Energy Efficiency of Public Buildings in Alaska: Metrics and Analysis

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Overview:

Energy costs in Alaska differ significantly from the contiguous United States, with costs in more remote parts of the state reaching up to $10 a gallon for heating fuel.[1] The energy costs of municipal, state, and tribal buildings in Alaska can be significant burdens on a community, especially in more remote areas lacking large cash economies. Data analyzed from building energy audits conducted in programs by AHFC and ANTHC showed energy efficiency measures typically provide a very cost effective means of reducing the long-term costs of energy, and thus the local taxpayer burden. At the same time, analysis of the ANTHC audits done in rural Alaska found that many of these energy efficiency measures can also be implemented with local labor, boosting local economies and decreasing reliance on the importation of fossil fuels.

Energy use by commercial-scale buildings in Alaska also varies significantly from other areas of the U.S. Because Alaska's climate requires more heating and rarely necessitates cooling, national statistics on building energy use do not provide a reliable comparison metric for local buildings. The White Paper on Energy Use in Alaska's Public Facilities was the first examination of relative energy use in public facilities in Alaska; before this, facility managers statewide had no way to accurately compare their energy use to similar building types facing comparable climatic conditions. This paper builds on work done in the White Paper, expanding the amount of data analyzed to increase the reliability of the energy use and cost metrics, and investigating the potential causes of differences in energy efficiency between public buildings that have received energy audits. While these metrics are Alaska specific and are based on significant amounts of data, the data was not randomly sampled, and so it is unknown how representative they are of the Alaska public building stock as a whole.

There was notable variation in energy efficiency even when comparing buildings of the same type that are located in the same general climate. For example, some schools that are even in the same district use over five times as much energy per square foot as the most efficient building in that district. These relatively high energy use buildings that were found in almost every building type and climate underscore the large potential in the state for energy efficiency measures to reduce energy costs for local governments and organizations. At a current estimated cost of over $641 million spent annually on energy in public buildings, the potential savings of energy efficiency measures statewide are significant.[2] The following section highlights the key findings and recommendations of this study for buildings as a whole and for each specific building usage type that had sufficient data for an in-depth analysis.

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[1] *Current Community Conditions Alaska Fuel Price Report*. (2012). Department of Commerce, Community, and Economic Development. Retrieved December 11, 2012 from http://www.commerce.state.ak.us/dca/pub/Fuel_Report_2012_July.pdf

[2] Armstrong, Richard, Luhrs, Rebekah, Diemer, James, Rehfeldt, Jim, Herring, Jerry, Beardsley, Peter, et. al. (2012). *A White Paper on Energy Use in Alaska's Public Facilities*. Alaska Housing Finance Corporation. Available online at: http://www.ahfc.us/iceimages/loans/public_facilities_whitepaper_102212.pdf

Key Findings:

I. All Buildings

Figure 1: Overall Findings for 744 buildings (Audited and Benchmarked)

Total Square Footage	26,034,649 square feet
Annual Energy Consumption	3.26 trillion BTUs* of energy
Annual EUI Range	33,102 BTU/SF* — 1,973,345 BTU/SF*
Annual EUI Median	113,142 BTUs/SF*
Annual ECI Range**	$0.68/SF — $32.96/SF
Annual ECI Median**	$4.31/SF
Square Footage Range	1,200 SF — 361,698 SF
Square Footage Median	19,332 SF
Building Age Median (All)	30 years
Building Age Median (Schools)	32 years

*British Thermal Unit

**Benchmark data not used in cost numbers

- On average, the audit process found that cost effective energy efficiency improvements could save $21,800 in energy cost savings per year for participating public buildings. The average installed cost of these improvements was $82,000.
- If all cost effective energy efficiency measures in the audited buildings were implemented, Alaskans would save $79 million in energy costs over the life of the measures. The initial investment required to implement these measures was estimated by energy auditors to be $29 million.
- On average, more than 70% of energy used in the audited commercial buildings in Alaska is for space heating. The majority of this energy is lost through air movement, due to a combination of mechanical ventilation and air leakage.
- Energy efficiency and energy costs in the audited public buildings tend to vary widely, even within a particular usage type and climate zone. This suggests that there is significant room for improvements in energy efficiency in many buildings.
- Building energy use is a function of the energy efficiency of the building and its systems and of the efficiency of operation. Analysis of audited public buildings found a lack of correlation with factors that typically influence thermal energy use, including: building age, building size, age of remodel, energy price, and additional capital costs due to remote locations. The unexplained

