

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

Final Report

prepared by

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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 CO2 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.

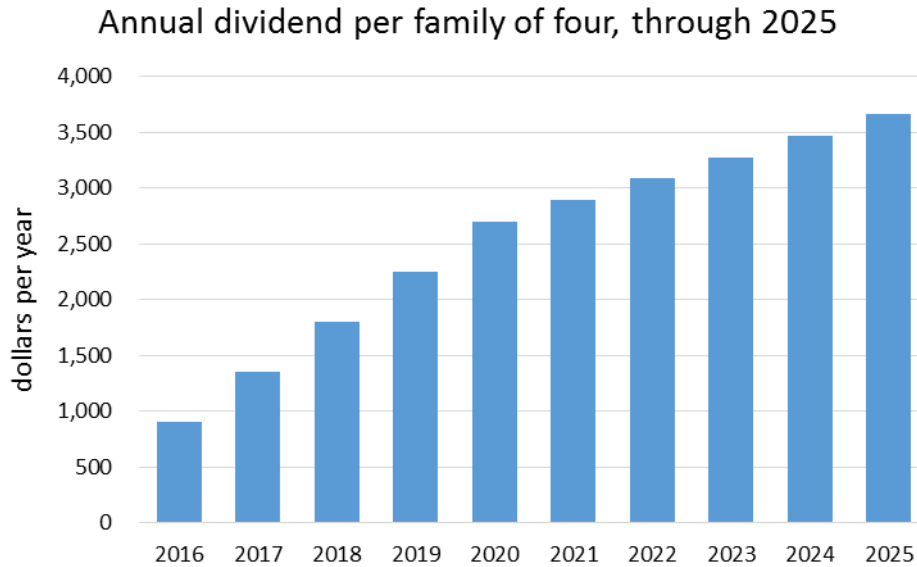
sources: U.S. Census 2010 (population, households, income); *Alaska Fuel Price Report: Current Community Conditions January 2015*

[http://commerce.state.ak.us/dnn/Portals/4/pub/Fuel\\_Price\\_Report\\_Jan-2015.pdf](http://commerce.state.ak.us/dnn/Portals/4/pub/Fuel_Price_Report_Jan-2015.pdf)

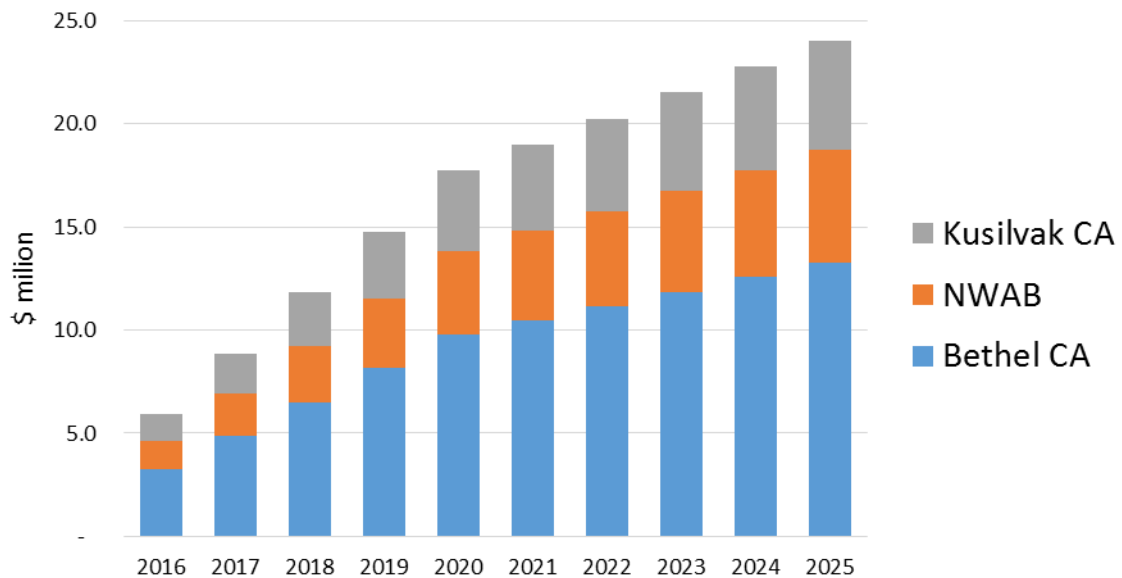
**Methodology.** Carbon fees paid by a household depend on the quantity of energy used, while dividends depend on household size. Both energy use and household size vary widely and more or less independently among individual households. It is critical to consider this variation when evaluating the CFD 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.<sup>1</sup>

