Alaska Energy Authority
End Use Study: 2012

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Produced by:

WHPacific

with Brian Saylor and Associates, CTG Energetics, and Craciun Research Group

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Acronyms

AAAT	Annual Average Ambient Temperature
AEA	Alaska Energy Authority
ANCSA	Alaska Native Claims Settlement Act
ANTHC	Alaska Native Tribal Health Consortium
ARIS	Alaska Retrofit Information System
ARUC	Alaska Rural Utilities Consortium
AVEC	Alaska Village Electric Cooperative
BEES	Building Energy Efficiency Standards
BTUs	British Thermal Units
CCHRC	Cold Climate Research Housing Center
CFL	Compact Fluorescent Light Bulbs
CZ	Climate Zone
DHW	Domestic Hot Water
EUS	End Use Study
EWAT	Extreme Winter Ambient Temperature
HID	High Intensity Discharge
HVAC	Heating, Ventilation, and Air Condition
ISER	Institute of Social and Economic Research
KBTU	British Thermal Units X1000
LED	Light-Emitting Diode
LPS	Low Pressure Sodium
MH	Metal Halide
MMBTU	British Thermal Units x 1 million
RDI	Resource Data Inc.
SEAK	Southeast Alaska
UAA	University of Alaska Anchorage
VSW	Village Safe Water

Alaska Energy Authority End-Use Study
Executive Summary

Overview

The primary purpose of this End-use Study (EUS) is to provide energy end use details for residential and non-residential buildings in Southeast Alaska (Climate Zone 6), Southcentral Alaska (Climate Zone 7), Fairbanks/Interior (Climate Zone 8), and the rural North/Northwest Alaska. Building upon this geographic stratification, it is important to place building energy use in context of statewide energy consumption at the regional level. The AEA/EUS also provided basic end-use energy and building benchmark information on several non-building categories, including street lighting and water/waste water treatment infrastructure. In conjunction with AEA, the data was amalgamated to document overall statewide energy use for residential and non-residential buildings in Climate Zones 6-8, water/wastewater infrastructure energy use, and non-Residential rural community buildings.

Specifically, the purposes of the AEA End-Use Study are to:

- Provide baseline data on energy use in residential and nonresidential buildings through statistical estimates of building energy consumption by "end-use" (e.g., heating, cooling, lighting, etc.), stratified by building type, location, and other parameters.
- Establish a framework for future end-use studies.

This end-use data may be used to:

- Identify opportunities for energy efficiency measures.
- Track changes over time in building and community energy use intensities and greenhouse gas emissions.

The report presents information on residential, nonresidential energy end-use data for communities in the Railbelt and Southeast Alaska Regions further disaggregated by Climate Zone. The conclusions noted below are shown in greater detail in the conclusions section of the report. The conclusions are derived from data shown in the baseline study narrative tables and graphs and are presented in the order that they are presented in the report.

Railbelt and Southeast Residential Energy Use

- The average residence in Railbelt and Southeast Alaska regions uses 269 MMBTUs in energy each year, and total energy use of 59 million MMBTUs.

- Residents of Railbelt and Southeast Alaska use about 80% of their total energy (in MMBTUs) to heat their homes.
- Single family detached residences use more energy than other types of residences. Multifamily residences use the least.
- Natural gas is the primary fuel for home heating in 64% of households in Railbelt and Southeast Alaska, and oil is the primary fuel in Southeast Alaska.
- Domestic hot water uses between 9% and 11% of energy in Railbelt and Southeast Alaskan homes.
- Electrical appliances use between 8% and 10% of all MMBTUs among respondent households in Railbelt and Southeast Alaska, but consume 65% of all electrical energy.
- The operation of major appliances such as refrigerators, freezers, washers and dryers is the largest single residential use of electrical energy in all the Climate Zones within Railbelt and Southeast Alaska (24% of electrical energy.
- Mobile homes have the highest energy intensity (KBTU/ft^2) in space heating, domestic hot water production and operating appliances.

Railbelt and Southeast Non-residential Energy Use

- Based on average energy use by various non-residential building types, Railbelt and Southeast Alaska regions use over 29,974.000 MMBTUs of energy each year.
- It is important to estimate both the total energy use in MMBTUs and the energy intensity in kBTUs per square foot.
- Food service facilities have more energy intensity than any other type of building in Climate Zones 6, 7, and 8.
- Healthcare facilities have the second highest energy intensity, about one half that of food service buildings.
- Heating accounts for just over 50% of total building energy used.
- Primary cooking is the second highest energy use for all fuel types, at 26%.
- Lighting uses the largest proportion of energy (28%) in non-residential buildings in all three Climate Zones.
- Lighting has the highest energy intensity of non-residential end use, at 36% of all kBTUs.
- Laundry services in healthcare facilities are a major use of energy.
- Lighting is the highest use of energy in retail buildings, using over half of all of the energy consumed in MMBTUs.
- While total non-residential energy use is higher in more northerly Climate Zones, it appears to be lower when energy intensity is measured.

Energy use in rural Alaska

- Bethel is estimated to use almost 1.3 million MMBTUs of energy per year.

- Oil is the primary heating fuel for Bethel residential use.
- On average, Bethel residents use almost 250MMBTUs of energy each year in home heating, domestic hot water, and the operation of electrical appliances.
- Space heating uses 72% of all energy among Bethel residences.
- Operating major appliances, including refrigerators, freezers, washers and dryers, uses 35% of all electrical energy in Bethel households.
- Office buildings in Bethel use more energy and MMBTUs than any other type of facility.
- Food service facilities have the highest energy intensity, at 335 kBTUs per square foot of any building type.
- Almost three quarters (72%) of all energy used by non-residential buildings in Bethel is used for heating, ventilation and air-conditioning.
- Space heating is the dominant use of energy in all building types except food service buildings.
- Together, the three rural communities included in the rural study use about 107 MMBTUs of energy per year.
- Almost 90% of all energy used in the three communities is for space heating.
- There are differences in the distribution of residential energy use between communities.
- Non-residential heating requires more energy in MMBTUs (72%) than any other application.

Rural Non-Residential community buildings

- Most (92%) of the almost 2000 rural non-residential buildings examined in this study are heated with fuel oil
- The building surge in rural Alaska during the 1980s suggests that many of the facilities may have inadequate insulation and weatherization.

Water and sewer

- There does not appear to be adequate data to measure the amount of energy used to operate rural water and sewer utilities.
- Energy data is not readily available with the engineering and other operational staff.
- Operating water and sewer utilities at higher temperatures than necessary or having inadequate utilidor insulation results in significantly higher utility systems costs.

Street lighting

- Communities who participated in the study used over 3.5 million kWh of energy to generate over 500,000 lumens of street lighting.

- High pressure sodium fixtures are clearly the most commonly used street lighting technology.
- Smaller communities are using more incandescent street lighting instruments than larger communities.
- There appears to be more interest among communities in switching to LED street lighting technology.

Energy Use Trends by Sector

- Industrial energy use comprises about half of all energy used in Alaska.
- Statewide Energy use in Alaska appears to be declining.
- The interpretation of changes in energy use may benefit from the use of denominators.
- AEA should be cautious in selecting the time period that it will use in developing forecasts.

Methods

- ARIS (from AkWarm© energy raters) was supplemented with survey data to provide a comprehensive picture of residential energy use.
- Survey research, combined with an on-site/walkthrough methodology, appears to be an effective way of collecting end-use energy data.
- Energy Wise energy use data appears to be a promising source of energy end-use characteristics in rural Alaskan communities.
- The State should carefully examine this baseline data to determine which variables are likely candidates to be included in a performance measurement system of overall statewide energy use.

Introduction

The intent of the Alaska Energy Authority End-use Study (AEA/EUS) is to:

- Establish baseline energy consumption data related to power and heat usage;
- Develop a repeatable methodology that will allow AEA, project partners, or others to measure changes in baseline energy use and evaluate energy efficiency measures over time;
- Guide energy efficiency policy and programs for residential and non-residential sectors of Southeast Alaska, the Railbelt, and Rural Alaska; and
- Inform policy makers, AEA stakeholders, and other project partners on energy consumption patterns in Alaska.

The energy end-use data collected is intended to provide a snapshot of energy use over a specific time period to support planning for energy efficiency programs. This report includes information and field data collection protocols used to collect energy end-use data for residential and non-residential buildings in Alaska. Due to the unique energy challenges in different regions of Alaska, multiple data collection methodologies were utilized. The methodology is further described in Appendix A.

The EUS focuses on energy consumption in the residential and non-residential building sectors[1] which are among the largest energy end users in Alaska. The EUS also explores several non-building end uses, such as street lighting and water/waste water treatment infrastructure. Energy end-use data combined to describe the overall energy use for:

- Residential and non-residential buildings in Climate Zones 6-8[2];
- Residential and non-residential buildings in selected rural communities;
- Rural non-residential community buildings; and
- Water/wastewater infrastructure and street lighting.

Specifically, the purposes of the AEA End-use Study are to:

- Provide baseline energy use data for residential and non-residential buildings through statistical estimates of building energy consumption by "end use" (e.g., heating, cooling, lighting, etc.); stratified by building type, location, and other parameters; and
- Establish a framework for future end-use studies.

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[1] The sector analysis shows that the non-residential sector is the third largest energy user.

[2] Climate Zones are defined in the Building Energy Efficiency Standards (BEES).

This end-use data is intended to:

- Identify opportunities for energy efficiency measures;
- Track changes over time in building and community energy use intensities and greenhouse gas emissions by establishing a baseline that can be replicated in future years; and
- Support the Alaska Legislature in achieving Alaska's 15% Energy Efficiency Goal.

ALASKA'S 15% ENERGY EFFICIENCY GOAL

In 2010 the Alaska Legislature and Governor passed HB306 that stated:

"It is the intent of the legislature that the state achieve a 15 percent increase in energy efficiency on a per capita basis between 2010 and 2020."

For the purposes of this study, the researchers have interpreted the 15% goal in the following manner:

"Alaska shall achieve a 15 percent reduction in the amount of heating fuel and electricity used on a per capita basis in the residential and commercial building sectors, as well as public facilities such as street lighting and water/sewer facilities, between the base year of 2010 and the year 2020."

For the purposes of this goal, some small manufacturing and light industrial users are included as part of the goal, but large industrial users are not. For the purposes of this goal, industrial users are defined as those that:

- Have commercial accounts with their electric utility (excluding industrial, interruptible or other very large customer accounts); or
- Would qualify for the Alaska Commercial Energy Audit Program.
- Federal buildings that were included in the End-use Study's sampling for commercial buildings are included in the goal.
- Military bases and military operations, aviation fuel operations, and transportation fuel operations, are excluded.

The State recognizes the value of efficiency improvements in all these excluded sectors and would like to set goals in future years with and for these sectors.

AEA intends to measure progress toward the goal based on:

- *Top down per capita*: Total energy distributed in applicable residential and non-residential sectors, divided by total population (i.e. total electrical sales divided by population);

- *Top down per square foot*: Total energy distributed in applicable sectors, divided by square footage of built environment. This measure allows for changes in the number of buildings, and the number of occupants per building, over time;
- *Bottom up per capita*: Sample building energy end uses by sector and by region, extrapolate across entire state, and divide by total population;
- *Bottom up per square foot*: Sample building energy end uses by sector and region, extrapolate across entire state, and divide by total square footage of built environment;
- *Average energy intensity measurement*: Measure longitudinal changes in energy intensity (BTU/sf/year), normalized by heating degree days, in selected buildings, by sector; and
- *Sum of known savings*: Sum all verified savings due to energy efficiency programs. Since this measure cannot capture energy savings from non-programmatic energy efficiency measures, it provides an incomplete picture of total energy savings. However, the measure is very accurate for the verified sample.

The 2011 End-use Study captures measures at the regional level, including:

- Southeast Alaska (Climate Zone 6);
- Southcentral Railbelt Alaska (Climate Zone 7);
- Interior Railbelt Alaska (Climate Zone 8); and
- Rural North and West Alaska.

In future years, the regions may be further sub-divided into the 11 energy regions monitored by AEA.

AEA/EUS Report Organization

This report is organized around major regions, building types, and independent studies. For those interested in the methodological approach, refer to the highly detailed, independent implementation plan entitled *AEA End-Use Study Methodology*[3].

The EUS is organized in the following sections:

- *Residential Energy End-use Results*. This section describes the energy end-use results for BEES Climate Zones 6 (Southeast AK), 7 (Southcentral), and 8 (Interior) for various types of residences;
- *Non-Residential Energy End-use Results*. This section describes the energy end-use results for Climate Zones 6, 7, and 8 for various Alaska non-residential buildings;
- *Rural North and West Results*. This section describes the energy end-use results as found in the rural north and north northwest;

[3] Copies of the AEA End-Use Study Methodology can be found in Appendix A or requested from AEA.

- *Independent Studies*. This section describes AEA requested independent studies to assess water/wastewater, and street lighting, and rural non-residential building energy uses;
- *Conclusions.* This sections highlights conclusions derived from the research team based upon the available data; and
- *Appendices*. This section includes methodology summary, data sets, supplemental analyses, and other information to support EUS conclusions.

Acknowledgements

AEA relied on many partners in the development of this study, including the Alaska Housing Finance Corporation (AHFC), the University of Alaska (Anchorage) Institute of Social and Economic Research (ISER), Chugach Electric Association, Cold Climate Research Housing Center (CCRHC), Resource Data Inc. (RDI), RurAL CAP, Alaska Native Tribal Health Consortium (ANTHC), Alaska Village Electric Cooperative (AVEC), State of Alaska school districts, and staff from many Alaska city and tribal governments. The US Department of Energy and Chugach Electric Association provided funding for this report.

AEA contracted WHPacific to design and implement the study and teamed with Brian Saylor and Associates, CTG Energetics, and Craciun Research Group.

Southeast and Railbelt Alaska Residential Energy Use

Introduction

This section summarizes residential energy use for Climate Zones 6, 7 and 8 for the Railbelt and Southeast Alaska by end use, climate zone, region and residence type. Alaska Retrofit Information System (ARIS) data sets were used to calculate residential end-use study for heating and domestic hot water use. This is a very rich source of HVAC and DHW data which provides significant data on building envelope, heating equipment, and other housing characteristics which can be used by future researchers to further explore the end-use data. Furthermore, the ARIS data contains both pre and post retrofit data[4], which provides a source of actual energy savings and associated measures that can be further analyzed.

ARIS data currently does not contain detailed information on lighting, appliances, and other "plug loads." Therefore, a supplemental survey was performed to provide additional data on these end uses. Throughout the rest of this report, these end uses are collectively referred to as "appliance" end uses.[5] The survey used a stratified random sampling approach for each residence type within each of the three climate zones in the study area. This defines the smallest unique strata for which the study provides statistically valid data. The aggregate results reported here have been population weighted (pop wt) so that they are representative of the entire study-area population. For easy comparison, energy use for all fuel types was converted into British Thermal Units (BTUs)[6].

Note that all energy consumption data presented in this report is "site energy", or the amount of energy that is actually used or purchased by a facility. "Source energy" is not reported. Source energy includes upstream energy conversion losses in the power plant; transmission and distribution losses; and extraction, processing and transportation of fuels. This is particularly significant for electricity, which has significant losses in the power plant and in the transmission and distribution system. Alaskan transmission and distribution losses are approximately 12.9%.

[4] For this end use study, the "pre-retrofit" data is assumed to be representative of the majority of Alaskan housing stock, which has not participated in the incentive program.

[5] Appliances include all lighting, electrical and non-electrical appliances and equipment not related to space heating or hot water heating

[6] The British thermal unit is a traditional unit of energy based on the amount of energy needed to keep 1 pound of water from 39°F to 40°F. It is often used to measure the heat value of fuels and the power of heating and cooling systems. A MMBTU is 1 million BTUs.

For every kWh of delivered (site) electricity, 3.65 kWh of source energy is consumed upstream[7]. In other words, the electricity supply system is only 27% efficient; 73% of the energy going into power plants is not delivered to end users.

Average energy use values calculated in this study were used to estimate total energy use for all residences in the Southeast and Railbelt regions. Table 1 shows the population totals per climate zone and residence type that were used for the population weighting.

Table 1: Population totals per climate zone

Strata	Population
Climate Zone 6 Total	**27,777**
Single Family Detached	13,611
Single Family Attached	1,389
Multi Family	9,999
Mobile Home	2,778
Climate Zone 7 Total	**159,451**
Single Family Detached	82,829
Single Family Attached	12,745
Multi Family	54,160
Mobile Home	9,717
Climate Zone 8 Total	**33,595**
Single Family Detached	17,452
Single Family Attached	2,685
Multi Family	11,411
Mobile Home	2,047
Study-Area Total	**220,823**
Single Family Detached	113,892
Single Family Attached	16,819
Multi Family	75,570
Mobile Home	14,542

Total Energy Use by Climate Zone & Fuel Type

Figure 1 shows the total energy used by residences in each of the climate zones for the Railbelt and Southeast Alaska (SEAK). On average, homes in the more temperate Climate Zone 6 use less energy than those in the colder climate zones. The use of energy in Southcentral Alaska (Railbelt, Climate Zone 7) is slightly higher than energy use in Climate Zone 8. On average homes were 6% larger in Climate Zone 7 than in Climate Zone 8.

[7] Deru, M., and Torcellini, P. "Source Energy and Emission Factors for Energy Use in Buildings." National Renewable Energy Laboratory. Technical Report NREL/TP-550-38617. June 2007.

This section focuses on total energy use, which is shown in MMBTUs. Data collected for the sample of residential facilities in the region is generalized to the total number of residences. This process of generalization is shown in most table headings in this report as "population weighted" (pop wt). This allows for generalization to the total number of residences in Climate Zone 6 (SEAK) and Climate Zones 7 and 8 (Railbelt Alaska). There is insufficient data on total residential square feet within these regions to present total energy use on a per square foot basis.

Figure 1: Total energy use/yr per home by climate zone for Railbelt & SEAK (pop weighted, MMBTU)

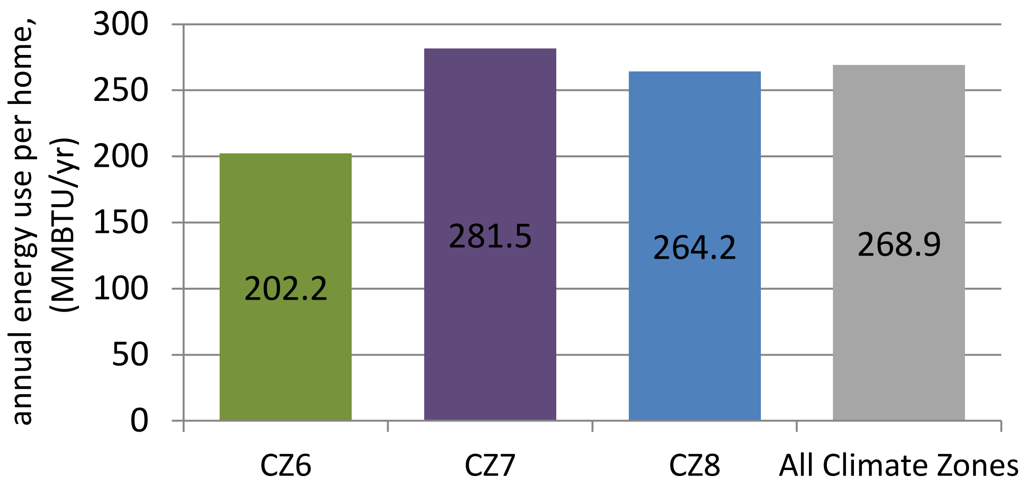


Figure 2 compares total energy use for all fuel types (includes birch, spruce, coal, fuel oil number 1 and fuel oil number 2 (combined as "oil"), natural gas, propane, electricity, and appliance fuels[8]).

[8] All non-electricity based fuel sources that power appliances have been broken out as 'Appliance Fuels'. Electricity includes electricity used for space heating, domestic hot water and appliance energy use.

Figure 2: Total annual energy use by fuel type for the Railbelt & Southeast (pop wt, % MMBTU)

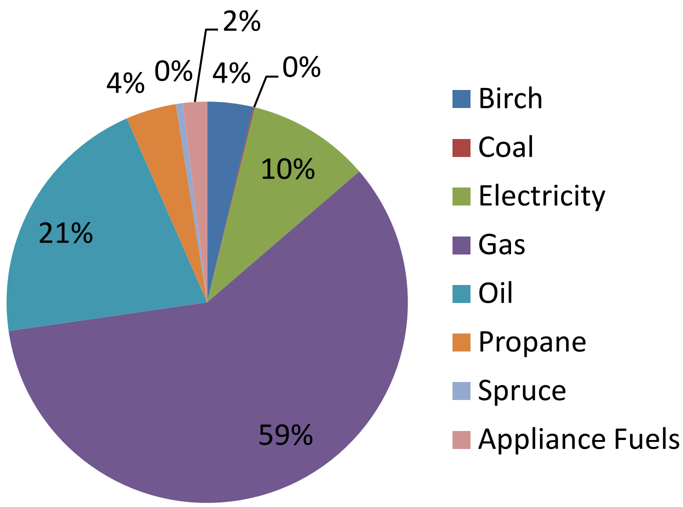
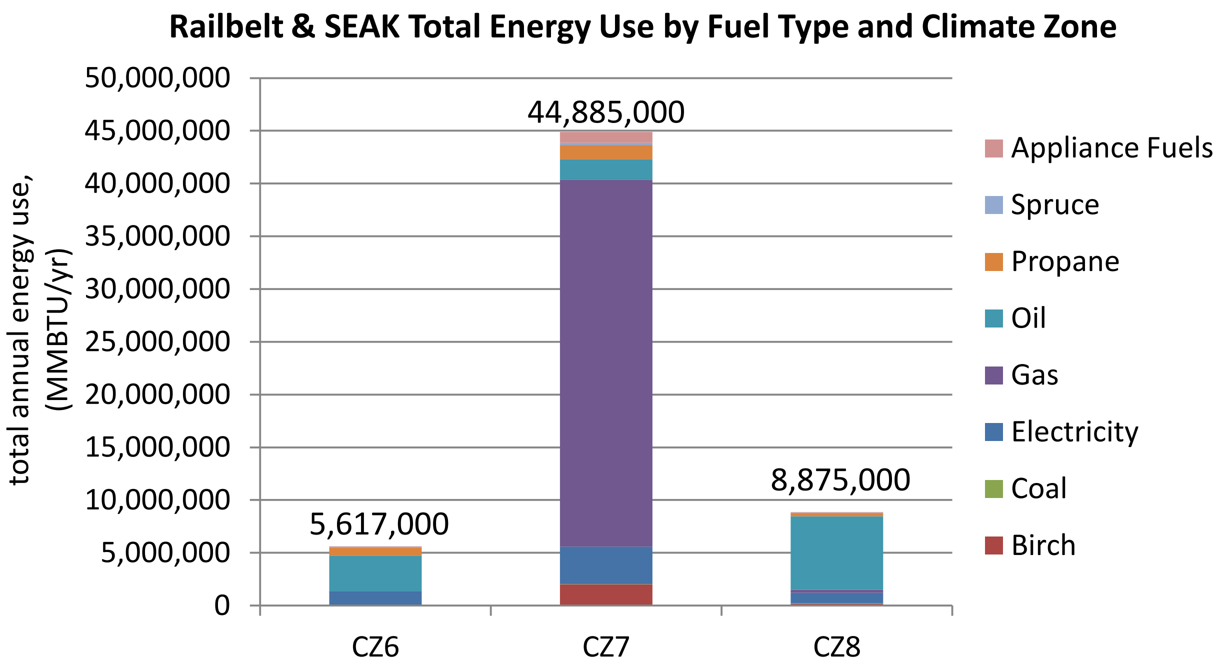


Figure 3 compares state-wide total energy use by all fuel types for each climate zone within the Railbelt and Southeast study areas. Climate Zone 7 has by far the largest total energy use due to a substantially larger population than other climate zones. Total Railbelt and Southeast residential energy use within this study is 59.38 million MMBTUs.

Figure 3: Total annual energy use per home by fuel type and CZ for the Railbelt & Southeast (pop wt, MMBTU)



Energy Uses by Climate Zone, Region and Residence Type

Figure 4 shows the breakdown of major energy uses (space heating, domestic hot water, and appliance energy use) in MMBTUs for all climate zones for the Railbelt and Southeast regions. For this study, appliance energy includes all electrical and non-electrical appliances and equipment and lighting not directly related to space heating or the heating of domestic hot water. Appliance energy use across climate zones is very similar. Climate Zone 6 has significantly less space heating and domestic hot water energy use then Climate Zones 7 and 8.

Figure 4: Total energy by major energy use per home by Climate Zone (pop wt, MMBTU)

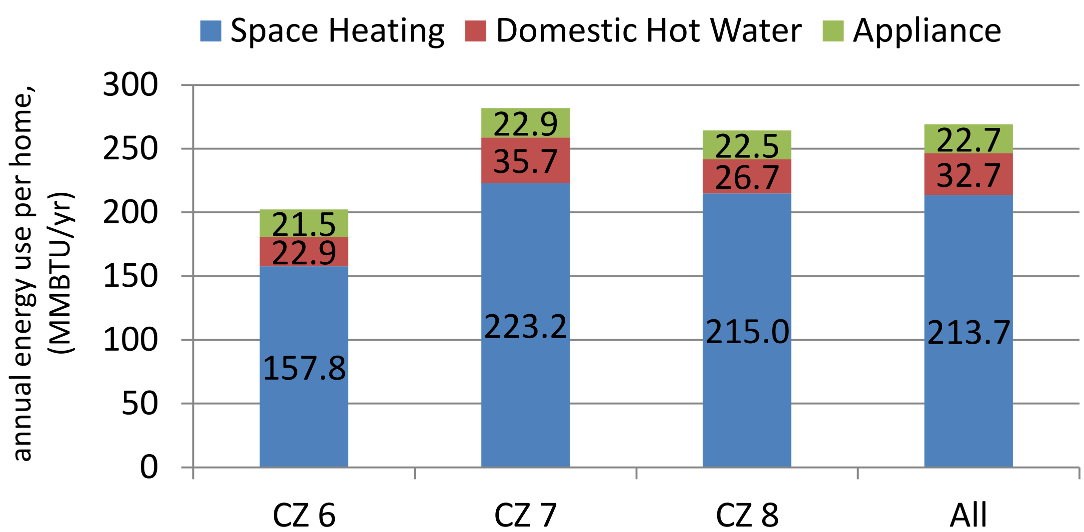


Table 2 shows population weighted space heating, hot water, appliance and total energy use per home for each of the residence types and for each of the three Climate Zones.

Table 2: Total annual energy use per home for major energy uses by Climate Zone and residence type for the Railbelt & Southeast, (pop wt, MMBTU)

Climate Zone	Total	Space Heating	Domestic Hot Water	Appliance
Climate Zone 6	**202.23**	**157.80**	**22.88**	**21.54**
Mobile Home	193.61	146.83	25.31	21.47
Multi Family	141.39	106.01	18.67	16.71
Single Family Attached	163.12	121.86	21.46	19.79
Single Family Detached	252.68	201.76	25.63	25.29
Climate Zone 7	**281.73**	**223.19**	**35.65**	**22.90**
Mobile Home	251.74	193.46	36.28	22.00
Multi Family	177.20	134.08	26.39	16.74
Single Family Attached	278.48	214.96	42.30	21.22
Single Family Detached	354.10	286.20	40.61	27.29
Climate Zone 8	**264.21**	**215.01**	**26.72**	**22.48**
Mobile Home	308.49	266.09	21.40	21.00
Multi Family	198.74	154.33	24.20	20.22
Single Family Attached	246.14	191.81	30.07	24.26
Single Family Detached	304.61	252.27	28.48	23.86
All Climate Zones	**269.07**	**213.72**	**32.69**	**22.66**
Mobile Home	248.63	194.78	32.09	21.76
Multi Family	175.72	133.42	25.03	17.26
Single Family Attached	263.79	203.57	38.63	21.59
Single Family Detached	334.40	270.91	36.96	26.52

Figure 5 shows space heating, domestic hot water, and appliance energy uses for each region in MMBTUs. Homes in the Southeast region use less space heating and domestic hot water energy than those in the Railbelt while appliance energy has smaller differences.

Figure 5: Total energy use per home for major energy uses by region (pop wt, MMBTU)

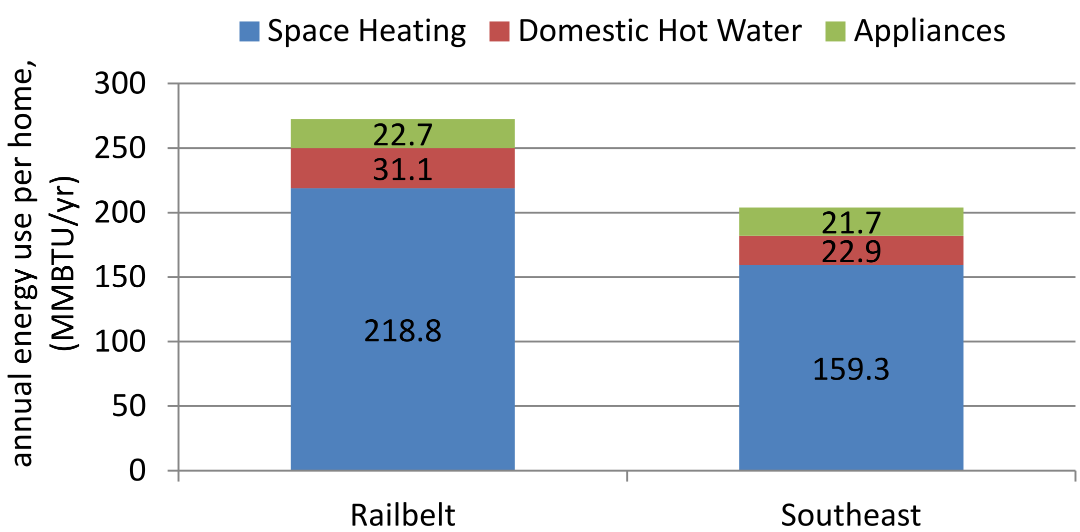


Figure 6 shows space heating, domestic hot water and appliance energy uses for each residence type for all Climate Zones in the Southeast and Railbelt. The figure shows highest energy use by families living in single family detached residences and the lowest energy use in multifamily residences. Single family detached homes use the largest absolute and relative amount of total energy to heat the home and multifamily the least. The relative amount of energy used to operate appliances, including primary cooking and lighting, is approximately the same (between 8-10%) in all types of residences.

Figure 6: Total energy use per home for major energy uses by residence type (pop wt, MMBTU)

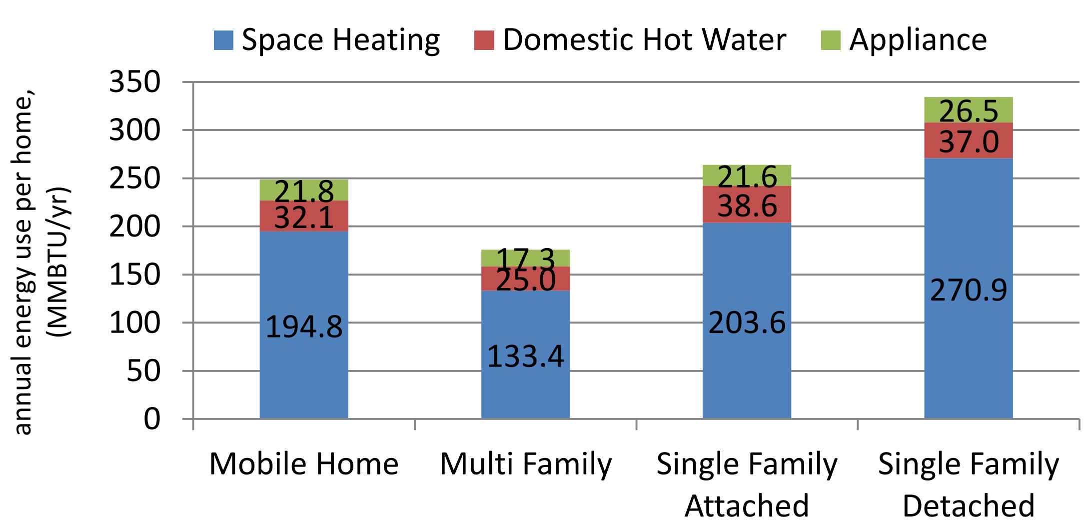
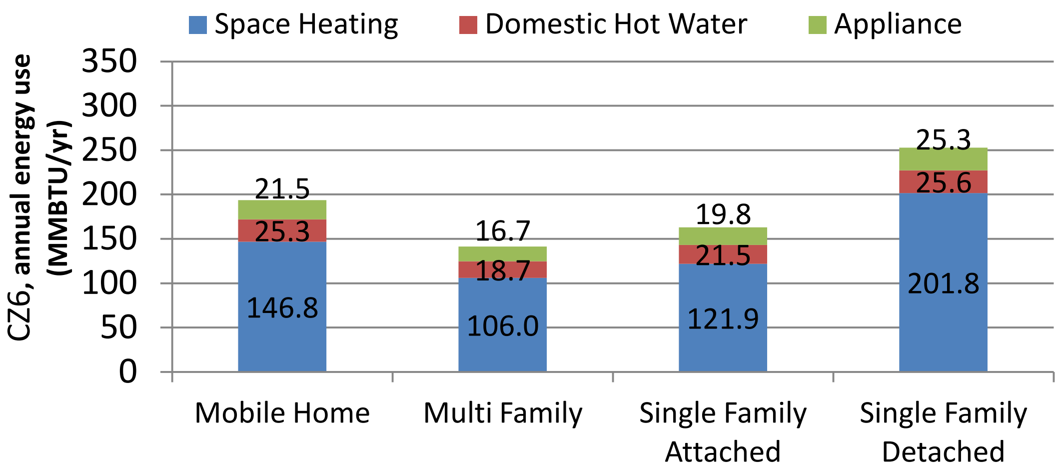
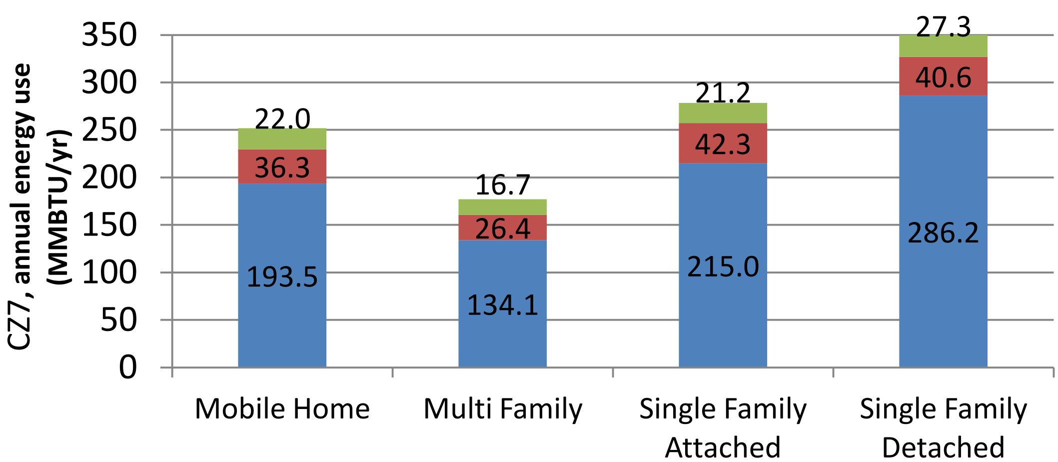


Figure 7 shows similar data for Climate Zones 6, 7 and 8 individually. There are statistically significant differences in energy use between residence types. A similar pattern is shown in all three Climate Zones; home heating is the largest energy use (between 76-83%), single family detached residences use the most energy, and multifamily residences the least. In Climate Zone 6 and 8, mobile homes use more overall energy then single family attached homes, where in Climate Zone 7, single family attached homes use more than mobile homes.

Figure 7: Total energy use per home for major energy uses by residence type for CZ6, CZ7, and CZ8 respectively (pop wt, MMBTU)





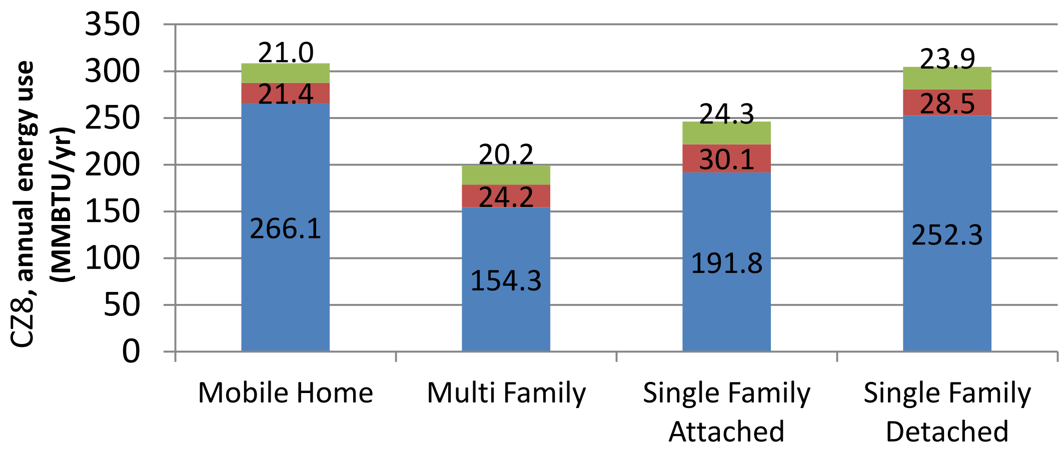
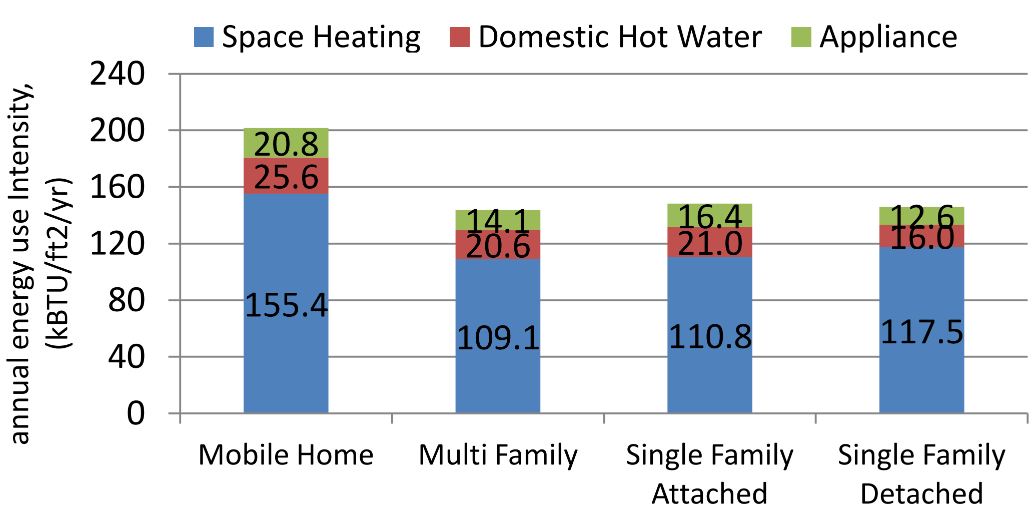


Figure 8 compares the average energy intensity per home area in kBTU/ft² for each residence type. Mobile homes have the largest average energy use intensity of the four residence types while the other three residence types are very similar. Space heating energy use intensity in particular is significantly larger for mobile homes then for other residence types. The space heating and domestic hot water energy use intensities for multifamily and single family attached homes both relied on the same housing type definition from the ARIS data (the ARIS database does not distinguish between these residence types). Differences in intensities between the two are due to population difference in residence types across Climate Zones.

Figure 8: Total energy use intensity for major energy uses by residence type (ARIS, pop wt, kBTU/ft²)



Energy End Uses

Space heating, domestic hot water and appliance energy use were further broken down into end-use categories and sub end-use categories within those end uses. The space heating and domestic hot water energy consumption relied on ARIS data, while the data collection for the appliance end uses was done through a stratified random survey. Table 3 expands the information on the organization of appliance end-use categories used for the Railbelt and Southeast residential study by adding space heating and domestic hot water. Some appliance sub end uses were combined after analysis, when and where appropriate.

Table 3: Energy end use categories organization for the Railbelt and Southeast residential study

Major Use	End Use	Sub End Use
Space Heating	Space Heating	Birch Space Heating, Coal Space Heating, Electric Space Heating, Gas Space Heating, Oil1 Space Heating Oil2 Space Heating, Oil Space Heating, Propane Space Heating, Spruce Space Heating
Domestic Hot Water	Domestic Hot Water	Birch DHW, Coal DHW, Electric DHW, Gas DHW,Oil1 DHWOil2 DHW, Oil DHW, Propane DHW, Spruce DHW Heating
Appliance (electrical and non-electrical appliances, equipment and lighting)	Interior Lighting	Fluorescent, Incandescent.CFL, Small Halogen, Large Halogen LED, Other Bulb
	Exterior Lighting	Fluorescent _ext, Incandescent_ext, CFL_ext, Small Halogen_ext, Large Halogen_ext, LED_ext Other Bulb_ext
	Major Appliances	Refrigerator, Freezer, Dishwasher , Washer/ Dryer
	Primary Cooking	Oven, Stove, Microwave
	Other Kitchen Equipment	Coffee Maker, Electric Deep Fryer, Electric Fry Pan Electric Kettle, Slow Cooker, Toaster/Toaster Oven
	Entertainment	Television, Gaming Console , DVD Player VCR, Digital Video Recorder (DVR), Standalone Cable Box Cable box with DVR , Music playing system, Satellite Dish
	Information Technology	Computer/ Office Equipment, Small Low Tech Electronics (e.g. radios, clocks, phones), Small High Tech Electronics (e.g. cell chargers, tablets)
	Seasonal Decorative Lighting	Seasonal Decorative Lighting
	Miscellaneous Appliances	Garage door opener , Electric waterbed Hot Tub, Waterwell pumps , Sewage lift pump Sump pump , RV trickle charger, Engine Block Heater Heat Trace/ Heat Tape, Electric Vehicle Charging

Space Heating and Domestic Hot Water Use

Space heating and domestic hot water energy use was calculated using existing residential ARIS data from 2008-2011. Average energy use intensities were calculated for all regions, Climate Zones, and residence types. Space heating and hot water energy usage was available by individual fuel type consumption and included birch, spruce, coal, oil number 1, oil number 2, natural gas, propane and electricity. The ARIS database does not distinguish between a multifamily residence type and a single family attached residence type, so the same space heating and hot water energy use intensities were applied to both residence types from the survey. Differences in total space heating and hot water energy use for these two residence types depend on home size as collected from the survey.

Energy intensity calculations are shown in Table 4.

Table 4: Annual space heating and hot water energy use intensities for Railbelt, SEAK & Rural residential according (ARIS, kBTU/ft^2)

Region	Climate Zone	Residence Type	Space Heating EUI kBTU/ft^2/yr	Domestic Hot Water EUI kBTU/ft^2/yr
Railbelt	7	Mobile Home	155.4	29.13
		Single Family	119.7	16.99
		Multi Family	115.4	22.71
	8	Mobile Home	213.8	17.20
		Single Family	117.6	13.28
		Multi Family	105.2	16.49
Southeast	6	Mobile Home	112.3	19.36
		Single Family	103.4	13.13
		Multi Family	79.2	13.95
Rural	8	Single Family	79.7	21.68
		Multi Family	71.8	23.27

Figure 9 shows space heating energy intensity per home area by fuel type for the Railbelt, Southeast, and the combined Railbelt and Southeast (ARIS data, not population weighted). Natural gas is the most prevalent fuel type by intensity in the Railbelt followed by oil (oil number 1 and oil 2 are combined), while oil heating is most common in the Southeast, followed by spruce. Overall, the Railbelt uses more energy per square foot to heat the home than the Southeast.

Figure 9: Space heating energy use intensity for the Railbelt and Southeast by fuel type and region (ARIS, un-weighted, kBTU/ft^2/yr)

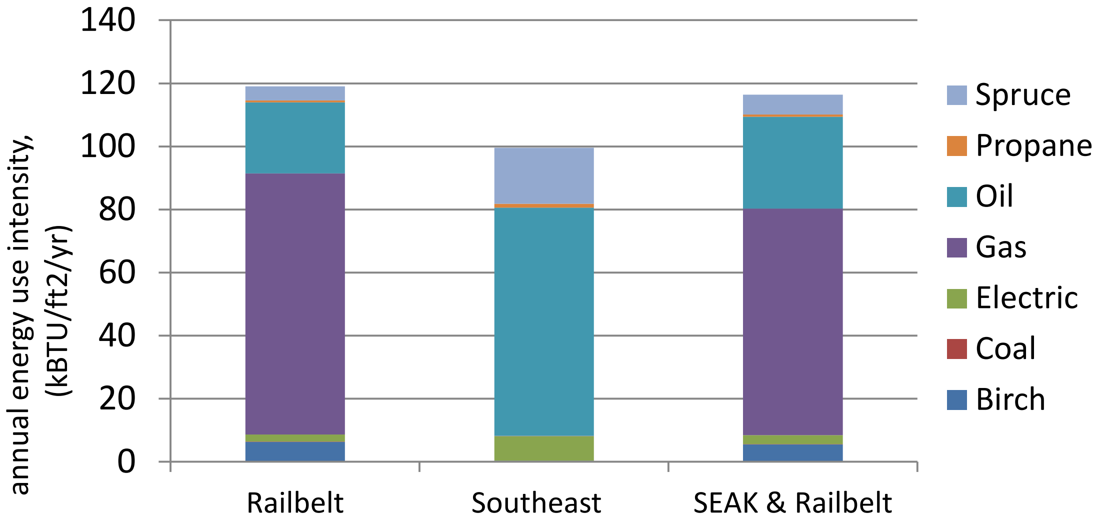


Figure 10 shows the breakdown of domestic hot water heating by fuel type for the Railbelt, Southeast, and the Railbelt and Southeast combined (ARIS data, not population weighted). Overall, the Railbelt uses more energy per square foot to heat hot water. As with space heating, natural gas is the dominant fuel type in the Railbelt, while oil dominates the Southeast. Electricity is a more common fuel type for hot water then for space heating, particularly in the Southeast.