variability of thermal energy use, combined with the findings of energy auditors reported in *A White Paper on Energy Use in Alaskan Public Facilities*, suggest that efficient building operation is likely one of the key factors driving energy use in public buildings. Recommendations for efficient building operation include setback thermostats, occupancy sensors, demand-controlled ventilation, and regular mechanical system maintenance.

- Based on Alaska Native Tribal Health Consortium (ANTHC) data, approximately half of the potential annual energy cost savings identified in audits of public buildings in rural Alaska can be obtained through retrofit measures performed or installed by local labor, provided that adequate training is supplied.
- Operations and maintenance energy efficiency measures identified in ANTHC audits, such as setting back temperatures at night, cleaning boilers, and air sealing, tend to have quicker paybacks than other measures, and on average require less capital investment. These types of energy savings measures make up a significant portion of the total potential savings recommended by auditors.
- Energy prices do not correlate directly with the differences in thermal energy efficiency of public buildings in Alaska, suggesting that they are not the strongest driving factor.
- Building insulation levels are generally lower than the recommended levels in the 2009 Alaska Building Energy Efficiency Standards adopted by AHFC, in some cases by a significant amount. This highlights the potential areas for retrofit throughout the state for its older building stock.
- The data collected in AHFC's benchmarking effort are consistent with the building audit data, after records with incomplete fuel numbers and outliers are removed. Data collected in this manner and stored in AHFC's Alaska Retrofit Information System (ARIS) has the potential to provide increasingly reliable energy consumption and cost metrics for comparison and planning purposes.
- The median air leakage rate for audited commercial buildings with a blower door test is 0.67 cfm / square foot of above grade envelope area at 75 pascals; this is significantly higher than the 0.40 cfm / square foot @ 75 pascals recommended by the International Energy Conservation Code (IECC) for commercial buildings. The range of leakage values obtained from blower door tests across the buildings examined was quite large covering values from 0.05 cfm / sf @ 75 pascals to 5.14 cfm / sf @ 75 pascals.

II. Schools

- $49 million public dollars per year are spent on energy in the 67% of schools that have available data.
- On average, audited schools in Fairbanks used less than half the amount of energy[3] for space heating per square foot than audited schools in other urban school districts when climate has been factored out.

[3] 3.2 Btus/square foot/heating degree day versus 7.6 to 8.3 for other urban districts

- Incentive systems for energy management appear to be one of the biggest factors in this difference.
- The level to which valuing energy efficiency has been institutionalized and operational efficiencies have been maximized also are likely contributing factors to differences in school energy efficiency.

- Audited schools in rural areas of the state tend to have lower electric use per square foot than those in urban areas.
- Ventilation and air leakage is most likely the largest source of thermal energy loss in a school building.
- There is often significant variation in energy use and costs even within a school district, meaning there are likely many cost effective opportunities for energy retrofits.

III. Offices

- Buildings in rural Alaska have lower electric use per square foot on average than buildings in urban Alaska. For example, offices in the Calista region on average use less than one quarter the amount of electricity per square foot as office buildings in Anchorage.
- Building size appears to play a larger role in energy use for offices than for other building usage types, with larger audited buildings having lower average thermal EUI/HDDs[4] and at the same time higher average electricity use per square foot.

IV. Public Order and Safety

- Audited buildings in climate zone 8 use significantly less energy per square foot annually than the audited buildings in other climate zones[5].
- Electric use per square foot varies significantly between buildings, with some buildings using over 10 times more electricity than others.

V. Maintenance / Shop

- Ventilation and air leakage account for 50% of the total energy use for the average maintenance / shop building in Alaska.
- Maintenance / shop buildings tend to be significantly leakier than other building usage types.
- Buildings in this category use more energy per square foot than the majority of other usage types.

