559 |
| 80 | -1.5508 | -1.5508 | 36 | 47 | 83 | 852 | | 0.566265 | 8.714263 |
| 81 | -0.43389 | -0.43389 | 38 | 47 | 85 | 868 | | 0.552941 | 9.777879 |
| 82 | -0.68998 | -0.68998 | 38 | 45 | 83 | 844 | | 0.542169 | 9.478691 |
| 83 | -0.21947 | -0.21947 | 50 | 47 | 97 | 964 | | 0.484536 | 9.718672 |
| 84 | -1.8155 | -1.8155 | 52 | 48 | 100 | 992 | | 0.48 | 8.104504 |
| 85 | -0.38974 | -0.38974 | 52 | 48 | 100 | 992 | | 0.48 | 9.530256 |
| 86 | -0.91784 | -0.91784 | 55 | 50 | 105 | 1040 | | 0.47619 | 8.986926 |
| 87 | 0.779013 | 0.779013 | 57 | 48 | 105 | 1032 | | 0.457143 | 10.60758 |
| 88 | 1.561301 | 1.561301 | 57 | 50 | 107 | 1056 | | 0.46729 | 11.43046 |
| 89 | -0.82095 | -0.82095 | 56 | 51 | 107 | 1060 | | 0.476636 | 9.085589 |
| 90 | -1.18297 | -1.18297 | 54 | 49 | 103 | 1020 | | 0.475728 | 8.71994 |
| 91 | 0.597525 | 0.597525 | 54 | 50 | 104 | 1032 | | 0.480769 | 10.5206 |
| 92 | 1.113355 | 1.113355 | 57 | 100 | 157 | 1656 | | 0.636943 | 11.66113 |
| 93 | -1.70114 | -1.70114 | 30 | 99 | 129 | 1428 | | 0.767442 | 9.368627 |
| 94 | 0.342589 | 0.342589 | 29 | 98 | 127 | 1408 | | 0.771654 | 11.4292 |
| 95 | 1.252366 | 1.252366 | 30 | 96 | 126 | 1392 | | 0.761905 | 12.29999 |
| 96 | -0.45309 | -0.45309 | 30 | 94 | 124 | 1368 | | 0.758065 | 10.57917 |
| 97 | -0.29691 | -0.29691 | 28 | 92 | 120 | 1328 | | 0.766667 | 10.76976 |
| 98 | 1.294622 | 1.294622 | 29 | 89 | 118 | 1300 | | 0.754237 | 12.31157 |
| 99 | -0.05549 | -0.05549 | 28 | 89 | 117 | 1292 | | 0.760684 | 10.98725 |
| 100 | 0.093562 | 0.093562 | 28 | 87 | 115 | 1268 | | 0.756522 | 11.11965 |