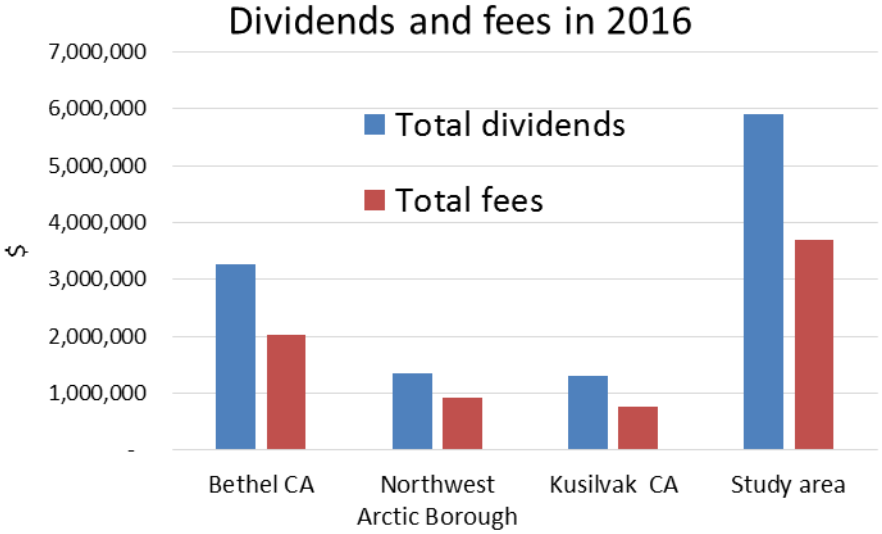


- A total of \$5.9 million in dividend payments would flow to the three regions in 2016. Total dividends would increase to \$24 million by 2025.

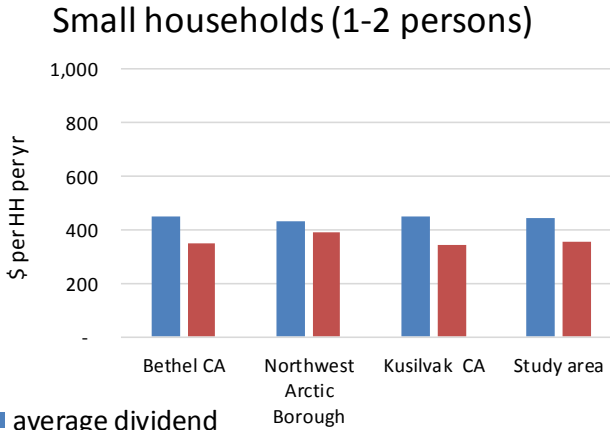
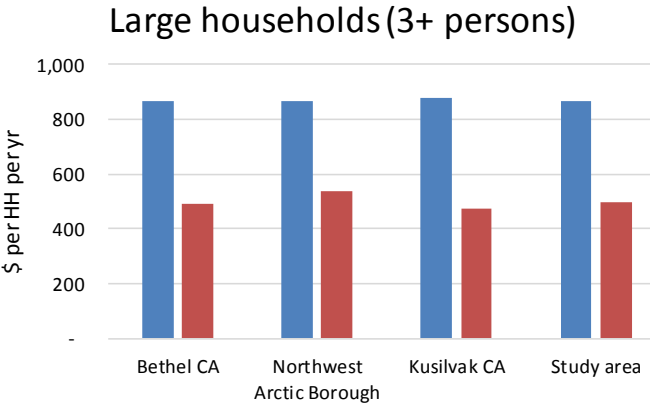


<sup>1</sup> All amounts are real dollars of year 2016 purchasing power.

- 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.



■ average dividend  
■ average fee

- 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 outcomes 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
<b>Initial year dividends and fees</b>				
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
<b>Small households (1-2 people)</b>				
Average dividend per HH	447	434	448	444
Average fee per HH	351	388	341	358
<b>Average net cash benefit per HH</b>	<b>96</b>	<b>45</b>	<b>106</b>	<b>86</b>
Number of households	1,846	727	518	3,091
Share of region population	16%	15%	10%	14%
<b>Large households (3+ persons)</b>				
Average dividend per HH	867	865	876	869
Average fee per HH	490	536	476	497
<b>Average net cash benefit per HH</b>	<b>377</b>	<b>329</b>	<b>400</b>	<b>372</b>
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