Figure 10: Domestic hot water energy use for the Railbelt and Southeast by fuel type and region (ARIS, un-weighted, kBTU/ft^2/yr)

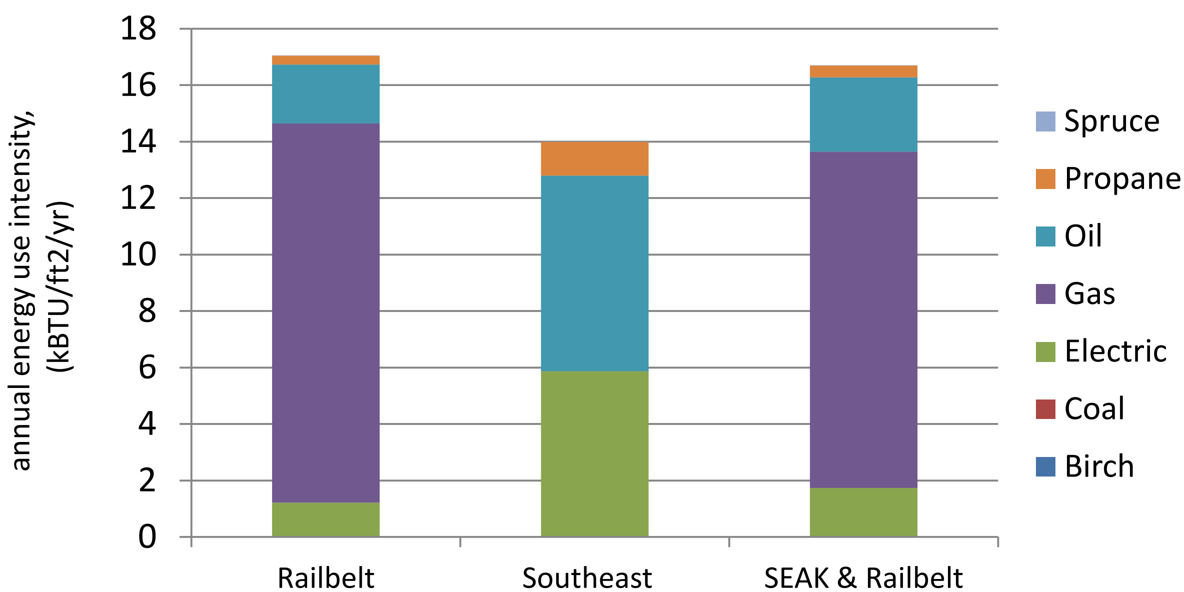
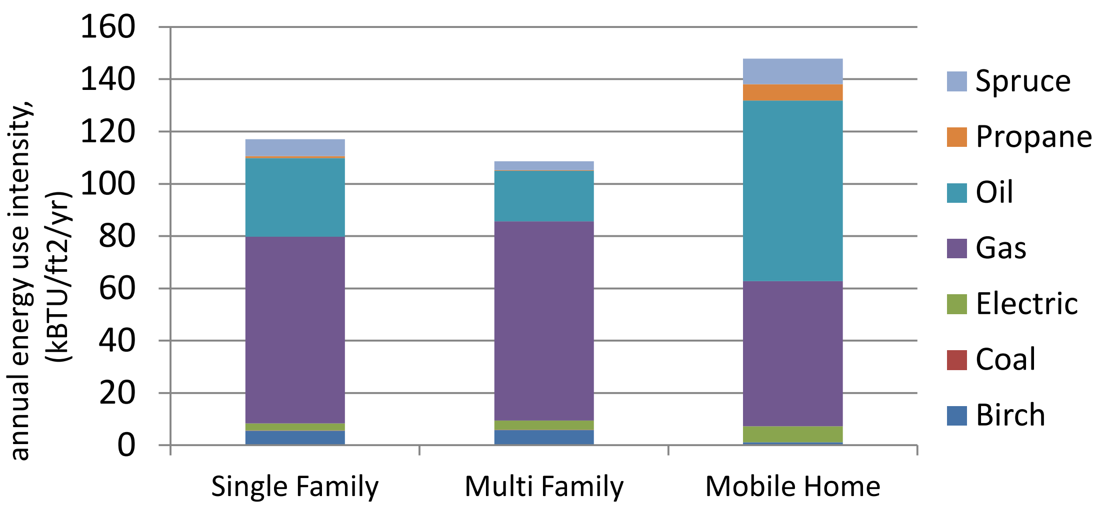


Figure 11 shows the breakdown of space heating by fuel type and residence type for all Climate Zones in the Railbelt and Southeast regions. Multifamily and single family residence types most heavily used natural gas as a space heating fuel while mobile homes more heavily used oil. For multifamily homes on a MMBTU basis, 70% of space heating was attributed to natural gas use.

Figure 11: Space heating energy use intensity for the Railbelt and Southeast by fuel type and residence type (ARIS, un-weighted, kBTU/ft^2/yr)



Appliance Use - Appliances, Equipment & Lighting

Appliance energy use accounts for 8% of total energy use for all fuel types; but, as shown in Figure 12, appliances consume 65% of total electricity use.[9]

[9] Appliances include all lighting, electrical and non-electrical appliances and equipment not related to space heating or hot water heating

Figure 12: Appliance electrical energy use by major uses (pop wt, % MMBTU)

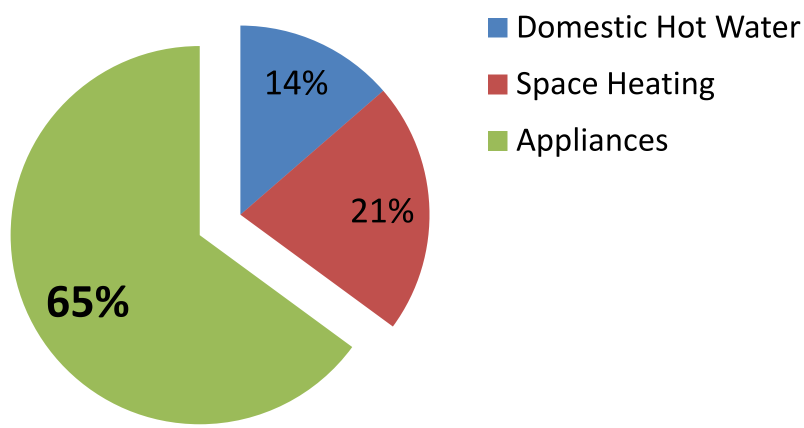
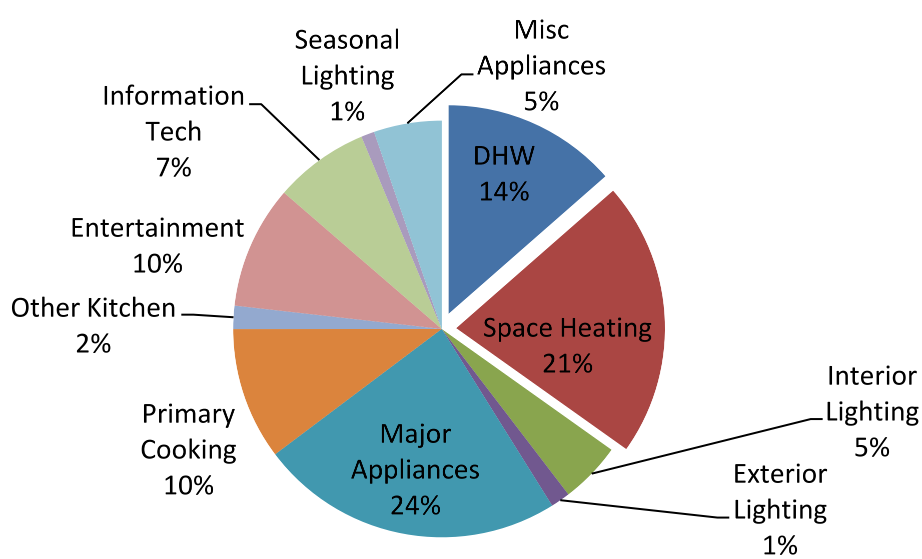


Figure 13 shows a further breakdown of total electricity use per home by all the end uses as listed in Table 3. The single largest use is for operating major appliances, such as refrigerators, freezers, washers and dryers (24%). Space heating is the second largest application of electrical power at 21%, and domestic hot water production is third at 14%.

Figure 13: Total electricity use for the Railbelt and Southeast by end use (pop wt, % MMBTU)



Focusing now only on appliances, Figure 14 shows total appliance energy by fuel type per home. The majority of appliance energy is supplied by electricity. Certain end uses can be powered by electricity or others fuels (in most cases natural gas). These include primary cooking (ovens and stoves), major appliances (washers and dryers), and miscellaneous appliances (hot tubs).

Figure 14: Total appliance energy use by fuel type (pop wt, % MMBTU)

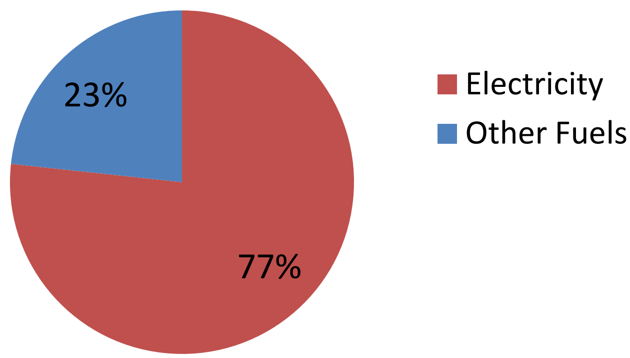


Figure 15 shows total appliance energy use (all fuel types) per home for each appliance end use defined in Table 2. Aggregating by fuel type shows major changes in the distribution of end uses. While operating major appliances is still the largest end use (31%), primary cooking uses increased from 10% to 26% of all energy used.

Figure 15: Total appliance energy by end use (pop wt, % MMBTU)

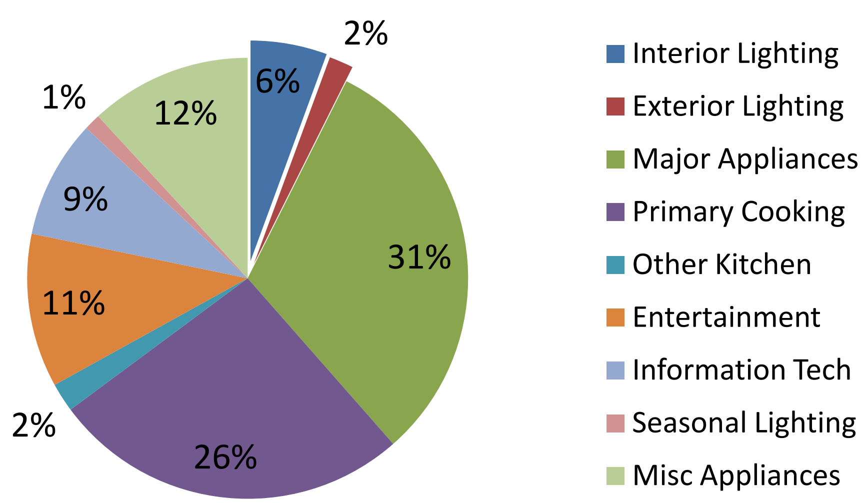
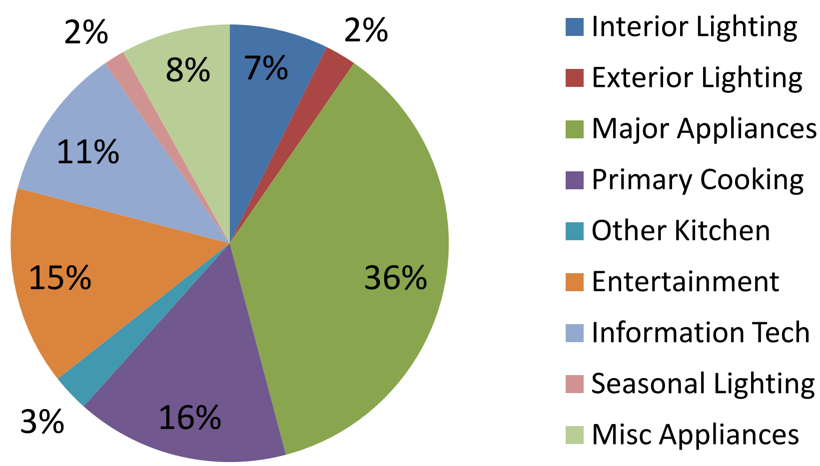


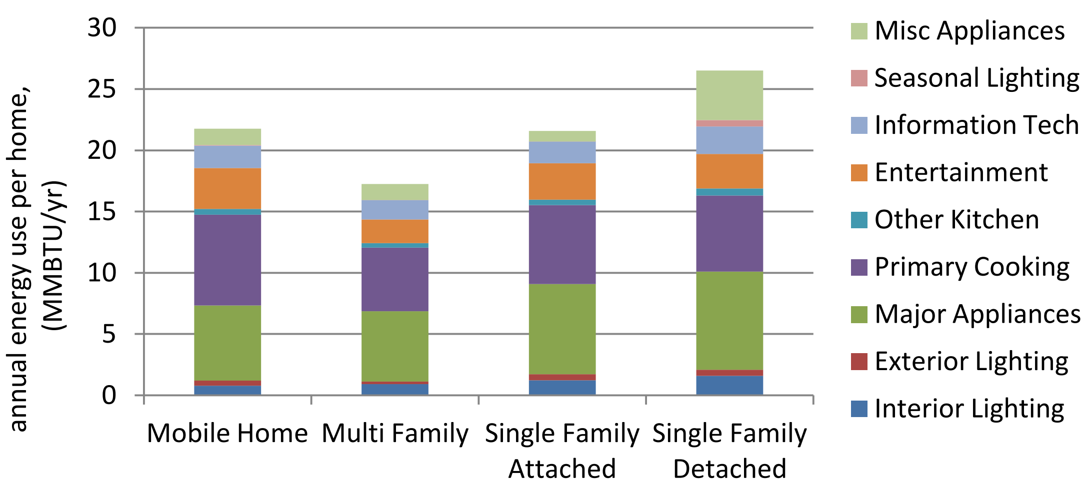
Figure 16 shows total appliance electricity use (this excludes all fuel-powered ovens, stoves, washer/dryers, and hot tubs) per home for each appliance end use as defined in Table 2. Primary cooking (specifically ovens and stoves) relies equally on electricity and other fuel sources and therefore makes up 26% of total appliance energy use but only 16% total appliance electricity use.

Figure 16: Total appliance electricity by end use (pop wt, % MMBTU)



Major appliances are the largest energy consuming appliance end use for all Climate Zones. This is followed by primary cooking. Figure 17 shows total appliance energy use (all fuel types) per home by appliance end use for by residence type. Mobile homes have the largest primary cooking and entertainment energy use. Single family detached homes have the largest major appliances, interior lighting and miscellaneous appliance energy use. Other end uses are very similar across residence types. The breakdown of appliance energy by appliance end uses across Climate Zones showed little variation.

Figure 17: Total appliance energy by end use by residence type (pop wt, MMBTU)



Each end use is discussed in detail in the following sections. The energy use for each end-use category is comprised of a number of sub end uses as shown in Table 2. Survey data collection has provided extensive information on appliance saturations, use patterns and energy consumptions of the specific appliances. The energy use is shown in detail in Table *5.*

Table 5: Railbelt and Southeast appliance energy use by end use for each Climate Zone and residence type (pop wt, MMBTU)

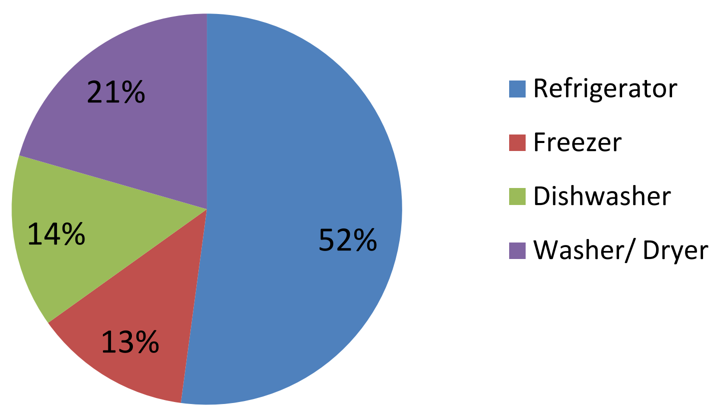
	Interior Lighting	Exterior Lighting	Major Appliances	Primary Cooking	Other Kitchen Equipment	Entertainment	Information Technology	Seasonal Lighting	Miscellaneous Appliances	Total
Climate Zone 6	**1.30**	**0.31**	**6.43**	**6.09**	**0.54**	**3.12**	**2.40**	**0.01**	**1.33**	**21.54**
Mobile Home	0.96	0.39	7.16	6.56	0.45	3.13	1.85	0.01	0.96	21.47
Multi Family	1.59	0.49	4.45	4.32	0.57	2.47	1.67	0.00	1.15	16.71
Single Family Attached	0.99	0.70	6.20	6.35	0.50	2.13	1.68	0.03	1.21	19.79
Single Family Detached	1.18	0.13	7.77	7.27	0.54	3.69	3.12	0.02	1.55	25.29
Climate Zone 7	**1.29**	**0.36**	**7.24**	**5.96**	**0.47**	**2.47**	**1.86**	**0.37**	**2.88**	**22.90**
Mobile Home	0.74	0.43	5.95	7.99	0.48	3.39	1.84	0.01	1.18	22.00
Multi Family	0.79	0.09	6.04	5.09	0.28	1.70	1.52	0.00	1.23	16.74
Single Family Attached	1.27	0.49	7.59	6.56	0.39	2.90	1.72	0.00	0.30	21.22
Single Family Detached	1.68	0.51	8.12	6.21	0.61	2.80	2.11	0.71	4.55	27.29
Climate Zone 8	**1.17**	**0.68**	**6.70**	**5.86**	**0.48**	**2.50**	**2.14**	**0.04**	**2.91**	**22.48**
Mobile Home	0.76	0.40	5.65	5.82	0.44	3.30	1.90	0.20	2.54	21.00
Multi Family	0.88	0.55	5.53	6.42	0.46	2.58	2.01	0.01	1.78	20.22
Single Family Attached	1.13	0.45	6.85	6.02	0.51	3.88	2.00	0.05	3.38	24.26
Single Family Detached	1.42	0.84	7.56	5.48	0.49	2.14	2.27	0.05	3.61	23.86
All Climate Zones	**1.27**	**0.40**	**7.05**	**5.96**	**0.48**	**2.56**	**1.97**	**0.27**	**2.69**	**22.66**
Mobile Home	0.78	0.41	6.14	7.41	0.47	3.33	1.85	0.04	1.33	21.76
Multi Family	0.91	0.21	5.75	5.19	0.35	1.93	1.61	0.00	1.31	17.26
Single Family Attached	1.22	0.50	7.36	6.46	0.42	2.99	1.76	0.01	0.87	21.59
Single Family Detached	1.58	0.51	7.99	6.22	0.58	2.81	2.25	0.52	4.05	26.52

Major Appliances

The major appliances category was the largest energy-consuming end use for all Climate Zones in the Railbelt and Southeast, contributing to 31% of total appliance energy use and 37% of total appliance electricity use. Figure 18 shows the relative contribution of the four sub end uses (refrigerators, freezers, washer/dryers, and dishwashers). Major appliance use across individual Climate Zones and residence types followed a similar breakdown.

Refrigerator use was the largest appliance use in this category, with 52% of all energy used. Washer/Dryers accounted for 21% of total major appliance energy use, using either electricity or natural gas as a fuel source. Survey respondents were asked what fuel type was used for both their washer and dryer. If unknown, the primary heating fuel for the home was used as the default. On average, 70% of washer/dryer energy was derived from electricity.

Figure 18: Major appliances energy use for the Railbelt and Southeast by sub end use (pop wt, % MMBTU)

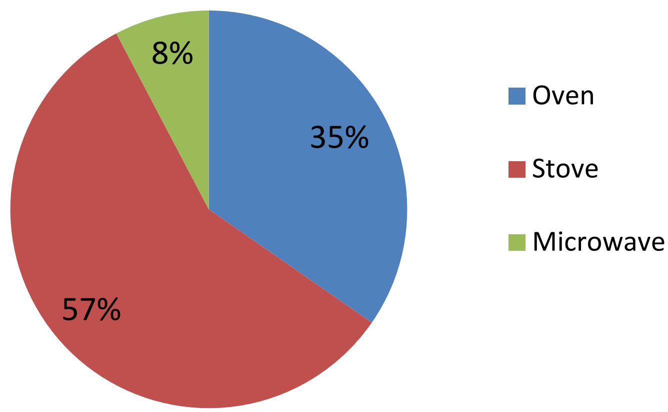


Other available characteristics on major appliances in the home include: number of refrigerators/freezers, age of refrigerators/freezers, size of refrigerators/freezers, age of dishwasher, dishwasher loads per week, energy star rating for all major appliances, and laundry loads per week.

Primary Cooking

Primary cooking was the second largest energy end use for all Climate Zones in the Railbelt and Southeast, contributing to 27% of overall appliance energy use and 16% of total appliance electricity use. Figure 19 shows the relative contribution of the three sub end uses (ovens, stoves and microwaves). Stove use was the largest appliance use in this category. Approximately 40% of stove energy use was electricity based.

Figure 19: Primary cooking energy use for the Railbelt and Southeast by sub end use (pop wt, % MMBTU)



Other available characteristics on primary cooking in the home include: fuel type used for oven/stove, hours of oven/stove/microwaves use per week, number of ovens/stoves/microwaves. The average daily stove use as collected by the survey was 1.75 hours per day for the Railbelt and Southeast. The average weekly oven use was 5.4 hours. The unit energy consumption value used was 1.0 kWh/hr for electric ovens and 0.09 therms/hr for gas stoves[10].

Entertainment

The entertainment category was the third largest energy end use in all Climate Zones for the Railbelt and Southeast, contributing to 11% of overall appliance energy use and 15% of total appliance electricity use. Figure 20 shows the relative contribution of the various sub end uses within this category. Television energy use was the largest component of this category.

[10] http://evanmills.lbl.gov/pubs/pdf/home-energy-saver.pdf

Figure 20: Entertainment energy use for the Railbelt and Southeast by sub end use (pop wt, % MMBTU)

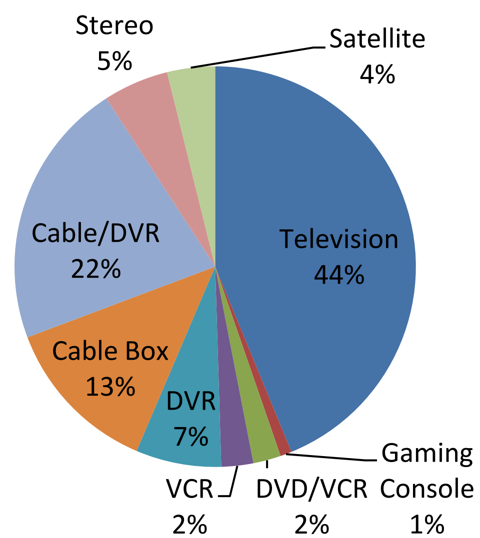
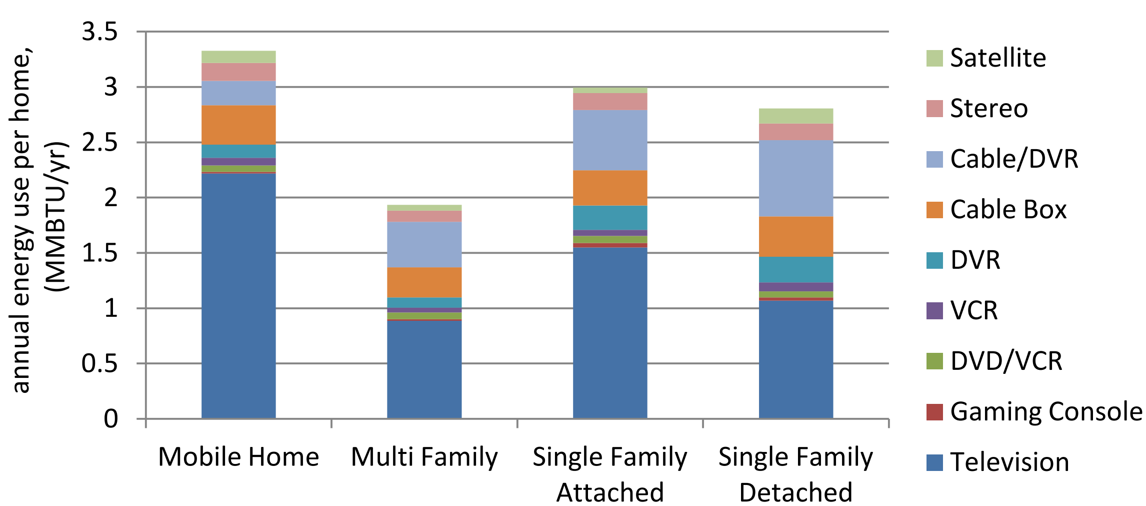


Figure 21 shows the entertainment energy use by sub end use for each of the residence types. Mobile homes had the largest energy use in the entertainment end-use category.

Figure 21: Entertainment energy use for the Railbelt and Southeast by sub end use and residence type (pop wt, % MMBTU)

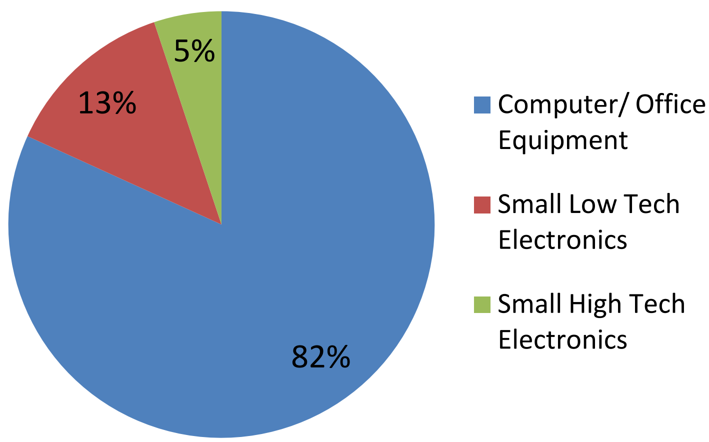


Other available characteristics on entertainment in the home include: number of televisions, type of television, and hours of television use per week. There was not significant variation in this end use between Climate Zones.

Information Technology

The information technology category accounted for about 9% overall appliance energy use and 11% of total appliance electricity for the three Climate Zones in the Railbelt and Southeast. Figure 22 shows the relative contribution of the various sub end uses within this category. Computers and other office equipment were the largest energy sub end use of this category. There was no significant variation in this end use between Climate Zones or residence types.

Figure 22: Information technology energy use for the Railbelt and Southeast by sub end use (pop wt, % MMBTU)

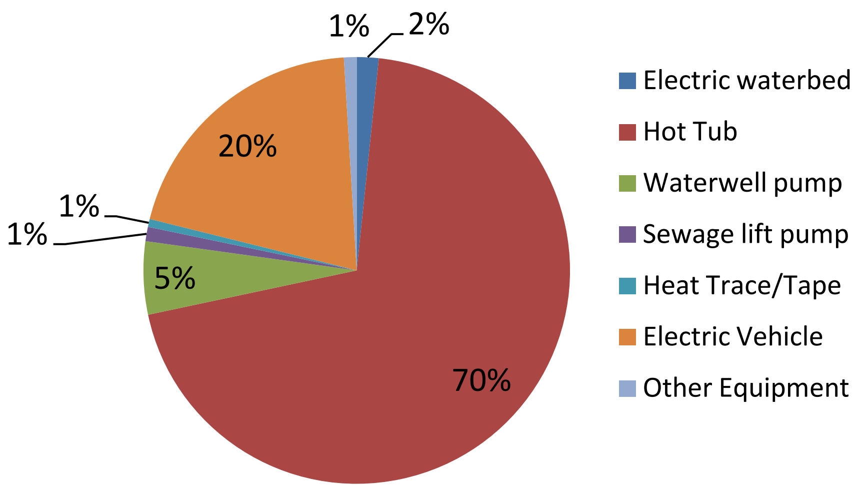


The information technology category covers a wide range of electronics and other equipment. Available data for computer/office equipment includes: the number of desktop computers, monitors, laptops, printers, multi-functioning devices, modems, copy machines, fax machines. Available data for small low tech electronics includes number of: alarm clocks, wall clocks, radios, and cordless telephones. Small high tech electronics include items such as IPods, mobile phone chargers, tablets, etc.

Miscellaneous Appliances

Miscellaneous appliances accounted for about 12% overall appliance energy use and 8% of total appliance electricity use for the three Climate Zones in the Railbelt and Southeast. Figure 23 shows the relative contribution of the various subcategory end uses within this category. Hot tubs were the largest consumer of energy in this category, and included both electric and fuel powered hot tubs. Approximately 55% of hot tubs were electric powered. 'Other Equipment' accounted for 1% of total miscellaneous energy use and included trickle chargers, garage door openers and sump pumps. There was no significant variation in this end use between Climate Zones or residence types.

Figure 23: Miscellaneous appliances energy use by sub end use (pop wt, % MMBTU)



Interior Lighting

Interior lighting accounted for 6% of overall appliance energy use and 7% of total appliance electricity use for the three Climate Zones in the Railbelt and Southeast. Figure 24 shows the relative contribution of the various bulb types that were used in the homes surveyed. Incandescent bulbs were the most prevalent lighting type, accounting for 48% of total lighting by energy (MMBTU), followed by compact fluorescent bulbs (CFLs) at 11%. Survey respondents were asked to categorically estimate the wattage of their incandescent bulbs. The CFL bulb wattage was assumed to be 13 watts.

Figure 24: Interior lighting energy use by bulb type (pop wt, % MMBTU)

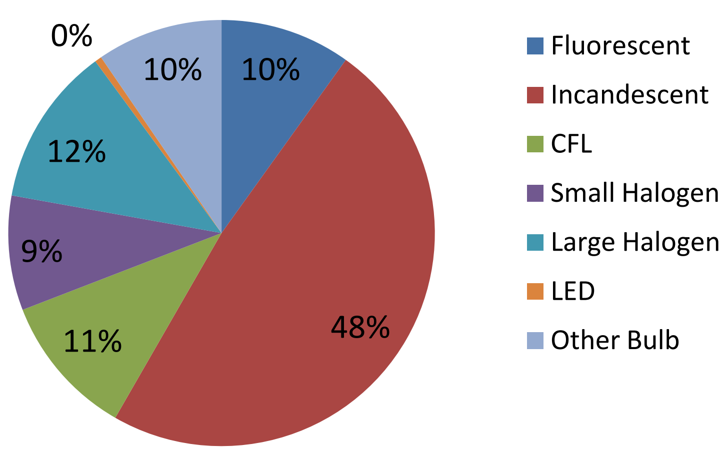
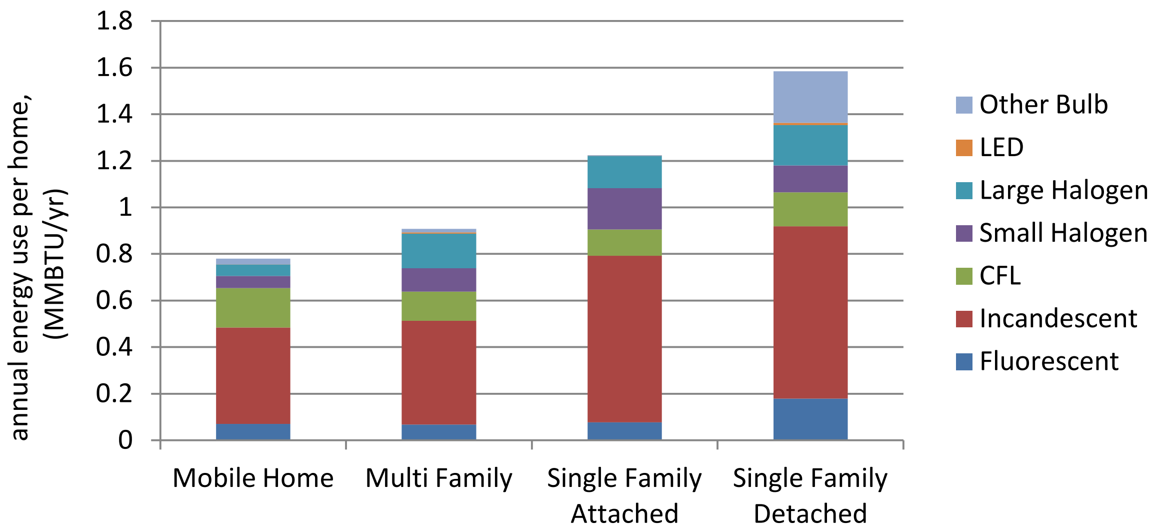


Figure 25 shows the interior lighting energy use by bulb type for each of the residence types. Mobile homes had the least interior lighting energy use and single family detached the largest. Proportionally, mobile homes had the greatest amount of CFL bulb energy usage.

Figure 25: Interior lighting energy use by bulb type and Climate Zone (pop wt, % MMBTU)

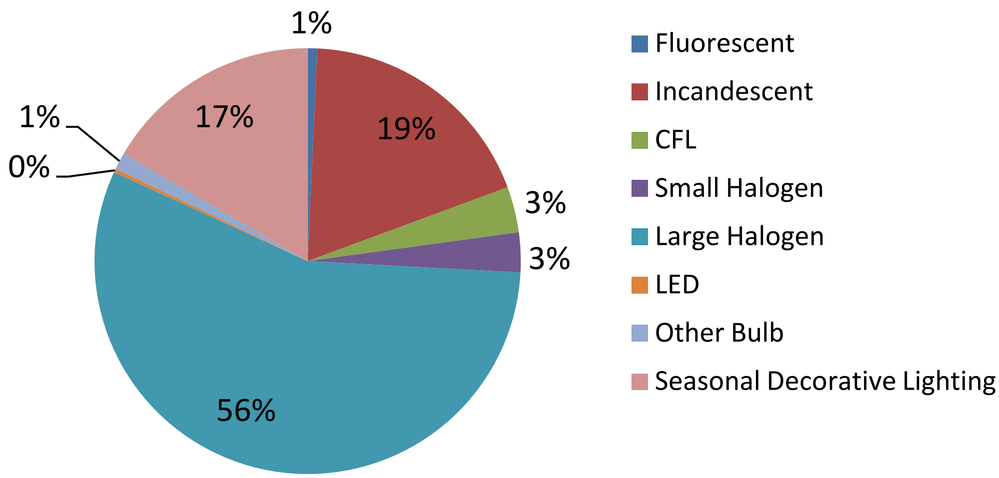


Other available characteristics on interior lighting include: number of bulbs of each type, hours on/off per bulb type, and type of incandescent bulb. There was no significant variation in this end use between Climate Zones.

Exterior Lighting & Seasonal Decorative Lighting

Exterior lighting accounted for 2% of overall appliance energy use and seasonal decorative lighting accounted for 1% for the three Climate Zones in the Railbelt and Southeast. Figure 26 shows the relative contribution of the various bulb types that were used for exterior lighting combined with the total for seasonal decorative lighting. Large halogen bulbs consumed the largest amount of energy.

Figure 26: Exterior & seasonal lighting energy use by bulb type (pop wt, % MMBTU)

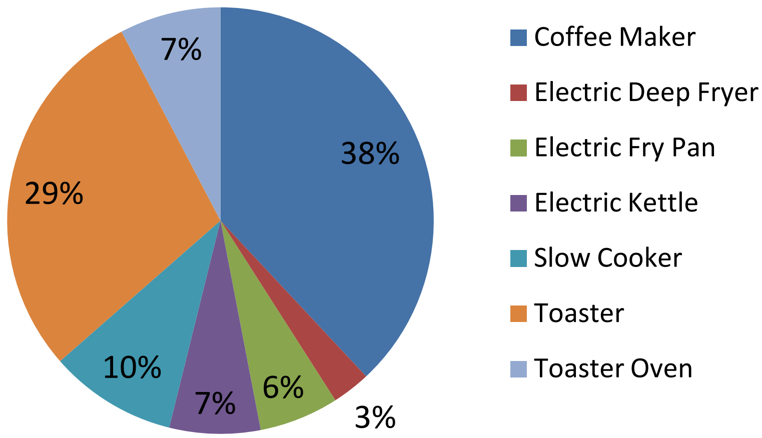


Other available characteristics on exterior lighting include: number of bulbs of each type, hours on/off per bulb type, and type of incandescent bulb. Other available characteristics on seasonal decorative lighting include: number of light strands of each type (large incandescent, small incandescent, LED), type of light strand, hours on/off, months on/off.

Other Kitchen Equipment

Figure 27 shows that "Other kitchen equipment" (including coffee makers, deep fryers, electric frying pans, electric kettles, slow cookers, toasters and toaster ovens) accounted for 2% of total appliance energy use and 3% of total appliance electrical use. However, each appliance contributes to this total load. Coffee makers are the largest sub category at 38%, followed by toasters at 29%.

Figure 27: Other kitchen equipment energy use by sub end use (pop wt, % MMBTU)



Other available characteristics on other kitchen equipment include: number of coffeemakers/ toasters/toaster ovens, type of coffeemaker.

Southeast and Railbelt Alaska Non-Residential Energy Use

Introduction

This section summarizes non-residential energy use for Climate Zones 6, 7 and 8 for the Railbelt and Southeast Alaska by end use, climate zone, and building use. A detailed description of the energy end-use methodology is provided in the Methods section located in the appendices. This includes detailed discussion of the available non-residential building data in the study region, the sampling and survey approach used for this study, and detailed energy end-use calculation methodologies.

All of the available parcel data and assessor records were obtained and reviewed. Parcel data was not obtainable for all areas within the study. Furthermore, there is a lack of consistent descriptive data for non-residential buildings in the Railbelt and Southeast (e.g., building counts, building types, square footage, etc.). A stratified random sample of the Railbelt and Southeast Alaska was conducted. The study region was divided by Climate Zone and building type (9 primary building type categories as shown in Table 6). For each of these "strata", a random set of buildings was selected to be surveyed, to provide statistics on building characteristics and energy end use that can be extrapolated to the entire population. Table 6 summarizes key statistics on the survey sample, and the population of buildings represented in each strata.

Table 6: Railbelt and Southeast non-residential building summary data

Building Type	Climate Zone	Survey Data			Population Data	
		Average SF/Bldg	Survey Total SF	Surveyed Buildings	Total Bldgs in Population	Estimated Population SF
Food service	6	5,866	76,259	13	111	651,135
Healthcare	6	34,694	416,332	12	38	1,318,385
Institutional	6	9,292	139,387	15	124	1,152,266
Lodging	6	9,076	117,985	13	77	698,834
Office	6	10,036	210,758	21	349	3,502,597
Other	6	8,238	65,900	8	364	2,998,450
Retail	6	22,394	425,477	19	349	7,815,341
Service	6	7,929	142,715	18	134	1,062,434
Warehouse	6	13,240	251,551	19	874	11,571,346
Food service	7	7,750	131,747	17	579	4,487,148
Healthcare	7	26,635	399,522	15	229	6,099,369
Institutional	7	21,962	307,465	14	935	20,534,270
Lodging	7	17,370	330,022	19	437	7,590,506
Office	7	24,927	598,237	24	1,562	38,935,258
Other	7	16,843	286,323	17	1,634	27,520,693
Retail	7	18,562	464,038	25	1,782	33,076,629
Service	7	10,646	180,980	17	977	10,401,027
Warehouse	7	19,658	353,843	18	4,496	88,382,118
Food service	8	5,147	87,504	17	136	700,032
Healthcare	8	42,981	644,710	15	40	1,719,227
Institutional	8	13,463	484,655	36	162	2,180,948
Lodging	8	9,973	179,521	18	81	807,845
Office	8	7,137	228,391	32	406	2,897,711
Other	8	5,443	136,066	25	415	2,258,696
Retail	8	11,323	283,087	25	398	4,506,745
Service	8	8,422	218,981	26	152	1,280,197
Warehouse	8	15,796	426,483	27	997	15,748,280
Totals				**525**	**17,838**	**299,897,483**

Energy Use by Climate Zone

Figure 28 shows the total non-residential building energy use for each of the Climate Zones in the study area. Some light industrial facilities are included in the non-residential sample. Facilities supporting large industrial enterprises are not included. The total number of buildings and the non-residential square footage by Climate Zone is shown in Appendix A. Total energy use calculations use standard calculation protocols described in the methodology section, also included in Appendix A.

Climate Zone 6 generally corresponds to the Southeast, Climate Zone 7 to the Anchorage Area, and Climate Zone 8 to the Fairbanks area. Climate Zone 7 contains the largest population of non-residential buildings and accounts for the largest percentage of non-residential building energy use.

Figure 28: Total non-residential energy use in the Railbelt and Southeast by Climate Zone

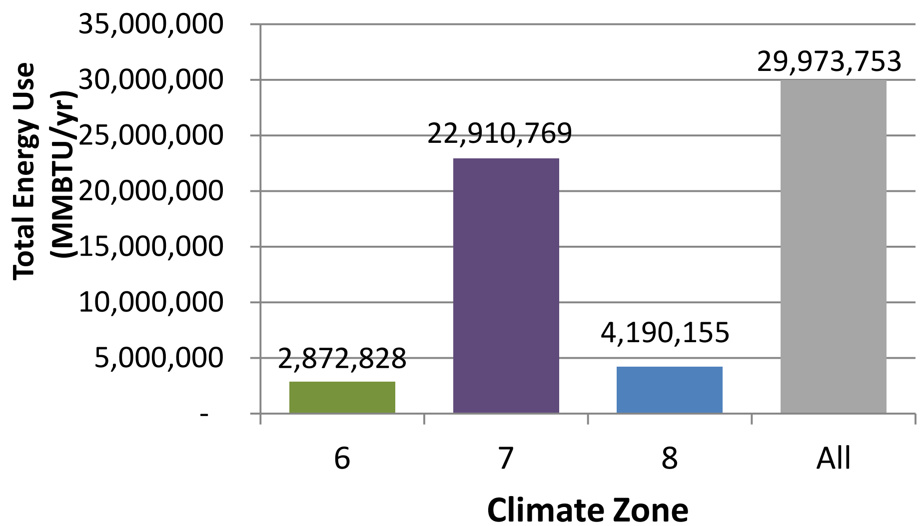
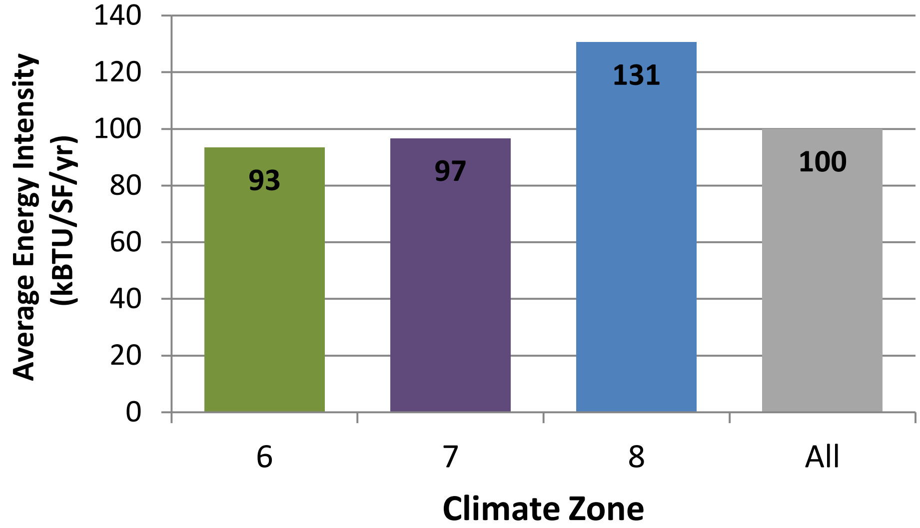


Figure 29 shows similar data, but represents the average non-residential building energy intensity (kBTU/ft^2/year) for each Climate Zone and the entire study area. Climate Zone 8 is the most extreme and buildings use the most energy per square foot.

Figure 29: Average non-residential building energy intensity by Climate Zone



Energy Use by Fuel Type

Figure 30 shows non-residential building energy use by fuel type. Electricity accounts for 44% of building energy use. Natural gas is the next largest fuel source, accounting for 39% of building energy

Figure 30: Total non-residential building energy use (MMBTU) by fuel type.

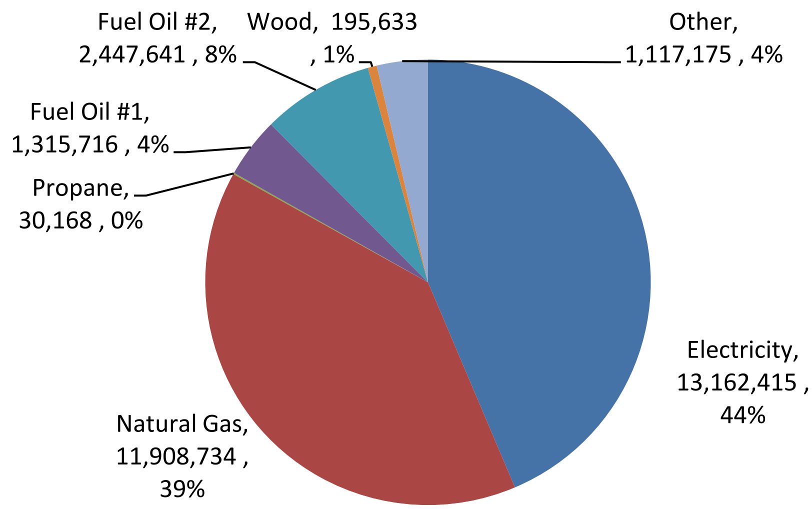
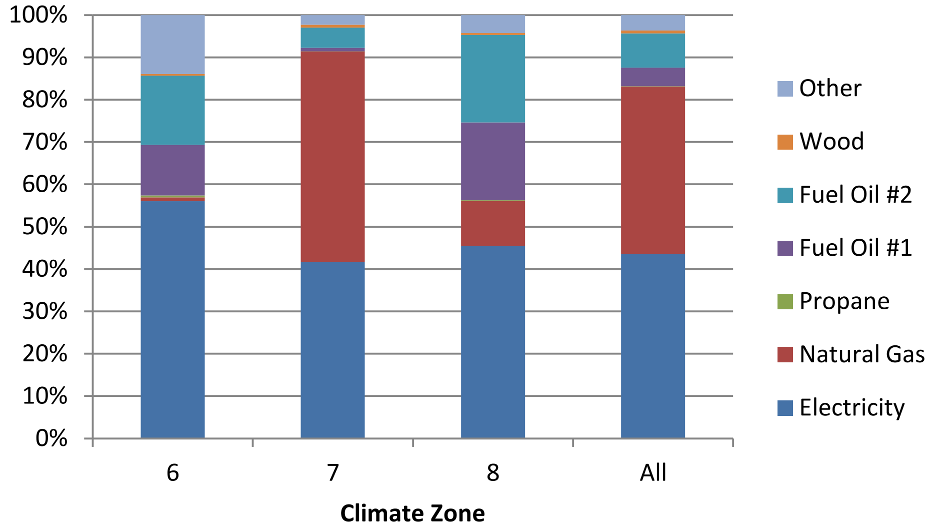


Figure 31 shows similar data of fuel type by Climate Zone. Climate Zone 7 (Anchorage area) has a large penetration of natural gas, while the other Climate Zones do not and rely on other fuel types.

Figure 31: Fuel type by Climate Zone



Energy Use by Building Type

Figure 32 and Table 7 show the total Railbelt and Southeast non-residential building energy use broken down by building type (blue bars, read from left axis). Warehouse type buildings use the largest amount of energy. Also plotted is the total building area by building type (red bars read on right). The total building energy use correlates to total building area for each building type.

Figure 32: Total building energy use and area by building type

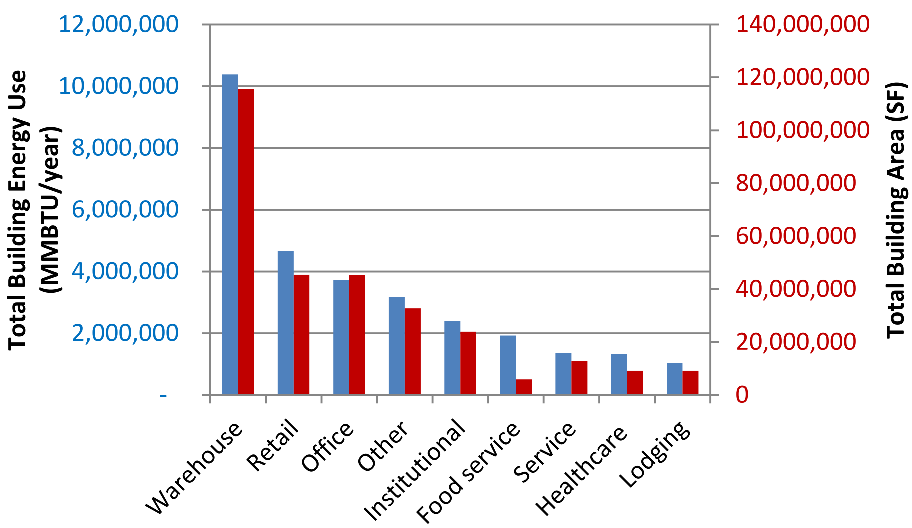
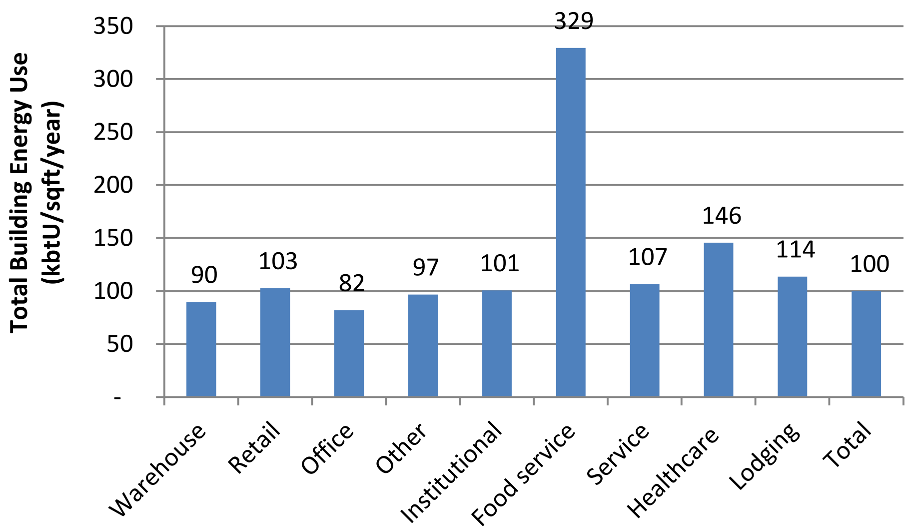


Table 7: Total building energy use and area by building type

Building Type	Total Energy Use, MMBTU/year	Estimated Building Area (SF)
Foodservice	1,922,406	5,838,314
Healthcare	1,329,890	9,136,981
Institutional	2,402,436	23,867,483
Lodging	1,034,281	9,097,185
Office	3,714,242	45,335,566
Other	3,170,122	32,777,839
Retail	4,660,790	45,398,714
Service	1,358,434	12,743,658
Warehouse	10,381,152	115,701,744
Total	**29,973,753**	**299,897,483**

Figure 33 shows average energy intensity (kBTU/SF) for all Climate Zones by building type. Food service is the most energy intensive building type due to cooking energy. Healthcare facilities are the second most energy intensive building type.

Figure 33: Average building energy intensity by building type for all Climate Zones



Energy Use by End Use

Figure 34 shows total building energy use by primary end-use categories for all non-residential buildings in the Railbelt and Southeast Alaska. Total annual energy consumption (MMBTU) and percent of the total non-residential energy use is shown. Heating accounts for just over 50% of the total building energy use, followed by interior lighting (23%), domestic hot water heating (DHW), and office equipment.

Figure 34: Total non-residential energy end-use consumption in MMBTU/yr, Climate Zones 6, 7 and 8.

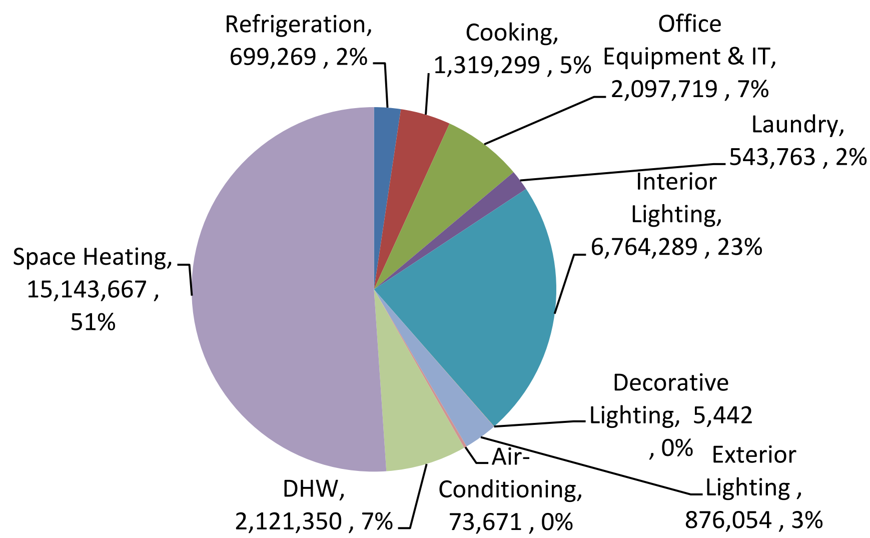


Figure 35 shows similar total energy end-use data for each of the building types, aggregated for Climate Zones 6, 7 and 8. This shows how total energy end-use consumption varies by building type. In general, heating accounts for around 50% of total energy use in all building types *except* for healthcare and food service facilities, where laundry and cooking, respectively, represent significant portions of total energy use.

Figure 35: Total non-residential energy end-use consumption by building type in MMBTU/yr, Climate Zones 6, 7 and 8.

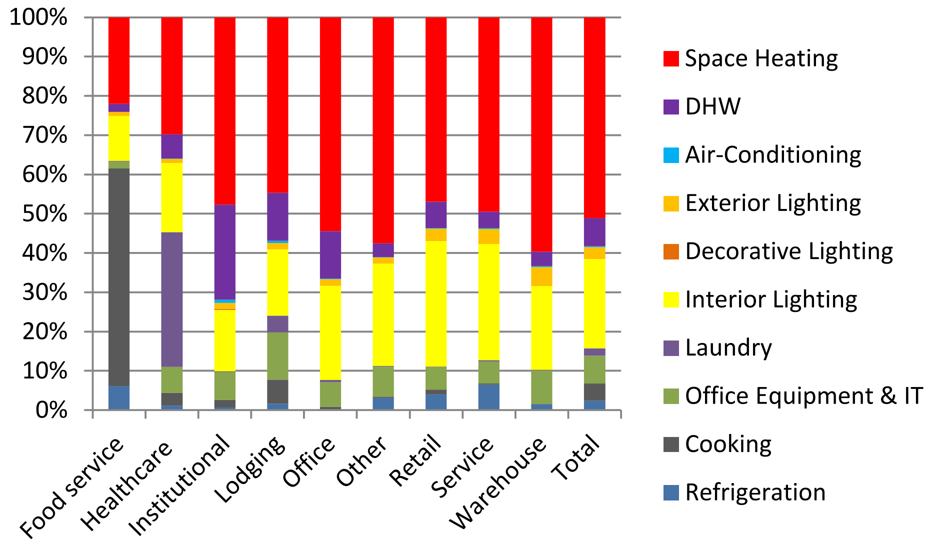


Table 8 shows average end-use energy intensities (kBTU/SF/year) for each of the primary non-residential building types.

Table 8: Average energy end-use Intensity (kBTU/SF/year) for nonresidential buildings for climate zones 6, 7, and 8

Building Type	Refrigeration	Cooking	Office Equipment & IT	Laundry	Interior Lighting	Decorative Lighting	Exterior Lighting	Air-Conditioning	DHW	Space Heating	Total
Food service	20.1	182.7	5.5	0.6	37.8	0.1	3.1	0.1	6.8	72.4	329.3
Healthcare	1.6	4.7	9.4	49.0	25.3	0.0	1.4	0.2	8.8	42.6	145.6
Institutional	0.7	1.9	7.1	0.2	15.7	0.2	1.6	0.8	24.3	47.8	100.7
Lodging	1.9	6.8	13.4	4.7	18.9	0.0	1.7	0.6	13.7	49.7	113.7
Office	0.2	0.5	5.2	0.4	19.6	0.0	1.3	0.1	9.8	44.4	81.9
Other	3.0	0.3	7.2	0.2	24.7	0.0	1.5	0.0	3.4	54.6	96.7
Retail	4.1	1.3	5.9	0.1	32.9	0.0	3.1	0.2	6.9	48.1	102.7
Service	6.9	0.3	5.9	0.4	31.4	0.0	4.0	0.3	4.4	52.6	106.6
Warehouse	1.3	0.1	7.5	0.1	18.8	0.0	4.2	0.2	3.2	52.5	89.7
Total	**2.3**	**4.4**	**7.0**	**1.8**	**22.6**	**0.0**	**2.9**	**0.2**	**7.1**	**50.5**	**99.9**

Figure 36 shows Climate Zone 6 Railbelt and Southeast non-residential building energy use and total building area (SF) broken down by building type (blue bars are MMBTUs, red bars are SF). Retail type buildings use the largest amount of energy. The total building energy use correlates to total building area for each building type.

Figure 36: Total building energy use and area by building type for Climate Zone 6

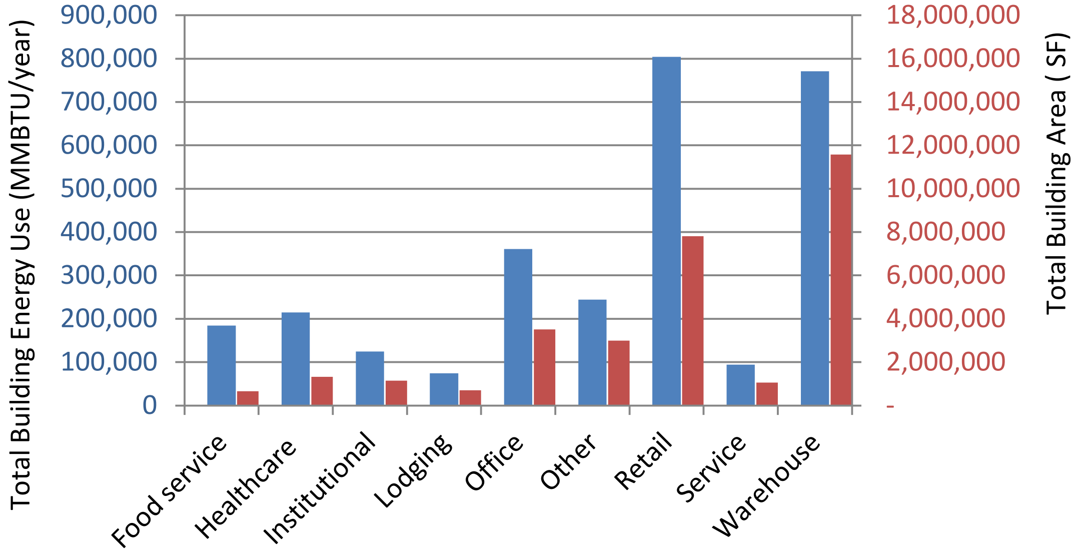


Figure 37 shows Climate Zone 7 Railbelt and Southeast non-residential building energy use and total building area (SF) broken down by building type (blue bars are MMBTUs, red bars are SF). Warehouse type buildings use the largest amount of energy. The total building energy use correlates to total building area for each building type.

Figure 37: Total building energy use and area by building type for Climate Zone 7

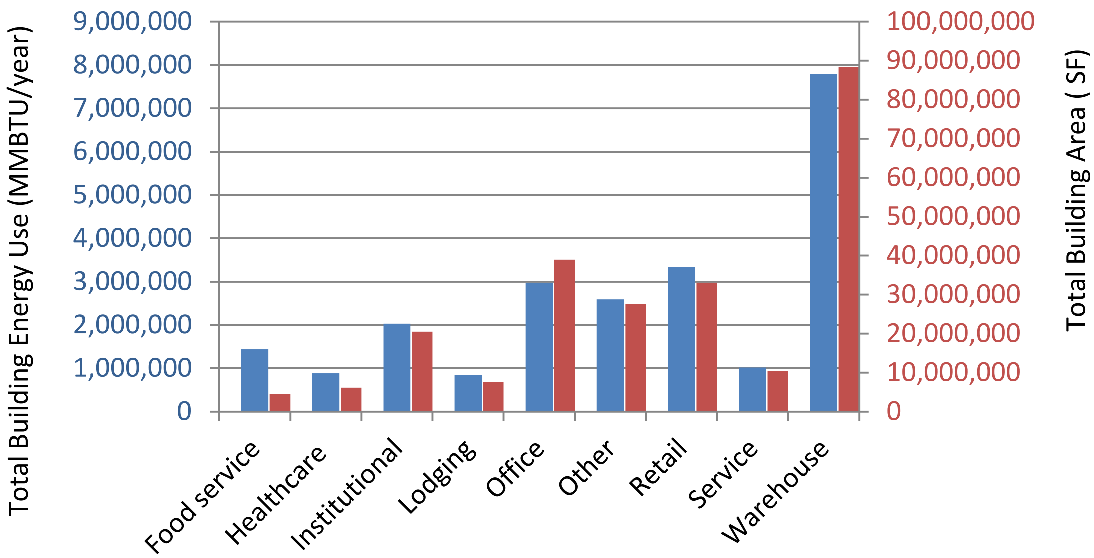


Figure 38 shows Climate Zone 7 Railbelt and Southeast non-residential building energy use and total building area (SF) broken down by building type (blue bars are MMBTUs, red bars are SF). Warehouse type buildings use the largest amount of energy. The total building energy use correlates to total building area for each building type.

Figure 38: Total building energy use and area by building type for Climate Zone 8

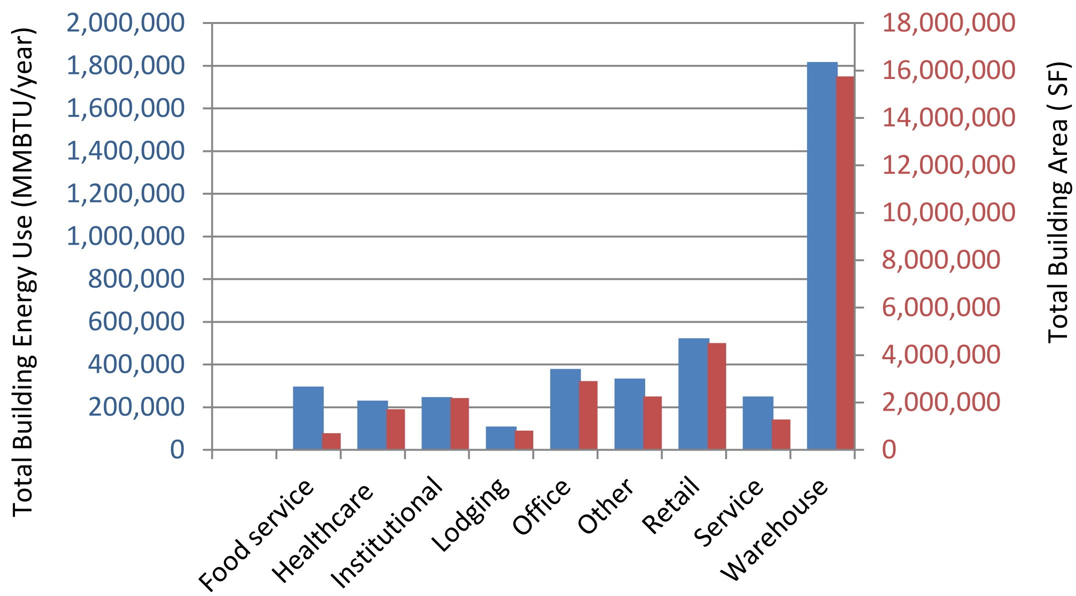


Figure 39 shows total energy end use data for each of the building types for Climate Zone 6.This shows how total energy end use consumption varies by building type. In general, heating accounts for around 49% of total energy use in all building types *except* for healthcare and food service facilities, where laundry and cooking, respectively, represent significant portions of total energy use. Interior Lighting makes up a significant portion of total energy use in both Retail and Office buildings for Climate Zone 6.

Figure 39: Total non-residential energy end use consumption by building type in MMBTU/yr, Climate Zone 6

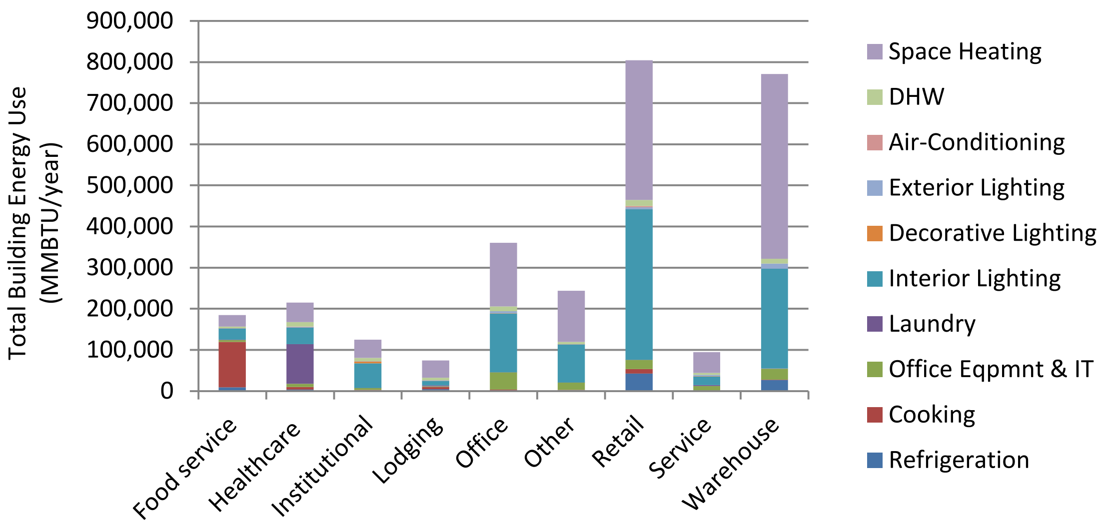


Figure 40 shows total energy end use data for each of the building types for Climate Zone 7.This shows how total energy end use consumption varies by building type. In general, heating accounts for around 51% of total energy use in all building types *except* for healthcare and food service facilities, where laundry and cooking, respectively, represent significant portions of total energy use.

Figure 40: Total non-residential energy end use consumption by building type in MMBTU/yr, Climate Zone 7

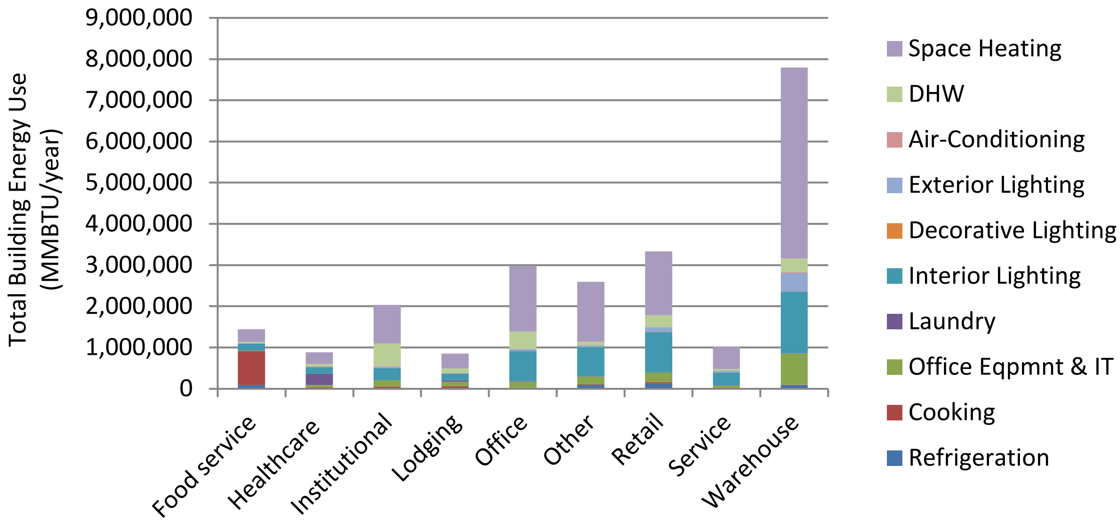
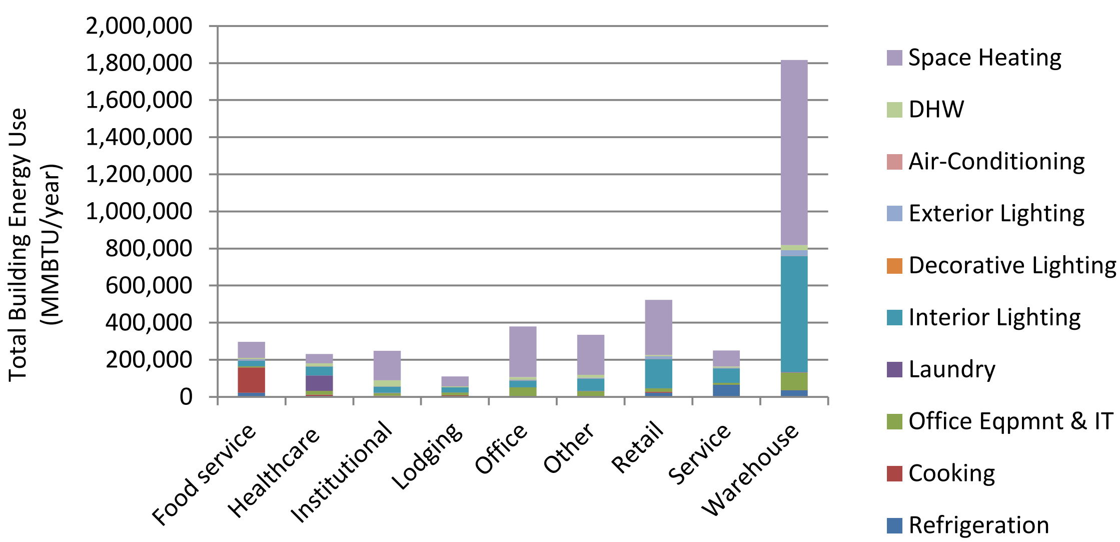


Figure 41 shows total energy end use data for each of the building types for Climate Zone 8.This shows how total energy end use consumption varies by building type. In general, heating accounts for around 56% of total energy use in all building types *except* for healthcare and food service facilities, where laundry and cooking, respectively, represent significant portions of total energy use.

Figure 41: Total non-residential energy end use consumption by building type in MMBTU/yr, Climate Zone 8



Energy Consumption Details by Climate Zone and Building Type

Table 9 summarizes key energy intensity data (kBTU/SF/year) for each building type in each of the three climate zones covered. Note that more detailed data on specific energy end uses is available in the detailed energy end-use spreadsheets provided as an electronic appendix to this document.

Table 9: Detailed energy intensity data (kBTU/SF/year) for the primary end uses for each building type and climate zone

Climate Zone	Building Type	Refrigerators-Residential	Freezers - Residential	Commercial Refrigeration Cases	Walk in Coolers	Cooking	Office & IT Equipment	Laundry Residential Equip.	Laundry Commercial	Total Laundry	Lighting Interior	Lighting Decorative	Lighting Exterior	Lighting Total	Cooling
6	Food service	0.5	0.3	3.5	9.1	-	0.5	42.0	0.0	1.5	43.5	0.1	5.2	43.2	283.6
	Healthcare	0.2	0.0	0.6	2.0	73.0	73.1	18.8	0.0	1.2	20.0	0.2	8.0	36.2	163.1
	Institutional	0.4	0.1	-	-	-	0.1	50.2	3.9	0.6	54.7	0.1	6.4	38.7	108.4
	Lodging	0.5	0.1	0.6	5.0	2.0	2.5	8.3	0.0	1.7	10.0	-	9.1	60.3	106.4
	Office	0.3	0.1	-	-	-	0.1	40.6	0.0	1.5	42.1	-	3.2	44.3	103.0
	Other	0.4	0.3	0.0	-	-	0.2	30.8	0.0	0.2	31.0	-	2.0	41.5	81.4
	Retail	0.1	0.0	2.0	3.3	-	0.0	47.4	0.0	0.6	48.0	0.4	1.8	43.5	102.9
	Service	0.2	0.1	-	-	2.0	2.2	16.1	0.0	3.3	19.4	-	4.2	47.7	88.9
	Warehouse	0.1	0.0	0.1	2.1	-	0.1	13.3	-	1.1	14.3	-	1.0	38.8	66.6
7	Food service	0.4	0.3	0.8	17.9	0.6	0.7	36.8	0.1	2.1	39.0	0.1	6.4	68.6	321.2
	Healthcare	0.1	0.0	0.5	0.6	44.0	44.2	25.8	0.0	1.4	27.3	0.2	9.1	47.7	144.9
	Institutional	0.2	0.0	0.1	0.3	-	0.1	14.2	0.0	1.7	15.9	0.9	26.3	45.7	98.9
	Lodging	0.2	0.1	0.4	0.6	5.0	5.3	19.2	0.0	1.8	21.0	0.7	14.8	47.0	111.9
	Office	0.1	0.0	-	-	0.5	0.5	18.2	0.0	1.3	19.5	0.1	10.8	40.7	76.4
	Other	0.2	0.1	0.1	3.0	-	0.1	23.7	0.0	1.6	25.3	0.0	3.2	52.7	94.2
	Retail	0.1	0.0	1.2	2.4	-	0.1	29.2	0.0	3.7	32.9	0.1	8.8	46.8	100.8
	Service	0.2	0.0	0.4	1.4	-	0.2	29.4	0.0	4.2	33.6	0.4	4.3	51.3	97.5
	Warehouse	0.1	0.0	-	0.9	-	0.1	15.8	0.0	5.0	20.8	0.3	3.8	52.4	88.2
9	Food service	0.4	0.3	2.3	27.3	-	0.2	40.4	0.1	11.1	51.6	0.3	10.3	123.8	423.7
	Healthcare	0.1	0.0	0.2	2.0	47.8	47.9	28.3	0.0	1.3	29.6	0.0	8.4	29.4	134.2
	Institutional	0.2	0.0	0.1	0.6	0.4	0.6	12.1	0.0	1.0	13.1	0.1	14.5	72.8	113.5
	Lodging	0.4	0.1	-	1.6	0.8	1.2	24.6	0.0	0.9	25.5	0.0	6.9	65.8	136.6
	Office	0.3	0.0	-	-	0.1	0.2	12.3	0.0	1.7	14.0	0.3	4.2	94.7	131.2
	Other	0.5	0.2	0.1	-	0.6	0.8	28.4	0.0	2.3	30.7	-	7.3	95.2	147.8
	Retail	0.1	0.0	1.5	3.3	-	0.0	34.6	0.0	3.6	38.2	0.1	1.6	65.9	116.2
	Service	0.4	0.1	0.3	50.3	0.8	1.0	60.1	0.0	3.2	63.4	0.0	4.8	67.6	195.3
	Warehouse	0.1	0.0	0.2	2.0	0.2	0.2	39.7	0.0	2.0	41.7	0.1	1.7	63.5	115.4

Energy End-use Details

The energy end-use study has provided detailed information on a wide range of specific building energy end uses and building characteristics. This provides a rich data set that can be mined and explored to understand Alaskan non-residential building energy use, appliance and equipment saturations, building characteristics, etc. This data can be used to inform policy, serve as the baseline to measure policy effectiveness (e.g., the penetration on energy efficient lighting products), etc. This section provides a brief summary of some of the key end-use data available in the complete results.

Figure 42 provides a breakdown of total nonresidential lighting energy by lighting technology/lamp type. Fluorescent lighting (including T12, T8 and T5 lamps) accounts for nearly 60% of the total lighting. Inefficient lamp types for which there are good energy efficiency upgrades available constitute approximately 51% of the total lighting energy, and presents a good opportunity for the state to focus on lighting efficiency policy in the nonresidential sector.

Figure 42: Total non-residential lighting electricity use (kWh/year) by lamp type, Climate Zones 6, 7 and 8

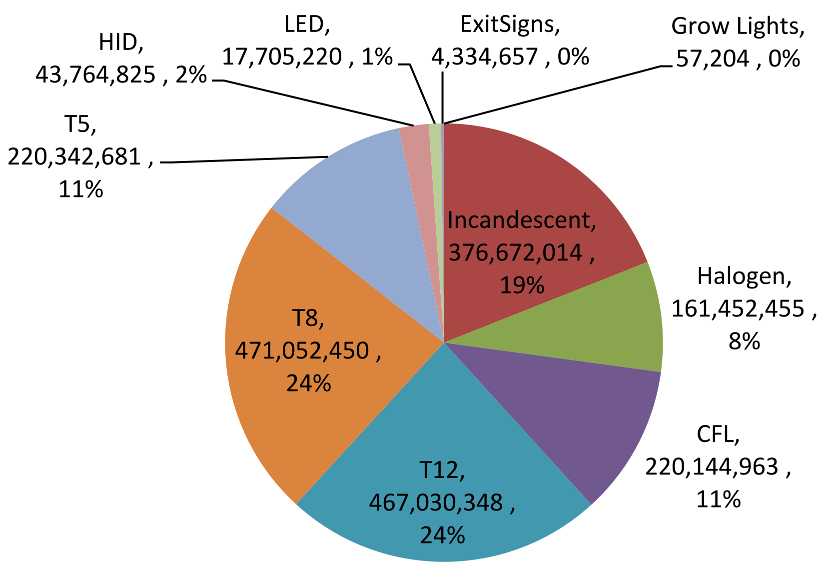
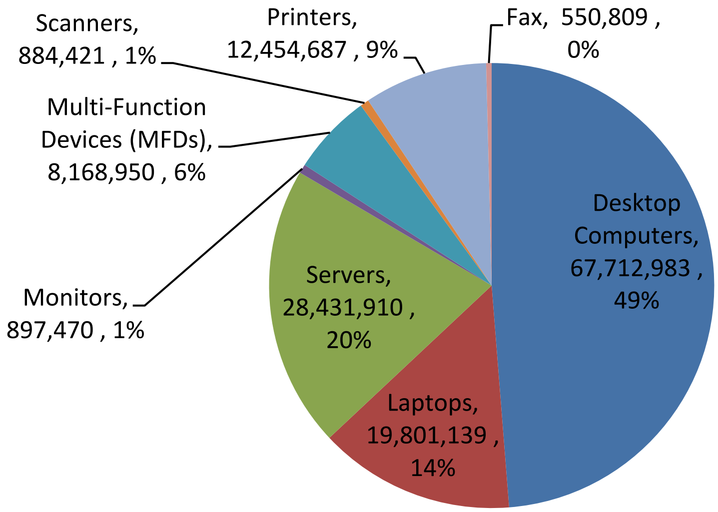


Figure 43 shows total computer and IT related energy consumption for nonresidential buildings.

Figure 43: Total non-residential computer and IT electricity use (kWh/year), Climate Zones 6, 7 and 8



Policy Implications of Statistically Significant Differences in Energy Use

Statewide energy policy is more easily drafted and applied to types of facilities that have similar energy use patterns. Interventions may be far more difficult to promote and implement for facilities that have different energy use characteristics.

A statistical analysis of total energy use (not adjusted for the total population of buildings in the three Southeast and Railbelt Climate Zones) was performed at both the building level (i.e., total building energy use) as well as on an energy intensity basis (e.g., kBTU/SF). These are shown as Table 10 and Table 11. When looking at total building energy use, there are statistically significant differences between climate zones and energy used to produce hot water, provide laundry services and total energy use.

However, when looking at building energy intensity data, many of the statistical differences disappear. The amount of energy required for laundry services, measured in KBTU/ft2, is the only energy use category that maintains statistically significant differences between climate zones. This analysis suggests that a policy focused on managing end-use energy on a per-square-foot basis may be appropriate for statewide implementation. Laundry services could receive special consideration in certain climate zones.

Table 10: Climate Zones 6, 7 and 8 Mean Non-Residential Energy Use in MMBTUs/yr

Building Type	Heating ventilation and air conditioning MMBTU	Hot water MMBTU*	Food service, cooking and refrigeration MMBTU	Office equipment and information technology MMBTU	Laundry MMBTU ***	Lighting MMBTU	All end uses MMBTU *
Food service	508.67	47.46	1326.56	355.74	3.08	312.59	2554.11
Healthcare	1394.21	330.95	267.74	2000.69	9590.82	2493.70	16078.12
Institutional	761.36	266.26	35.86	169.42	1.59	592.17	1826.66
Lodging	717.38	157.89	128.09	185.18	54.76	785.54	2028.83
Office	689.42	126.28	11.05	140.39	5.90	400.12	1373.16
Other	689.07	39.44	30.84	97.83	1.61	464.90	1323.69
Retail	902.88	88.54	289.50	92.72	1.08	1896.03	3270.75
Service	523.34	44.78	227.91	76.54	7.20	532.70	1412.47
Warehouse	894.35	39.03	31.38	103.42	1.18	798.39	1867.75
Total	776.36	118.80	247.02	303.05	811.00	896.02	3152.25

*ANOVA significant at .05, ** significant at .01, ***significant at .001

Table 11: Climate Zones 6, 7 and 8 Mean Non-Residential Energy Use in kBTUs per Square Foot/yr

Building Type	HVAC kBTUsqft	Hot Water kBTUsqft	Food Service, Cooking & Refrigeration kBTUsqft	Office Equipment & Information Technology kBTUsqft	Laundry kBTUsqft *	Lighting kBTUsqft	All End Uses kBTUsqft
Food service	93.14	9.59	211.60	139.83	0.73	64.82	519.71
Healthcare	75.42	17.18	9.09	69.64	27.95	75.14	274.41
Institutional	63.99	15.97	2.88	23.21	0.18	57.06	163.29
Lodging	81.36	11.60	11.26	32.69	5.41	176.41	318.73
Office	83.77	7.05	1.61	31.01	1.17	45.68	170.29
Other	84.39	6.80	2.85	29.32	0.55	54.13	178.04
Retail	70.77	4.78	244.22	17.56	0.17	302.14	639.64
Service	69.88	10.06	4.47	14.88	0.77	69.08	169.13
Warehouse	68.24	3.87	1.60	8.22	0.22	52.96	135.11
Total	76.44	9.13	57.01	37.87	3.33	102.67	286.46

*ANOVA significant at .05, ** significant at .01, ***significant at .001

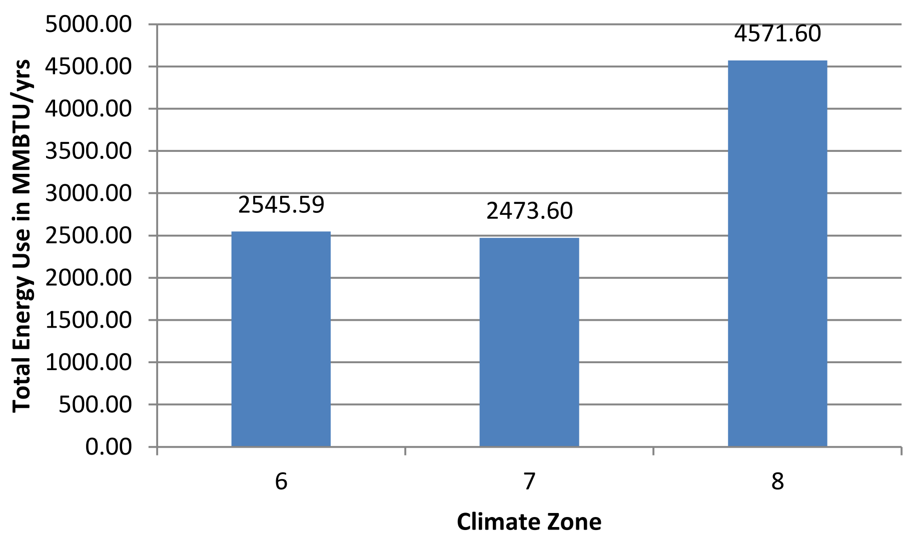
Characteristics of Energy Use in the Non-Residential Sample

The underlying energy end-use study data contains many more details that are available to be analyzed and processed to inform Alaskan energy policy. The following sections present data on energy use within each climate zone. Unlike the previous section, this information emphasizes the average end-use energy values for each type of building in the non-residential sample. This data is not generalized to the total population, but allows policy makers and program planners to use baseline building specific data to plan program interventions and measure the effectiveness of initiatives within each climate zone.

Non-Residential Energy use by Climate Zone

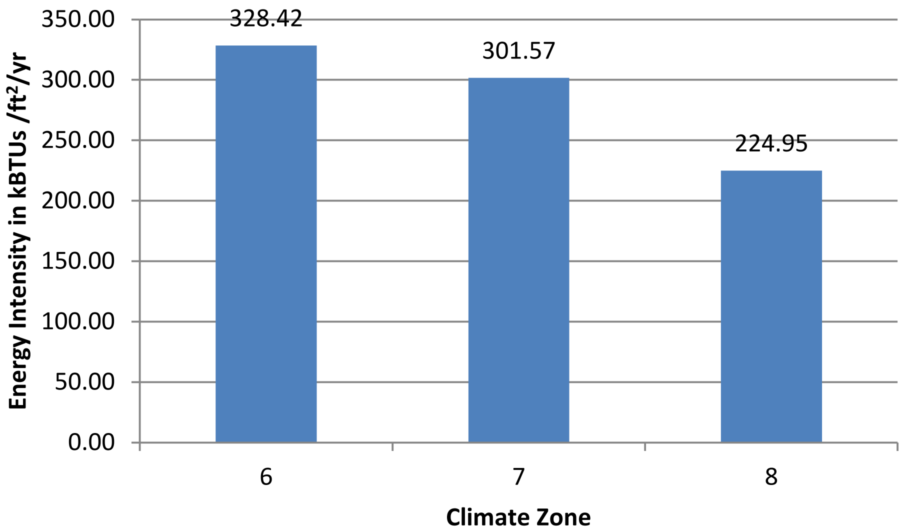
Figure 44 shows that buildings in Climate Zone 8 use substantially more energy than buildings in Climate Zones 6 or 7 when measured on a MMBTU basis.

Figure 44: Total Non-Residential Energy Use by Climate Zone in MMBTUs/yr



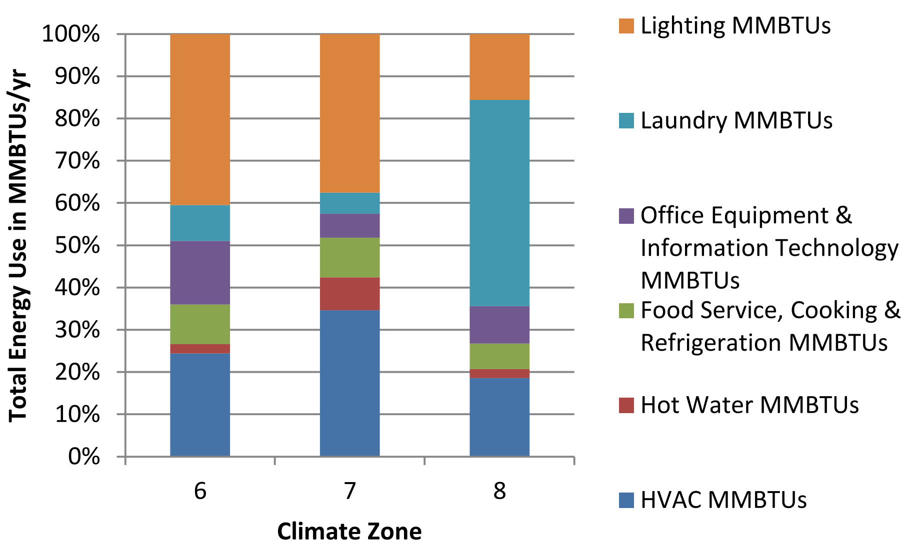
However, when energy intensity is measured by dividing the total energy use by the square footage of the building, the pattern is reversed. Buildings in Climate Zone 6 use more energy than those in either Climate Zone 7 or 8 (Figure 45). The differences appear to be attributable to heating energy use.

Figure 45: Total Non-Residential Energy Intensity by Climate Zone in kBTUs /ft^2/yr



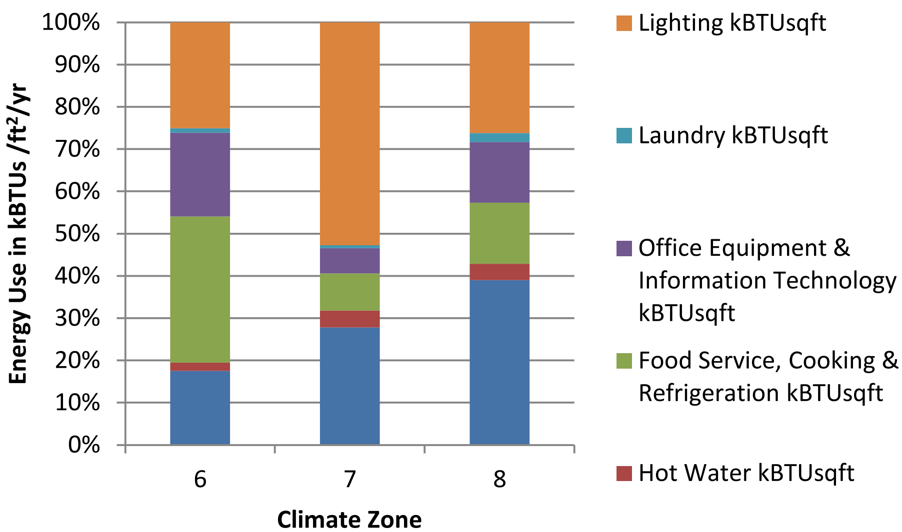
Each Climate Zone has a different distribution of total energy use. Figure 46 shows that the amount of energy used for heating, ventilation and air-conditioning is highest in Climate Zone 7. Laundry is highest in Climate Zone 8. Hot water production, while a small overall portion of total energy use, is the only single use that shows statistically significant differences between Climate Zones.

Figure 46: Energy distribution in MMBTUs/yr, Climate Zones 6, 7 and 8



An analysis of energy intensity, measuring annual energy use by building square foot, shows a far different picture of the distribution of energy use (Figure 47). As would be expected, the per-square-foot energy requirements for heating are highest in Climate Zone 8. The per-square-foot energy requirements for lighting are highest in buildings in Climate Zone 7.

Figure 47: Energy intensity (kBTUs /ft^2/yr) by use category and Climate Zone.



Detailed energy use data by Climate Zone is shown in Table 12 and Table 13.

Table 12: Total energy use by Climate Zone, all building types, in MMBTUs/yr.

Climate Zone	HVAC MMBTUs	Hot Water MMBTUs	Food Service, Cooking & Refrigeration MMBTUs	Office Equipment & Information Technology MMBTUs	Laundry MMBTUs	Lighting MMBTUs	All End Uses MMBTUs
6	620.20	57.00	238.12	382.61	216.81	1030.85	2545.59
7	855.17	194.48	230.60	140.30	123.38	929.67	2473.60
8	849.63	96.54	275.30	406.98	2227.57	715.58	4571.60
Total	776.36	118.80	247.02	303.05	811.00	896.02	3152.25

*ANOVA significant at .05, ** significant at .01, ***significant at .001

Table 13: Total energy intensity by Climate Zone, all building types, in kBTUs/ft²/yr

Climate Zone	HVAC kBTUs/ft²/yr	Hot Water kBTUs/ft²/yr	Food Service, Cooking & Refrigeration kBTUs/ft²/yr	Office Equipment & Information Technology kBTUs/ft²/yr	Laundry kBTUs/ft²/yr	Lighting kBTUs/ft²/yr	All End Uses kBTUs/ft²/yr
6	57.56	6.38	113.68	64.97	3.39	82.44	328.42
7	83.92	11.99	26.52	18.00	2.12	159.02	301.57
8	87.66	8.72	32.59	32.29	4.67	59.02	224.95
Total	76.44	9.13	57.01	37.87	3.33	102.67	286.46

*ANOVA significant at .05, ** significant at .01, ***significant at .001

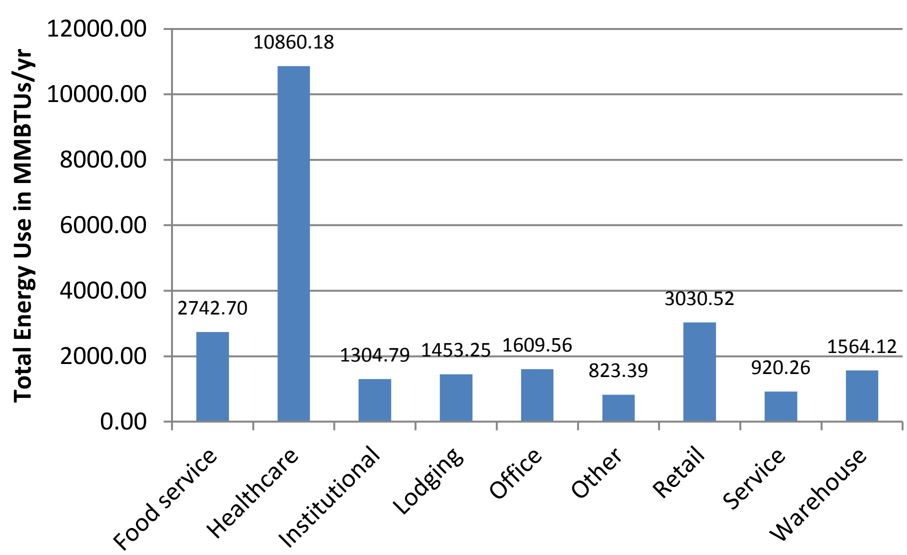
Climate Zone 6 non-residential energy use

Climate Zone 6 is most of Southeast Alaska, but includes non-residential buildings in Haines and Kodiak. The decision to include these two areas in Climate Zone 6 was made to account for the similarity in the air maritime climate.