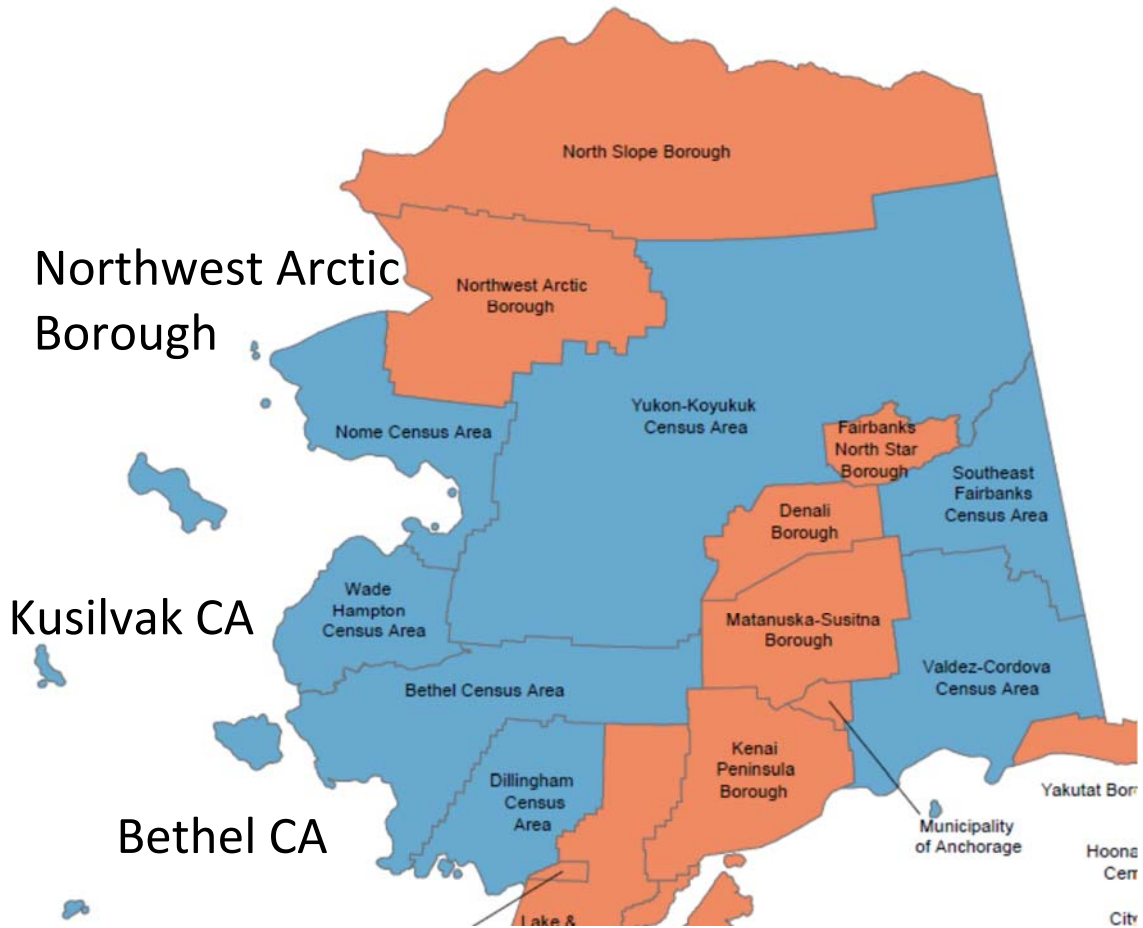
The study area consists of the Bethel Census Area, the Kusilvak Census Area,<sup>2</sup> and the Northwest Arctic Borough (Figure 1). These three regions have the state’s highest fuel prices, low median incomes, and very cold climates (Table 1). Each region is analyzed separately. By using these three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

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<sup>2</sup> formerly known as the Wade Hampton Census Area.



**Figure 1. Study area**



Map source: Alaska Department of Labor and Workforce Development

**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](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 CO<sub>2</sub>, 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.<sup>3</sup>
- The carbon dividend amounts increase annually consistent with growth in the national total of fees received.<sup>4</sup>
- The carbon emission factors and the resulting initial fees per gallon are as shown in Table 2.<sup>5</sup>

**Table 2. Carbon emission factors**

	kg CO <sub>2</sub> / mmbtu	mmbtu / gal	kg CO <sub>2</sub> /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.<sup>6</sup> 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.

<sup>3</sup> initial dividend amounts are estimated from current CO<sub>2</sub> emissions.

<sup>4</sup> I used projections of future dividend amounts per household from REMI (2014), figure 3.18.

<sup>5</sup> Carbon emission factors from [http://www.eia.gov/oiaf/1605/excel/Fuel\\_Emission\\_Factors.xls](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.

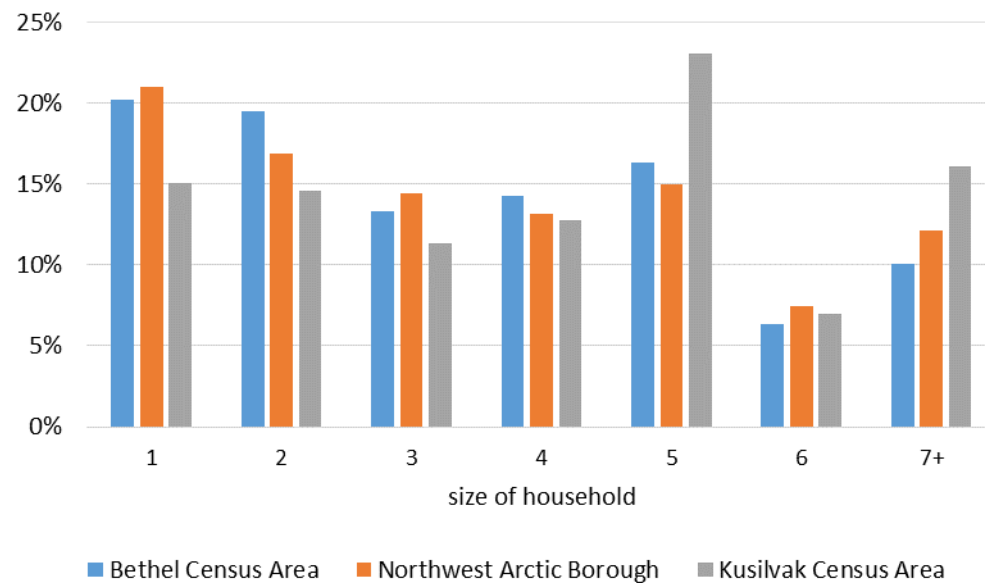
<sup>6</sup> The question of “who ultimately pays” is the age-old problem known in economics as *tax incidence*.