Overall Energy Use in All Buildings

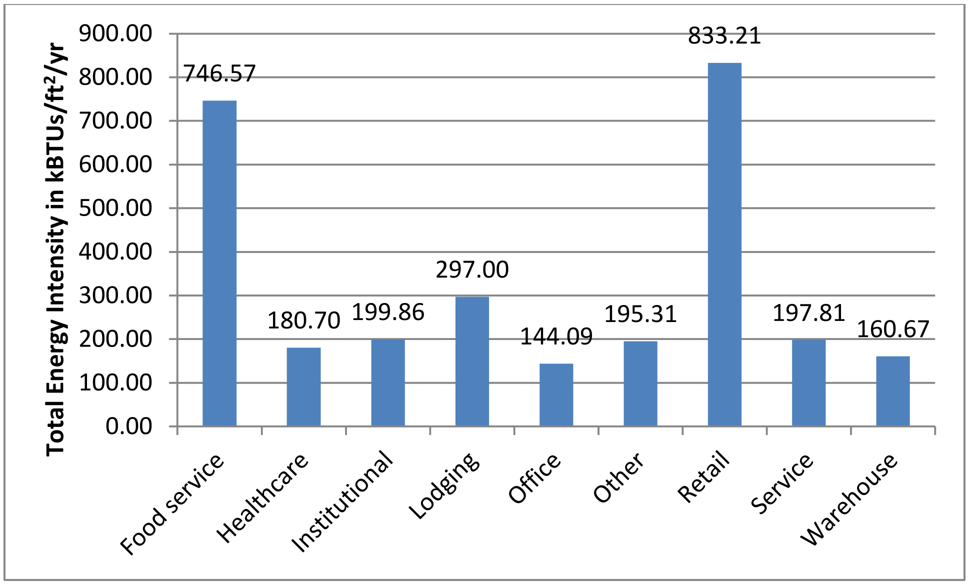
In Climate Zone 6, healthcare facilities are by far the largest energy user when measured by their total MMBTU use. Figure 48 shows that their use is over 10 times that of "Other" buildings, which include parking facilities, sports facilities, multipurpose centers and other types of facilities.

Figure 48: Total Energy Use in MMBTUs.yr, Climate Zone 6



When divided by the square footage of each building, energy use patterns shift. Figure 49 shows that retail and food service buildings become the most energy intensive buildings, and healthcare facilities drop down considerably.

Figure 49: Total Energy Intensity in kBTUs/ft²/yr, Climate Zone 6



Distribution of Total Energy Use

Lighting uses a higher proportion of the energy (41%) in buildings sampled in Climate Zone 6 than any other single use. Heating, ventilation and air-conditioning use 24% of all of the energy, and office equipment and information technology use an additional 15%. These are shown in Figure 50.

The energy intensity calculations, however, show a different perspective. When the total square footage of each building is taken into account, the proportion of energy required for lighting drops from 41% to 24%. Energy required to operate office and information technology equipment increases from 15% to 20%. Heating, ventilation and air-conditioning are a smaller portion of energy use when examined on a per square foot basis, decreasing from 24% of total energy use to 17% of energy use on a per square foot basis per year (see Figure 51).

Figure 50: Distribution of Total energy use in MMBTUs/yr, Climate Zone 6.

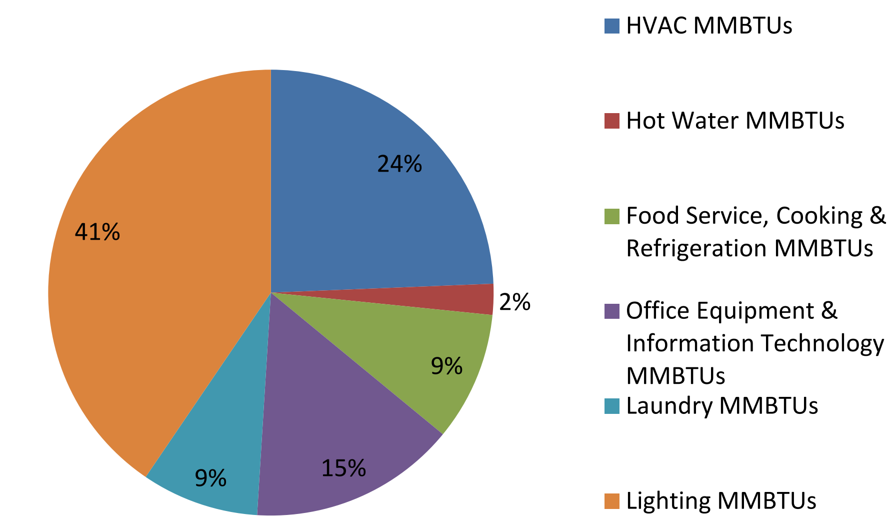
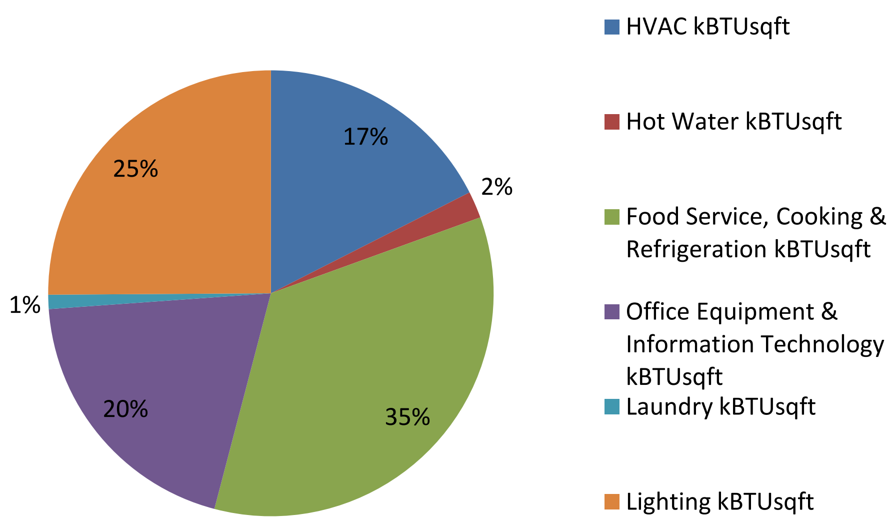
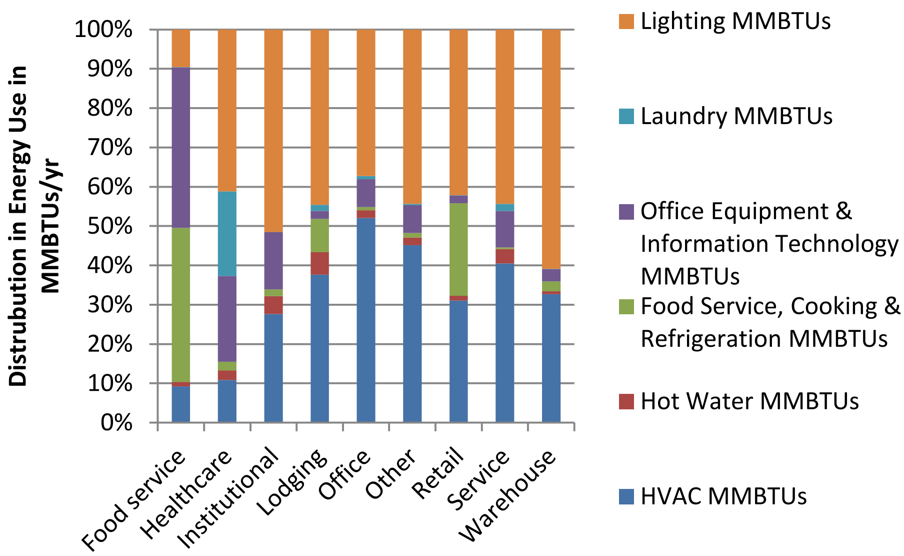


Figure 51: Distribution on Non-Residential Energy Use, kBTUs /ft^2/yr Climate Zone 6.



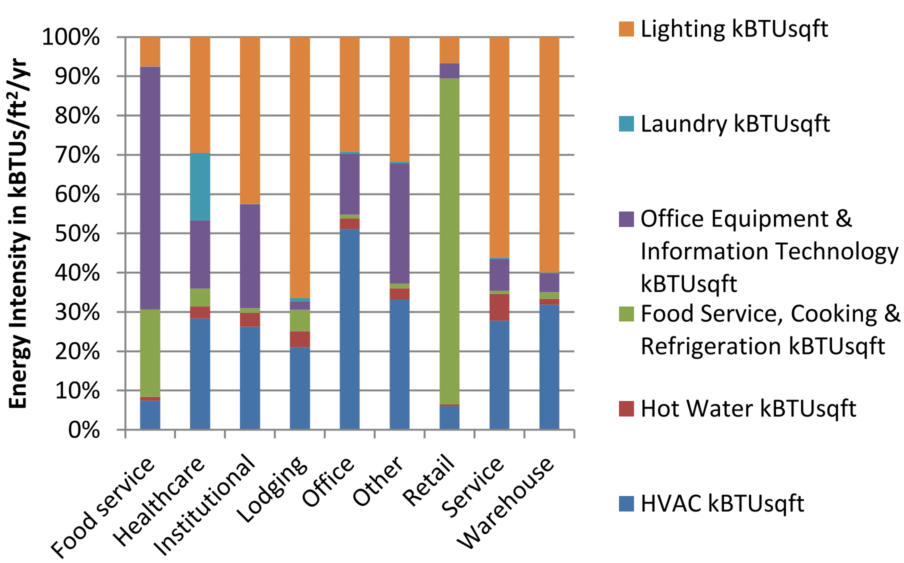
There is substantial variation in the overall distribution of energy use in non-residential buildings in Climate Zone 6. Figure 52 shows that heating, ventilation and air-conditioning require the largest amount of energy in office buildings. Food service buildings, on the other hand, devote a smaller portion of their MMBTUs to this energy use. As would be expected, food service, cooking and refrigeration require far more energy in food service facilities than in other types of buildings.

Figure 52: Energy distribution in MMBTUs/yr, Climate Zone 6.



When examined on a per-square-foot basis, the energy used for lighting retail spaces decreases, and the amount of energy for food service, cooking and refrigeration increases dramatically. The amount of energy required for heating office space, however, remains largely unchanged (Figure 53).

Figure 53: Energy intensity (kBTUs /ft^2/yr) by use category, Climate Zone 6.



Detailed information on energy use in Climate Zone 6 is shown in Table 14 and Table 15.

Table 14: Total energy use by Climate Zone by building types, in MMBTUs/yr, Climate Zone 6.

Building Type	HVAC MMBTUs	Hot Water MMBTUs *	Food Service, Cooking & Refrigeration MMBTUs	Office Equipment & Information Technology MMBTUs	Laundry MMBTUs ***	Lighting MMBTUs	All End Uses MMBTUs *
Food service	253.68	30.72	1073.49	1119.81	2.67	262.33	2742.70
Healthcare	1182.12	258.66	245.46	2362.99	2340.85	4470.09	10860.18
Institutional	360.93	59.48	21.78	190.10	0.61	671.90	1304.79
Lodging	547.37	82.68	123.23	29.41	22.46	648.10	1453.25
Office	838.37	31.60	12.80	114.22	12.96	599.60	1609.56
Other	371.90	15.82	9.54	58.60	2.07	365.46	823.39
Retail	940.19	39.09	711.08	60.70	1.02	1278.45	3030.52
Service	373.07	33.37	3.92	85.49	16.15	408.26	920.26
Warehouse	510.59	12.57	38.78	48.75	1.32	952.12	1564.12
Total	620.20	57.00	238.12	382.61	216.81	1030.85	2545.59

*ANOVA significant at .05, ** significant at .01, ***significant at .001

Table 15: Total energy intensity by Climate Zone by building types, in kBTUs /ft^2/yr, Climate Zone 6.

Climate Zone	HVAC kBTUs/ft^2/yr	Hot Water kBTUs/ft^2/yr	Food Service, Cooking & Refrigeration kBTUs/ft^2/yr	Office Equipment & Information Technology kBTUs/ft^2/yr	Laundry kBTUs/ft^2/yr **	Lighting kBTUs/ft^2/yr	All End Uses kBTUs/ft^2/yr
Food service	55.40	7.17	165.94	460.95	0.63	56.48	746.57
Healthcare	51.29	5.39	8.30	31.48	30.86	53.38	180.70
Institutional	52.47	7.02	2.41	52.95	0.16	84.84	199.86
Lodging	62.52	11.94	16.25	6.26	2.69	197.34	297.00
Office	73.58	3.92	1.45	22.31	0.68	42.15	144.09
Other	64.86	5.47	2.45	59.69	0.93	61.92	195.31
Retail	50.66	2.98	691.70	31.56	0.17	56.13	833.21
Service	55.03	13.50	1.35	16.23	0.70	110.98	197.81
Warehouse	51.23	2.32	2.80	7.70	0.18	96.44	160.67
Total	57.56	6.38	113.68	64.97	3.39	82.44	328.42

*ANOVA significant at .05, ** significant at .01, ***significant at .001

Climate Zone 7 Non-residential energy use

Climate Zone 7 is the region that incorporates much of Southcentral Alaska. Its climate is slightly cooler than that in Climate Zone 6.

Buildings in Climate Zone 7 showed the same basic pattern of energy use as those in Climate Zone 6. Healthcare facilities and retail buildings appeared to have the highest overall energy use, measured in MMBTUs (Figure 54).

Figure 54: Total Energy Use in MMBTUs/yr, Climate Zone 7

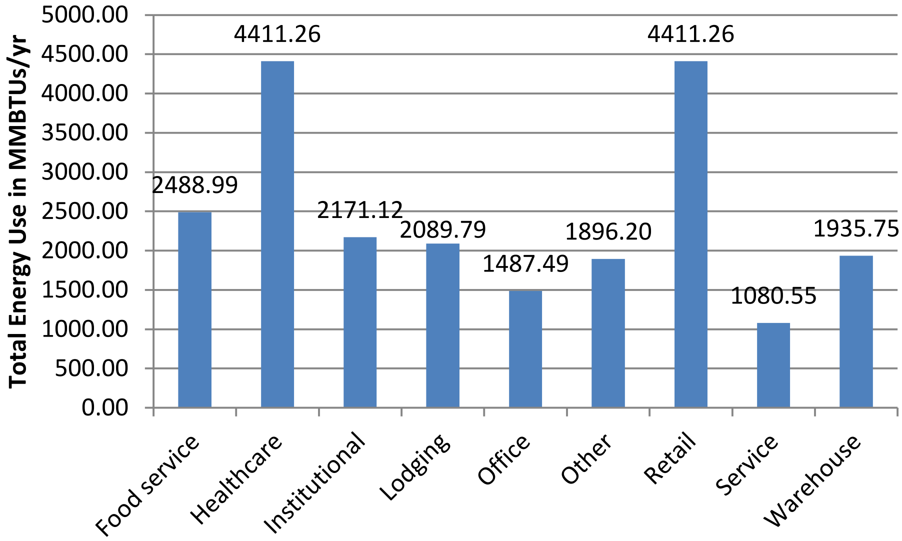
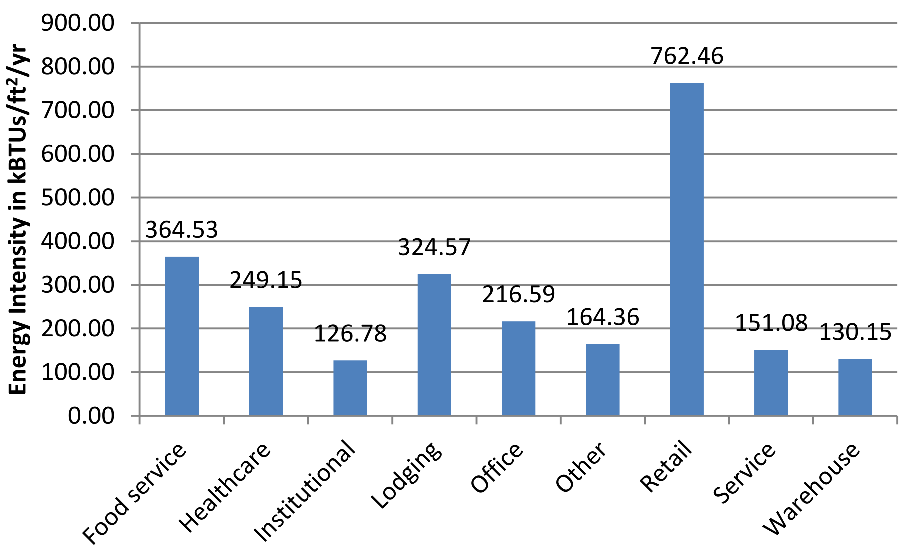


Figure 55 shows that retail buildings have the highest energy consumption per square foot of any building type in Climate Zone 7. This is similar to what was seen in Southeast Alaska (Climate Zone 6). Healthcare facilities, on the other hand, have a substantially lower energy use per square foot.

Figure 55: Energy Intensity, Climate Zone 7, kBTUs /ft^2/yr



Distribution of Total Energy Use

Figure 56 shows the total distribution of energy use within all Climate Zone 7 buildings. Energy used for lighting and for heating ventilation and air conditioning are similar (38% and 34% respectively.) All other energy uses are approximately the same at less than 10%.

Figure 56: Distribution of Total energy use in MMBTUs/yr, Climate Zone 7.

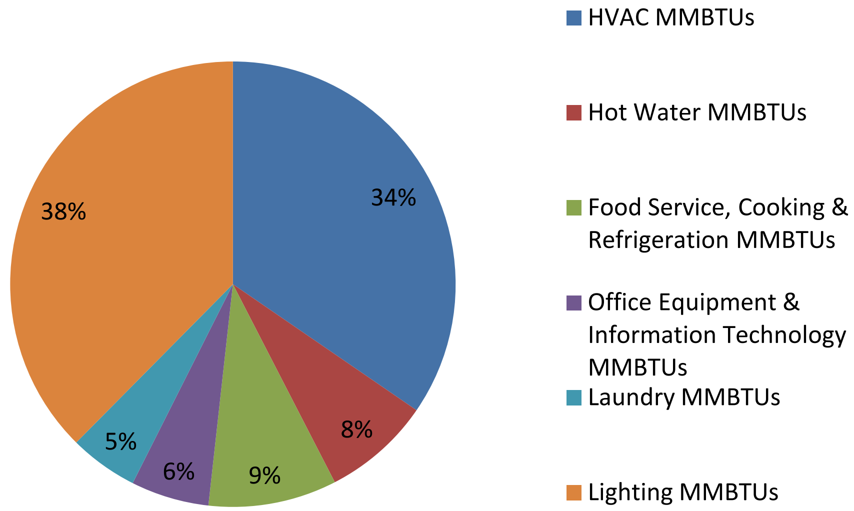
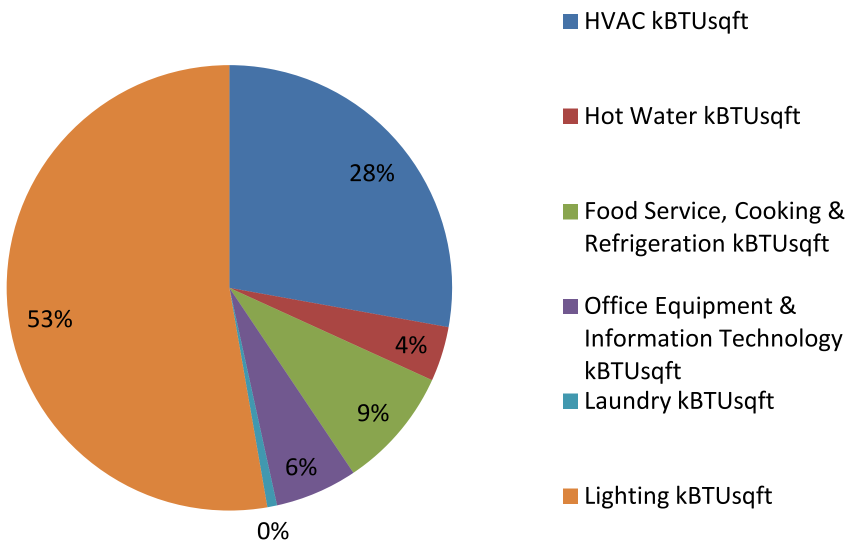


Figure 57 presents the distribution of energy on a per-square-foot basis. This figure shows the energy intensity of all facilities in Climate Zone 7. When viewed in this way, lighting becomes a more intensive use of energy, rising from 38% to 53% of all energy used by all types of buildings. The amount of energy used by heating, ventilation and air-conditioning, on the other hand, consumes a smaller portion of energy, decreasing from 34% to 28%. All other energy use categories each comprise less than 10% of total energy use per square foot.

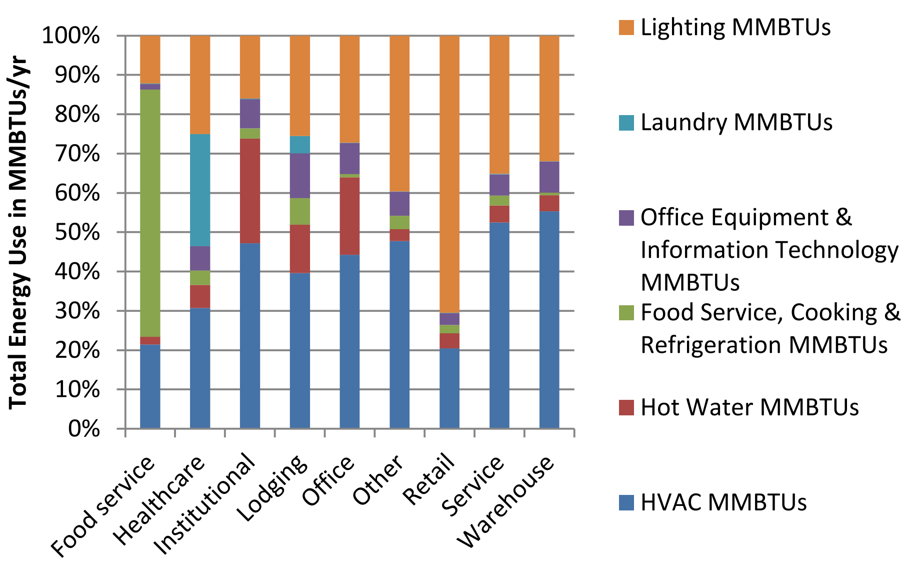
Figure 57: Distribution on Non-Residential Energy Use, kBTUs /ft^2/yr, Climate Zone 7



Energy Use by Building Type

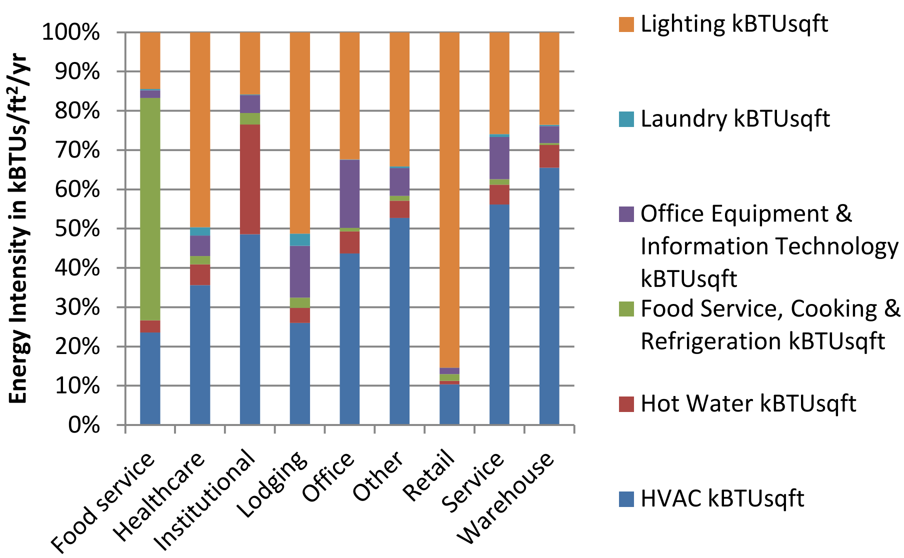
As with Climate Zone 6, there is substantial variation in the use of energy in various building types. In this Climate Zone, warehouses and buildings used in the service industry (cinemas and theaters, automotive oriented buildings, spas and salons, etc.) are examples of this variation. Retail buildings used most of their energy in lighting. As expected, food service buildings have their highest use in food service, cooking and refrigeration (Figure 58).

Figure 58: Energy distribution in MMBTUs/yr, Climate Zone 7.



The energy intensity of Climate Zone 7 buildings is different than their total energy use. When divided by the building square footage, the proportion of energy used for lighting increases even more within retail facilities. Energy used for food service, cooking and refrigeration appears to decrease slightly within food service facilities when examined on a per-square-foot basis. One of the greatest changes appears to be the sharp reduction in laundry energy requirements for healthcare facilities (Figure 59).

Figure 59: Energy intensity (kBTUs /ft²/yr) by use category, Climate Zone 7.



Detailed information on energy use is shown in Table 16 and Table 17.

Table 16: Total energy use by Climate Zone by building types, in MMBTUs/yr, Climate Zone 7.

Building Type	HVAC MMBTUs	Hot Water MMBTUs	Food Service, Cooking & Refrigeration MMBTUs ***	Office Equipment & Information Technology MMBTUs	Laundry MMBTUs	Lighting MMBTUs	All End Uses MMBTUs
Food service	532.84	49.86	1564.86	34.12	5.05	302.26	2488.99
Healthcare	1354.96	257.78	163.74	271.06	1259.32	1104.39	4411.26
Institutional	1023.82	577.97	57.58	161.01	2.49	348.25	2171.12
Lodging	827.76	256.99	141.72	238.22	91.22	533.88	2089.79
Office	658.78	292.11	12.02	118.38	0.51	405.69	1487.49
Other	906.19	56.22	65.76	115.25	1.84	750.93	1896.20
Retail	901.06	169.70	95.61	132.20	1.38	3111.31	4411.26
Service	566.95	46.58	27.76	57.57	1.88	379.82	1080.55
Warehouse	1070.28	79.26	12.70	153.53	1.75	618.23	1935.75
Total	855.17	194.48	230.60	140.30	123.38	929.67	2473.60

*ANOVA significant at .05, ** significant at .01, ***significant at .001

Table 17: Total energy intensity by Climate Zone by building types, in kBTUs /ft^2/yr Climate Zone 7.

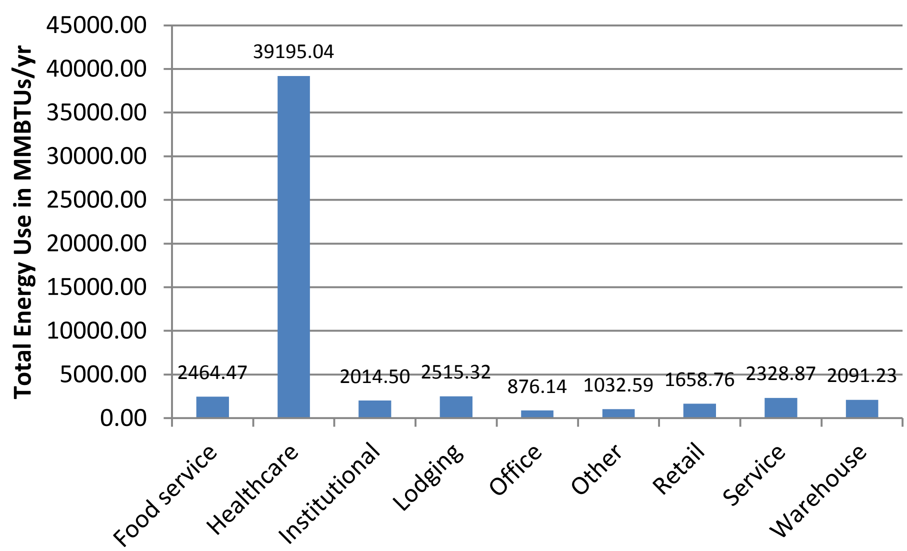
Climate Zone	HVAC kBTUs/ft^2/yr	Hot Water kBTUs/ft^2/yr ***	Food Service, Cooking & Refrigeration kBTUs/ft^2/yr ***	Office Equipment & Information Technology kBTUs/ft^2/yr**	Laundry kBTUs/ft^2/yr*	Lighting kBTUs/ft^2/yr	All End Uses kBTUs/ft^2/yr
Food service	85.94	11.14	206.46	7.01	1.20	52.78	364.53
Healthcare	88.79	13.21	5.19	12.91	5.46	123.59	249.15
Institutional	61.53	35.46	3.69	5.78	0.24	20.08	126.78
Lodging	84.33	12.49	8.35	42.89	10.04	166.47	324.57
Office	94.58	12.18	1.95	37.59	0.25	70.05	216.59
Other	86.69	7.22	2.04	11.59	0.66	56.17	164.36
Retail	79.23	6.90	12.64	12.50	0.22	650.97	762.46
Service	84.84	7.56	2.13	16.23	1.11	39.21	151.08
Warehouse	85.25	7.52	0.67	5.55	0.46	30.70	130.15
Total	83.92	11.99	26.52	18.00	2.12	159.02	301.57

*ANOVA significant at .05, ** significant at .01, ***significant at .001

Climate Zone 8 Non-residential energy use

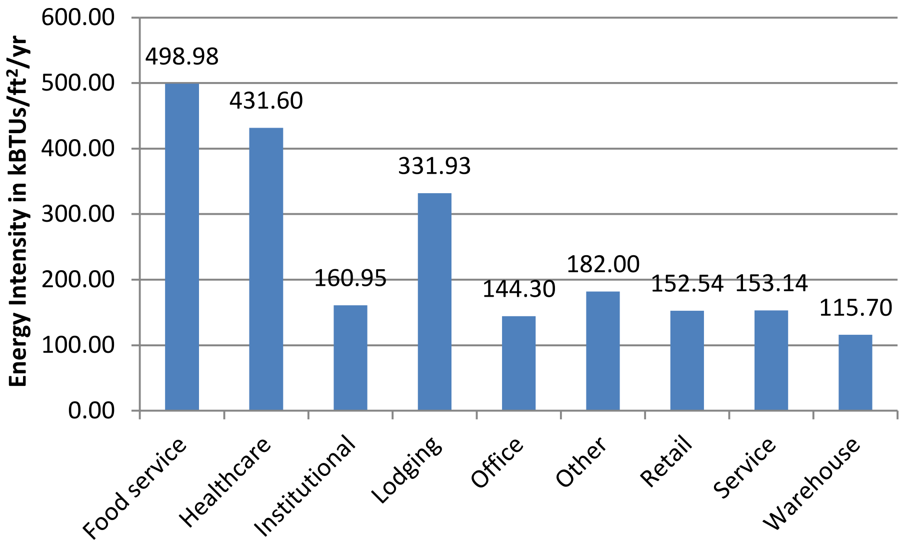
Climate Zone 8 includes the Denali and Fairbanks North Star Boroughs, and is the most northerly portion of the Railbelt region. It is generally cooler than Climate Zones 6 and 7. Healthcare buildings use more energy than any other building category and Climate Zone 8 (Figure 60).

Figure 60: Total Energy Use in MMBTUs/yr, Climate Zone 8



However, the picture changes when energy intensity is measured by dividing total energy use by building square feet. Food service facilities, which use less energy than many of the other facilities in Climate Zone 8, are seen to be the largest energy users per Square foot. Healthcare facilities, which were the largest energy users in terms of the amount of energy used, dropped to second place in energy intensity. These changes are shown in Figure 61.

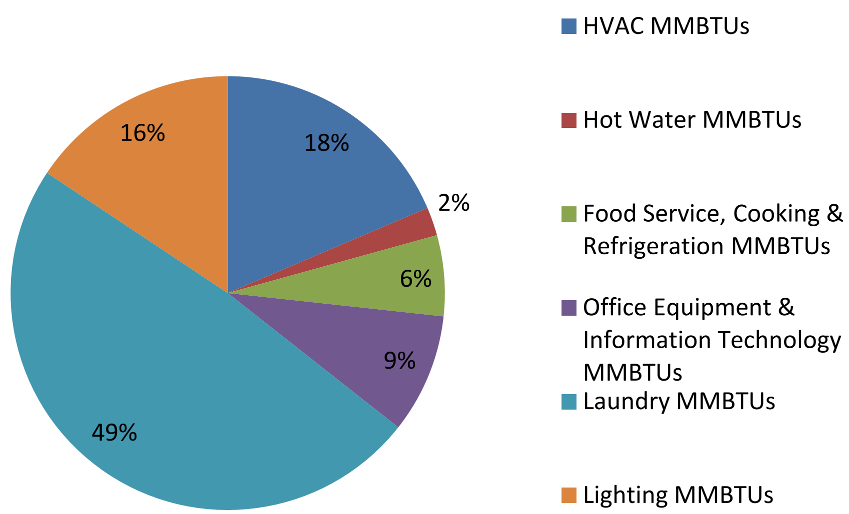
Figure 61: Energy Intensity, Climate Zone 8, kBTUs /ft^2/yr



Distribution of Total Energy Use

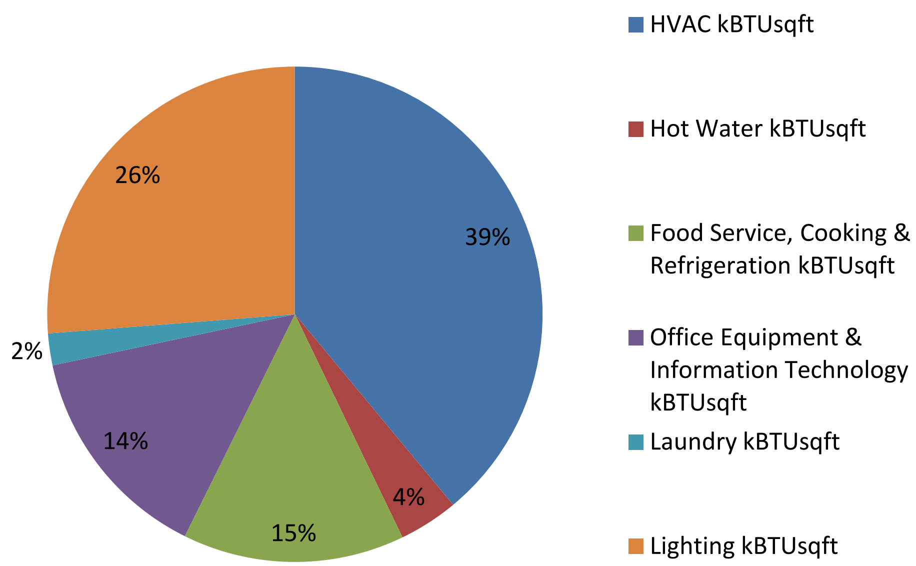
Almost half of the energy used in Climate Zone 8 buildings is used for laundry. Heating, ventilation and air-conditioning are the second largest energy use, followed by lighting. These proportions are shown in Figure 62.

Figure 62: Distribution of Total energy use in MMBTUs, Climate Zone 8.



When energy intensity is measured by dividing total energy use by the total building square footage, the proportion of energy used for various purposes changes (Figure 63). For example, laundry services which consume 49% of all energy show that they consume only 2% of the energy on a square foot basis. Heating ventilation and air conditioning consume twice as much energy on a square footage basis, using 18% of all MMBTUs, but using 39% on a square footage basis. Food service, cooking and refrigeration more than double the energy used when measured on a square footage basis than when measured on a overall energy consumption level (15% vs 9%).

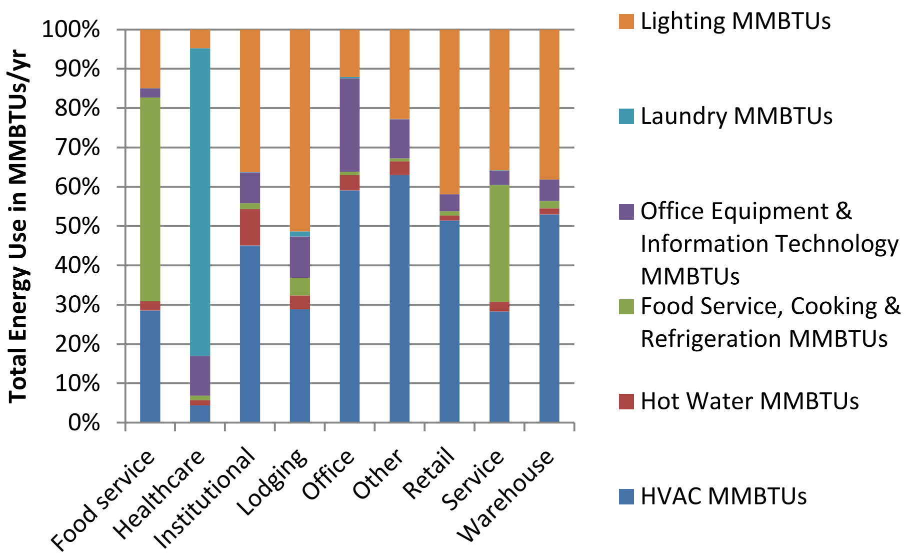
Figure 63: Distribution on Non-Residential Energy Use, kBTUs /ft^2/yr Climate Zone 8



Energy Use by Building Type

Similar to Climate Zones 6, and 7, facilities in Climate Zone 8 show a substantial variation in their proportional use of energy. Figure 64 shows that food service, cooking and refrigeration are a major energy use for service facilities. Healthcare institutions in Climate Zone 8 have the expected high energy requirements for laundry services. Facilities which support lodging have a large proportion of total energy use dedicated to interior and exterior lighting of the buildings.

Figure 64: Total Energy distribution in MMBTUs/yr, Climate Zone 8.



The same basic pattern shown in Climate Zones 6 and 7 appears when energy intensity is measured for facilities in Climate Zone 8. The proportion of energy on a square footage basis for food service, cooking and refrigeration in food service facilities begins to decrease, and the energy requirements for laundry within healthcare facilities declines (Figure 65).

Figure 65: Energy intensity (kBTUs /ft^2/yr) by use category, Climate Zone 8.

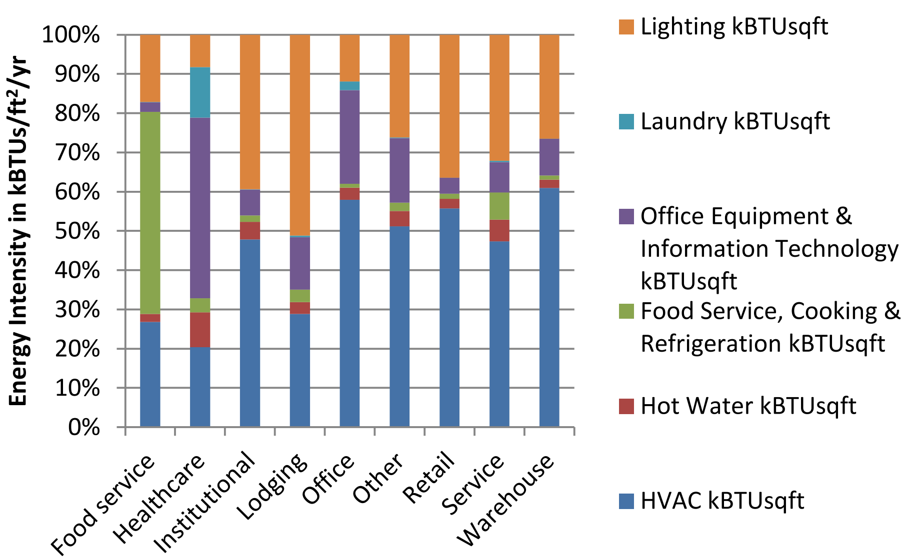


Table 18 and Table 19 show the detailed information on energy use within Climate Zone 8 on an MMBTU and a kBTUs per-square-foot basis.

Table 18: Total energy use by Climate Zone by building types, in MMBTUs/yr, Climate Zone 8.

Building Type	HVAC MMBTUs	Hot Water MMBTUs **	Food Service, Cooking & Refrigeration MMBTUs **	Office Equipment & Information Technology MMBTUs ***	Laundry MMBTUs	Lighting MMBTUs	All End Uses MMBTUs
Food service	702.27	59.26	1275.81	58.06	1.21	367.86	2464.47
Healthcare	1724.89	527.36	442.32	3951.16	30679.87	1869.44	39195.04
Institutional	907.11	187.38	30.06	157.40	1.71	730.85	2014.50
Lodging	726.06	88.25	113.03	263.42	33.79	1290.78	2515.32
Office	517.42	34.37	7.21	208.26	3.16	105.72	876.14
Other	650.37	35.95	7.90	102.47	1.11	234.80	1032.59
Retail	852.69	20.07	19.60	70.78	0.67	694.96	1658.76
Service	658.17	56.52	694.04	84.89	1.91	833.34	2328.87
Warehouse	1107.28	32.01	39.08	114.40	0.61	797.85	2091.23
Total	849.63	96.54	275.30	406.98	2227.57	715.58	4571.60

*ANOVA significant at .05, ** significant at .01, ***significant at .001

Table 19: Total energy intensity by Climate Zone by building types, in kBTUs /ft²/yr, Climate Zone 8.

Building Type	HVAC kBTUs/ft²/yr *	Hot Water kBTUs/ft²/yr *	Food Service, Cooking & Refrigeration kBTUs/ft²/yr ***	Office Equipment & Information Technology kBTUs/ft²/yr *	Laundry kBTUs/ft²/yr	Lighting kBTUs/ft²/yr **	All End Uses kBTUs/ft²/yr ***
Food service	134.01	9.94	257.01	12.04	0.27	85.70	498.98
Healthcare	88.08	38.07	15.56	198.66	55.63	35.60	431.60
Institutional	76.93	7.29	2.62	10.59	0.16	63.36	160.95
Lodging	95.86	9.95	10.53	44.23	1.36	169.99	331.93
Office	83.56	4.51	1.37	34.46	3.13	17.27	144.30
Other	93.09	7.13	3.89	29.96	0.22	47.71	182.00
Retail	84.99	3.72	1.97	6.22	0.08	55.57	152.54
Service	72.54	8.47	10.53	11.91	0.50	49.19	153.14
Warehouse	70.55	2.46	1.23	10.75	0.07	30.65	115.70
Total	87.66	8.72	32.59	32.29	4.67	59.02	224.95

*ANOVA significant at .05, ** significant at .01, ***significant at .001

Rural North & Northwest

This section presents data on energy use for a hub community and three smaller communities. The selection of the communities was intended to provide a representative snapshot of rural Alaska energy use. In collaboration with the UAA/ISER, this data will be used as the benchmark in estimating energy use of similar community configurations.

The section first presents energy use data regarding the hub community of Bethel. Both residential and non-residential energy use data are summarized. In addition, data on energy requirements for water and wastewater utilities is also included. Next, information on residential and non-residential energy use in the three village communities is presented. As with the hub community, information on water and wastewater utility energy use is also included in the analysis.

Bethel residential energy use & comparison with ARIS

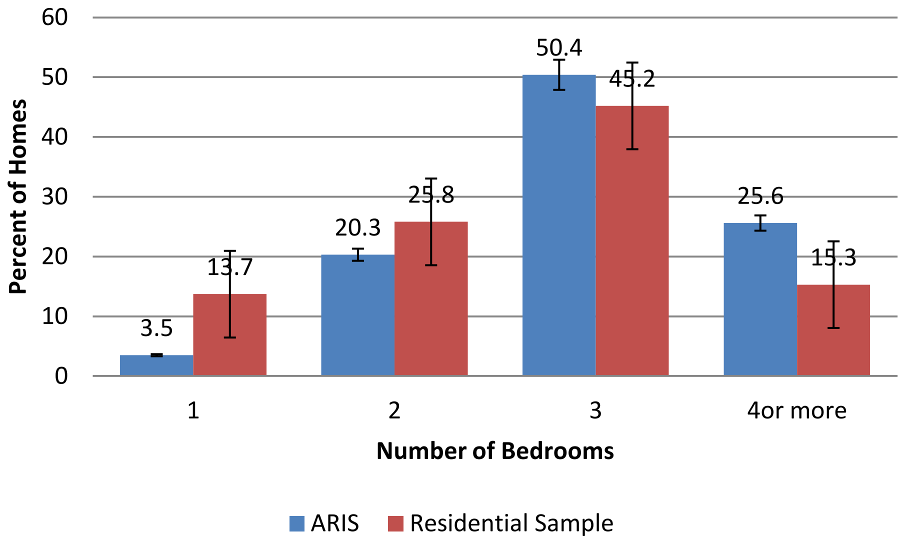
Bethel residential end-use energy calculations were compiled using existing ARIS data, supplemented by information on residential electric use obtained through a survey. Table 20 shows the number of observations in each residential housing type. The table suggests that data on mobile home energy use may not be as reliable as the survey data used to collect additional information on the residential electrical energy use.

Table 20: ARIS and survey end-use energy records

Housing Type	ARIS		Survey	
	#	%	#	%
Mobile Home	1	0.8	16	12.9
Single Family Detached	116	89.9	78	62.9
Multi Family	12	9.3	16	12.9
Single Family Attached			14	11.3
All Types	129		124	

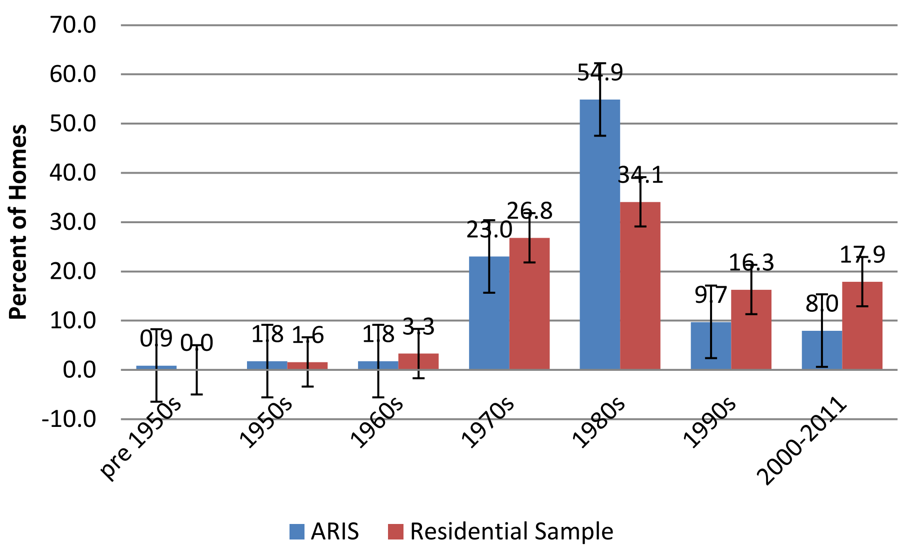
This section presents basic data on the characteristics of the residential ARIS database and the survey sample. Figure 66 compares the number of bedrooms of homes included in the ARIS database with those in the residential survey. The figure suggests that smaller homes are underrepresented and larger homes (four or more bedrooms) are overrepresented in the ARIS database. This is an expected difference; obtaining an AkWarm© energy rating, the data from which is included in the ARIS database, is voluntary. Homeowners with larger more energy consumptive homes may have a greater incentive to obtain an energy assessment than those with smaller less energy consumptive homes. The residential electrical survey, on the other hand, was a random sample of all types of residences, and paid specific attention to obtaining reliable data on all four residences types.

Figure 66: Number of Bedrooms, ARIS and Bethel Residential Sample



There also appears to be a difference in the decade of home construction. Figure 67 compares the decade of construction of homes in the ARIS database with those in the residential survey sample. Error bars using a projected standard error are used to compare the two data sets. The error bars show that the two data sets do not appear to be significantly different with the exception of the number of homes in Bethel that were built during the 1980s. The ARIS data includes substantially more homes than the Bethel residential survey sample.

Figure 67: Decade of Home Construction, ARIS and Bethel Residential Sample



Characteristics of the Bethel residential survey sample

This section briefly describes the Bethel residential survey sample, including square footage, decade built, and primary heating fuel and compares this to relevant examples.

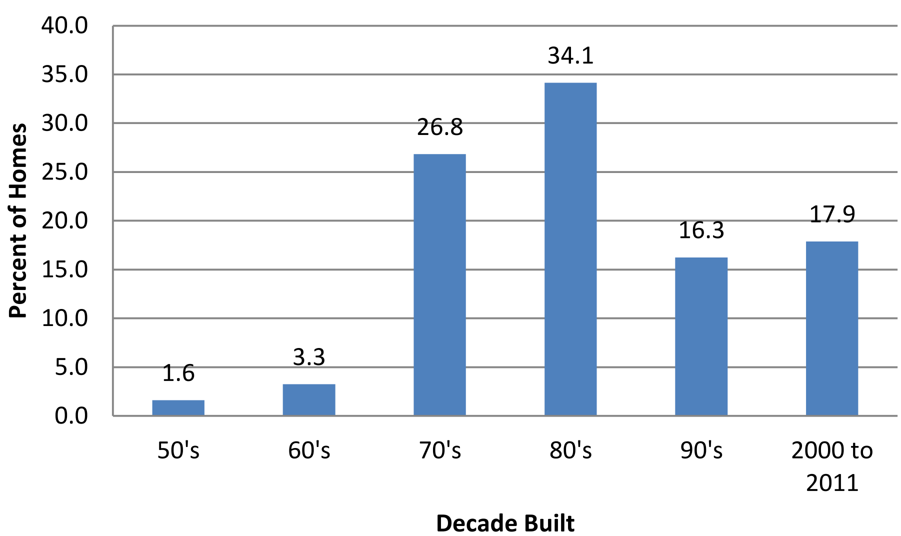
The estimated square feet of living space in Bethel is not significantly different than the square footage of homes in other regions (F= .616, p=.764). The number of bedrooms in Bethel is not significantly different than the square footage of homes in other regions (F= 389, p=.926).

Table 21: Residential Projected and Actual Samples

Housing Type	Size Measure	
	Square Feet	Number of Bedrooms
Single Family Detached	1592.1	2.76
Single Family Attached	1385.6	2.43
Multifamily	1328.1	1.88
Mobile Home	1462.0	2.88
Average	1519.6	2.62

Figure 68 shows that 95% of homes surveyed in Bethel were built since 1970, with the highest proportion being built in the decade of the 80s. By contrast, 85% of all residential homes in the survey were built since 1970. The more modern construction of homes in Bethel may be related to improved construction techniques yielding greater energy efficiency.

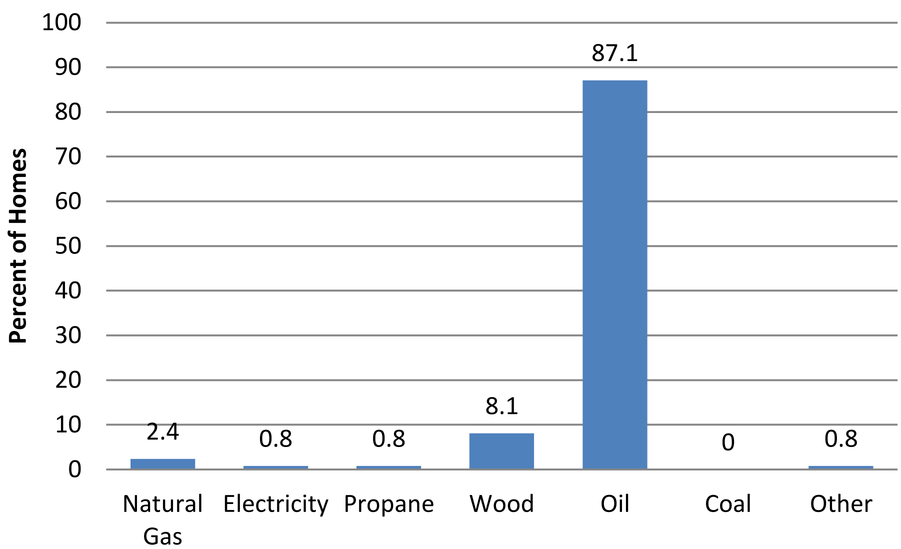
Figure 68: Decade Built of Bethel Residential Sample*



*(N=332, 6 missing, Significant Differences, Chi Sq=32.24, p=.001).

Oil is the most common source of heating fuel in Bethel homes. Figure 69 shows that over 87% of all homes are heated with oil. The use of electricity as a primary heating fuel in Bethel is also lower than the Railbelt (Climate Zones 7 and 8) or Southeast regions (Climate Zone 6)

Figure 69: Primary Heating Fuel, Bethel Residential Sample*



*(N=203, 1 missing, Significant Differences, Chi Sq=110.21, p=.000).

Bethel residential energy use

Table 22 and Figure 70 summarized Bethel residential energy use. As with other parts of this analysis, space heating and domestic hot water energy intensities derived from the ARIS database are applied to the residential survey (by survey home area) and combined with the appliances survey data to develop an estimate of total energy use (in MMBTUs/yr) by residence type.[11]

Overall, the average residents in Bethel uses 193 MMBTUs of energy each year home heating, providing domestic hot water and operating appliances. Families living in mobile home residences appeared to use the most energy, at 334 MMBTUs per year[12]. Families living in multi family residences use the least amount of energy. By far, more energ y is spent in home heating than for any other purpose.

[11] Appliances include all lighting, electrical and non-electrical appliances and equipment not related to space heating or hot water heating

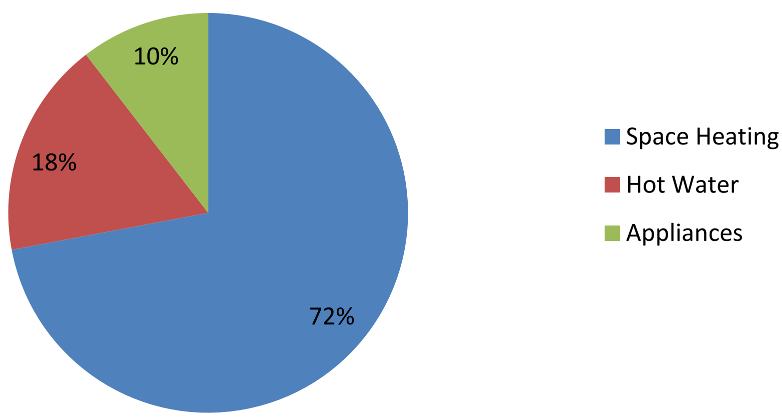
[12] Mobile home space heating energy intensity was based on only a single record in the ARIS database. This single record (191 kBTU/ft^2) however compared closely to 27 other records of mobile homes in the Railbelt, Climate Zone 8 (214 kBTU/ft^2)

Table 22: Summary of Bethel residential energy use in MMBTUs/yr

Residence Type	Space Heating	Domestic Hot Water	Appliances, Lighting, etc.	Total
Mobile Home	280.24	34.32	19.92	334.47
Multi Family	95.30	30.91	17.63	143.83
Single Family Attached	99.42	32.25	20.15	151.82
Single Family Detached	126.92	34.51	20.83	182.07
Total	139.22	33.79	20.24	193.12

Figure 70 shows the overall distribution of residential energy use. Almost ¾ (72%) of all energy is used in home heating. The remainder is distributed between domestic hot water (18%) and the operation of appliances, lighting and other plug loads[13] (10%). Note that the electrical energy is reported as site energy, and does not include generation losses (i.e., site energy, not source energy is reported).

Figure 70: Summary of Residential Energy Use in Bethel in MMBTUs/yr



[13] Note that lighting, plug loads, and appliance use is lumped together under the "appliances" heading for tables and figures in this report.

A closer analysis shows some pronounced differences between residence types in the distribution and extent of energy use. Figure 71 present this data in MMBUTs/yr and as a percent of total energy use respectively. Figure 72 shows that mobile home dwellings use more energy than other residence types both in a relative (%) and absolute sense (MMBTUs), followed by single family detached homes. Single-family attached and multifamily residences use the least space heating and total energy in similar proportions.

Figure 71: Residential Energy Use, Bethel, in MMBTUs/yr

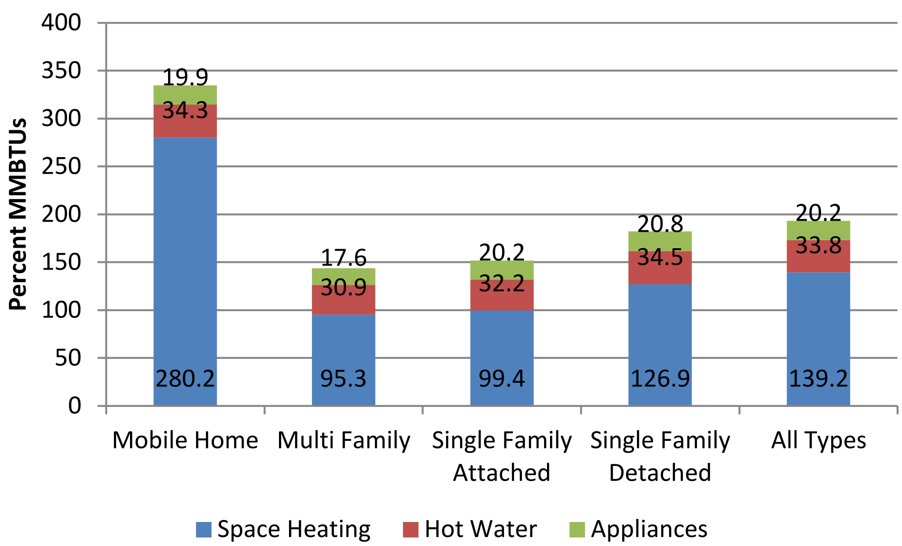
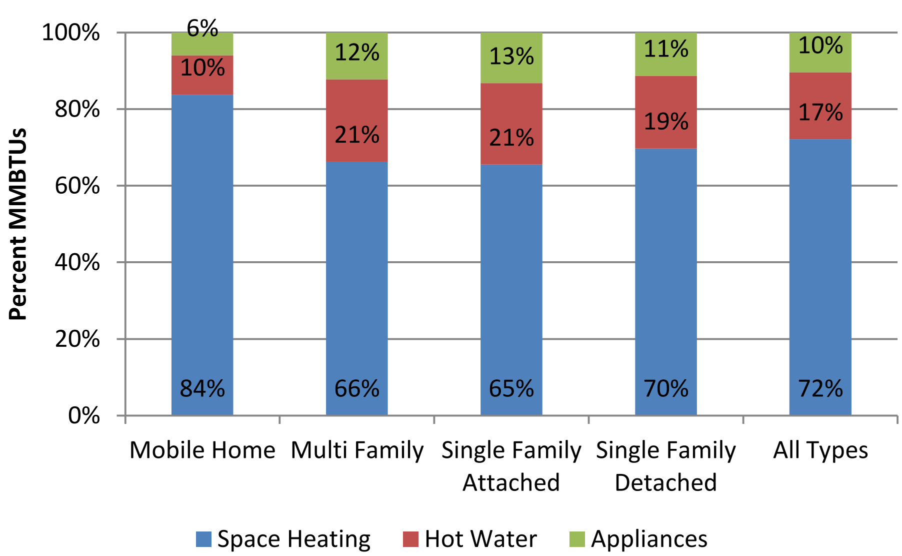


Figure 72: Residential Energy Use, Bethel, in Percent MMBTU/yr



Lighting, appliance and other energy use

Appliance energy use data was collected through a survey of Bethel households. Table 23 presents the energy use for each type of residence in MMBTUs. The table shows that major appliances are the category of highest energy use, followed by primary cooking, entertaining and information technology. An analysis of variance (ANOVA) was used to test the differences between types of facility in appliance energy uses. There are no statistically significant differences in the distribution of appliance energy use by residence type with the exception of the use of information technology. In this case, it appears as if there are statistically significant differences in the use of appliance energy for information technology between residence types.

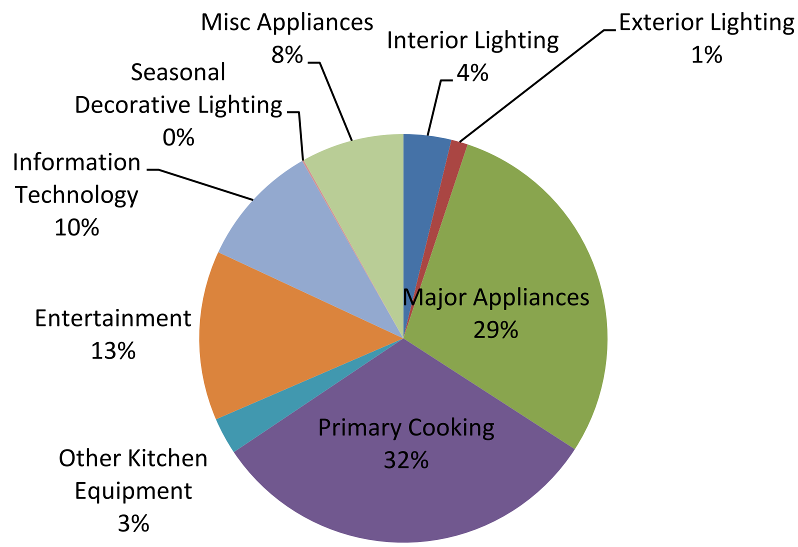
Table 23: Bethel residential appliance energy use, in MMBTUs

Residence Type >> **End Use**	**Mobile Home**	**Single Family Attached**	**Multi Family**	**Single Family Detached**	**All Types**
Interior Lighting	0.51	0.74	0.68	0.83	0.76
Exterior Lighting	0.15	0.05	0.15	0.35	0.26
Major Appliances	7.68	5.02	5.88	5.61	5.83
Primary Cooking	5.14	6.22	5.22	6.75	6.31
Other Kitchen Equipment	0.65	0.47	0.53	0.60	0.58
Entertainment	2.63	2.50	2.69	2.74	2.69
Information Technology*	1.44	1.56	2.34	2.09	1.97
Seasonal Decorative Lighting	0.11	0.00	0.00	0.02	0.03
Misc Appliances	1.59	0.90	2.38	1.65	1.63
Appliance Total	19.92	17.48	19.88	20.64	20.07

*ANOVA significant at .05

Figure 73 shows that primary cooking is the largest appliance end use at 32%. Major appliances are the next largest application of appliance energy (29%). Entertainment, including televisions, VCRs, gaming consoles and television reception, follow at 13%.

Figure 73: Bethel Residential Appliance Energy Use in MMBTUs/yr



Bethel non-residential energy use

An experienced energy rater was retained to collect data on energy use in non-residential facilities in Bethel. The analytic technique for estimating total energy use was the same as that used for the Railbelt and Southeast Alaska regions, Climate Zones 6,7,and 8. The distribution of building types in Bethel is shown in Table 24.

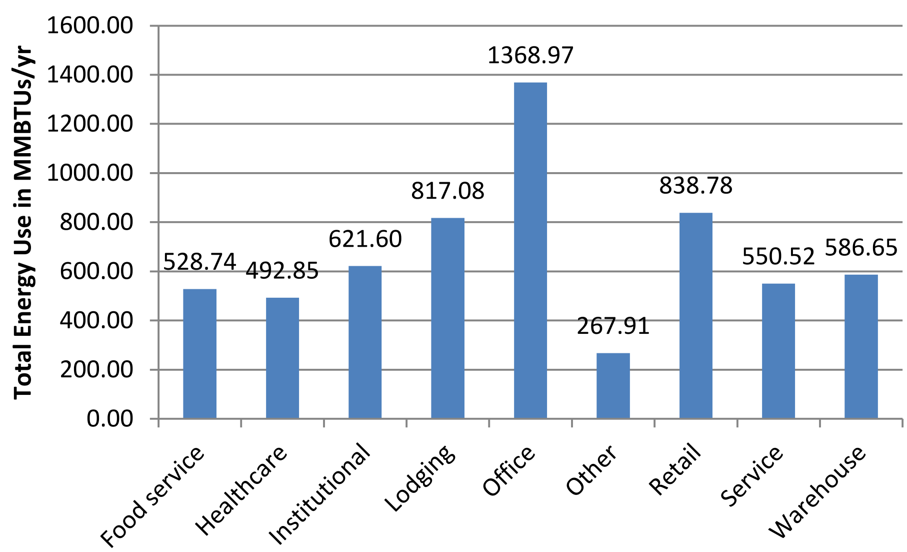
Table 24: Distribution of Non-Residential Building Types, Bethel Sample

Building Type	Frequency	Percent
Food service	2	4.0
Healthcare	2	4.0
Institutional	10	20.0
Lodging	3	6.0
Office	7	14.0
Other	5	10.0
Retail	6	14.0
Service	10	20.0
Warehouse	4	8.0
Total	50	100.0

Overall energy use by building type

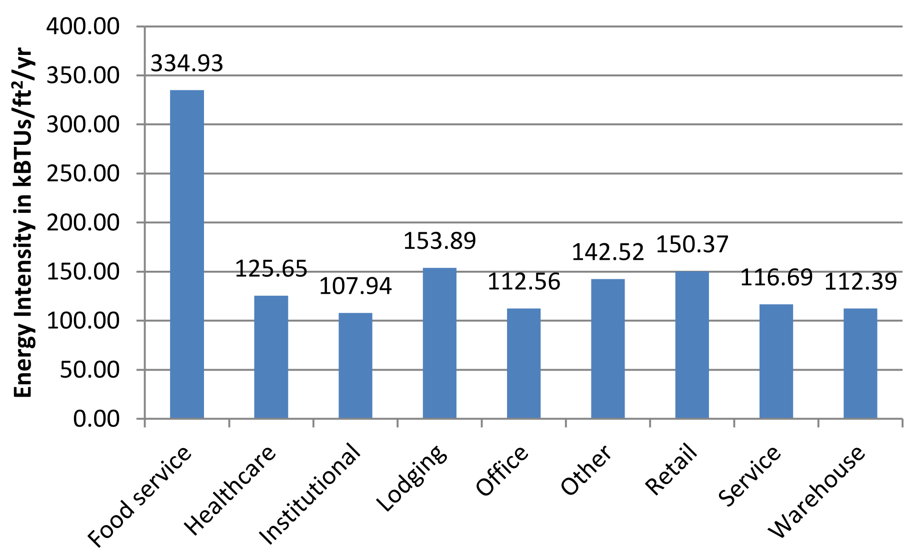
Figure 74 shows that office buildings in Bethel use more energy in MMBTUs than any other type of facility. "Other" types of facilities, a category that includes parking garages, sports complexes and multiuse facilities, are the lowest users of energy.

Figure 74: Total energy use in MMBTU/yrs, Bethel



When the energy intensity of buildings in Bethel is analyzed by dividing total energy use by the square foot of each facility, food service buildings are the highest energy users. Other building types have similar per-square-foot energy usage, between 107 and 150 kBTUs per square foot (Figure 75.)

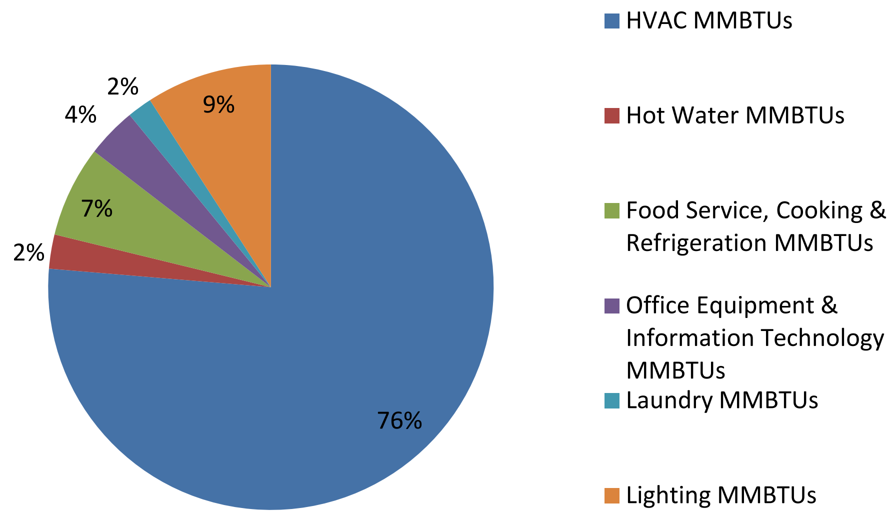
Figure 75: Energy Intensity in kBTUs /ft²/yr, Bethel.



Distribution of energy use

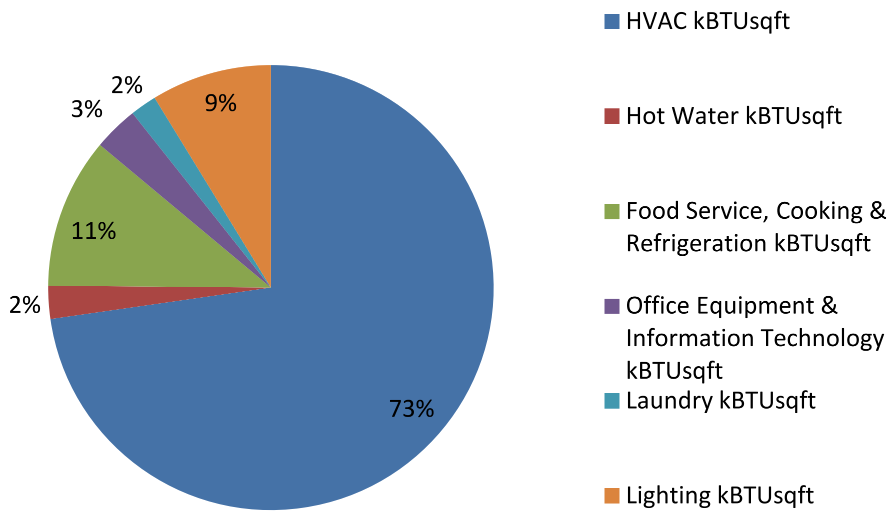
Figure 76 shows that over three quarters (76%) of all energy used by non-residential buildings in Bethel is used to heat the facility. This second highest use is in interior and exterior lighting (9%). All other energy uses comprise about 15% of all MMBTUs.

Figure 76: Distribution of Total energy use in MMBTUs/yr, Bethel



Surprisingly, this distribution does not change much when the energy intensity of each facility is calculated. After dividing total energy use by the building square feet, the proportion of energy used for heating remains approximately the same, decreasing only to 73% (Figure 77). The energy intensity of food service, cooking and refrigeration increases slightly, from 7% of total energy use to 11% of energy use on a square footage basis. All other values remain essentially unchanged.

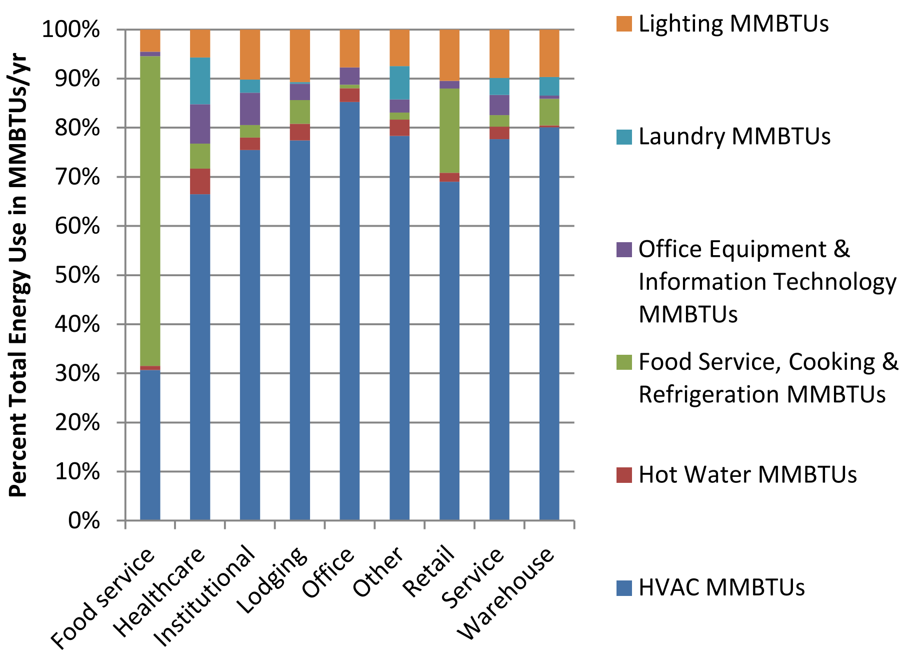
Figure 77: Overall Distribution on Non-Residential Energy Use, kBTUs /ft^2/yr, Bethel



Distribution of energy use by building type

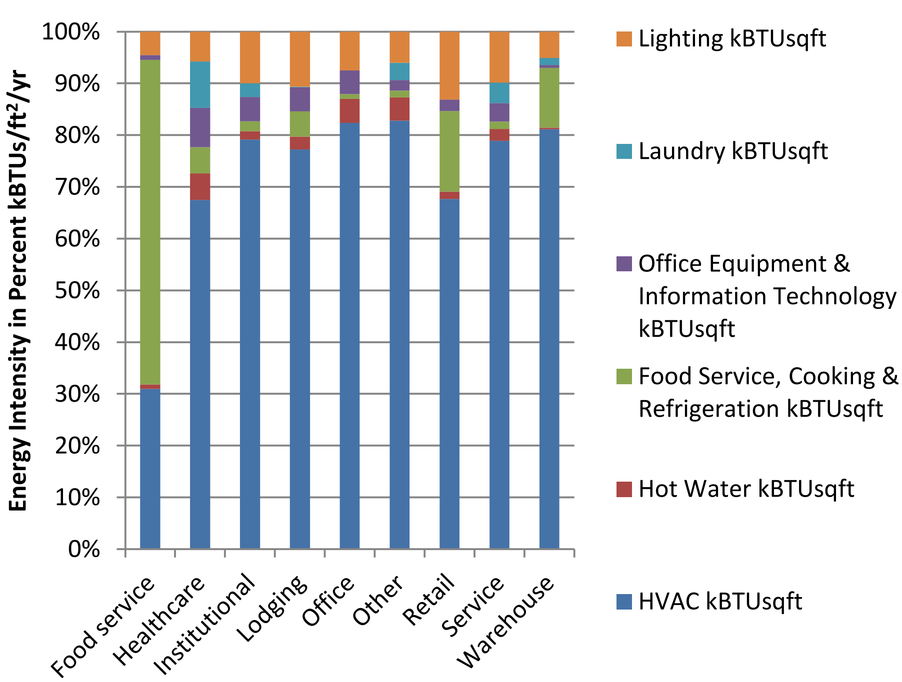
Different building types have different patterns of energy use. Figure 78 shows that food service buildings develop a smaller proportion of their total energy use to heat than all other facility types. Office buildings have the largest proportion of their energy budgets devoted to heating the facility. As expected, food service, cooking and refrigeration use the highest proportion of energy within food service establishments. Interior and exterior lighting is fairly consistent across all building types.

Figure 78: Distribution of energy use by building type, MMBTUs/yr, Bethel.



As with the overall distribution of energy shown in Figure 79, calculating the energy intensity does little to alter the proportion of energy dedicated to different uses. Figure 79 looks much like the overall distribution of energy use in total MMBTUs by energy use category shown in Figure 78.

Figure 79: Distribution of energy uses by building type,in kBTUs/ft^2/yr, Bethel



Detailed energy statistics are shown in Table 25 and Table 26. Statistically significant differences are noted.

Table 25: Bethel Mean Non-Residential Energy Use in MMBTUs/yr

Building Type	Heating ventilation and air conditioning MMBTU	Hot water MMBTU*	Food service, cooking and refrigeration MMBTU ***	Office equipment and information technology MMBTU	Laundry MMBTU ***	Lighting MMBTU	All end uses MMBTU ***
Food service	162.11	4.48	333.43	4.74	0.00	23.97	528.74
Healthcare	327.66	25.74	24.99	39.54	46.74	28.18	492.85
Institutional	468.98	15.99	15.59	40.97	16.61	63.47	621.60
Lodging	632.28	27.70	39.78	27.24	2.47	87.61	817.08
Office	1166.42	38.69	10.09	47.69	0.00	106.09	1368.97
Other	209.82	8.98	3.75	7.29	18.11	19.97	267.91
Retail	578.75	15.55	143.39	13.42	0.00	87.66	838.78
Service	427.53	14.02	12.91	22.59	18.99	54.48	550.52
Warehouse	469.92	2.04	31.82	3.87	22.15	56.86	586.65
Total	539.73	17.53	46.83	25.71	12.72	64.60	707.12

*ANOVA significant at .05, ** significant at .01, ***significant at .001

Table 26: Bethel Mean Non-Residential Energy Use in kMBTUs /ft^2/yr

Building Type	HVAC kBTU/ft^2/yr	Hot Water kBTU/ft^2/yr	Food Service, Cooking & Refrigeration kBTU/ft^2/yr ***	Office Equipment & Information Technology kBTU/ft^2/yr	Laundry kBTU/ft^2/yr *	Lighting kBTU/ft^2/yr	All End Uses kBTU/ft^2/yr
Food service	103.63	2.85	210.15	3.17	0.00	15.12	334.93
Healthcare	84.77	6.41	6.40	9.59	11.26	7.22	125.65
Institutional	85.43	1.73	2.06	5.08	2.86	10.79	107.94
Lodging	118.82	3.84	7.49	7.10	0.26	16.38	153.89
Office	92.74	5.15	1.11	5.11	0.00	8.46	112.56
Other	117.97	6.44	1.87	2.92	4.76	8.56	142.52
Retail	101.70	2.13	23.40	3.38	0.00	19.75	150.37
Service	92.07	2.66	1.68	4.20	4.55	11.53	116.69
Warehouse	91.20	0.35	12.98	0.57	1.58	5.71	112.39
Total	96.48	3.17	14.52	4.32	2.55	11.60	132.64

*ANOVA significant at .05, ** significant at .01, ***significant at .001

Water and Wastewater Energy Requirements

Units of local government often maintain water and wastewater utilities on behalf of its citizens-Bethel operates and maintains a water and sewer facility. The energy requirements to maintain these basic services were estimated by calculating the amount of energy required to heat water to a high enough temperature to prevent water and wastewater systems from freezing. While detailed calculations are provided in a different section of this report, the energy requirements to keep the water and wastewater system in Bethel at 50° operating temperature are presented in the Bethel end-use energy summary.

Summary of Bethel energy use

Table 27 summarizes energy use in Bethel. Residential energy use was calculated using the average energy used by all households[14]. Non-residential energy use was calculated using the mean energy use by a non-residential facility type multiplied by the estimated number of non-residential facilities in the community. Two additional healthcare facilities were added to the estimate by multiplying the square footage estimates of similar facilities by the kBTUs used. Street lighting information was estimated using the average number of kilowatt hours per year for a community of about 5000 people. This data is shown in a separate section of this report. Information on the use of energy to power water and wastewater systems assumed a 50° operating temperature. Detailed calculations of alternative energy use estimates are shown in a separate section of this report.

Table 27: Summary of Bethel Energy Use

Component	Units	Mean Use (MMBTU/yr)	Total MMBTUs/yr
Residential	2364	193.1	456,488.4
Non Residential			729,925.3
Food Service	8	528.74	4,229.9
Warehouse	14	586.65	8,213.2
Institutional	44	621.60	27,350.4
Health Care	4	492.85	1,971.4
Regional Administration[15] (60,000 sqft)	1	1,251.65 kBTU/sqft[16]	75,099.0
Hospital (115,000 sqft)	1	4,411.26 kBTUs//ft^2/yr[17]	507,294.9

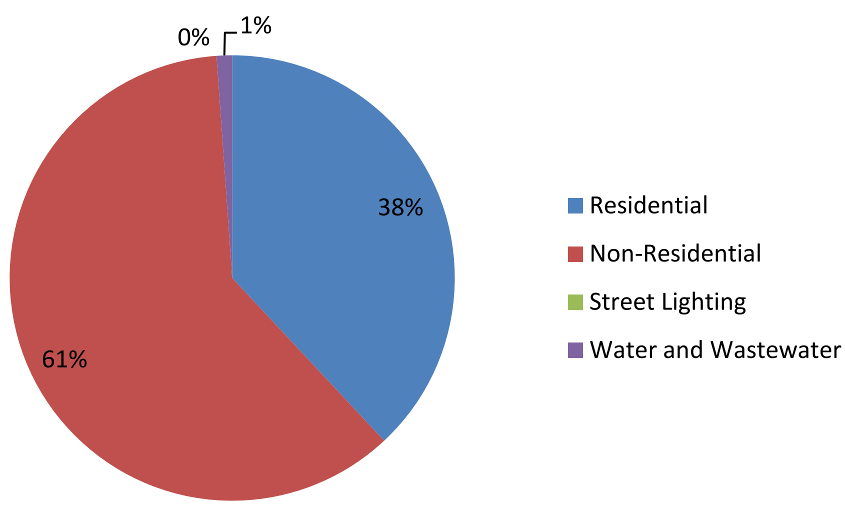
[14] There is insufficient data on the distribution of types of housing in Bethel, therefore a more precise estimate could not be developed. US census data for the City of Bethel was accessed at http://factfinder2.census.gov, February, 2012.

[15] Building size estimates provided by Bethel energy auditor based on locally available information.

[16] Non Residential data from Bethel, see Table 33

Component	Units	Mean Use (MMBTU/yr)	Total MMBTUs/yr
Lodging	5	817.08	4,085.4
Office	40	1368.97	54,758.9
Mercantile/ retail	15	838.78	12,581.7
Service	60	550.52	33031.2
Other	5	267.91	1339.6
Total	197		
Street Lighting			2.6
Water and Waste Water (50^0)			13,463.0
Total			1,199,879.4

Figure 80: Bethel Energy Use



Rural Village Communities

Three rural communities were selected for a detailed energy end-use analysis. Descriptions of the communities of New Stuyahok, Savoonga and Selawik are presented in the methodology appendix of this report. Data on residential energy use was obtained through the Energy Wise Program operated by the Rural Alaska Community Action Program (RurAL CAP). Data on non-residential energy use were collected by a field technician and the end-use analysis conducted under a similar analytic framework as the Railbelt & SEAK. Data on water and wastewater was calculated using information from ANTHC and modeled.

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[17] Based in energy intensity of Climate Zone 7 healthcare buildings.

Table 28 shows the number of households within each of the communities that provided information for the Energy Wise program.

Table 28: Number of observations from participating rural communities

Community	Number	Percent
New Stuyahok	45	17.3
Savoonga	103	39.6
Selawik	112	43.1
Total	260	100.0

Small Community Residential Energy Use

Energy use in the three rural communities was calculated using RurAL CAP Energy Wise data. There was insufficient data in the database to calculate the square footage of each type of residence required to calculate "energy intensity." Therefore, residential square footage in the three rural communities was based on the data contained in the ARIS database communities of similar size. The estimate is shown in Table 29.

Table 29: Estimated Residence Size in Square Feet

Community	Population[18]	Mean Residence Size (Square Feet)[19]	Climate Zone	Square Foot Estimate[20]
Akiachak	655	855.0	8	
Kaktovik	247	643.8	9	
Napaskiak	428	988.0	8	
Naknek	571	1983.17	7	
Mekoryuk	215	1024.7	8	
Hooper Bay	1137	927.4	7	
New Stuyahok	501		7	988
Savoonga	704		8	655
Selawik	868		8-9	644

Overall Energy Use

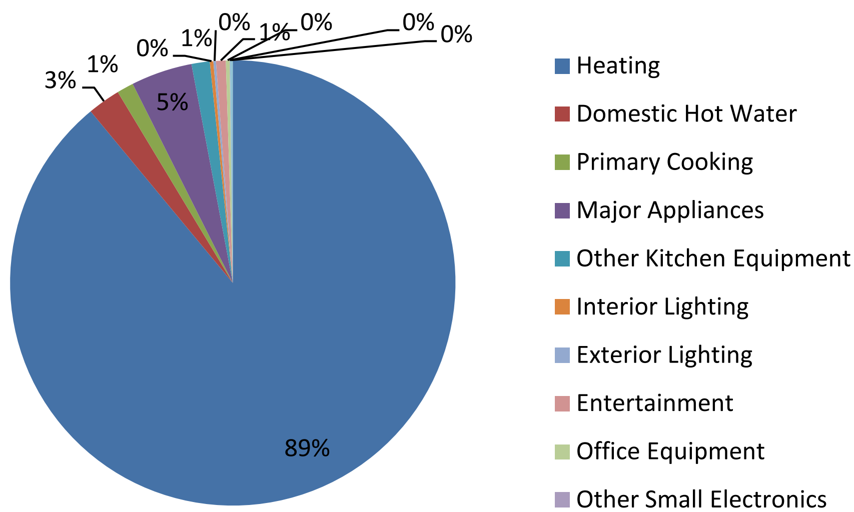
Almost 90% (89%) of total residential energy is used for home heating. Another 5% is used for major appliances, such as washing machines, dryers, refrigerators and freezers (Figure 81).

[18] State of Alaska Community Profiles, most recent data, usually 2011.

[19] ARIS data from AkWarm© energy Audits.

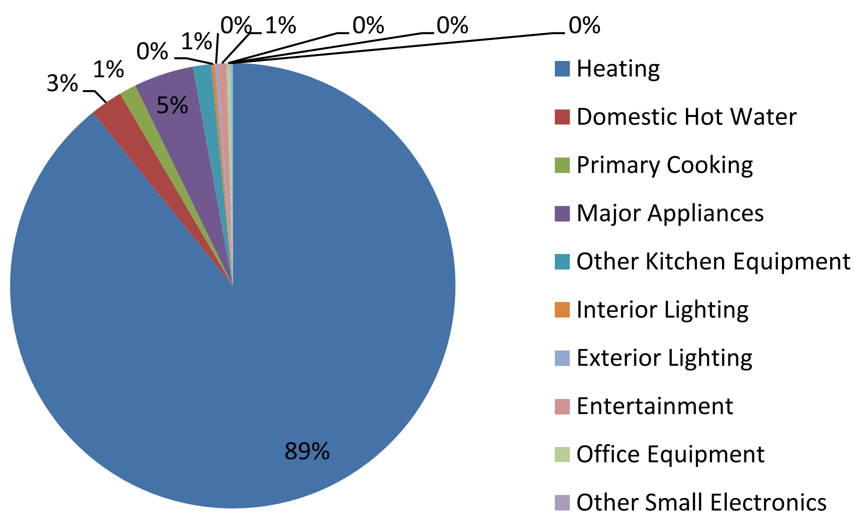
[20] Based on community size and region.

Figure 81: Distribution of Total energy use in MMBTUs, Rural Communities



The energy intensity results are similar. Heating is still the largest energy use in the three communities. This may be attributable to the similar square footage of average houses in the three communities.

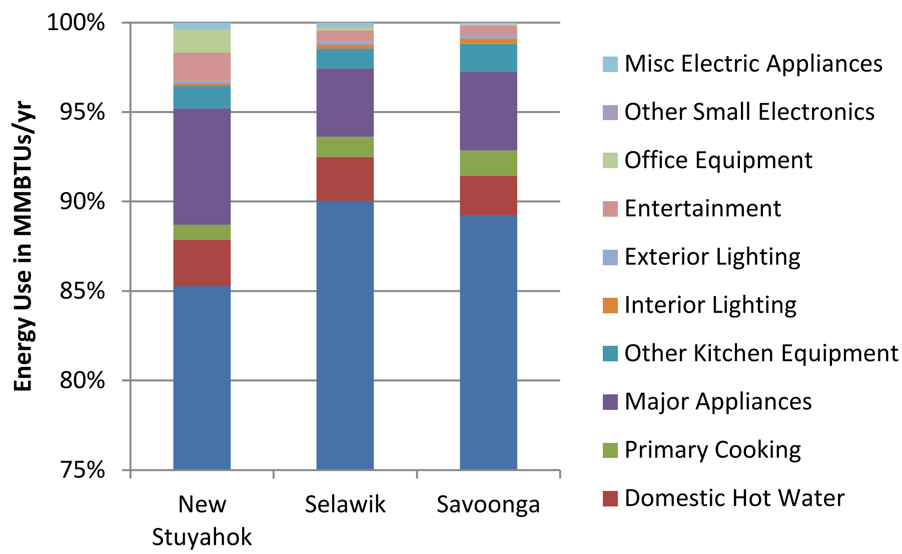
Figure 82: Overall Distribution on Non-Residential Energy Use, kBTUs /ft^2/yr, Three Small Communities



Community Differences in Energy Use

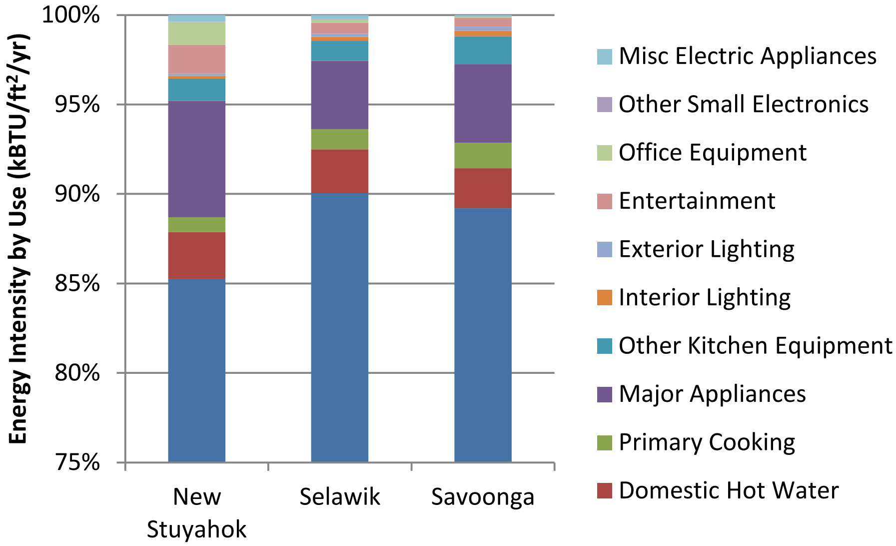
The three communities have some notable differences in their energy use patterns. Figure 83 and Figure 84 show these differences. Selawik uses a higher proportion of its total energy in space heating than the other communities. New Stuyahok uses far more energy than other communities in operating office and entertainment devices.

Figure 83: Distribution of energy use by building type, MMBTUs/yr, Three Small Communities



The energy intensity, or energy per square foot, mirrors the overall energy use largely due to the similar average sqare footage of homes as found in these communities. While all three communities dedicate a large portion of energy to home heating, Savoonga uses a significantly greater amount of energy per square foot than the other communities in heating, domestic hot water, primary cooking, major appliances and other kitchen equipment. New Stuyahok appears to be a greater user of energy for entertainment and office equipment.

Figure 84: Distribution of energy uses by building type,in kBTUs/ft²/yr, Three Small Communities



Detailed information on the mean MMBTU/yr energy use is shown in Table 30.

Table 30: Energy use characteristics of three rural Alaskan communities in MMBTUs/yr

Community	**New Stuyahok**		**Selawik**		**Savoonga**		**All Three**	
Use	Mean MMBTUs	Mean kBTUs	Mean MMBTUs	Mean kBTUs	Mean MMBTUs	Mean kBTUs	Mean MMBTUs	Mean kBTUs
Heating**###	86.79	87.84	86.79	167.50	86.79	180.62	108.35	158.91
DHW###	2.65	2.68	2.95	4.58	2.96	4.52	2.90	4.23
Primary Cooking*##	0.85	0.86	1.35	2.10	1.88	2.87	1.48	2.19
Major Appliances***###	6.60	6.68	4.56	7.09	5.83	8.90	5.42	7.73
Other Kitchen Equipment#	1.28	1.30	1.32	2.05	2.07	3.16	1.61	2.36
Interior Lighting*##	0.16	0.16	.29	0.44	.40	0.62	.31	0.46
Exterior Lighting	0.14	0.15	.20	0.32	.28	0.43	.23	0.33
Entertainment***	1.62	1.64	.73	1.14	.67	1.03	.86	1.18
Office Equipment***##	1.29	1.30	.19	0.30	.07	0.10	.33	0.39
Other Small Electronics	0.03	0.03	.05	0.08	.01	0.02	.03	0.05
Misc Electric Appliances	0.38	0.39	.29	0.44	.14	0.21	.24	0.34
Total* ###	101.78	103.02	119.80	186.03	132.62	202.47	121.76	178.18

*ANOVA MMBTUs significant at .05, ** significant at .01, ***significant at .001*ANOVA kBTUs per square foot significant at .05, ** significant at .01, ***significant at .001

Non-residential energy use

The three communities did not have all non-residential building type categories (Table 31) represented in the sample. Furthermore, the numbers appear to be too small to be stable. Therefore, non-residential energy use estimates used data from all three communities.