## 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							Overall
	1	2	3	4	5	6	7+	
dividend per HH:	\$ 300	\$ 600	\$ 750	\$ 900	\$ 900	\$ 900	\$ 900	
<b>Bethel Census Area</b>								
# 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
<b>Northwest Arctic Borough</b>								
# 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
<b>Kusilvak Census Area</b>								
# 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**

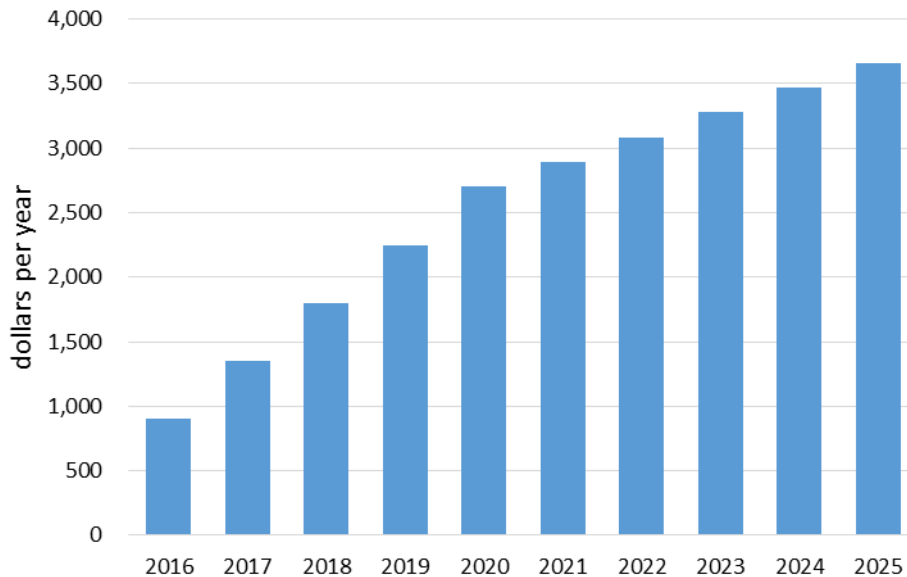
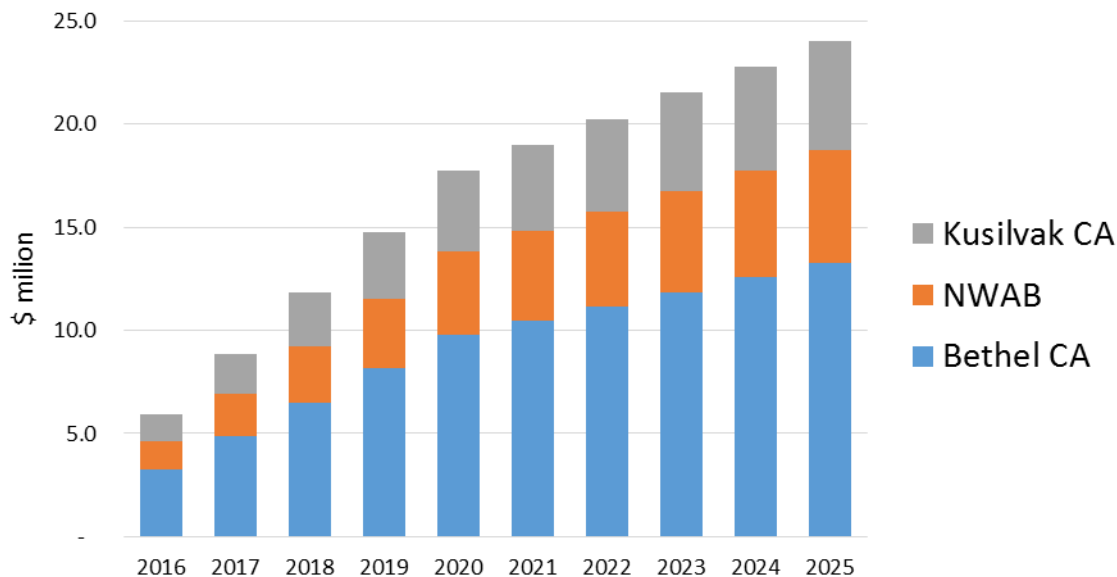


Figure 4 shows how total annual dividends to study area households would grow to almost \$25 million by 2025.