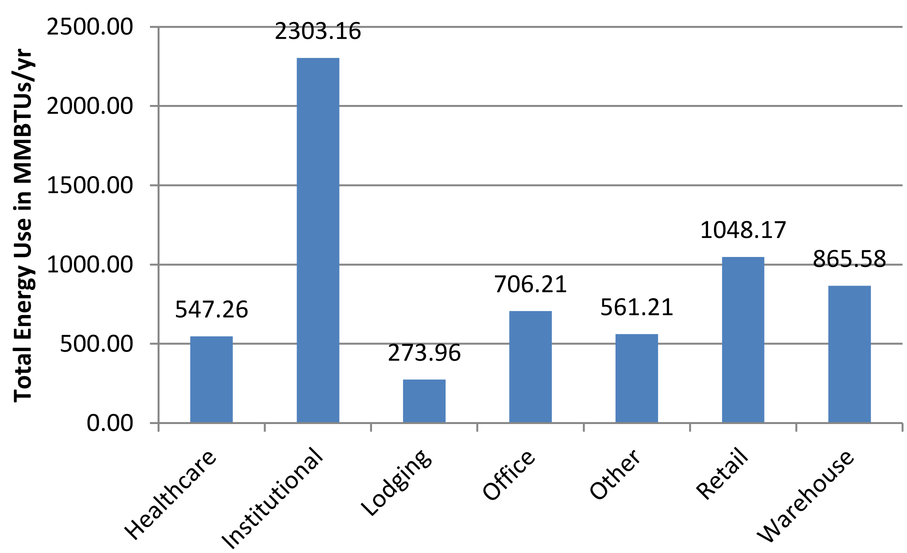
Table 31: Non-Residential buildings sample, three smaller rural communities

Building Type	Frequency	Percent
Healthcare	3	9.1
Institutional	10	30.3
Lodging	2	6.1
Office	9	27.3
Other	4	12.1
Retail	4	12.1
Warehouse	1	3.0
Total	33	100

Overall energy use

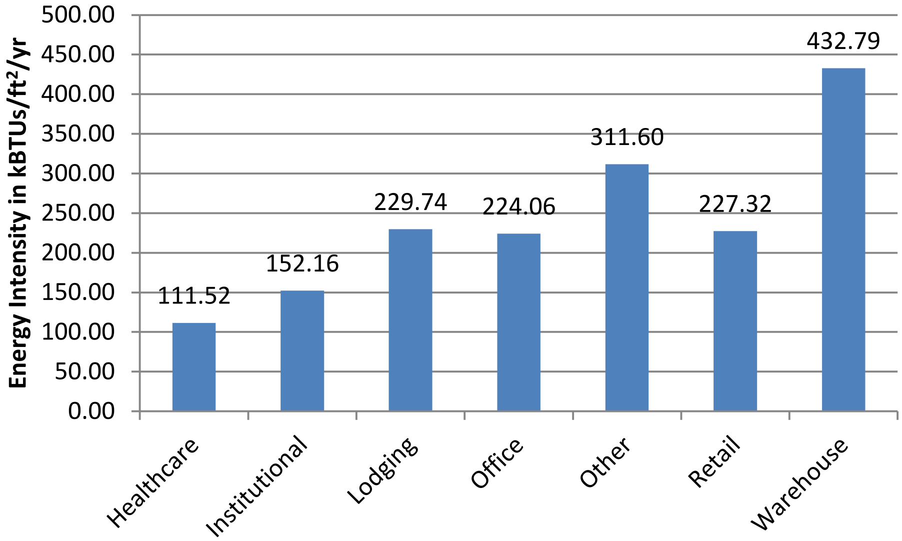
Figure 85 shows that buildings used for institutional purposes have by far the highest energy use. Facilities used for lodging had the lowest use.

Figure 85: Total energy use in MMBTUs/yr, Three Small Communities



However, when the energy intensity is measured by dividing the total energy use by the building square footage, a much different picture emerges. Figure 86 shows that the highest use as measured by kBTUs per square foot, is in warehouses. The second highest use is in other facilities, which include multipurpose facilities. These are common in many smaller communities.

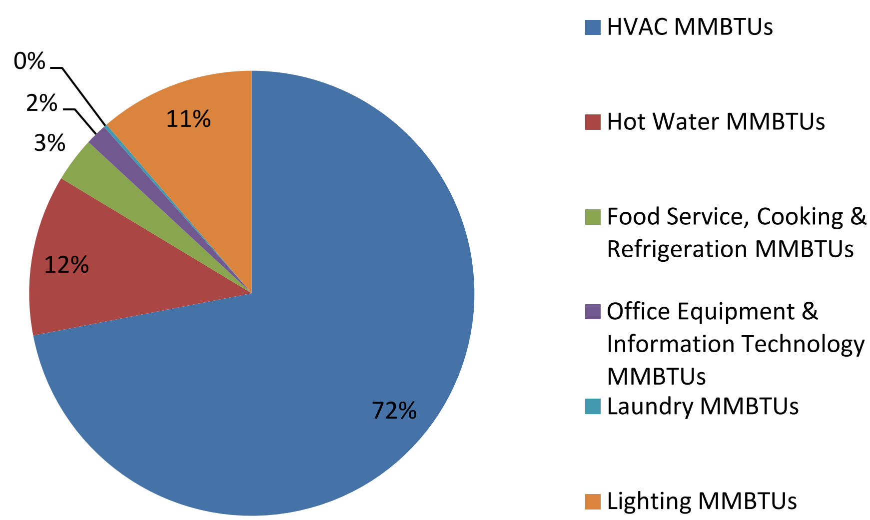
Figure 86: Energy Intensity in kBTUs /ft^2/yr, Three Small Communities



Distribution of non-residential energy use

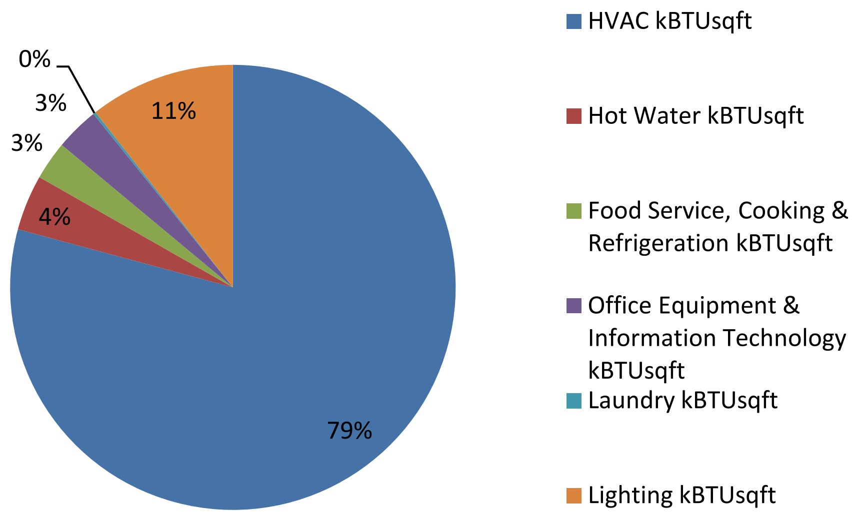
As with residential uses, heating requires more energy in MMBTUs/yr (72%) than any other application. The production of hot water is second (12%), followed by the operation of the interior and exterior lighting (11%) as shown in Figure 87.

Figure 87: Distribution of Total energy use in MMBTUs/yr, Three Small Communities



The figures do not change substantially when the energy intensity is measured by dividing the total energy use by the square footage of the building as illustrated in Figure 88. Again, heating, at 79%, requires far more energy than any other use. Domestic hot water, on the other hand, is reduced from 12% to 4% when measured by the energy per square foot.

Figure 88: Overall Distribution on Non-Residential Energy Use, kBTUs /ft²/yr, Three Small Communities



Distribution of energy uses

Warehouses use the largest proportion of their energy for heating in the targeted three communities. Healthcare facilities and retail establishments use a higher proportion of their energy for lighting (Figure 89).

Figure 89: Distribution of energy use by building type, MMBTUs/yr, Three Small Communities

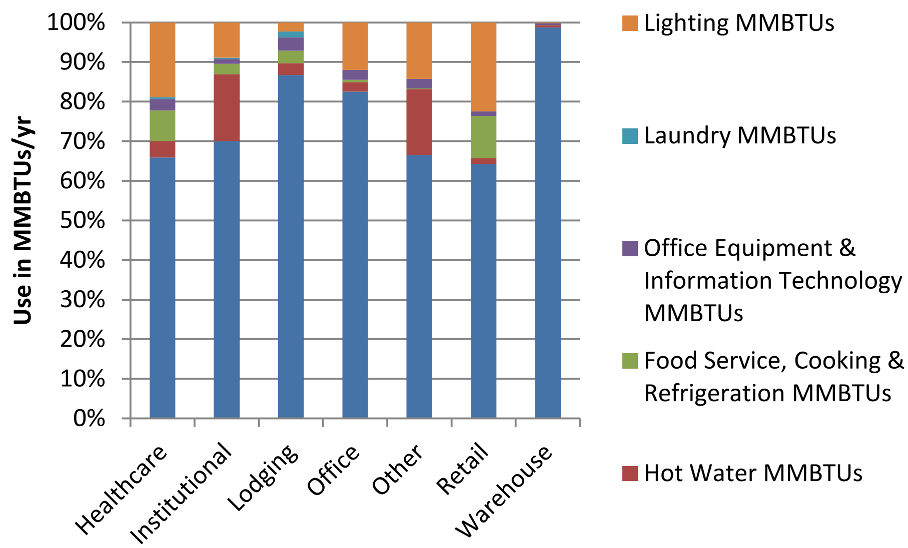
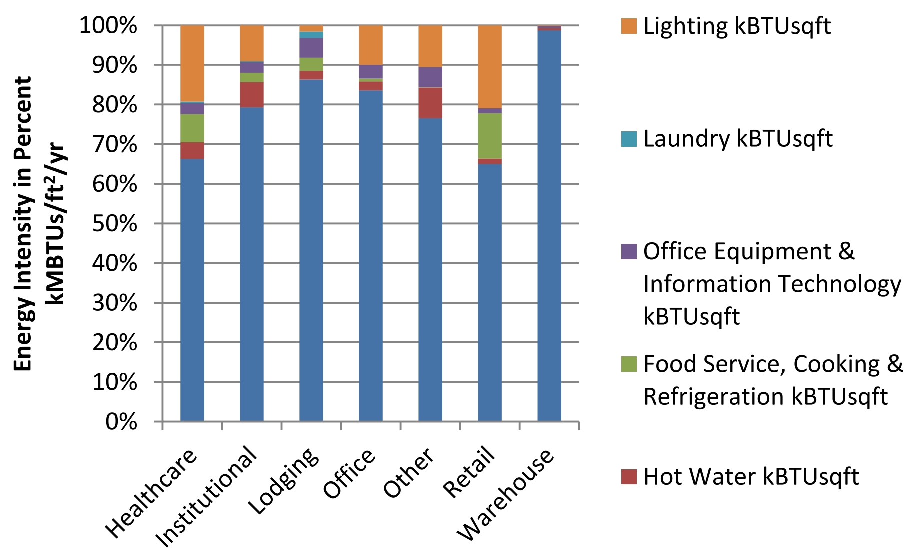


Figure 90 shows that the picture does not change much when energy intensity is measured, by dividing the total energy use by the building square feet. Again, warehouses use a higher proportion of energy for heating then any other building type. Health care facilities and retail establishments use approximately the same proportions of energy.

Figure 90: Distribution of energy uses by building type,in kBTUs/ft^2/yr, Three Small Communities



Detailed energy statistics for energy use within the three communities are shown in Table 32 and Table 33. Statistically significant differences are noted.

Table 32: Three Small Communities' Mean Non-Residential Energy Use in MMBTUs/yr

Building Type	Heating ventilation and air conditioning MMBTU	Hot water MMBTU	Food service, cooking and refrigeration MMBTU	Office equipment and information technology MMBTU	Laundry MMBTU	Lighting MMBTU	All end uses MMBTU
Healthcare	360.76	22.35	42.45	15.98	2.58	103.15	547.26
Institutional	1613.29	387.16	62.87	27.46	7.82	204.56	2303.16
Lodging	237.55	8.29	8.47	9.44	3.94	6.28	273.96
Office	582.90	16.31	4.46	17.62	0.00	84.91	706.21
Other	373.37	93.60	0.84	13.38	0.00	80.02	561.21
Retail	673.85	14.74	111.74	11.90	0.00	235.95	1048.17
Warehouse	854.60	4.95	0.14	4.41	0.00	1.49	865.58
Total	847.87	137.59	38.29	18.35	2.84	133.25	1178.19

*ANOVA significant at .05, ** significant at .01, ***significant at .001

Table 33: Bethel Mean Non-Residential Energy Use in kMBTUs /ft^2/yr

Building Type	HVAC kMBTUs /ft^2/yr *	Hot Water kMBTUs /ft^2/yr	Food Service, Cooking & Refrigeration kMBTUs /ft^2/yr *	Office Equipment & Information Technology kMBTUs /ft^2/yr	Laundry kMBTUs /ft^2/yr **	Lighting kMBTUs /ft^2/yr *	All End Uses kMBTUs /ft^2/yr **
Healthcare	73.90	4.72	7.89	3.08	0.42	21.50	111.52
Institutional	120.61	9.73	3.59	4.06	0.40	13.76	152.16
Lodging	198.22	5.06	7.59	11.58	3.68	3.60	229.74
Office	187.19	5.20	1.51	7.80	0.00	22.36	224.06
Other	238.51	24.07	0.39	15.89	0.00	32.74	311.60
Retail	147.77	3.11	26.13	2.66	0.00	47.64	227.32
Warehouse	427.30	2.47	0.07	2.20	0.00	0.75	432.79
Total	166.10	8.47	5.90	6.65	0.38	22.21	209.72

*ANOVA significant at .05, ** significant at .01, ***significant at .001

Summary of Average Energy Use in Three Small Communities

Table 34: summarizes energy use in the three smaller communities. Residential energy use was calculated using the average energy used by all households[21]. Non-residential energy use was calculated using the mean energy use by a non-MMBTU residential facility type multiplied by

[21] There is insufficient data on the distribution of types of housing in rural communities. Therefore a more precise estimate could not be developed. The number of households was taken from Community Profiles, accessed at http://commerce.alaska.gov/dca/commdb, February, 2012.

the estimated number of non-residential facilities in the community. Street lighting information was estimated using the average number of kilowatt hours per year for a community of about 100-199 people. This data is shown in a separate section of this report. Information on the use of energy to power water and wastewater systems assumed a 50° operating temperature. Detailed calculations of energy use estimates are shown in a separate section of this report.

Table 34: Summary of Energy Use in Three Communities

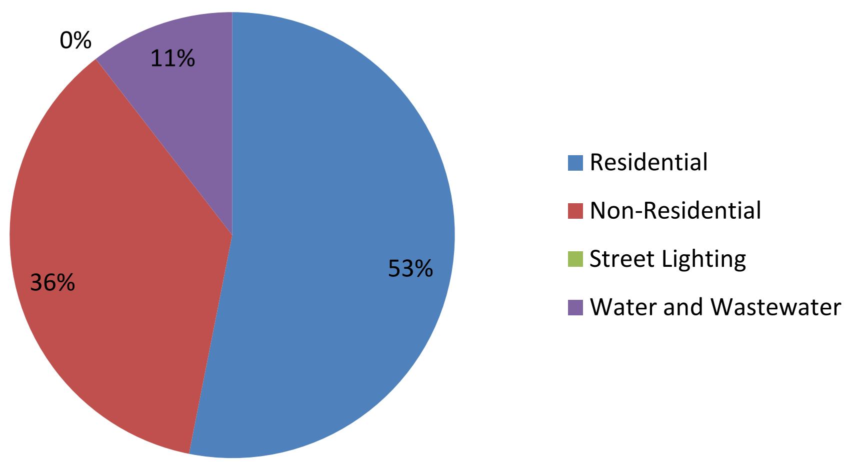
Component	Units	Mean MMBTU Use	Total MMBTUs
Residential	466	121.76	56,740
Non Residential[22]			38,880.9
Food Service	0	0	0
Warehouse	1	865.6	865.6
Institutional	10	2303.2	23032.0
Health Care	3	547.3	1641.9
Lodging	2	274.0	548.0
Office	9	706.2	6355.8
Mercantile/ retail	4	1048.2	4192.8
Service	0	0	0
Other	4	561.2	2244.8
Total	33		
Street Lighting[23]	3		3.48
Water and Waste Water (50^0)[24]			11,213
Total			106,837.4

[22] Average energy use for each type of facility in each community multiplies by the number of facilities in Energy Wise data.

[23] Based on average use for a community less than 199 people.

[24] See section on Water and Waste Water energy use.

Figure 91: Summary of Energy Use in Three Communities



Water and Sewer- Study

The objective of this task is to gain an understanding of the scope and magnitude of energy use associated with water supply and sewerage systems in rural Alaskan communities. The following communities were identified for inclusion in this energy use assessment:

- Bethel;
- New Stuyahok;
- Selawik; and
- Savoonga.

Descriptions of these communities were provided in another section of this report.

Data Collection

The research team met with Alaska Native Tribal Health Consortium (ANTHC), Village Safe Water (VSW) engineers, and other water and sewer stakeholders to discuss this assessment and to obtain available water and sewer data available from these agencies. ARUC is an organization sponsored by ANTHC to facilitate operation of water supply and sewerage facilities in rural Alaska communities. There are currently 23 member communities and that number is growing. The current ARUC community list can be seen in Table 35.

ANTHC provided water and sewer data from October 2010 through September 2011 for energy use in the 23 ARUC communities. A summary of this data is presented in Table 35. ANTHC also provided very useful information on the water supply and sewerage system details for three of the four communities of interest for this report, including Selawik, Savoonga, and New Stuyahok.

As part of the rural non-residential building data collection, the research team also targeted rural communities and its related infrastructure for additional building benchmark data, including water and sewer facilities. This resulted in very little useable data, largely due to lack of sub-metering fuel oil of water and sewer facilities throughout rural Alaska and due to poor accounting records. Although in its infancy, ARUC staff have collected over 12 months of fuel data in over 23 communities. This data set represents the only reliable source of rural water and sewer data currently available.

ANTHC also provided energy audit reports for 12 rural Alaska communities. These communities are Akiak, Eek, Kongiganak, Lower Kalskag, Napaskiak, Nulato, Russian Mission, Savoonga, Selawik, Sleetmute, Teller, and Toksook. Among the communities audited are two of the four communities of interest for this report: Selawik and Savoonga.

The research team contacted VSW to obtain any rural utilities energy use information available from them. WHP was advised that VSW does not have reliable and current data concerning energy use by water and sewerage utilities in rural Alaska.

Table 35: Data Furnished by Alaska Rural Utility Cooperative, an organization sponsored by the Alaska Native Tribal Health Consortium

FY 2011	ARUC DATA												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Water Produced	8,733,300	8,416,962	9,937,548	9,712,363	9,407,541	10,072,738	8,610,740	8,173,998	7,397,884	7,463,763	7,158,810	7,852,171	102,937,818
Ambler							504,690	459,620	408,301	350,929	0	591,920	2,315,460.0
Chevak	740,474	805,558	790,007	848,680	759,592	698,015	889,476	1,118,167	683,524	707,789	753,632	753,684	8,002,566.0
Chignik Lagoon				239,797	259,748	175,448	125,702	358,734	286,090	355,618	372,509	198,011	2,371,656.6
Chignik Lake						234,714	?	?	175,714	163,000	245,000	249,000	1,067,428.0
Golovin		101,168	123,690		88,459	101,657	98,717	127,522	103,859	145,850	163,600	116,435	1,069,789.0
Goodnews Bay	205,322	148,726	161,421	272,218	176,258	243,806	210,545	176,174	183,486	191,312	291,013	221,786	2,128,019.0
Holy Cross	JOINED ARUC MAY 2011							289,900	306,700	347,500	333,700	402,600	1,680,400.0
Kiana	820,971	751,068	988,912	1,237,207	735,444	1,006,760	632,225	733,108	594,983	790,881	733,365	0	7,452,883.7
Kobuk			282,800	304,117			203,736	147,244	196,600	167,946	164,386	0	1,466,828.1
Kotlik	463,900	307,300	395,700	462,900	534,700	261,500	393,400	319,600	364,400	301,000	385,300	511,200	3,929,700.0
Lower Kalskag	169,692	205,810	263,968	238,708	95,453	161,904	113,019	174,025	147,833	166,765	185,913	197,114	1,744,702.0
New Stuyahok	2,597,851	2,416,523	2,534,130	2,514,031	2,623,205	2,864,333	1,676,055	525,000	525,000	525,000	525,000	0	14,311,754.0
Noorvik	JOINED ARUC JUNE 2011								0	0	0	722,557	722,557.0
Newhalen			361,031		112,030	93,200	83,000	60,600	58,900	62,300	79,600	72,570	983,231.0
Russian Mission	400,945	399,444	399,912	433,331	431,974	426,618	430,512	433,114	412,448	449,282	426,952	406,036	4,250,179.0
Savoonga	535,896	518,884	510,620	616,260	556,693	591,090	565,532	599,244	497,131	497,540	516,151	520,570	5,470,831.0
Selawik	825,095	666,930	844,762	631,283	720,730	782,698	703,626	666,492	817,927	819,335	459,003	974,450	7,420,306.0
Sleetmute	61,829	63,219	83,906	86,400	64,677	63,527	78,349	76,422	49,326	97,515	57,638	622,283	1,280,043.0
South Naknek							?		?	?	10,019	0	10,019.0
St. Michael	443,603	435,406	244,071	150,689	559,897	276,978	217,714	166,144	182,443	134,877	152,118	92,119	2,177,050.0
Toksook Bay	484,900	489,400	642,600	495,300	512,400	588,200	472,500	626,300	605,000	514,000	627,300	598,000	5,681,600.0
Tyonek	982,822	1,107,526	1,310,018	1,181,442	1,176,281	1,502,290	1,211,943	1,116,588	798,219	675,325	676,611	601,836	10,250,553.0
Fuel Inventory-gal	4829.70	6243.09	13664.42	10035.39	10859.41	12236.79	8564.10	5549.30	1957.10	1893.91	1820.12	2318.10	79,971.43
Ambler	0	0	0	0	0	0	253	500	0	0	0	250	1,003.00
Chevak	1,200	600	1,860	2,100	1,120	2,400	1,200	1,240	300	1,240	120	600	13,980.00
Chignik Lagoon	24	25	26	37	0	69	28	58	15	0	29	44	355.00
Chignik Lake	55	55	56	65	56	5	55	0	0	0	0	0	347.00
Golovin	250	28	291	450	1,019	574	590	481	23	29	336	32	4,102.53
Goodnews Bay	142	186	535	467	320	574	212	181	141	70	107	99	3,033.80
Holy Cross	JOINED ARUC MAY 2011												-
Kiana	0	0	0	0	0	739	365	375	0	0	332	0	1,811.00
Kobuk	0	0	448	400	0	0	450	200	0	0	150	0	1,648.00
Kotlik	343	457	465	440	313	153	202	80	16	0	0	312	2,781.00
Lower Kalskag	34	195	308	360	350	260	125	145	4	10	10	200	2,001.00
New Stuyahok	0	0	0	0	0	0	0	0	0	0	0	0	-
Newhalen	0	0	0	0	10	81	100	30	76	54	0	0	351.00
Noorvik	JOINED ARUC JUNE 2011												-
Russian Mission	53	272	362	242	217	281	232	145	80	62	73	55	2,074.00
Savoonga	385	678	1,274	0	1,113	1,030	890	763	144	0	100	0	6,377.70
Selawik	1,305	2,066	4,685	2,002	2,235	2,887	1,810	0	0	0	0	0	16,990.60
Sleetmute	150	260	350	380	400	400	225	100	25	0	0	25	2,315.00
South Naknek	30	35	45	0	0	15	30	0	0	15	20	0	190.00
St. Michael	623	1,337	2,522	2,468	2,845	2,230	1,149	528	450	0	130	309	14,591.00
Toksook Bay	236	49	437	624	429	326	548	656	646	392	413	355	5,111.00
Tyonek	0	0	0	0	433	213	100	67	37	22	0	37	908.80
Upper Kalskag	0	0	0	0	0	0	0	0	0	0	0	0	-

FY 2011	ARUC DATA												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Electricity (kWh)	156,533	185,941	228,863	283,382	225,835	230,173	221,330	194,191	163,779	132,478	148,351	144,993	2,315,849
Ambler	11,419	12,358	13,329	15,877	12,190	11,981	11,248	10,498	7,735	5,663	5,680	7,285	125,263.00
Chevak	17,305	21,324	21,958	24,366	21,872	24,192	22,290	22,153	18,150	16,906	18,042	19,818	248,376.00
Chignik Lagoon	931	885	796	769	1,021	1,279	1,059	888	1,033	1,191	1,226	628	11,706.00
Chignik Lake	2,333	2,186	2,078	2,353	2,045	2,026	2,057	1,879	1,805	1,843	1,629	1,258	23,492.00
Golovin	3,080	3,377	4,685	3,245	3,861	3,965	3,477	3,423	2,953	2,109	2,094	0	36,269.00
Goodnews Bay	1,588	1,821	2,684	2,656	2,857	2,513	2,332	1,883	1,782	1,536	1,739	1,416	24,807.00
Holy Cross	JOINED ARUC MAY 2011								5,636	767	1,674	1,824	9,901.00
Kiana	8,690	9,700	12,549	13,185	11,797	12,612	12,223	11,729	9,016	8,731	9,323	10,333	129,888.00
Kobuk	4,914	8,649	8,752	8,744	8,322	8,540	8,999	7,399	2,782	2,751	2,704	1,985	74,541.00
Kotlik	12,822	16,224	16,946	19,240	18,160	18,907	17,668	16,876	16,357	15,229	18,674	14,595	201,698.00
Lower Kalskag	4,666	5,390	8,205	9,249	5,649	7,359	8,611	7,512	6,186	653	2,204	1,835	67,519.00
New Stuyahok	5,005	4,961	5,809	3,219	4,907	5,486	4,853	4,025	3,880	4,337	4,461	4,646	55,589.00
Newhalen	1,291	3,788	6,947	7,244	4,085	1,267	1,188	1,198	1,052	1,153	911	1,382	31,506.00
Noorvik				JOINED ARUC JUNE 2011					18,488	15,520	19,742	20,498	74,248.00
Russian Mission	2,457	3,639	4,155	4,398	3,821	4,055	4,209	3,206	1,258	1,386	1,173	1,248	35,005.00
Savoonga	6,500	6,550	11,142	55,959	17,840	17,840	17,840	17,840	7,176	8,754	10,000	10,000	187,441.00
Selawik	34,226	42,070	58,246	61,931	57,625	58,724	58,365	46,134	25,408	19,158	17,375	19,962	499,224.00
Sleetmute	2,332	2,782	2,574	2,902	2,467	2,506	2,517	2,311	2,236	2,225	2,283	0	27,135.00
South Naknek	534	997	1,355	2,097	2,512	2,058	1,152	768	617	570	650	577	13,887.00
St. Michael	17,761	23,297	26,724	27,063	23,126	26,868	24,968	19,090	14,824	14,939	16,412	17,972	253,044.00
Toksook Bay	10,832	10,984	12,505	11,224	15,994	10,225	9,912	9,096	9,688	3,282	8,817	3,947	116,506.00
Tyonek	3,760	3,840	4,120	4,520	3,720	4,760	3,960	3,160	2,520	2,320	0	2,960	39,640.00
Upper Kalskag	4,087	1,119	3,304	3,141	1,964	3,010	2,402	3,123	3,197	1,455	1,538	824	29,164.00

Alaska Rural Utilities Cooperative, an organization sponsored by the Alaska Native Tribal Health Consortium
DEHE-#128018-v1-ARUC_Monthly_Source_Data_FY11-bud edit 02Feb12.xls

Data Review and Evaluation

The ANTHC engineers collected and evaluated 2010 and 2011 data from the 23 ARUC water and sewer operations during the summer and fall of 2011. The data was analyzed extensively for useful patterns or trends, such as energy use per capita, per connection, per unit of water produced, and Climate Zone. Unfortunately, the results of their evaluation did not reveal any useful patterns or trends in the data available. This data was independently evaluated by the research team, which confirmed the ANTHC findings that the data did not reveal any useful patterns or trends.

It appears that there are two fundamental problems with the ARUC energy and operations data. First, the systems in the various villages are not directly comparable due to differences in the type of facilities (i.e. aboveground vs. buried water lines, or vacuum sewers vs. gravity sewers, or arctic pipe vs. utilidors). Second, and perhaps the main problem, the data may simply be incorrect or inaccurate. There are indications of this second problem in the calculated water use per person, which varies from 4 to 111 gallons per person per day.

The ANTHC energy audits contain information about electrical consumption records and the reported annual cost of energy for the water and sewer systems. The audits also report on the evaluation of boiler efficiencies, building insulation and thermal evaluation, electrical equipment loads, and operating temperatures. A main focus of the energy audit report is the identification and quantification of potential energy savings that could be achieved by facilities upgrades. This information was valuable both for inputs to the energy use model and for comparison with the results of the energy use model.

While energy audits and energy use modeling are similar in nature, there is an important difference between them. An energy audit tends to focus on finding inefficiencies in system facilities and proposing facility modifications to improve efficiencies, to save energy, and to reduce cost. In contrast, system modeling is an attempt to model energy demands for a system which is assumed to be operating with reasonable efficiency. The concept is to better understand a system's expected energy demands for its different functions as a means of assessing actual performance and opportunities for energy demand reduction.

ANTHC provided very useful information and details about the three ARUC systems to be modeled and evaluated. This information concerned pipe sizes and lengths, type of piping systems (aboveground vs. buried water lines, or vacuum sewers vs. gravity sewers, or arctic pipe vs. utilidors), utilidor details, pump sizes and operating temperatures.

Information concerning the Bethel water and sewerage systems was obtained from sources in the Bethel community and Bethel community websites. It should be noted that only approximately

30 percent of the Bethel population is served by piped water and sewer services, and the modeling effort is concerned only with the piped systems.

Additional information about systems details in all four communities, such as pipe lengths and loop layouts, building sizes, service line lengths etc, was obtained from the latest Community Maps prepared by the Department of Commerce, Community and Economic Development, and from community aerial views obtained using Google Earth images.

For all communities, the available data was incomplete to varying degrees. For example, there was very limited data about the raw water supply pipelines or raw water flow rates. For modeling purposes, it was necessary to make assumptions about pipeline diameters and degree of exposure (i.e. buried or above ground). Similarly, water/sewer buildings' exposed surface areas were estimated from footprints. In some cases, there was conflicting information. In all such cases, reasonable assumptions were made based on normal practice. For below ground pipelines, the ground temperature has been assumed.

Overall, the information finally used in the modeling is deemed to provide a reasonably accurate description of the systems in each of the communities. If the model results are considered to have a useful role to play in systems operation, it will be essential to verify the system information in the field and to eventually calibrate the model to reflect actual system performance under a range of operating conditions.

Energy Use Models for Rural Communities

Due to the lack of useful patterns and trends in the available data, it was decided to attempt to model the water supply and sewerage systems in use in the four target communities. A summary of the systems data which was collected and used in the preparation of energy models for each of the four communities is presented in Table 36. These four systems represent a variety of types of water and sewerage facilities. This variation has made the modeling effort and results variable as well.

Table 36: Water and Sewerage Utilities Systems Data Summary

Community	Bethel	New Stuyahok	Savoonga	Selawik
Population Served	1800*	510	700	830
Water Supply gallons per day (gal/capita day)	123,100 (68.4)**	17,500 (34.3)	15,200 (21.7)	20,330 (24.5)
Fuel Cost $/gal	$4.00	$5.92	$4.18	$3.70
Power Cost $/kWh	$0.15	$0.15	$0.14	$0.17
Water Source	Well	Well	Well	River
Raw Water Temperature	34 F	34 F	34 F	34 F
Average Ambient Temperature	31 F	31 F	28 F	24 F
Water Supply Type	Arctic Pipe Loops and Services Above Ground	Arctic Pipe Loops and Services Buried	Utilidor Loops and Services Above Ground	Arctic Pipe and Utilidor Loops and Services All Above Ground
Number of Water Loops	5	2	3	2 Pipe Loops 1 Utilidor at Island
Total Water Loop Length, ft	35,000	12,000	Util-15,400 Loop-30,800	Util-9,200 Island Loop 18,400 Loops-9,200
Number of Services	362	95	182	189
Total Length of Services, ft	16,220	4,750	9,100	15,120
Type of Sewerage	Gravity with 7 Pump Stations	Gravity with 2 Pump Stations	Vacuum with 1 Vac Station	Vacuum with 2 Vac Stations

*Only 30 percent of Bethel population is connected to piped water and sewer services
**Includes water used by Hospital and High School serving the entire community

The basic model is a spreadsheet into which the system details are entered. An example of this complex spreadsheet model for Bethel is shown in Table 37. These details include pipe loop and services sizes and lengths, pipe locations above or below ground, utilidor details, insulation thicknesses, flow rates, raw water temperature, and ambient temperature to set the stage for water supply model. Also required are buildings sizes or exposed surface areas for all utilities buildings to be kept warm. Once this system is set up in the spreadsheet, various operating temperatures and ambient temperatures can be run to estimate energy requirements as a function of these two variables. Energy requirements are primarily for pumping, initial heating, and heat losses from pipelines and buildings.

Table 37: Model of Water System Energy Use Calculations

Existing — **Water System Energy Use Calculations for** **BETHEL, ALASKA**

Service Area Population =	1800	Raw water flow	129260 gal/day	**Raw Water Temperature:**	34 deg. F
Average Service-AKIAK , ft =	75	Raw water flow	89.8 gal/min	**Running Temperature:**	55 deg. F
Average Service-BETHEL HTS , ft =	20			**System type:**	Water loops, Above ground arctic pipe w/ 4" insulation, pitorifices for H.C. loop
Raw Water flow, gal/pers/day	71.8	Treated water flow	123104.76 gal/day	**Heat/Power Production Efficiency =**	0.65
Treated water flow, gal/pers/day	68.4	Treated water flow	85.5 gal/min		

Description	Length ft	I.D. inch	O.D. inch	Insulation T, inch	Insulation R ft2-hr-F per BTU-inch	Insulation Effective R	Insulation Effective k (1/R) BTU per ft2-hr-F	Water Temp °F	External Temp °F AMBIENT -40 DEG F	Pipeline Area ft2	Heat Loss BTU/hr	Flow Rate gpm	Temp Drop °F	Fuel Cost $/gal 4.00	Energy Cost $/d	No. of Services 382	Energy Cost $/mo-svc	Percent of Total
											Efficiency Adusted Fuel Cost $/gal			6.15				
Raw Water Pumping	3.98 kW										13,569	89.8		6.15	$14.84	382	$1.19	0.7%
Raw Water Pipeline	3000	4	12	4.0	5	30	0.033	34.00	-40	9,425	23,248	89.8	0.52	6.15	$32.03	382	$2.56	1.4%
Heating all raw water produced											943,463	89.8		6.15	$1,299.83	382	$103.78	57.8%
Tank 1 Heat Losses	24' water depth			5.0	5	25	0.040	55.00	-40	7,351	27,935			6.15	$38.49	382	$3.07	1.7%
Tank 2 Heat Losses	24' water depth			5.0	5	25	0.040	55.00	-40	7,351	27,935			6.15	$38.49	382	$3.07	1.7%
WTP Building 1	10,000 sf surface area			5.0	4	20	0.050	70.00	-40	10,000	55,000			6.15	$75.77	382	$6.05	3.4%
WTP Building 2	7,000 sf surface area			5.0	4	20	0.050	70.00	-40	7,000	38,500			6.15	$53.04	382	$4.24	2.4%
Initial Pressurization	5.29 kW										18,046	85.5		6.15	$19.74	382	$1.58	0.9%
AKIAK SERVICE AREA																		
Loop A	6000	6	14	4.0	5	30	0.033	54.48	-40	21,991	69,260	188.1	0.74	6.15	$75.77	43	$53.74	3.4%
Loop A Services (43)	3225	4	12	4.0	5	30	0.033	54.12	-40	10,132	31,785	43	1.48	6.15	$34.77	43	$24.66	1.5%
Loop A Pumping	2.97 kW										10,149			6.15	$11.10	43	$7.88	0.5%
Loop B	9000	6	14	4.0	5	30	0.033	54.48	-40	32,987	103,890	188.1	1.10	6.15	$113.66	72	$48.15	5.1%
Loop B Services (72)	5400	4	12	4.0	5	30	0.033	53.93	-40	16,965	53,117	72	1.47	6.15	$58.11	72	$24.62	2.6%
Central Loop Pumping	4.02 kW										13,705			6.15	$14.99	72	$6.35	0.7%
Loop C	5000	6	14	4.0	5	30	0.033	54.48	-40	18,326	57,717	188.1	0.61	6.15	$63.14	41	$46.97	2.8%
Loop C Services (41)	3075	4	12	4.0	5	30	0.033	54.18	-40	9,660	30,326	41	1.48	6.15	$33.18	41	$24.68	1.5%
Loop C Pumping	2.63 kW										8,964			6.15	$9.81	41	$7.30	0.4%
BETHEL HEIGHTS SERVICE AREA																		
Loop 1	8000	6	13	3.5	5	26.25	0.038	54.48	-40	27,227	98,000	188.1	1.04	6.15	$107.21	113	$28.94	4.8%
Loop 1 Services (113)	2260	4	11	3.5	5	26.25	0.038	53.96	-40	6,508	23,297	113	0.41	6.15	$25.49	113	$6.88	1.1%
Loop 1 Pumping	3.67 kW										12,520			6.15	$13.70	113	$3.70	0.6%
Loop 2	7000	6	13	3.5	5	26.25	0.038	54.48	-40	23,824	85,750	188.1	0.91	6.15	$93.81	113	$25.32	4.2%
Loop 2 Services (113)	2260	4	11	3.5	5	26.25	0.038	54.03	-40	6,508	23,313	113	0.41	6.15	$25.50	113	$6.88	1.1%
Loop2 Pumping	3.32 kW										11,335			6.15	$12.40	113	$3.35	0.6%

BETHEL 55 DEGREES - AMBIENT TEMP -40 F					cost per service	
Note: 1 gpm heated 1 ºF = 500.5 BTU/hour	**1 kWh = 3412.0 BTU**	Total Energy Use, BTU/h	1,780,825			
Assumed Fuel is Fuel Oil No. 1 @ 135,000 BTU/gal	**= 39.57 kWh/gal**	BTU/1000 gal	330,650	Total Cost, $/d	$2,250.05	382 $5.9
Water use gal per capita day = 71.811		kWh/1000 gal	97			
Water use 1000 gal/cap-mo = 2.15		kWh/cap-mo	209	Total Cost, $/mo	$68,627	382 $179.7
Water use 1000 gallons per hour = 5.39		kWh/svc.con-mo	984			
Water use 1000 gal/svc conn-mo = 10.15		Average kW	522	Total Cost, $/yr	$823,519	382 $2,155.8

Pumps and Pipeline Hydraulic and Energy Calculations

Pump Station ID	Pipe IDia inches	Pipe Area sq. ft.	Pipe Length feet	Avg Flow gpm	Peak Factor	Peak Flow gpm	Peak Flow cfs	Peak Flow cms	H-W C value	Peak Flow Velocity fps	Peak Velocity Head ft	Peak Friction Head psi	Peak Friction Head ft	Average Static Head ft	Total Head m	Peak Pumping Power kW	Pumping Efficiency	Minimum Pump Motor kW	Pumping Energy kWh/d
Initial Pressurization	-	-	-	-	-	85.5	0.19	0.00540	-	-	-	-	-		60.00	3.1735	0.6	5.29	126.94
Raw Water Pumping-1	4	0.111	3000	89.76388889	1	89.8	0.20	0.00567	125	1.80	0.00	8.84	20.41	15	10.83	0.6014	0.6	1.00	24.06
Loop A Pumping	5.47	0.208	6000	17.0978836	11	188.1	0.42	0.01187	125	2.01	0.01	15.22	35.15	15	15.34	1.7847	0.6	2.97	6.49
Loop B Pumping	5.47	0.208	9000	17.0978836	11	188.1	0.42	0.01187	125	2.01	0.01	22.82	52.72	15	20.71	2.4101	0.6	4.02	8.76
Loop C Pumping	5.47	0.208	5000	17.0978836	11	188.1	0.42	0.01187	125	2.01	0.01	12.68	29.29	15	13.55	1.5763	0.6	2.63	5.73
Loop 1 Pumping	5.47	0.208	8000	17.0978836	11	188.1	0.42	0.01187	125	2.01	0.01	20.29	46.86	15	18.92	2.2016	0.6	3.67	8.01
Loop 2 Pumping	5.47	0.208	7000	17.0978836	11	188.1	0.42	0.01187	125	2.01	0.01	17.75	41.01	15	17.13	1.9932	0.6	3.32	7.25

Existing		Sewer System Energy Use Calculations for	BETHEL, ALASKA
Service Area Population =	1800	Sewage as fraction of water flow	0.90
Average Service , ft =	50	Sewage flow	110794.3 gal/day
Sewage flow, gal/pers/day	61.6	Avg. sewage flow	76.9 gal/min
Number of sewer connections	382.0	ASSUME EQUAL CATCHMENT FOR EACH PS	
Sewage flow, cal/conn/day	290.0	Sewage flow per catchment	11.0 gal/min

Raw Water Temperature: 34 deg. F **Heat/Power Production Efficiency =** 0.75
Running Temperature: 50 deg. F
System type: Gravity buried service conn and buried gravity sewers. 2 catchments.
services heat traced for emergency thawing
7 pump stations pumping in series in 2 lines:
4-3-2-1 7-6-5-1 PS 1 pumps to treatment/disposal

		Insulation T, inch	Insulation R ft2-hr-F per BTU-inch	Insulation Effective R	Insulation Effective k (1/R) BTU per ft2-hr-F	Inside Temp °F	External Temp °F	Surface Area ft2	Heat Loss BTU/hr	Heat Loss BTU/d	Fuel Cost $/gal	Energy Cost $/d	Energy Cost $/mo-svc	Percent Water System Cost
Heating Sewage Pump Statio	1000 ft^2/PS	5.0	4	20	0.050	50.00	-40	7,000	31,500	756,000	6.15	$34.46	$2.75	1.5%

Pumps and Pipeline Hydraulic and Energy Calculations

Pump Station ID	Number of Catchments	Pipe IDia inches	Pipe Area sq. ft.	Pipe Length feet	Avg Flow gpm	Peak Factor	Peak Flow gpm	Peak Flow cfs	Peak Flow cms	H-W C value	Peak Flow Velocity fps	Peak Velocity Head ft	Peak Friction Head psi	Peak Friction Head ft	Average Static Head ft	Total Head m	Peak Pumping Power kW	Pumping Efficiency	Minimum Pump Motor kW	Pumping Energy kWh/d
Pump Station No. 1	7	6	0.250	5000	76.9	4	307.762	0.68	0.0194	100	2.74	0.02	30.43	70.29	20	27.62	5.26	0.65	8.09	48.54
No. 2	3	4	0.111	500	33.0	4	131.898	0.29	0.0083	100	2.64	0.00	4.53	10.48	15	7.79	0.64	0.65	0.98	5.87
No. 3	2	4	0.111	1000	22.0	6	131.898	0.29	0.0083	100	2.64	0.00	9.07	20.95	15	11.00	0.90	0.6	1.50	5.98
No. 4	1	4	0.111	1000	11.0	8	87.932	0.20	0.0056	100	1.76	0.00	4.28	9.90	15	7.61	0.41	0.5	0.83	2.49
No. 5	3	4	0.111	1000	33.0	4	131.898	0.29	0.0083	100	2.64	0.00	9.07	20.95	15	11.00	0.90	0.6	1.50	8.97
No. 6	2	4	0.111	1500	22.0	6	131.898	0.29	0.0083	100	2.64	0.00	13.60	31.43	15	14.20	1.16	0.6	1.93	7.72
No. 7	1	4	0.111	1000	11.0	8	87.932	0.20	0.0056	100	1.76	0.00	4.28	9.90	15	7.61	0.41	0.5	0.83	2.49

Total Energy Use, BTU/h	11,666
BTU/1000 gal	2,527
kWh/1000 gal	0.74
kWh/cap-mo	1.39
kWh/svc.con-mo	6.55
Average kW	3.42

Energy Cost, $/day	$12.76
Energy Cost, $/day-conn	$0.03
Energy Cost, Percent of Water System cost	0.57 percent

Total kWh/d	82.06
Total BTU/day	279,985
Average kW	3.42
Total kWh/yr/person	16.64

Note: Vacuum sewers reported to use 10-30 kWh/pers/yr for the vacuum pumps
This calculation shows around 20 kWh/person/yr for the collection pumps - excluding pumping to treatment
CONCLUSION: EXCLUDING HEATING, ENERGY COST FOR VACUUM SYSTEM AND FOR GRAVITY + PUMPING SYSTEM ARE SIMILAR

Additional energy for Vacuum systems

Assumptions

Air to Liquid Ratio =	3.00 (normal minimum)	Air Flow =	332,383 gpd	= 1,636 kg/d	Heat needed =	130,886 BTU/d
Air Specific Gravity =	0.0013	Air Temp=	-40 deg C			
Air Specific Heat=	1.00 kJ/kg-deg C	Sewage Temp=	40 deg C		This adds	39 percent to the sewage collection energy

Leaking Vacuum Valve

Air to Liquid Ratio =	10.00 (leaking)	Air Flow =	1,107,943 gpd	= 5,454 kg/d	Heat needed =	436,288 BTU/d
Air Specific Gravity =	0.0013	Air Temp=	-40 deg C			
Air Specific Heat=	1.00 kJ/kg-deg C	Sewage Temp=	40 deg C		This adds	130 percent to the sewage collection energy

Vacuum pumping energy would also triple

Note: 1 BTU = 1 kJ (close enough; 1.005)

Summary Water & Sewer - 35 degrees			Percent of Total
	Efficiency factor	0.65	
	Ambient Temperature, deg F	-40	
Total Energy Requirement	Raw Water Temperature, deg F	34	
	Heating & Pumping Raw Water Line	36,817 BTU/h	1.99
	Heating Raw Water	943,463 BTU/h	51.07
	Heating WTP Bldg & Water Tank	149,370 BTU/h	8.09
	Initial Pressurization	18,046 BTU/h	0.98
	Loop and Services Heat Loss	576,455 BTU/h	31.20
	Loop Pumping	56,673 BTU/h	3.07
	Sewage Pumping	11,666 BTU/h	0.63
	Lift Station Heating (use WTP bldg value)	55,000 BTU/h	2.98
	Total Energy Estimate	1,847,491 BTU/h	

For the community sewers, the principal energy use is for pumping the sewage for the gravity sewers, and for operating the vacuum pumps and disposal pumps for the vacuum systems. Additionally, the heating of all associated buildings is calculated. For gravity sewers, it is assumed that heating of the sewage is not required. For vacuum sewers, the heat required to warm the air sucked into the system to above freezing has been included. The energy demand of sewerage facilities is calculated and reported separately from the water supply energy demand.

For pumping facilities, the spreadsheet includes sections for calculating pipeline heat losses and pumping energy requirements.

Energy calculations and results are based on net energy demand, without consideration of the efficiencies of energy delivery systems. This is done in order to avoid any confusion with respect to energy delivery efficiencies. It is also convenient for comparing the performance of the utilities systems without the complication of the effects of energy delivery methods.

All energy demands are calculated in net BTUs/hr, regardless of the energy source. Similarly, all energy costs are calculated from the energy demands using the efficiency adjusted cost of heating fuel in each community. No differentiation is made between fuel energy and electrical energy. Energy results are expressed as both BTUs and kWh in the model.

Summaries of the AAAT and EWAT model runs for each community are presented in Table 38 through Table 42 together with an example model run output at an operating temperature of 45°, 50° and 55°F for each climatic condition in each community.

The results of the modeling are most easily seen using a chart presentation as shown in Figure 92 through Figure 99. For each community, a chart has been made showing the relative energy demand for five components of energy demand:

- Raw Water Heating;
- Loops and Service Lines;
- Heating Buildings and Tanks;
- Sewerage; and
- Raw Water Pumping and Heat Loss.

In general, this listing is presented in the order of energy demand, with the exception that for systems with above ground utilidors, the largest energy demand is for the loops and services, followed by raw water heating. In all cases, these two categories account for most of the energy demand of all four systems. For ease of comparison, the charting is presented based on Energy Use per 1,000 gallons of water produced.

No use of heat trace has been included in the calculations. The assumption is that heat trace is not used for routine operations, and is only activated for thawing purposes, when something has gone wrong in the system.

The model does allow for selection of overall energy delivery efficiency, and the selected efficiency factor is applied exclusively to the cost of fuel. The predicted energy costs of operation are therefore the only place where energy delivery efficiency is taken into account. For all of the results presented in this report, an energy efficiency factor of 0.65 has been used.

Model Results

The systems in all four communities have been modeled for two climatic conditions. One of the conditions is for the Annual Average Ambient Temperature (AAAT), and the other is for an assumed Extreme Winter Ambient Temperature (EWAT). For all communities the EWAT has been taken as -40 F. Wind chill has not been included for above ground facilities.

For each condition, AAAT and EWAT, the model has been run for operating temperatures of 35°, 40°, 45°, 50°, 55°, and 60° F. These operating temperatures are intended to cover the full range of anticipated operating values. Available data indicates that water systems are normally operated in a range between 40° and 55°. Raw water source temperatures have been set at 34° F without any variation, mostly due to the lack of any data in this regard.

Figure 92: Bethel Energy Use Model for Water & Sewer

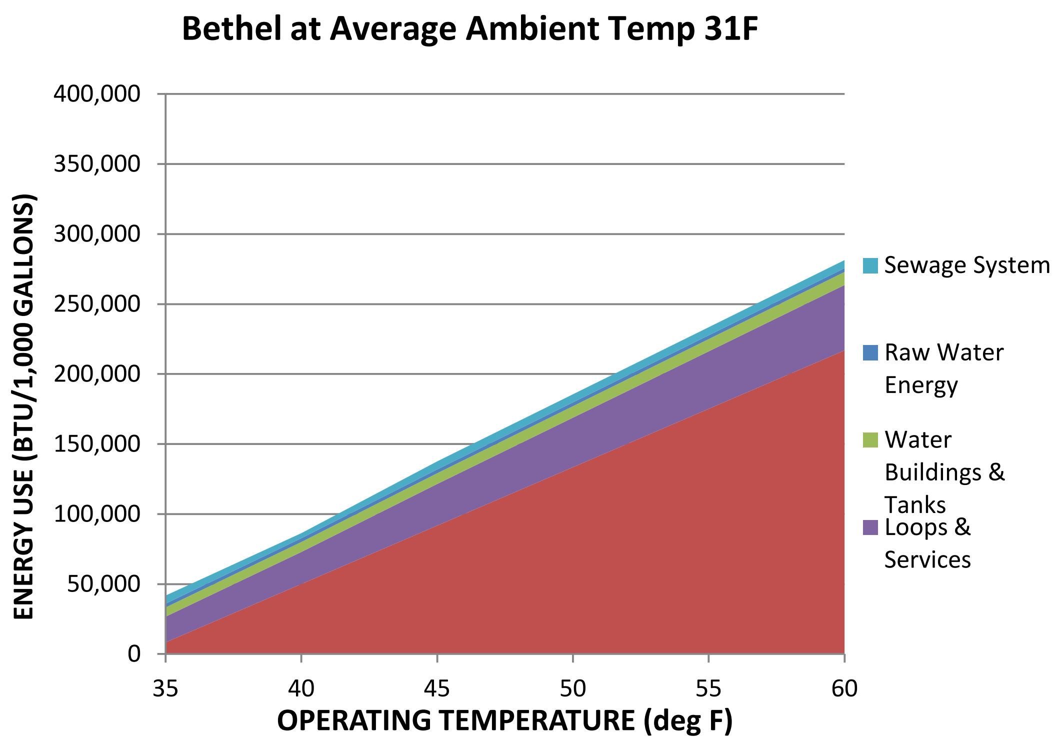


Figure 93: Bethel Energy Use Model of Water & Sewer

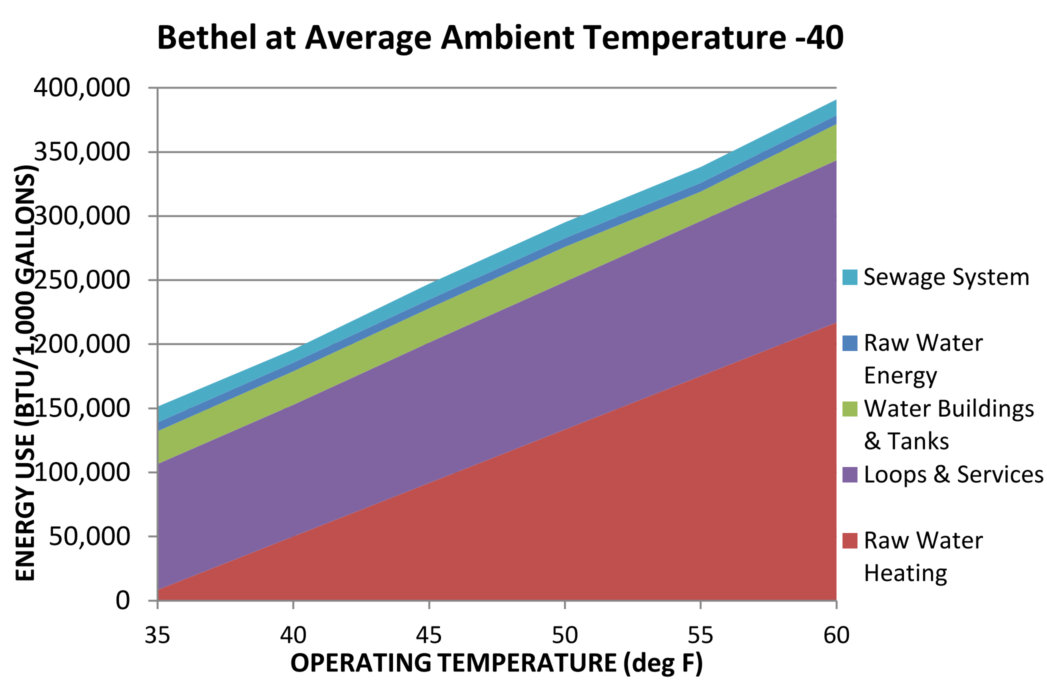


Figure 94: New Stuyahok Energy Use Model for Water & Sewer

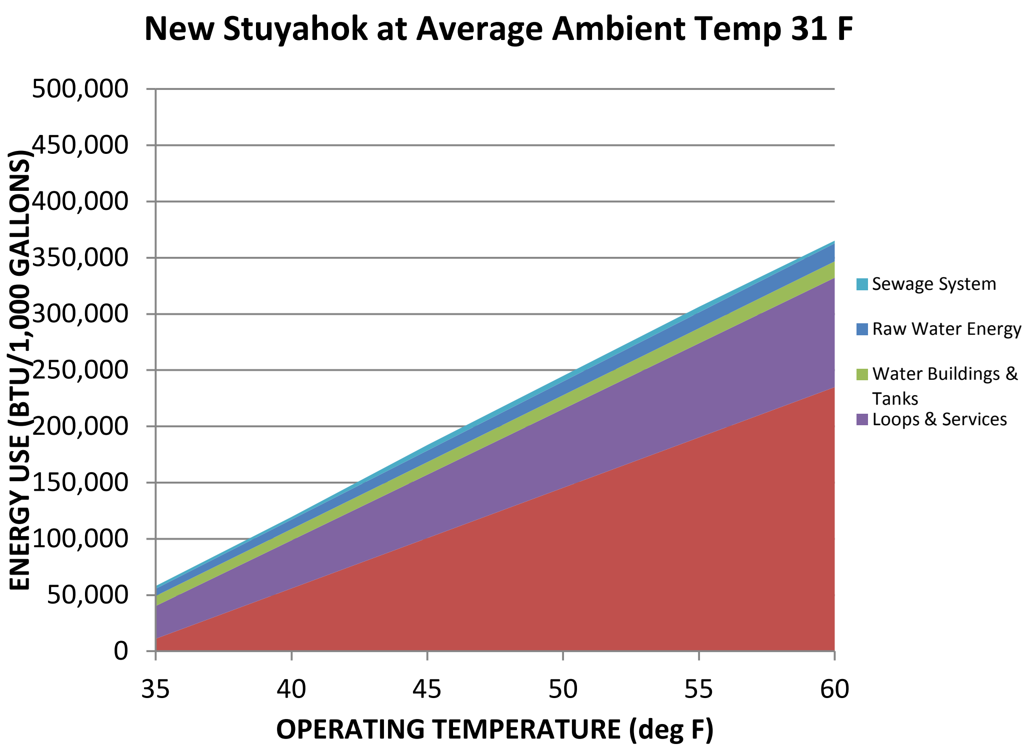


Figure 95: New Stuyahok Energy Use Model for Water & Sewer

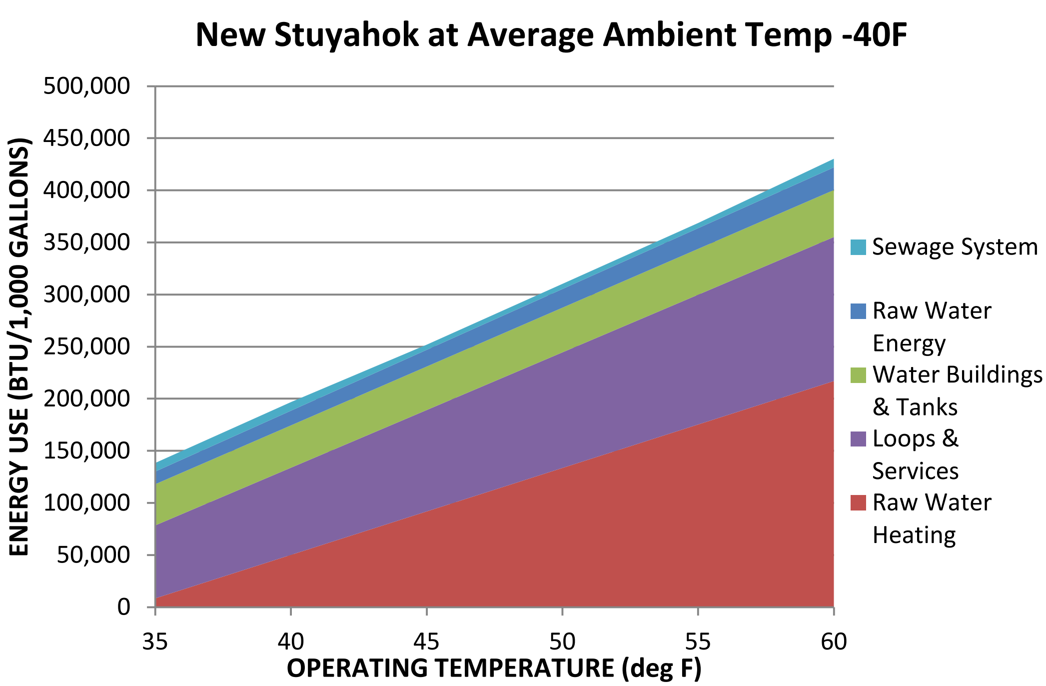


Figure 96: Selawik Energy Use Model for Water & Sewer

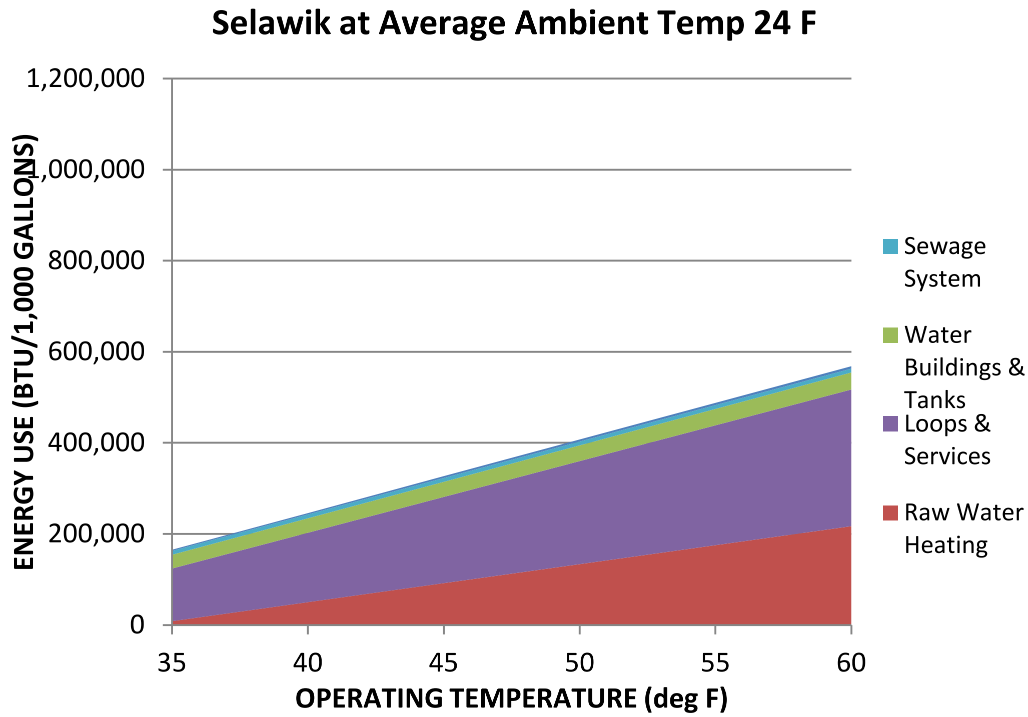


Figure 97: Selawik Energy Use Model for Water & Sewer

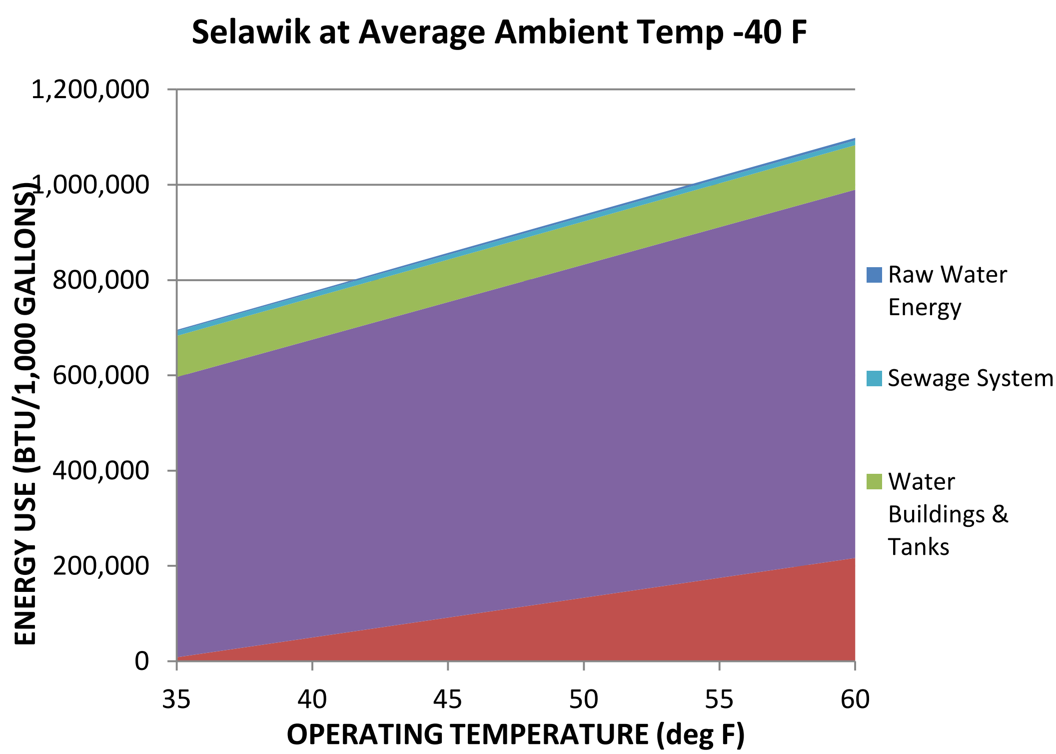


Figure 98: Savoonga Energy Use Model for Water & Sewer

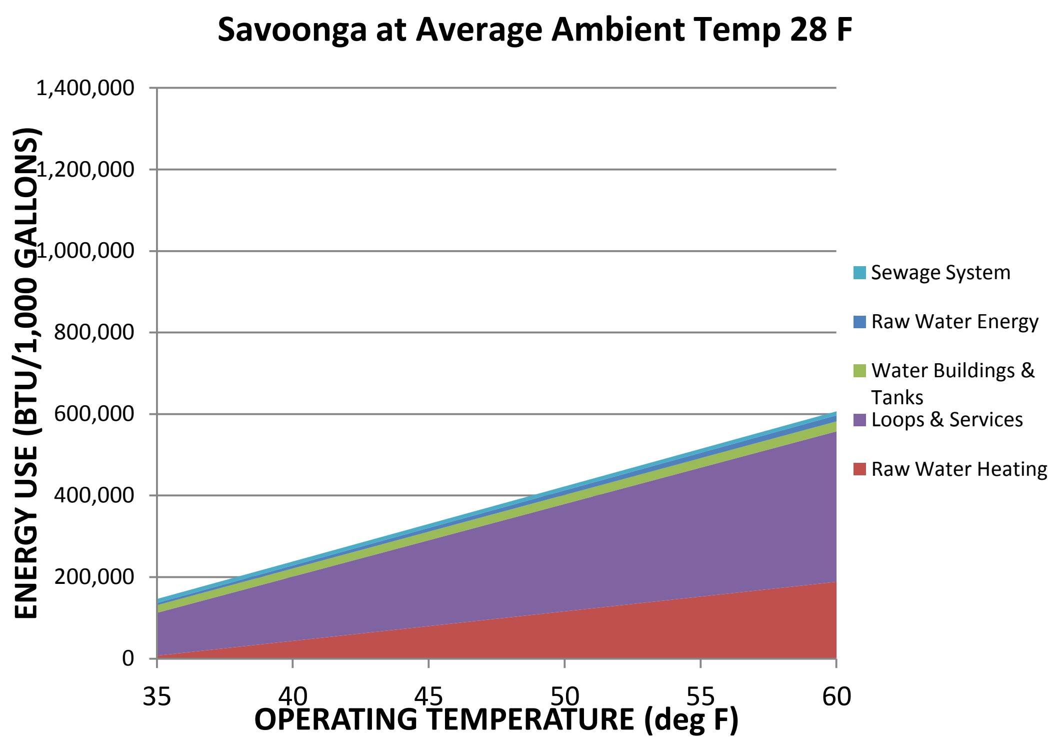
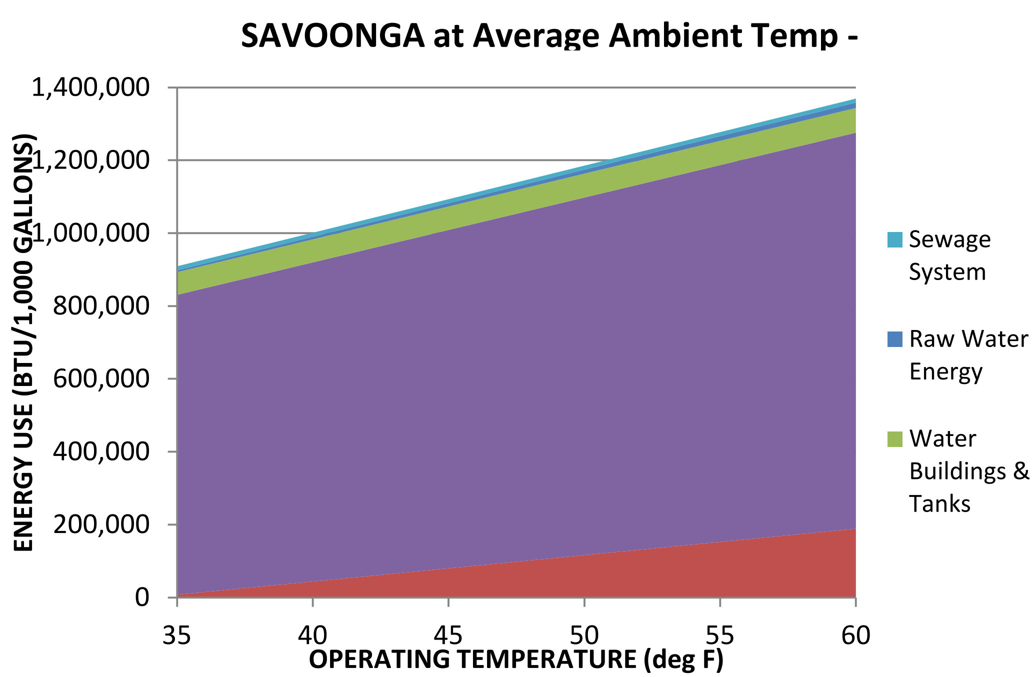


Figure 99: Savoonga Energy Use Model for Water & Sewer



Another way to present the model results is seen in Table 38 through Table 39. For the tabular presentation in this table, a set operating temperature of 45° F has been selected to limit the complexity of the table and also reflect a typical operating temperature.

Table 38: Model Results at AAAT and 45 Deg F Operating Temperature[25][26]

Community	Bethel	New Stuyahok	Savoonga	Selawik
AAAT, deg f	31	31	28	24
Total energy	741,264	133,765	242,586	286,289
Total energy/ 1000 gal	137,526	183,240	385,057	336,811
Percent of energy requirement by component				
Raw water pmp & hl	2.0	5.6	2.8	1.2
Water heating	66.7	54.9	24.0	29.5
Bldgs & tanks	5.6	6.1	6.3	9.8
Loops & svcs heat	11.5	22.3	54.0	45.9
Loops pumping	10.1	8.5	8.5	10.1
Sewage total	4.2	2.7	3.6	3.5

Table 39: Model Results at EWAT and 45 Deg F Operating Temperature

Community	Bethel	New Stuyahok	Savoonga	Selawik
EWAT, deg f	-40	-40	-40	-40
Total energy	1,331,330	183,598	797,799	727,554
Total energy/1000 gal	247,000	251,504	1,266,348	855,946
Percent of energy requirement by component				
Raw water pmp & hl	2.8	6.4	0.8	0.5
Water heating	37.1	36.4	7.3	10.7
Bldgs & tanks	10.8	16.6	5.9	10.4
Loops & svcs heat	38.7	32.5	82.1	73.1
Loops pumping	4.3	6.1	2.9	4.0
Sewage total	5.0	2.0	1.1	1.4

[25] All Energy units are Net BTU/hr

[26] Heat trace loads not included because heat trace should not be needed for normal operating conditions. Energy Demand is calculated in terms of net energy, without regard to Energy Production Efficiency. Energy Use is Energy Demand divided by Energy Production Efficiency. Typical Operating Temperatures are in the range 45 F to 55 F

Table 40: Model Results at Avg Annual Temp and 45 Deg F Operating Temperature

Community	Bethel	New Stuyahok	Savoonga	Selawik
Avg annual temp, deg f	31	31	28	24
Total energy demand, btu/h	741,000	134,000	241,000	277,000
Total energy demand, mmbtu/yr	6,491	1,174	2,111	2,427
Est. Energy production efficiency	.65	.65	.65	.65
Total energy use, mmbtu/yr	9,989	1,803	3,269	3,860

Table 41: Model Results at Avg Annual Temp and 50 Deg F Operating Temperature

Community	Bethel	New Stuyahok	Savoonga	Selawik
Avg annual temp, deg f	31	31	28	24
Total energy demand, btu/h	999,000	179,000	308,000	345,000
Total energy demand, mmbtu/yr	8,751	1,568	2,698	3,022
Est. Energy production efficiency	.65	.65	.65	.65
Total energy use, mmbtu/yr	13,463	2,412	4,151	4,650

Table 42: Model Results at Avg Annual Temp and 55 Deg F Operating Temperature

Community	Bethel	New Stuyahok	Savoonga	Selawik
Avg annual temp, deg f	31	31	28	24
Total energy demand, btu/h	1,257,000	223,000	375,000	413,000
Total energy demand, mmbtu/yr	11,011	1,953	3,285	3,618
Est. Energy production efficiency	.65	.65	.65	.65
Total energy use, mmbtu/yr	16,940	3,005	5,054	5,566

When looking at the results in the graphs or in the table, it is useful to remember that for any given operating temperature, the energy to heat the raw water is the same for all systems. This means that if the percentage of energy use for heating the water is high, the overall system efficiency is high (smaller losses in the rest of the operations). If the percentage of energy use for heating the water is low, then the overall system efficiency is lower (larger losses in the rest of the operations).

The model results have been compared to existing data on system performance where available. This is possible only for the communities of Savoonga and New Stuyahok. In Savoonga, the annual cost of operation for 2010 is reported in the Energy Audit Report to be $64,200, with a fuel cost of $3.10 per gallon and an operating temperature of around 45° F. Using this fuel price, the Savoonga model estimates operating energy costs to be $56,000/year at 40° F and $78,000/year at 45° F. This indicates that the model results are within a reasonable range.

In New Stuyahok, operating energy data is less precise, but estimated by ANTHC to average approximately 50 million BTUs per month. Assuming an operating temperature of 40° F, the Savoonga model estimates the average water utility energy demand to be 61 million BTUs per month.

Data for the Selawik utilities operations is available but the information is not useful due to some operating problems that have been discovered and documented in the ANTHC Energy Audit report. For Bethel, utilities electrical power usage data is available but not fuel usage data.

Conclusions

The main conclusion from these results is that the energy requirements of rural water and sewerage facilities that are operating well and operated properly are dominated by raw water heating and heat losses from the water loops and service connections. Heat losses from water/sewer utility buildings and water tanks come in a distant third in most cases. Raw water delivery and sewerage system energy requirements represent only a small percentage of the total in all cases. Higher operating temperature has predictably higher energy demand and cost. The model demonstrates this clearly and dramatically.

Where it is possible to compare the model results with operating energy requirements in the communities modeled, there is a close fit between the model and the operating data. This is a very encouraging result.

In looking at the results for both AAAT and EWAT conditions, it is apparent that the loop unit heat losses in Savoonga and Selawik are much higher than in New Stuyahok and Bethel. This is a result of the much poorer heat containment properties of utilidors, as in Savoonga and Selawik, compared to the heat containment provided by the buried arctic pipe in New Stuyahok and even the above ground arctic pipe in Bethel. Savoonga has greater water loop heat loss than Selawik because the Selawik system is a mix of above ground arctic pipe and above ground utilidors, while Savoonga has all utilidors.

Comparing Bethel, with above ground arctic pipe, to New Stuyahok, with below ground arctic pipe, it can be seen that there is not much difference between the two systems' performance. New Stuyahok should have less energy required per 1,000 gallons because their pipe is below ground. However, this is offset by New Stuyahok having twice the length of pipe per 1,000 gallons compared to Bethel. Another factor is that Bethel has 4 inches of insulation on their arctic pipe compared with 3 inches on the arctic pipe in New Stuyahok. This is according to the available information and is subject to field verification.

Any model is only as good as the information input. In the case of these four communities, the data available was incomplete but adequate to prepare a reasonable model. However, to be useful, any desktop model must be field verified and field calibrated in order to reliably project actual system performance under a variety of operating conditions.

Recommendations

First and foremost, it is recommended that the models be verified in the field and then calibrated based on actual system performance. Field verification would deal with pipe sizes and lengths, pump sizes, insulation thicknesses, building surface areas, tank sizes and insulation, and raw water temperature. Field verification will assure that the model components accurately represent the actual system to the maximum extent possible. In particular, the sewerage system currently in the model is based primarily on assumptions due to very little data being available. Field verification would also provide data to allow the differentiation of fuel energy and electric energy in the model.

Model calibration would involve the establishment of a data collection and recording process to capture key systems operating parameters under different operating conditions. Once the data has been collected and recorded, the model would be adjusted (calibrated) to match the actual performance as best as possible. For example, the field verified model may estimate a temperature drop of 1°F in a given water loop for a certain operating temperature and a selected ambient temperature, but field observation for the same conditions may be different. The formulas in the model can be adjusted to better reflect the results observed in the field.

A field verified and calibrated model could be a very useful tool for operations and for energy management. The model would allow the operators to adjust the system operating temperature in response to ambient temperature changes to maintain a desired safety factor against the potential of freeze-up. An accurate model would allow managers to select the desired safety factor based on system performance and the projected cost of a range of settings.

Training should be provided to operators and managers regarding the use and limitations of the model. In this regard, the model should be expanded to include the impact and cost of activating emergency measures such as glycol or electric heat trace.

Finally, and assuming the recommendations above are adopted, this energy management tool should be provided to all communities where it is seen to be applicable. By providing a better understanding of the performance of the water and sewer utilities in each community, it will be possible to manage the energy requirements of each system while at the same time minimizing the risk of freezing problems.

Street Lighting- Independent Study

AEA requested energy use data on street lighting to evaluate energy efficiency upgrade opportunities, such as conversion to LED lamps, hi/low dimming coupled with occupancy sensors, etc.[27] This section describes the results of this independent study. A summary of the patterns and results is included. In addition, the results of the survey are provided per community and organized according to AEA energy region. The results provide an overall snapshot of street light usage. The objectives of this street lighting independent study are to:

- Identify street lighting energy efficiency opportunities; and
- Establish statewide baseline energy use data on street lighting in Alaskan communities.

Method

Data was collected and analyzed for units of local and regional government throughout Alaska. During the investigation, it was determined that the Boroughs were not responsible for street lighting. There are a variety of different owners of street lights in different across Alaska. In some areas it was discovered that the Boroughs, like the North Slope, did own and maintain the street lights. Ownership also included:

- Individual City and community ownership;
- State Department of Transportation (DOT); and
- Utility Cooperative.

In some communities, street lights were owned by multiple entities. The report collected information from numerous communities who were willing to participate.

Sample Selection

Data collection forms were sent to 150 Alaskan communities that have some form of government[28] in November 2011. One hundred, twenty-one (121) forms were returned. A summary of the relationship between the size distribution of Alaskan communities, the forms sent out, and the response rate are shown in Table 43. The size characteristics of Alaskan communities who responded to the survey closely resemble all Alaskan communities. Therefore, it appears as if this survey can provide accurate information on the street lighting technologies

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[27] AEA End-use Study- Implementation Plan page 8.

[28] Local Government in Alaska, Alaska Department of Commerce, Community and Economic Development, February 2001, accessed at State of Alaska, 2008,

used by Alaskan communities. Alaska Department of Transportation (ADOT) was targeted as a statewide owner and representative of street lighting infrastructure.

Table 43: Size Distribution of Alaskan Communities and Survey Response Rate

Community Size	2006[29] Census	Forms Sent	Sample (Forms Received)	Response Rate	Communities with Street Lights
100,000 or more	1	1	1	100%	1
10,000-99,999	2	4	3	75%	3
5,000-9,999	8	8	7	88%	6
1,000-4,999	16	20	15	75%	15
100-999	104	88	81	92%	75
Less than 100	19	13	10	77%	9
Total	150	134	117	87%	109

Table 43 also shows that eight communities who returned forms stated that they did not operate streetlights. In addition, four areas have their street lighting services provided in total or in part by the Alaska State Department of Transportation and Public Facilities. Anchorage, Fairbanks, the Mat Su area and the Kenai Peninsula receive DOTPF services.

Data Management

Data received was entered into an Excel spreadsheet. An additional variable on the number of hours each year that a streetlight could be expected to be operating was derived using the data on the annual amount of darkness in Alaskan communities. This allowed for the calculation of Kilowatt hours of street light operation. Information on the amount of light from each specific type of street lighting instrument was estimated. With this additional information, it was possible to estimate both the total power used in street lighting and the amount of light generated. Individual community response records are provided in the appendices. The community size was based on population of each community using community size categories used by the Alaska Division of Community and Regional Affairs.

[29] Estimates of 2006 Alaska City Population, US Census Bureau, US Department of Commerce.

Street Lighting Definitions[30]:

The data collection form asked local governments about their use of various street lighting technologies. Information was collected on the number of luminaires of each type and wattage. A definition of the light sources of the street lighting luminaires on which data were collected is presented below.

Incandescent: It is common type of lamp used in homes, indoors and outdoors. It is the most energy inefficient of the common lamp types. It produces light by electrical energy heating a filament of fine wire that glows white-hot when current flows through it. It produces a great deal of heat relative to the amount of light, only 10 percent of the energy goes to producing light.

Mercury Vapor: It is commonly used for a number of outdoor applications such as "security" lighting, as well as indoors for some applications. These lamps have a quartz tube filled with mercury gas under pressure. Light is produced when an electrical current passes through the mercury vapor. Like all such high intensity discharge (HID) lamps, a "ballast" is required to start and to operate the lamps at the correct voltage and current levels. This is typically a legacy system as few new mercury vapor luminaires are in production today.

Fluorescent (CFL): Fluorescent lamps are gas-discharge lamps that use electricity to excite mercury vapor. The excited mercury atoms produce shortwave ultraviolet light which cause the phosphor coating on the inside of the tube to fluoresce producing visible light. These lamps are approximately four times more efficient than incandescent lamps. In northern climates they are used primarily for indoor applications as colder temperatures inhibit the ability of the phosphor to fluoresce, limiting their outdoor applications in extreme environments.

Metal Halide (MH): These HID lamps are used for both outdoor and indoor applications. They are essentially mercury vapor lamps with additional rare earth metals in the arc tube to provide greater efficiencies, longer life and better color rendering.

Low Pressure Sodium (LPS): These HID lamps have borosilicate glass gas discharge tubes containing solid sodium, small amounts of neon and argon gas in a chemical mixture designed to start the gas discharge. The discharge tube may be linear or U-shaped. These lamps provide a very narrow bandwidth yellow light with virtually no color distinction. This light source is energy efficient but is limited to applications where monochromatic light is acceptable.

[30] Much of this information was taken from Efficient Outdoor Lighting Information Sheet #52, International Dark-Sky Association (IDA), accessed at http://www.darksky.org, January, 2012.

High Pressure Sodium (HPS): Like LPS, these HID lamps use sodium, neon and argon gas. HPS lamps are smaller and contain additional elements such as mercury, and produce a dark pink glow when first struck, and a pinkish orange light when warm. They are reasonably efficient, and have been widely used for outdoor and street lighting, parking lot lighting, and other such applications. It is more energy efficient and has a longer life than metal halide and is a good choice when true color is not critical.

Light Emitting Diode (LED): A light-emitting diode (LED) is a semiconductor light source. When a light-emitting diode is forward-biased (switched on), electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence and the color of the light (corresponding to the energy of the photon) is determined by the energy gap of the semiconductor. LEDs are often small in area (less than 1 mm^2), and integrated optical components may be used to shape its radiation pattern. LEDs present many advantages over incandescent and HID light sources including lower energy consumption, longer lifetime, improved robustness, smaller size, and faster switching. LEDs powerful enough for room lighting are relatively expensive and require more precise current and heat management than compact fluorescent lamp sources of comparable output.

Description of the Street Lighting Sample

Table 44 illustrates the distribution of communities by population. The largest proportion of communities is less than 1000 residents. Eight or about 10% of the smaller communities did not operate streetlights. This should be considered when preparing overall estimates of statewide street lighting energy use.

Table 44: Communities with streetlights by size

Community Size	Communities with Street Lights	
	Number	Percent
100,000 or more	1	.92
10,000-99,999	3	2.75
5,000-9,999	6	5.50
1,000-4,999	15	13.76
100-999	75	68.81
Less than 100	9	8.25
Total	109	

The regional distribution of participating communities is shown in Table 45. Most areas of the state appear to be represented in this data set. This suggests that the information collected may be useful in establishing statewide baseline energy use for street lighting.

Table 45: Participating Communities by AEA Region

AEA Region	Number of Communities	Percent of Communities
Aleutians	9	7.5
Bering Straits	14	11.7
Bristol Bay*	4	3.3
Copper River/ Chugach	4	3.3
Kodiak	2	1.7
Lower Yukon- Kuskokwim	25	20.8
North Slope	1	0.8
Northwest Arctic	11	9.2
Railbelt	17	14.2
Southeast	20	16.6
Yukon-Koyukuk/ Upper Tanana	13	10.8
	120	99.9

*The Bristol Bay Borough chose not to participate in the survey

Summary of Results

Table 46 shows the overall use of different lighting technologies. The sample of communities who provided data for this study used over 3.5 million kilowatt hours of energy to generate over 500,000 lumens of street lighting. HID-High Pressure Sodium fixtures are clearly the most commonly used street lighting technology, using 75% of all electrical power (in Kilowatt hours) and generating 91% of light (in lumens).

Table 46: Street light energy use (Kw hrs) and Illumination (lumens)

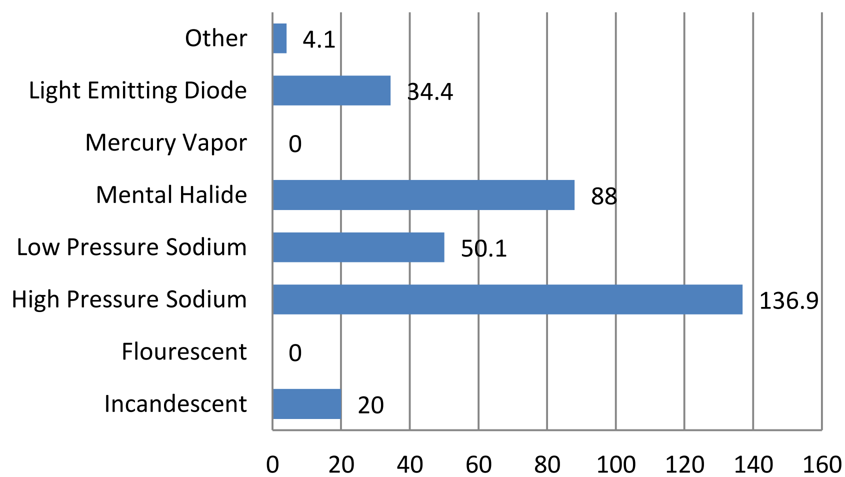
Lighting Type		Number	Percent
Incandescent	Kw hrs	37,875	1.03
	Lumens	755,870	.10
Fluorescent (CFL):	Kw hrs	0	0
	Lumens	0	0
High Pressure Sodium (HPS):	Kw hrs	2,750,295	74.6
	Lumens	450,828,585	91.0
Low Pressure Sodium (LPS):	Kw hrs	35,260	1.0
	Lumens	1,767,320	.3
Metal Halide (MH):	Kw hrs	474,650	12.9
	Lumens	41,786,700	8.4
Mercury Vapor (HID)	Kw hrs	32,325	.9
	Lumens	700	0
Light Emitting Diode (LED)	Kw hrs	343,808	9.3
	Lumens	81000	2.3
Other	Kw hrs	14,435	.4
	Lumens	59,450	0
Total	Kw hrs	3,688,648	
	Lumens	507,012,675	

Lighting Effectiveness

High pressure sodium streetlights are the most effective way of lighting public spaces, as measured by the number of lumens generated per kilowatt of power. Metal halide street lighting is the second most efficient instrument. The comparative effectiveness of these instruments is shown below.

Fewer communities are using newer and more efficient light emitting diode instruments for street lighting. Comments from survey respondents suggest that a majority of communities who use LED technology are satisfied with the results and have seen energy savings because of them. Many of these communities were able to switch to LED technology because of grant and funding assistance. Financial incentive is the key decision factor on why a community converts to LED or not.

Figure 100: Street Lighting Lumens per Kilowatt



Total energy use by community size

Table 47 presents data on the distribution of street lighting kilowatt hours and the amount of light each type of street lighting instrument can generate for communities of different sizes. Data is presented in thousands. The table shows that smaller communities are using more incandescent street lighting instruments than larger communities.

Table 47: Street lighting instrument energy use and brightness by community

Lighting Type	In Thousands	Community Size						
		Less than 100	100-999	1,000-4,999	5,000-9,999	10,000-99,999	100,000 or more	Total Use or Brightness (1000)
Incandescent	Kw hrs	.3	3.1	0	34.5	0	0	37.9
	Lumens	20.8	215.0	0	520.1	0	0	755.9
Fluorescent (CFL):	Kw hrs	0	0	0	0	0	0	0
	Lumens	0	0	0	0	0	0	0
High Pressure Sodium (HPS):	Kw hrs	9.5	286.8	385.8	663.1	577.1	825.0	2750.3
	Lumens	671.6	21804.3	40177.8	102052.9	82602.0	203.520	450828.6
Low Pressure Sodium (LPS):	Kw hrs	0	0	35.3	0	0	0	35.3
	Lumens	0	0	1767.3	0	0	0	1767.3
Metal Halide (MH):	Kw hrs	0	14.3	16.7	18.8	0	425.0	474.7
	Lumens	0	894.4	979.8	1312.5	0	38600.0	41786.7
Mercury Vapor (HID)	Kw hrs	0	13.1	11.1	0	18.2	0	32.3
	Lumens	0	.7	0	0	0	0	.7
Light Emitting Diode (LED)	Kw hrs	0	22.7	139.3	38.4	143.4	0	343.8
	Lumens	0	748.0	5318.2	1633.0	4114.9	0	11814.1
Other	Kw hrs	0	1.0	.3	13.1	0	0	14.1
	Lumens	0	59.5	0	0	0	0	59.5
Total	Kw hrs	1	343.9	578.3	767.9	738.7	1250.0	3688.6
	Lumens	692.4	23447.4	48243.1	104988.9	86716.9	242120.0	50619.4

Average street light energy use and illumination by community size

It appears as if the data in this street lighting survey is representative of community street lighting practices across Alaska. While there appear to be variations in the choice of street lighting technologies, the survey can be useful in preparing a baseline and use energy estimates for communities of various sizes. Table 48 shows the average street lighting energy use in thousands of kilowatt hours and the amount of brightness generated by the street lighting technology chosen by communities of various sizes.

Table 48: Average street light energy use and illumination by community size

Lighting Type	In Thousands	Community Size					
		Less than 100	100-999	1,000-4,999	5,000-9,999	10,000-99,999	100,000 or more
Incandescent	Kw hrs	33.3	41.33	0	5745.8	0	0
	Lumens	2311.7	2866.47	0	86680.0	0	0
Fluorescent (CFL):	Kw hrs	0	0	0	0	0	0
	Lumens	0	0	0	0	0	0
High Pressure Sodium (HPS):	Kw hrs	9500	3864.0	25718.0	110520.8	192366.7	825000
	Lumens	671600	290.724.1	2678517.3	170008823	27533993	203520000
Low Pressure Sodium (LPS):	Kw hrs	0	0	2350.7	0	0	0
	Lumens	0	0	117821.3	0	0	0
Metal Halide (MH):	Kw hrs	0	190.0	1110.0	3125.0	0	4250000
	Lumens	0	11925.3	65320.0	218750.0	0	38600000
Mercury Vapor (HID)	Kw hrs	0	9.33	70.0	0	6050	0
	Lumens	0	302.0	0	0	0	0
Light Emitting Diode (LED)	Kw hrs	0	302.0	9286.0	6405.8	0	0
	Lumens	0	10108.1	354546.7	272158.3	0	0
Other	Kw hrs	0	13.3	300	0	0	0
	Lumens	0	792.7	0	0	0	0

Many of the communities utilizing LED technology have a population between 100 and 10,000, while larger municipalities and cities have not yet converted. Most cities that have not already converted remain unable to afford the technology; while many of the utility cooperatives provide lighting for a flat rate and the energy savings from LEDs would not bring financial benefits to the utility provider or the customer.

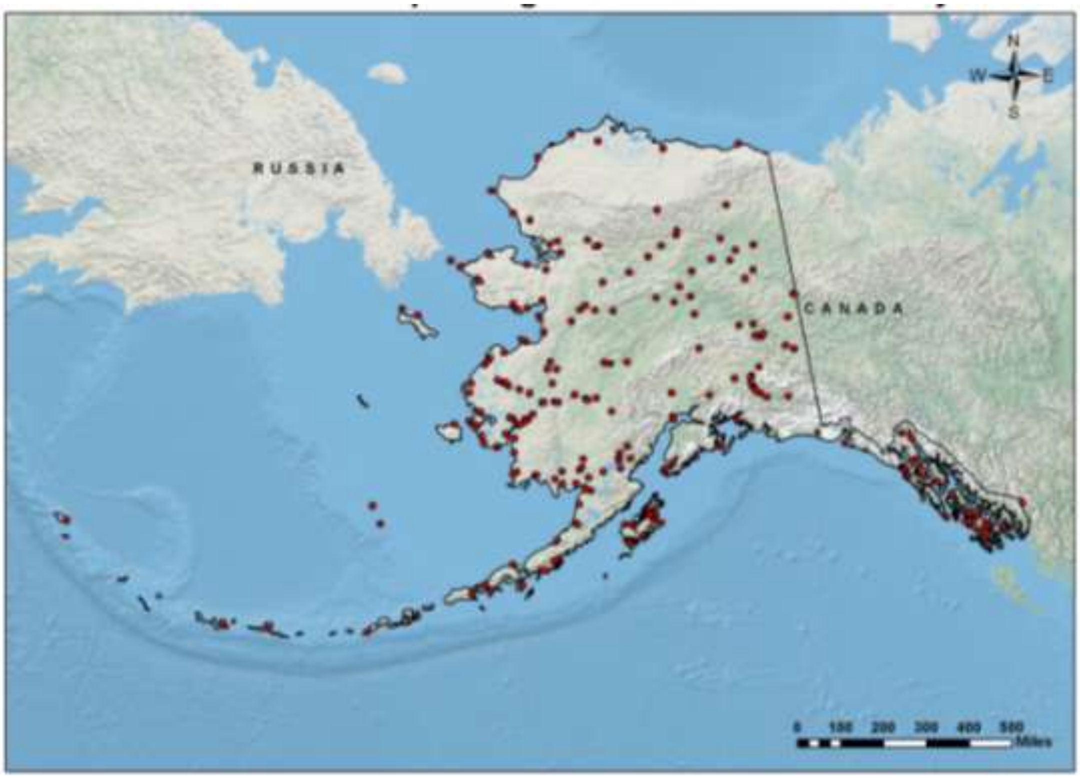
Traffic light instruments

There is insufficient survey data to develop baseline data on the choice of traffic light technology by Alaskan communities.