**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

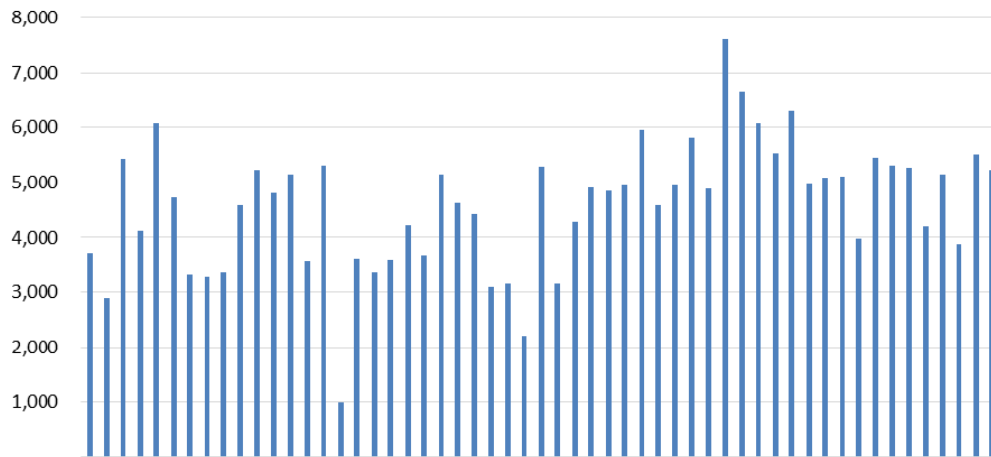
residents. This problem can be addressed through a more thorough analysis of these uses and payments.

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.<sup>7</sup> 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**



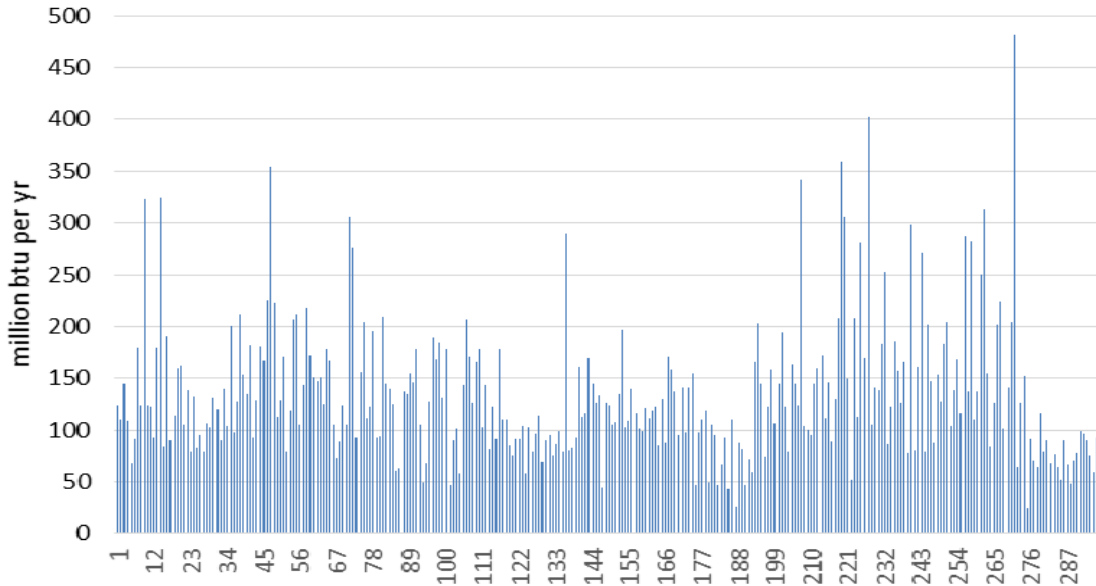
source: Alaska Energy Authority, Power Cost Equalization Program

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<sup>7</sup> 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.<sup>8</sup> 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**

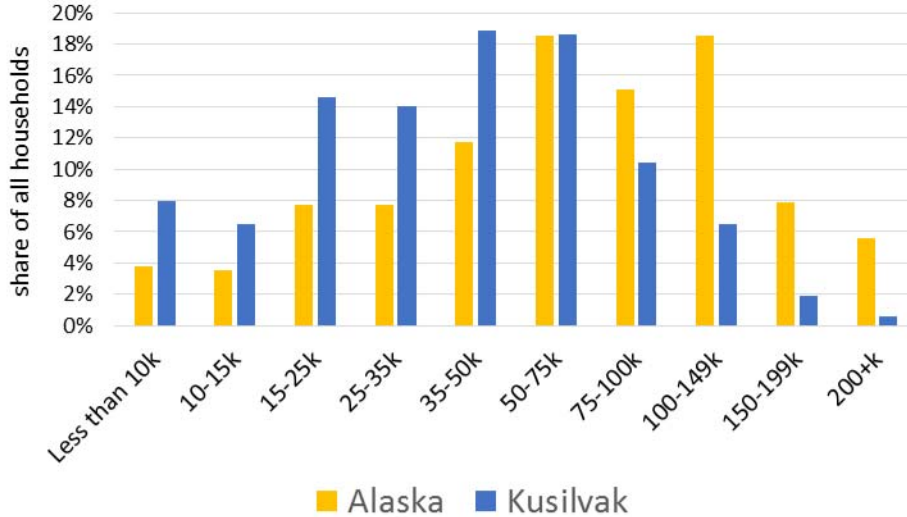


source: Alaska Retrofit Information System; Alaska Energy Authority & WH Pacific, Alaska End Use Study (2012)

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.

<sup>8</sup> 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.<sup>9</sup>

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.

<sup>9</sup> 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.<sup>10</sup> 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

<sup>10</sup> 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.<sup>11</sup>

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*.<sup>12</sup>

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

	ARIS rural	EUS Sample	Average of both samples			compare
	sample (318 houses)	(328 houses)	million million million	million million	million million	to NANA SEP
	million btu/yr	million btu/yr	million million million	million million	million million	million million
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.<sup>13</sup> With this

<sup>11</sup> See Alaska Housing Finance Corporation (2014).

<sup>12</sup> 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.

<sup>13</sup> 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**

	<b>Number of houses by HH type:</b>			<b>Fuel per house (gal/yr)</b>
	<b>Small HH (1-2 members)</b>	<b>Large HH (3+ members)</b>	<b>All HH</b>	
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.<sup>14</sup>

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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.

<sup>14</sup> 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 nonresidential 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.<sup>15</sup>

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.<sup>16</sup> 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

<sup>15</sup> 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.

<sup>16</sup> 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.<sup>17</sup> 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.<sup>18</sup> 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.

<sup>17</sup> 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.

<sup>18</sup> 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
<b>Total nonresidential heating fuel</b>			<b>1,555,561</b>

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**

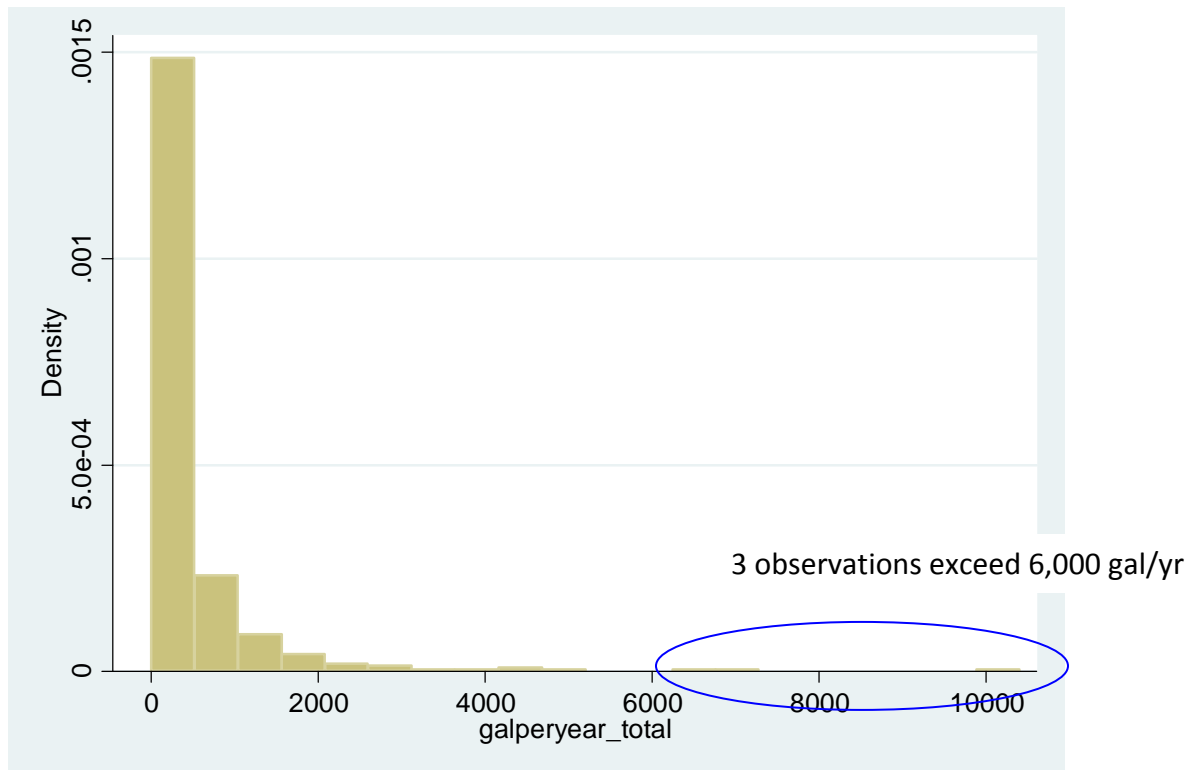
	Total gal/yr	Total fee \$/yr	Assumed local incidence	Total fees paid by all HH	Allocation method to HH groups	Total fees paid by small HH	Total fees paid by large HH
commercial	469,734	69,066	0.50	34,533	income	6,615	27,917
community facilities	430,949	63,363	1.00	63,363	equal per HH	18,809	44,554
government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