Non-Residential Rural Building-Independent Study

The primary purpose of this study is to provide energy end-use benchmark details for non-residential buildings in rural Alaska. Other sections of this report present information on non-residential energy end-use data for communities in the Rural, Railbelt and Southeast Alaska energy regions. This following section will provide information on sampling methods, data collection strategies, conclusions, and a general assessment of the data collected. Figure 101 highlights the geographic dispersion of communities.

Figure 101: Non-residential community response



Sampling Method

The list of communities that were initially considered for inclusion in the study included 390 communities, before being trimmed to 219. The criteria used for inclusion of communities in the study included the communities that are Rural; Communities that are not considered hub communities; and Communities with a population of less than 1,000 residents. In some cases, data was not collected for communities on the final list because they were found to be only seasonally occupied, or it was impossible to obtain current contact information.

It was decided that the list of building types included in the study would be narrowed to the following types of facilities: city offices, tribal offices, village corporation offices, clinics, schools, grocery stores, post offices, churches and water and sewer facilities. The research team also felt that the buildings included in this list are common to most rural, non-hub communities in Alaska. The list of communities was divided by ANCSA regions, and assigned to the research team. A list of questions was developed for each surveyor to use as a guide when conducting the telephone interviews[31].

Conclusions

Building Types

There were a total of 1,938 recorded attempts to gather commercial/public building information. Table 49 summarizes the building types and corresponding sub-types of the buildings included in this study.

Table 49: Non-Residential Building Types Represented

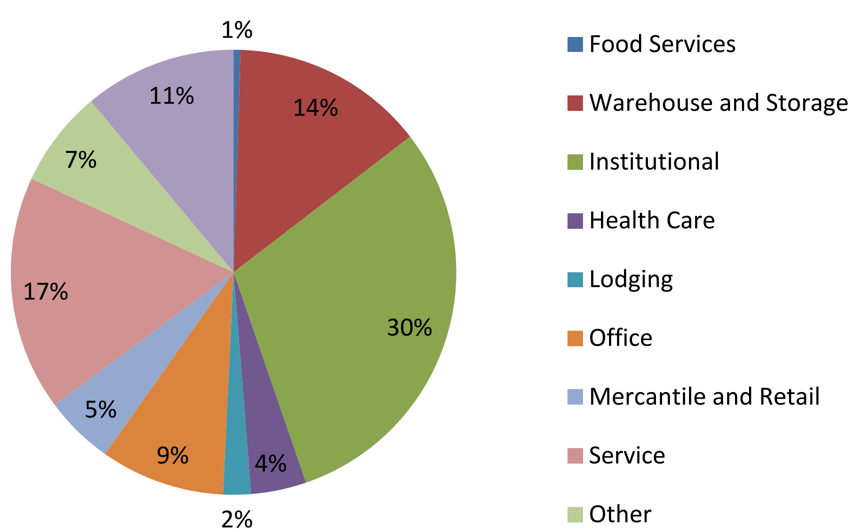
Building Type	Sub Type	Count	Percent
Food Services	Restaurant	5	0%
	Food Stand	0	0%
	Fast Food	0	0%
	Bar/Lounge	4	0%
	Night Club	0	0%
Warehouse and Storage	Hangar	4	0%
	Refrigerated Warehouse	3	0%
	Warehouse - General	262	14%
Institutional	Education	360	19%
	Public Assembly	33	2%
	Public Order and Safety	85	4%
	Religious Worship	71	4%
	Library	11	1%
	Cemetery	0	0%
	Institutional - Other	31	2%
Health Care	Health Care - Inpatient	9	0%
	Health Care - Outpatient	65	3%
	Nursing Home	0	0%
Lodging	Hotel/Motel	14	1%
	Dormitories	10	1%
	Home for the Elderly	0	0%
	Lodging - Other	18	1%

[31] Building owners/occupants were initially contacted by telephone. While the majority of data was collected through verbal contact, quite often respondents preferred to submit the information by facsimile or email. Attempts to collect information for each building or building owner (when multiple buildings were owned by the same entity) was limited to 3 attempts.

Building Type	Sub Type	Count	Percent
Office	Office	180	9%
Mercantile and Retail	Strip Malls	0	0%
	Enclosed Malls	0	0%
	Food Retail	78	4%
	Retail - Other	25	1%
Service	Cinema/Theater	0	0%
	Automotive Oriented Services	56	3%
	Spa/Salon	0	0%
	Communication	3	0%
	Service - Other	261	13%
Other	Parking	17	1%
	Sports Facilities	3	0%
	Multipurpose	51	3%
	Miscellaneous	70	4%
Not Recorded		209	11%
	Total	1938	100%

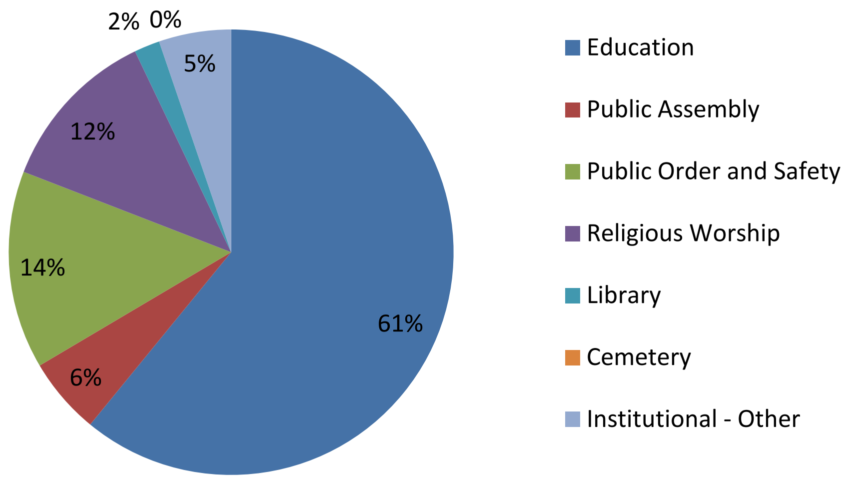
Figure 102 depicts the percentages of the types of all buildings included in the study. Institutional buildings represent 30% of all buildings included in the study, while only 1% of the buildings are in the food services category. The building type and sub-types were not recorded for 11% of the buildings in the study.

Figure 102: Distribution of Building Types



Buildings in the institutional type category make up about 30% of all buildings in the study. Figure 103 shows the distribution of institutional building sub-types. The majority of these buildings, or 61%, are schools or buildings affiliated with education. Also included in this building type were public order and safety (14%), religious worship (12%), public assembly (6%), institutional-other (5%), and the library (2%) sub-types. There were no buildings in the cemetery sub-type category.

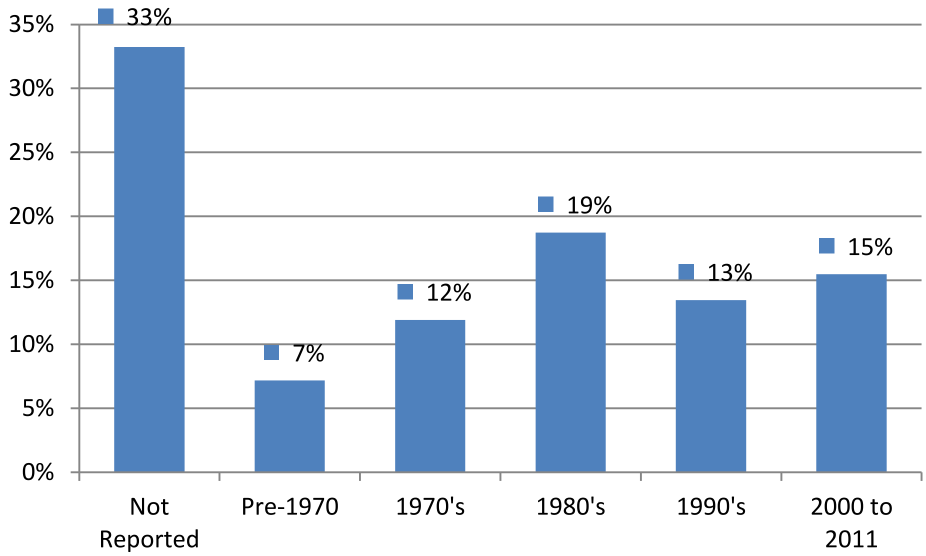
Figure 103: Distribution of Institutional Building Sub-Types



Building Construction

Figure 104 shows the percentages of buildings included in the study by the decade they were built. The year built was not reported for about a third (33%) of the buildings in the study. Seven percent of the buildings included in the study were built before 1970, 12% in the 1970's, 19% in the 1980's, 13% in the 1990's, and 16% between the year 2000 and 2011. The figure also shows the number of buildings that were constructed in each energy region by decade. Many of the survey respondents were unsure about the exact year of building construction, but in such cases approximate years or decades were provided.

Figure 104: Building Construction by Decade

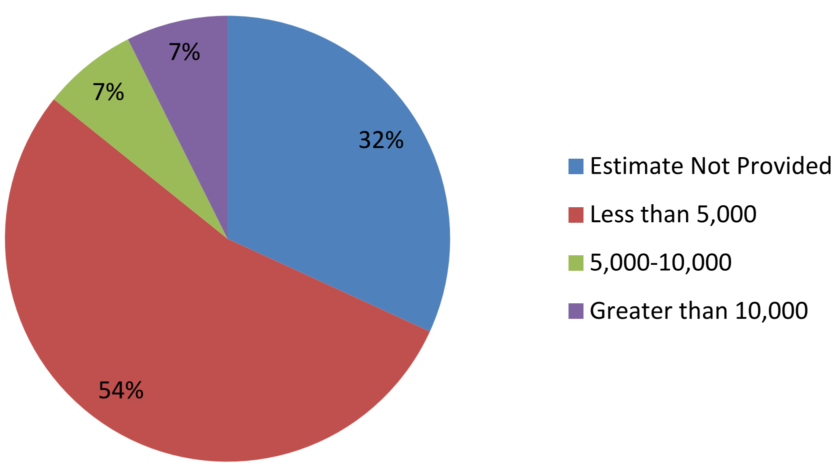


Building Size

Respondents were asked to provide the building size in square feet. When respondents did not know the exact measurements, they were asked for approximations.

Figure 105 shows that 54% of all buildings included in the study are less than 5,000 square feet. Seven percent of the buildings in the study were between 5,000 and 10,000 square feet, and 7% of the buildings were greater than 10,000 square feet in size. A size approximation was not provided for 32% of the buildings included in the study.

Figure 105: Building Size (square feet)



Fuel Usage

Respondents were asked what types of fuel were used to heat the buildings. They were then asked for approximations on the amount of fuel used on an annual basis. It is reported that 92% of the non-residential buildings included in the study are heated with fuel oil (see Figure 106.) Three percent of the buildings reportedly use burn wood for heat, followed by propane and waste heat used by 2% of the buildings in the study. Less than 1% of buildings included in the study use electricity or natural gas for heat, or are not heated at all.

Figure 106: Fuel Types

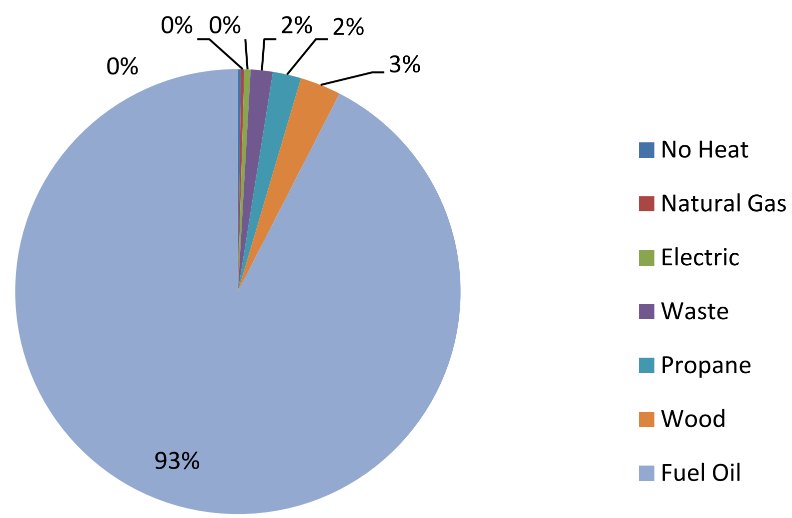
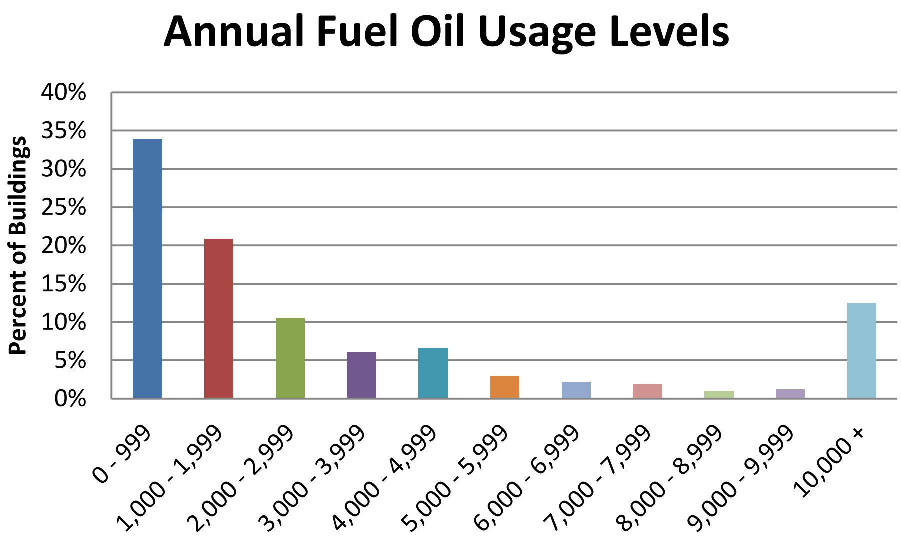


Figure 107 depicts the fuel oil annual usage rates. According to this figure, about 34% of all building occupants/owners in the study reported using between 0 and 999 gallons of fuel oil on an annual basis. Twenty-one percent of buildings use between 1,000 and 1,999. The percentage of buildings using increasing gallons of fuel oil on an annual basis steadily declines, until the 10,000 or more gallons level is reached. At this point about 13% of all buildings included in this study reportedly use 10,000 or more gallons of fuel oil on an annual basis.

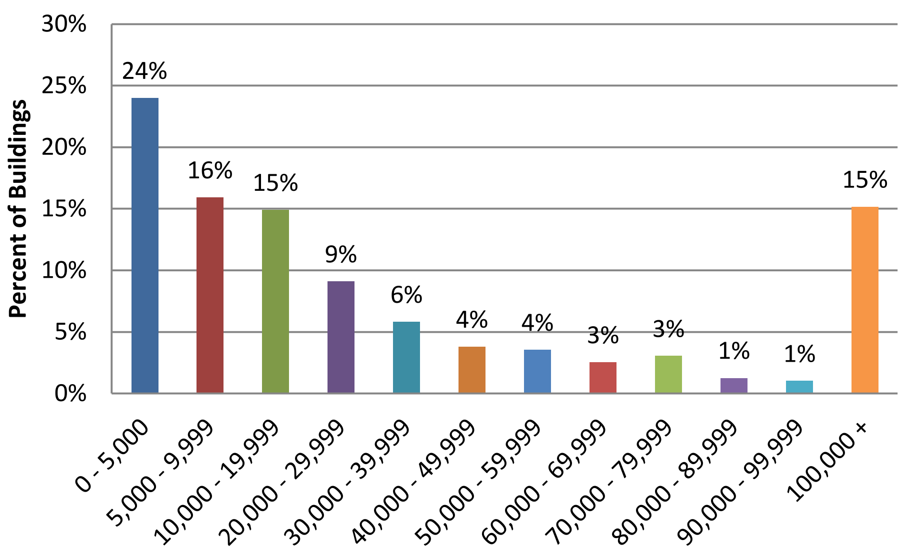
Figure 107: Annual Fuel Oil Usage



Annual Electricity Usage

Figure 108 depicts the annual electricity usage rates. About 24% of all building occupants/owners in the study reported using between 0 and 5,000 kilowatt hours on an annual basis. Sixteen percent of buildings use between 5,000 and 9,999. The percentage of buildings using increasing amounts of electricity on an annual basis steadily declines, until the 100,000 or more kilowatt hour level is reached. At this point about 15% of all buildings included in this study reportedly use 100,000 or more kilowatt hours on an annual basis.

Figure 108: Annual Electricity Usage



Statewide Energy Use by Sector

Introduction

The AEA End-use Study Implementation Plan stated that "the team will work with AEA to obtain total sector energy use summaries."[32] This section assumes that the purpose for this data is to help establish the baseline for setting the goal of increasing energy efficiency by 15% by the year 2020[33] as described in the section at the front of this report. Therefore, this section uses available energy consumption statistics to forecast energy use by the year 2020. In addition, the research team has developed a simple strategy to benchmark energy end-use dating back to 2010. The four basic sectors are industrial, residential, commercial and transportation.

Method

Data for this analysis was compiled by the US Energy Information Administration, and included in the State Energy Information System database.[34] The database includes information from 1960 through 2009. The available US Energy Information Administration provides summary energy use information using trillions of BTUs to describe energy use by year for each of the four major sectors. Detailed data on the number of trillions of BTUs by energy use sector and the proportion of total energy use is shown in the appendices. The lack of comparable data on residential or non-residential data square footage prevents an analysis of energy use on a per-square-foot basis. Appropriate denominators for transportation and industrial sectors have yet to be identified. Therefore, this analysis is limited to annual basic energy use statistics.

Forecasting is concerned with making educated guesses as to what will happen at some future time. The choice of the forecasting technique was limited by the specificity of the data. In this analysis, the independent variable is time (years from 1960 through 2009) and the dependent variable is trillions of BTUs. This limitation led to the selection of the use of a straight line (linear) least squares trend equation.[35]

Two alternative time frames were chosen following a review of the historical data. The first trend was developed using all annual data from 1960 through 2009. However, the total energy use appeared to begin a decline about the year 2000. For this reason, a second trend line was

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32 AEA End use Study Implementation Plan Final, WHPacific, September 1, 2011, Section 3.2 .1, page 8

33 Ibid, p. 4.

34 US Energy Information Administration, State Energy Information System, Alaska, Tables CT4, CT5, CT6 and CT7, Accessed at EAI.DOE.gov, January 2012.

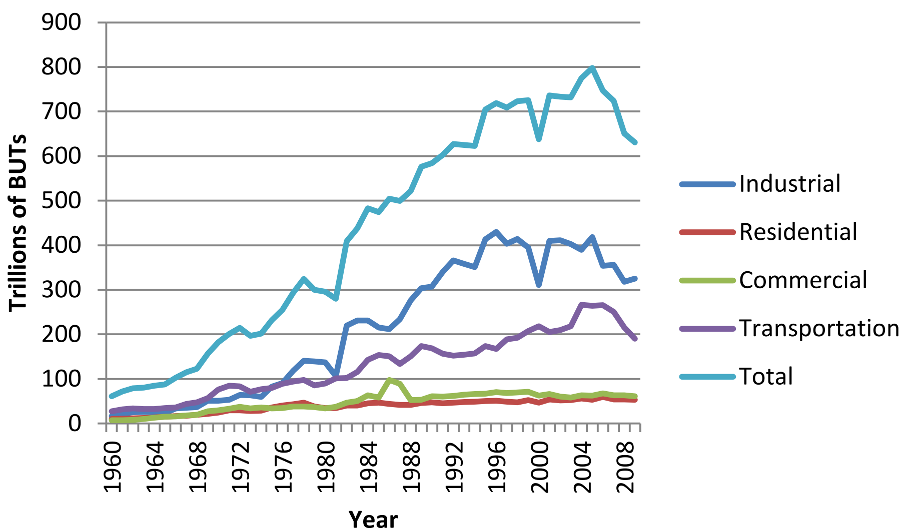
35 Hanke, JE, Reitsch, AG, Business Forecasting, Allyn and Bacon,1981, pp145-162.

developed using annual data from 2002 through 2009 to project future energy use. Forecasts were prepared using an Excel Forecasting function.

Overall Energy Use by Sector

Figure 109 shows total energy consumption by each sector (industrial, residential, commercial and transportation) from 1960 through 2009. An ordinary least squares trend line is presented to highlight the decrease in total energy consumption as well as the energy consumption in industrial and transportation sectors that appears to have started around 2002. The reason for this decrease in energy use is unclear.

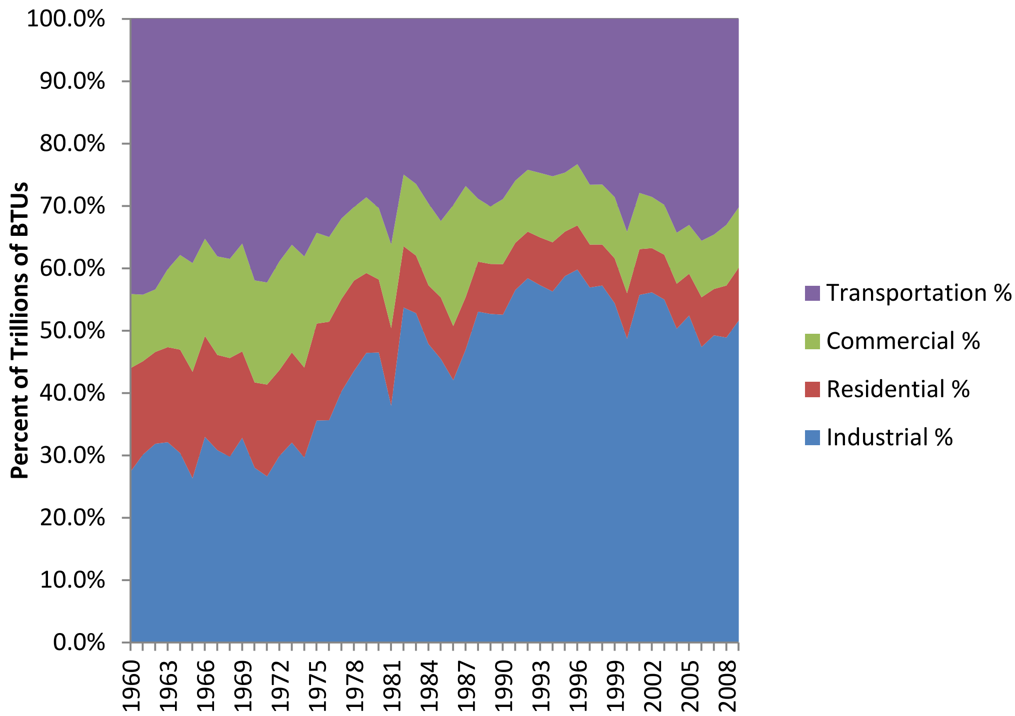
Figure 109: Alaska Energy Consumption Estimates and Trends



Energy Consumption by Sector

Figure 110 shows the proportion of energy use by each of the four sectors from 1960 through 2009. Clearly, the industrial sector uses the largest proportion of the energy used in Alaska. The second-largest user is the transportation sector. Commercial and residential sectors have been using about 10% of Alaska's energy over the last 15 years. This data is shown in detail in the appendices.

Figure 110: Percent Energy Consumption by Sector



Preliminary Energy Use Forecasts

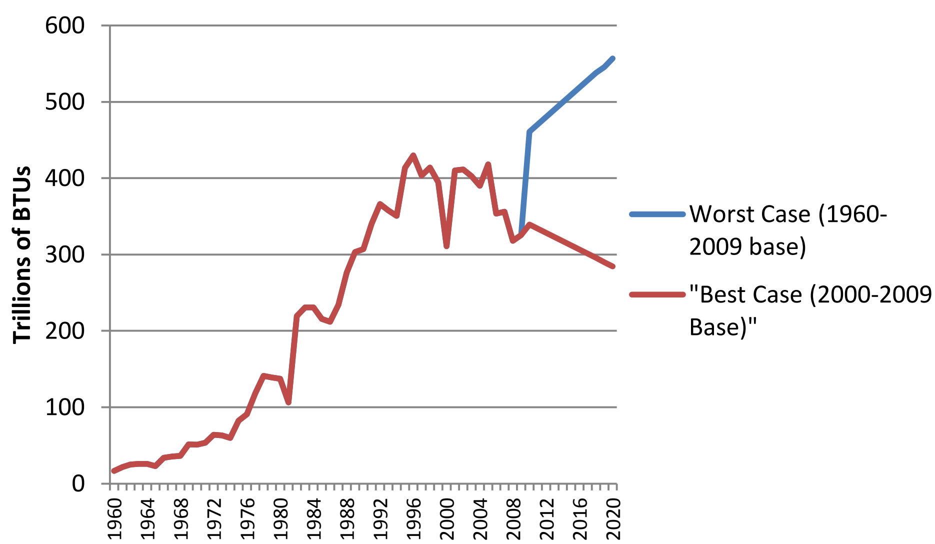
A linear projection of energy use for each sector using the energy use data from 1960 through 2009 shows a continued increase in energy use. However, energy use in recent years (2000-2009) appears to show a slight decline. These differences could influence the decision on the base time period that the AEA may choose in selecting its baseline measure.

Figure 111 uses two different periods to project energy use for each of the four sectors from 2010 through 2020. Each forecast uses the least squares approach, but changes the number of years included in the calculation of the linear forecast. The results show a dramatic difference. The use of all of available data shows a continued rise in energy use by all sectors through 2020. Using just the last nine years of data, data which highlights the recent decline in energy use, results in a projection of continued declines in energy use. The forecasts are shown graphically in Figure 111.

Table 50: Energy use forecasts by industrial sector, 2010 through 2020

Year	Industrial		Residential		Commercial		Transportation	
	1960-2009	2000-2009	1960-2009	2000-2009	1960-2009	2000-2009	1960-2009	2000-2009
2010	461	339.5	62.1	56.6	80.2	63	250.8	235.9
2011	470.6	334	63.1	57.2	81.5	63	255.5	236.9
2012	480.2	328.4	64	57.7	82.8	63	260.1	237.9
2013	489.9	323	64.9	58.3	84.1	63	264.8	238.9
2014	499.5	317.5	65.8	58.8	85.4	63.1	269.5	239.9
2015	509.1	312	66.7	59.4	86.7	63.1	274.2	240.9
2016	518.7	306.6	67.7	59.9	88	63.1	278.9	241.9
2017	528.3	301.1	68.6	60.5	89.3	63.1	283.6	243
2018	537.9	295.6	69.5	61.1	90.6	63.2	288.3	244
2019	545.5	290.1	70.4	61.6	91.8	63.2	293	245
2020	557.1	284.6	71.3	62.2	93.1	63.2	297.7	246

Figure 111: Alternative Industrial Energy Use Projections



Conclusions

Industrial energy use comprises about half of all energy used in Alaska. The transportation sector uses another 30% of Alaska's energy. Residential and commercial sectors each use about 10% of Alaska's energy.

Energy use in Alaska appears to be marginally declining. However, declines in energy use in the industrial and transportation sectors are more pronounced than changes in the residential or commercial sectors.

The interpretation of changes in energy use may benefit from the use of denominators. For example, using population as the denominator for residential energy use might give a more appropriate and defensible number for use in long-term energy use forecasts. Similarly, using total state economic output as a denominator for industrial energy use may help to better explain changes in long-term use and result in more reasonable forecasts.

AEA should be cautious in selecting the time period that it will use in developing forecasts. Clearly, the use of all available data yields a far different forecast than one which relies on the last 10 years of available data.

One possible approach for converting data collected in 2011 to estimated energy use in 2010 is to use the alternative energy forecasts shown in Table 50 to adjust more recent data. The table shows that residential energy use has increased between 1 and 1.4%, depending on the basic projection. The difference between 2010 and 2011, therefore, is a 1.6% increase (using 50 years of data for the projection) or 1.06% (using the past 10 years of data).

The 2011 residential survey data could be adjusted using the annual proportional increase, the rate of increase being chosen by AEA. A similar method could be used to adjust the nonresidential end-use energy calculations by applying commercial sector forecasts.

Table 51: Total Alaska Energy Use by Sector-1960-2009

Year	Trillions of BTUs					Percent of All BTUs			
	Industrial	Residential	Commercial	Transportation	Total	Transportation %	Industrial %	Residential %	Commercial %
1960	16.8	10.2	7.3	27.1	61.4	44.1%	27.4%	16.6%	11.9%
1961	21.7	10.8	7.7	31.9	72.1	44.2%	30.1%	15.0%	10.7%
1962	25.1	11.6	7.9	34.2	78.8	43.4%	31.9%	14.7%	10.0%
1963	25.9	12.3	10.1	32.4	80.7	40.1%	32.1%	15.2%	12.5%
1964	25.8	14.1	12.9	32.2	85	37.9%	30.4%	16.6%	15.2%
1965	23.1	15	15.3	34.4	87.8	39.2%	26.3%	17.1%	17.4%
1966	33.8	16.6	16	36.2	102.6	35.3%	32.9%	16.2%	15.6%
1967	35.5	17.6	18.2	43.9	115.2	38.1%	30.8%	15.3%	15.8%
1968	36.5	19.4	19.5	47.2	122.6	38.5%	29.8%	15.8%	15.9%
1969	51.4	21.7	27.1	56.5	156.7	36.1%	32.8%	13.8%	17.3%
1970	51	24.9	29.8	76.4	182.1	42.0%	28.0%	13.7%	16.4%
1971	53.5	29.6	32.9	85	201	42.3%	26.6%	14.7%	16.4%
1972	64.1	29.5	37.4	83.4	214.4	38.9%	29.9%	13.8%	17.4%
1973	63.1	28.5	34	71.4	197	36.2%	32.0%	14.5%	17.3%
1974	59.7	29.1	35.9	76.8	201.5	38.1%	29.6%	14.4%	17.8%
1975	82.6	36.1	33.8	79.7	232.2	34.3%	35.6%	15.5%	14.6%
1976	90.7	40.2	34.6	89.1	254.6	35.0%	35.6%	15.8%	13.6%
1977	118.2	43.5	37.9	94	293.6	32.0%	40.3%	14.8%	12.9%
1978	141	47	38.2	97.9	324.1	30.2%	43.5%	14.5%	11.8%
1979	139.1	38.4	36.4	85.8	299.7	28.6%	46.4%	12.8%	12.1%
1980	137.5	34.6	33.9	89.8	295.8	30.4%	46.5%	11.7%	11.5%
1981	106.1	34.8	37.5	101.2	279.6	36.2%	37.9%	12.4%	13.4%
1982	219.6	40.2	47	102.2	409	25.0%	53.7%	9.8%	11.5%

Year	Trillions of BTUs					Percent of All BTUs			
	Industrial	Residential	Commercial	Transportation	Total	Transportation %	Industrial %	Residential %	Commercial %
1984	231	45.5	63.3	143	482.8	29.6%	47.8%	9.4%	13.1%
1985	215.6	46.8	58.1	153.9	474.4	32.4%	45.4%	9.9%	12.2%
1986	212	43.8	97.8	150.7	504.3	29.9%	42.0%	8.7%	19.4%
1987	234.3	42	88.9	133.9	499.1	26.8%	46.9%	8.4%	17.8%
1988	276.5	41.8	52.6	150.5	521.4	28.9%	53.0%	8.0%	10.1%
1989	303.4	46.2	53.1	173.4	576.1	30.1%	52.7%	8.0%	9.2%
1990	306.9	47.4	60.9	168.9	584.1	28.9%	52.5%	8.1%	10.4%
1991	340.5	45.6	60.1	156.4	602.6	26.0%	56.5%	7.6%	10.0%
1992	366.2	46.9	62.2	151.9	627.2	24.2%	58.4%	7.5%	9.9%
1993	357.8	47.9	64.6	154.5	624.8	24.7%	57.3%	7.7%	10.3%
1994	350.6	49.2	65.9	157.4	623.1	25.3%	56.3%	7.9%	10.6%
1995	413.6	50.3	66.6	173.7	704.2	24.7%	58.7%	7.1%	9.5%
1996	429.7	50.9	70.6	167.6	718.8	23.3%	59.8%	7.1%	9.8%
1997	403.4	48.8	68	188.7	708.9	26.6%	56.9%	6.9%	9.6%
1998	413.9	47.6	69.6	192.3	723.4	26.6%	57.2%	6.6%	9.6%
1999	394.5	52.2	71.2	207.5	725.4	28.6%	54.4%	7.2%	9.8%
2000	310.7	46.5	62.8	217.9	637.9	34.2%	48.7%	7.3%	9.8%
2001	410	54	66.3	205.5	735.8	27.9%	55.7%	7.3%	9.0%
2002	411.4	52	60.2	209.4	733	28.6%	56.1%	7.1%	8.2%
2003	402.5	52.6	58.5	218.5	732.1	29.8%	55.0%	7.2%	8.0%
2004	389.9	55.9	63.4	266	775.2	34.3%	50.3%	7.2%	8.2%
2005	418.1	53.5	62.4	263.8	797.8	33.1%	52.4%	6.7%	7.8%
2006	353.7	59.6	67.6	265.9	746.8	35.6%	47.4%	8.0%	9.1%
2007	356.3	53.8	63.1	250.5	723.7	34.6%	49.2%	7.4%	8.7%
2008	318.1	54.3	63.3	215.1	650.8	33.1%	48.9%	8.3%	9.7%
2009	325.4	53.4	61	190.6	630.4	30.2%	51.6%	8.5%	9.7%

AEA End-use Study Conclusions

This final section suggests preliminary conclusions from this baseline study's extensive energy end-use research in residential and non-residential buildings in the Railbelt, Southeast, and rural region. It also includes conclusions on the targeted independent studies undertaken.

Railbelt and Southeast Residential Energy Use

The average residence in Railbelt and Southeast Alaska regions uses 269 MMBTUs in energy each year, for a total energy use of 59 million MMBTUs. This estimate is based on calculations of energy use on different types of residences in each of Climate Zones 6, 7 and 8. Mean energy use values for each residence type were applied to the total number of residences within each region, according to the 2010 US Census.

Residents of Railbelt and Southeast Alaska use about 80% of their total energy (in MMBTUs) to heat their homes. The balance of the energy use is divided between hot water heating (12%) and the energy required to power electrical appliances (8%). The proportion of the energy dedicated to home heating increases with more northerly Climate Zones.

Single family detached residences use more energy than other types of residences. Single family residences use 334 MMBTUs of energy each year. Single family attached homes are the second highest energy users, with 264 MMBTUs per year, followed by mobile homes (249) and multifamily residences (multifamily apartments and condominiums), which use 176 MMBTUs each year.

Natural gas is the primary fuel for home heating in 64% of households in Railbelt and Southeast Alaska. Half (50%) of the homes in Southeast Alaska (Climate Zone 6) rely on oil as the primary heating fuel. Southcentral (Climate Zone 7) residences prefer natural gas (58%), while oil is the primary (66.7%) heating fuel in Climate Zone 8.

Domestic hot water uses between 9% and 11% of energy in Railbelt and Southeast Alaskan homes. The most commonly used primary water heating fuel in Climate Zones 6 and 8 is electricity, where people in Climate Zone seven are evenly split between natural gas and electricity to generate domestic hot water.

Electrical appliances use between 8% and 10% of all MMBTUs among respondent households in Railbelt and Southeast Alaska. Households in Southeast Alaska (Climate Zone 6) use slightly more energy (21.5 MMBTUs) than those in either Climate Zone 7 (22.9) or Climate Zone 8(22.5.)

The operation of major appliances such as refrigerators, freezers, washers and dryers is the largest single residential use of electrical energy in all the Climate Zones within Railbelt and Southeast Alaska (24% of electrical energy). The next highest electrical energy use is in the production of domestic hot water (14%.) Primary cooking accounts for about 10% of all residential electrical energy use. Electrical energy used for information technology and entertainment devices account for another 17% of MMBTUs. Interior and exterior lighting account for only 6%.

Mobile homes have the highest level of energy intensity (kBTU/sq ft/year) for space heating. Domestic hot water production and the operation of electrical appliances are also higher in mobile homes.

Primary cooking is the second highest energy use for all fuel types at 26%.

Railbelt and Southeast Non-residential Energy Use

Based on average energy use by various non-residential building types, Railbelt and Southeast Alaska regions use over 29,974.000 MMBTUs of energy each year. This estimate is based on calculations of energy use in different types of non-residential buildings in each of Climate Zones 6, 7 and 8. Mean energy use values were applied to the total number of non-residential buildings within each region.

It is important to estimate both the total energy use in MMBTUs and the energy intensity in kBTUs per square foot. The first measure shows the total amount of energy by building type. It allows for a general understanding of the distribution of end uses within each facility type. However, it does not account for the size of the facility. Measuring energy intensity resolves this problem by dividing the total energy use by the square foot of the building. It also provides a baseline measurement for energy use that can be applied more broadly to facilities of different sizes.

Food service facilities have higher energy intensity than any other type of building in Climate Zones 6, 7 and 8. Healthcare facilities have the second highest intensity, about one half that of food service buildings. Most other building types used between 1300 and 3200 MMBTUs per year. However, when energy intensity is examined, buildings for retail sales and food service are the highest energy users at 640 and 520 kBTUs respectively.

Lighting uses the largest proportion of energy (28%) in non-residential buildings in all three Climate Zones. The second-largest use is for laundry, with 26% of all MMBTUs. The third largest energy use is for heating, ventilation and air conditioning (HVAC) at 25%.

Lighting is the highest use of energy in retail buildings, using over half of all of the energy consumed in MMBTUs. The energy demands of lighting in retail spaces is also seen when analyzing energy use by kBTUs per square foot.

While total non-residential energy use is higher in more northerly Climate Zones, it appears to be lower when energy intensity is measured. Total non-residential energy use in MMBTUs for Climate Zone 8 is almost 2 times higher than in Climate Zones 6 and 7. The trend is completely reversed, however, when total energy use is divided by the building square footage. Total energy intensity is about one-third less in Climate Zone 8 than in Climate Zone 6 or 7

Energy use in rural Alaska

Bethel is estimated to use almost 1.3 million MMBTUs of energy per year. This is a combined total which includes residential, non-residential, water and wastewater and street lighting uses. Bethel may be representative of Alaskan homes and communities and other HUB communities in its energy use patterns.

Oil is the primary heating fuel for Bethel residential use. Survey data showed that over 87% of Bethel homes use heating oil as their primary fuel source. The use of electricity as a primary heating source in Bethel is lower than the Southeast (Climate Zone 6) or the Railbelt region (Climate Zones 7 and 8).

On average, Bethel residents use almost 250MMBTUs of energy each year in home heating, domestic hot water, and the operation of electrical appliances. Families living in multifamily residences use the most energy, while those living in mobile homes use the least amount of energy.

Space heating uses 72% of all energy among Bethel residences. Hot water requires another 12% and the operation of electrical appliances uses 16% of all MMBTUs.

Operating major appliances, including refrigerators, freezers, washers and dryers, uses 35% of all electrical energy in Bethel households. The second largest uses are primary cooking (17%) and entertainment (16%). Interior and exterior lighting together comprise only three percent of total energy use.

Office buildings in Bethel use more energy and MMBTUs than any other type of facility. These buildings use, on average, just under 1400 MMBTUs of energy each year. Facilities for lodging and retail purposes are approximately equal at about 830 MMBTUs per year.

Food service facilities have the highest energy intensity, at 335 kBTUs per square foot of any building type. All other facilities surveyed, including health care organizations, are one half or less that level of energy intensity.

Almost three quarters (72%) of all energy used by non-residential buildings in Bethel is used for heating, ventilation and air-conditioning. The next highest use is for lighting (9%), followed by food service, cooking and refrigeration (7%).

Space heating is the dominant use of energy in all building types except food service buildings. Space heating energy requirements range between 65% and 85% of all MMBTUs. Buildings that focus on food service, as expected, use the largest portion of their energy in food service, cooking and refrigeration. The same pattern is seen when measuring energy intensity.

Together, the three communities included in the rural study use about 107 MMBTUs of energy per year. Over half of this (53%) is residential energy use. About one third is non-residential use.

Almost 90% of all energy used in the three communities is for space heating. All other uses, including the operation of major appliances, production of domestic hot water and primary cooking comprise the remaining 11% of all energy use in MMBTUs and in kBTUs per square foot.

There are differences in the distribution of residential energy use between communities. While all three communities dedicate the largest portion of energy to home heating, some use more energy per square foot than other communities in heating, domestic hot water, primary cooking, major appliances and other kitchen equipment. Still other communities appear to use greater amounts of energy for entertainment and office equipment. These community differences should be acknowledged when generalizing this data to other small rural Alaskan communities.

Non-residential heating requires more energy in MMBTUs (72%) than any other application. The production of hot water is second (12%), followed by the operation of interior and exterior lighting (11%).

Rural Non-Residential community buildings

Most (92%) of the almost 2000 rural non-residential buildings examined in this study are heated with fuel oil. Fuel delivery in rural Alaska can be to one large tank and service several buildings. This makes the measurement of fuel use by specific buildings difficult.

The building surge in rural Alaska during the 1980s suggests that many of the facilities may have inadequate insulation and weatherization. Other parts of the state may have some older buildings that were constructed during eras where energy conservation and energy-efficient construction methods were not as well understood. This could be a benefit to rural Alaska.

Water and sewer facilities

There does not appear to be adequate data to measure the amount of energy used to operate rural water and sewer utilities. ANTHC, ARUC units of local government and other sources were consulted in an effort to compile a realistic utility energy use database. Without available data, predictive models were developed to calculate energy use and to identify systems components which were using the most energy.

The statistical model that was developed has undergone peer review. However, the model has not undergone the required field verification or calibration required to refine the results to reflect actual conditions in the field.

Operating water and sewer utilities at higher temperatures than necessary or having inadequate utilidor insulation results in significantly higher utility systems costs. While basic water heating and water loop heat losses dominate the water and sewer energy requirements, there is still room for improvement in adjusting utility operating temperatures to protect systems from freezing, enhance efficiency and reduce cost . Additionally, energy costs can be reduced by providing as much as six or more inches of additional insulation on existing aboveground utilidors.

Energy Data is typically not immediately available to operational staff at water and sewer facilities, especially rural facilities. Typically, operations & engineering staff did not have immediate access to the data, or immediate knowledge of their consumption. The utilities are very helpful with providing consumption reports. Some facilities have ready access to the total spent on energy, but not actual consumption data.

Street lighting

Communities who participated in the study used over 3.5 million kWh of energy to generate over 500,000 lumens of street lighting. Data was collected from 117 communities across the state. Eighty-seven percent of the communities who received surveys returned them. Sixty-nine percent of the communities had less than 1000 residents.

High pressure sodium fixtures are clearly the most commonly used street lighting technology. These instruments use 75% of all electrical power and generate about 91% of all light produced by streetlights. These fixtures are seen as the most efficient way of lighting public spaces.

Smaller communities are using more incandescent street lighting instruments than larger communities. They often use security lighting at individual residences rather than street lighting.

There appears to be more interest among communities in switching to LED street lighting technology. However, the Department of Transportation and public facilities is unable to convert to LED lighting because those technologies do not meet FAA regulations. Most of the communities that have switched to LED street lighting have a population between 100 and 10,000. Larger municipalities and cities have not yet converted. In addition, many of the communities currently using LED lighting technology were able to switch by using grant or other funding assistance.

Energy Use Trends by Sector

Industrial energy use comprises about half of all energy used in Alaska. The transportation sector uses another 30% of Alaska's energy. Residential and commercial sectors each use about 10% of Alaska's energy. Therefore, the baseline data collected in this study comprises information on only about 20% of the State's energy use.

Statewide Energy use in Alaska appears to be declining. However, declines in energy use in the industrial and transportation sectors are more pronounced than changes in the residential or commercial sectors. The reasons for this decline is beyond the scope of this study.

The interpretation of changes in energy use may benefit from the use of denominators. For example, using population as the denominator for residential energy use might give a more appropriate and defensible number for use in long-term energy use forecasts. Similarly, using total state economic output as a denominator for industrial energy use may help to better explain changes in long-term use and result in more reasonable forecasts.

AEA should be cautious in selecting the time period that it will use in developing forecasts. Clearly, the use of all available data yields a far different forecast than one which relies on the last 10 years of available data.

Methods

ARIS (from AkWarm© energy raters) was supplemented with survey data to provide a comprehensive picture of residential energy use. Although the results of the baseline study have yet to be independently verified, this appears to be a reasonable and efficient way of compiling baseline energy use data.

Survey research, combined with an on-site methodology, appears to be an effective way of collecting end-use energy data. A mix of telephone surveys and web based applications were supplemented by on-site data collection to produce a complete baseline end-use data set. However, the data collection costs are high. This resulted in some compromises in the representativeness of the data (margin of error).

Energy Wise energy use data appears to a promising source of energy end-use characteristics in rural Alaskan communities. Energy Wise data (N= 212, mean = 108.60) was compared with similar information collected by AkWarm© energy raters (N=512, mean = 116.60) to check the accuracy of fuel use estimates. Total MMBTU home heating calculations showed no significant difference (t=1.421, p=.156). However, additional research should be conducted to assure its reliability.

The State should carefully examine this baseline data to determine which variables are likely candidates to be included in a performance measurement system of overall statewide energy use. Collecting energy data of this scope and complexity is an expensive and time-consuming undertaking. Among its many uses is the measurement of the extent to which Alaska has met its statutory target of a 15% improvement in energy efficiency by the year 2020. This suggests an ongoing procedure for measuring energy use is required. Such a performance measurement system would likely collect data on a number of critical energy use variables, at the least, annually. This data could be recalibrated every few years, similar to the US Census, which recalibrates population data every 10 years. The data collection responsibilities for this end-use energy performance measurement system should be assigned to an operating unit of state government and data should be routinely collected and analyzed.