### 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 transportation 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 transportation 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.<sup>19</sup>

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<sup>19</sup> M. Guettabi, Institute 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),<sup>20</sup> 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.<sup>21</sup>

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.<sup>22</sup> 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,

<sup>20</sup> 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.

<sup>21</sup> <http://web.mit.edu/airlinedata/www/default.html>

<sup>22</sup> 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),<sup>23</sup> from Department of Transportation flight segment statistics.<sup>24</sup> 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.<sup>25</sup>

**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 freight 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		

<sup>23</sup> See esp. pages 22,24

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

<sup>25</sup> 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.<sup>26</sup> 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 incidence	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 unbilled	436,289	64,148	0.00	0	0	0	0	0
	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
<b>Total</b>	<b>6,317,600</b>	<b>909,183</b>		<b>691,153</b>	<b>160,693</b>	<b>530,460</b>	<b>341</b>	<b>476</b>

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.

<sup>26</sup> 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 the 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 will 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.<sup>27</sup> 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 outcomes 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 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 population 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

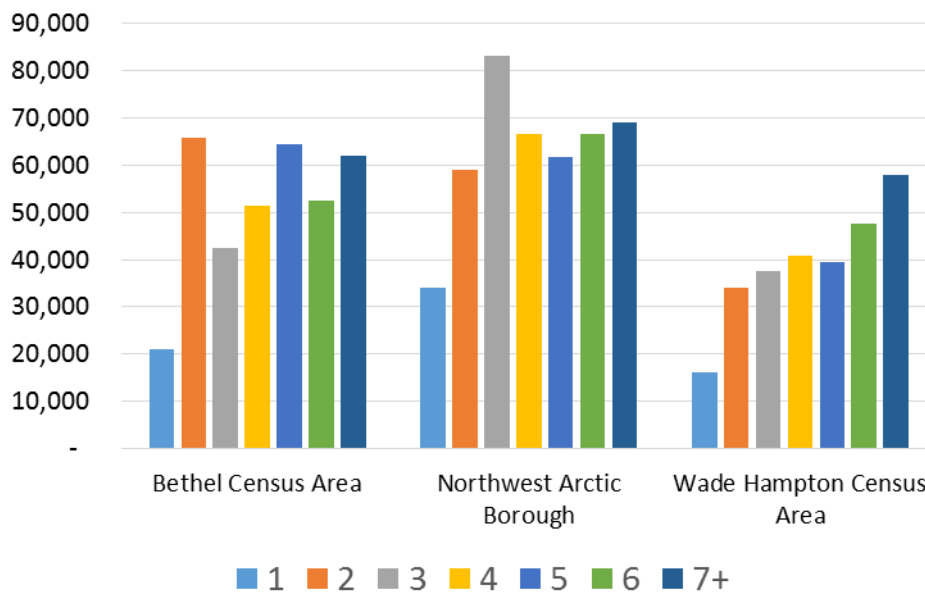
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<sup>27</sup> Numbers may not appear to add exactly due to rounding for display purposes.

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

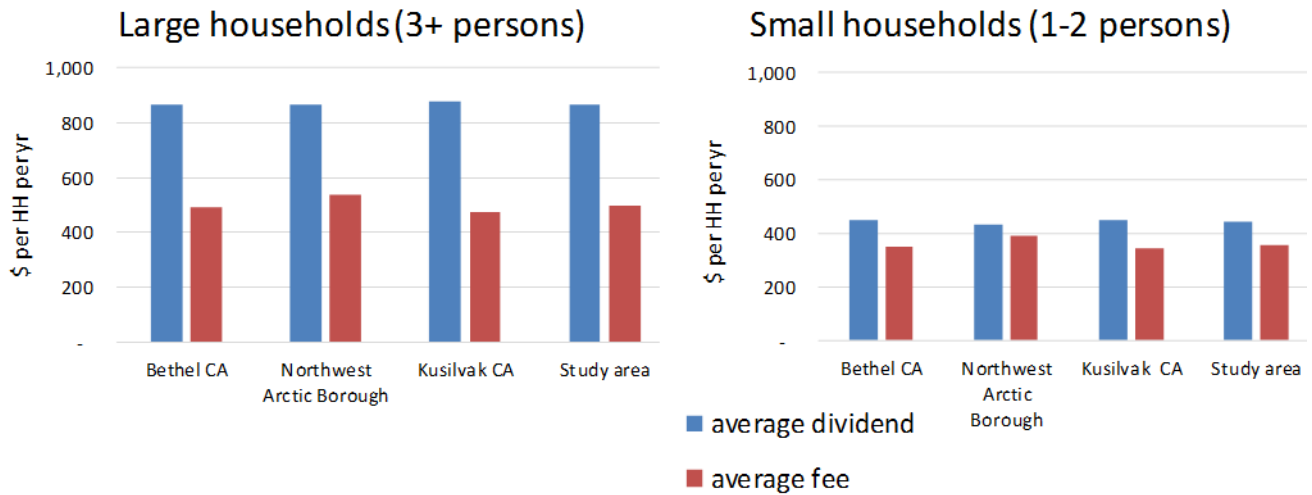
Table 15 and Figure 10 summarize the analysis of this section. They show the initial year outcomes for all three regions. Both small and large households in every region receive a net cash benefit because their average dividends exceed their average fees. Net cash benefits to small households range from \$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**

	Northwest			Overall Study Area
	Bethel Census Area	Arctic Borough	Kusilvak Census Area	
<b>Initial year dividends and fees</b>				
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
<b>Small households (1-2 people)</b>				
Average dividend per HH	447	434	448	444
Average fee per HH	351	388	341	358
<b>Average net cash benefit per HH</b>	<b>96</b>	<b>45</b>	<b>106</b>	<b>86</b>
Number of households	1,846	727	518	3,091
Share of region population	16%	15%	10%	14%
<b>Large households (3+ persons)</b>				
Average dividend per HH	867	865	876	869
Average fee per HH	490	536	476	497
<b>Average net cash benefit per HH</b>	<b>377</b>	<b>329</b>	<b>400</b>	<b>372</b>
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<sub>2</sub> 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 electricity 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.<sup>28</sup>

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).

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<sup>28</sup> 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.

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## 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  $(80 \times 8) + (20 \times 12) = 880$ .

**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:

$$80 \times use\_small + 20 \times use\_large = 880 = use\_total$$

$$50 \times use\_small + 50 \times use\_large = 1000$$

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

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  $k$ :

$$8 \times num\_small(k) + 12 \times num\_large(k) = use\_total(k)$$

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:

$$\mathbf{use\_average}(k) = use\_small \times \mathbf{frac\_small}(k) + use\_large \times \mathbf{frac\_large}(k) + \mathbf{error}(k)$$

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:

$$\mathbf{use\_average}(k) = use\_small + (use\_large - use\_small) \times \mathbf{frac\_large}(k) + \mathbf{error}(k)$$

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

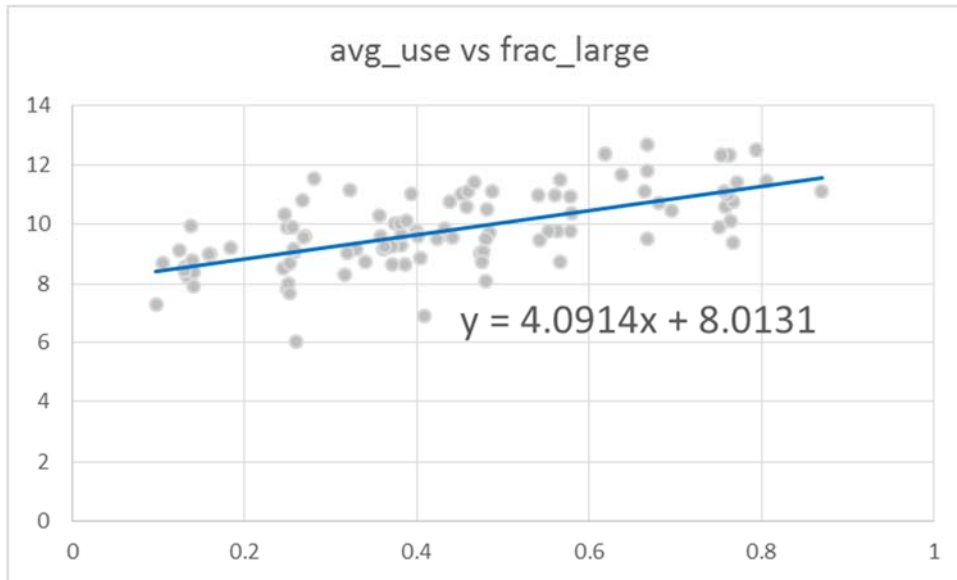
I created a made-up data set of 100 values for numbers of large and small hh in 100 communities. I then assumed that average consumption per small hh (= *use\_small*) = 8 and average consumption per large hh (= *use\_large*) = 12. I further generated total community use "data" as:

$$\mathbf{use\_total} = 8 \times \mathbf{number\ of\ small\ hh} + 12 \times \mathbf{number\ of\ large\ hh} + [\mathbf{random\ error}]$$

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