VI. Health Clinic

[4] Thermal EUI/HDD is the energy used for space heating in a building, normalized by square footage and climate.
[5] See Figure 3 on p. 14 for map of climate zones in Alaska

- Health clinics lose a much smaller portion of energy to ventilation and air leakage than other public building types.

VII. Athletic Facilities

- Athletic facilities in climate zone 7 use twice as much electricity and energy for heat per square foot as buildings in climate zone 6 and 8. Despite this, average energy costs per square foot are higher in zone 8.

VIII. Washateria / Water Plants

- Energy costs of running water facilities in rural Alaska are high, on average costing about $500 annually per household if costs were evenly distributed. Recommended retrofits on average could save each household almost $200 in energy costs, with estimated savings reaching $676 per household in one village.

Key Recommendations

- Low performing buildings should be identified by comparing energy consumption and costs to similar buildings and then aggressively managed using automated controls for lighting, heating, and ventilation. These controls should be reasonably simple, standardized across the state, and operators trained thoroughly, with a set of circuit riders assigned regionally.
- Ventilation is typically the largest energy use in commercial buildings, thus, facility managers should focus their attention on improving ventilation systems through more efficient controls, maintenance, and equipment.
- Mandatory statewide energy codes for commercial buildings should be adopted to reduce the lifetime operating costs of public buildings in Alaska.
- Future construction and renovation of public buildings in Alaska should significantly increase insulation for on-grade and below-grade floors, as well as ceilings.
- Building operators and maintenance staff should receive adequate training in energy saving measures; programs may need to be created to provide this training.
- As much as possible simple standardized Direct Digital Control (DDC) systems should be installed in a region. This allows for standardized training, technical support, and procurement.
- Install a building monitoring system. These systems allow staff to track energy usage of different building systems and diagnose inefficiencies before they cause equipment maintenance problems. AHFC has developed an inexpensive building monitoring package that has already allowed them to find significant energy cost savings.
- Blower door tests should be performed for commercial buildings. The International Energy Conservation Code (IECC) now requires that commercial buildings meet a measured air infiltration level.
- Create an incentive program for maintenance / operations / facilities departments.
    - Allow departments to retain some savings from energy conserved from retrofits to reinvest in additional energy efficiency measures.
- New building ventilation systems should:
    - Be adequately zoned such that most of the building can be turned off during after-hours activities / rentals.
    - Be installed with demand controlled ventilation based on CO_2 or other sensor systems.
    - Simple to operate, standard across the district / region / state.
- Hire a sufficient number of trained staff to operate DDC systems so that ventilation and setback temperatures can be optimized in every school.
- Require that energy efficiency improvements be evaluated and included in any significant building repair or replacement.

- Incorporate energy efficiency personnel in design decisions Retro-commission school buildings that have had significant deferred maintenance or that are high energy users.
- Standardize systems for ease of operations and maintenance.
  - For example, determine a high performing, low maintenance occupancy sensor and then install that in all buildings.

Introduction

Background

In 2008, fuel prices spiked, causing increased interest in energy efficiency. At the time, public and tribal buildings in Alaska had no way of accurately comparing their energy use to that of other Alaskan facilities. Using American Recovery and Reinvestment Act funds from the Department of Energy, the Alaska Housing Finance Corporation (AHFC) undertook a benchmarking project to collect data on energy use and costs of public facilities. This project laid the foundation for AHFC to contract four technical service providers to conduct 327 investment grade audits of public facilities in Alaska. These audits accurately report energy use and costs and identify energy efficiency measures which can be undertaken to reduce energy consumption of the building.

These audits showed that there were opportunities for significant cost savings by implementing energy efficiency measures. By implementing only cost effective measures[6], public building owners could save an average of $21,800/year in energy savings per building for an average cost of approximately $82,000. Taking into account all audited buildings, an auditor-estimated investment of $29 million would save $79 million in energy costs over the life of the energy efficiency investment, resulting in more sustainable communities throughout the state.

The audit process uncovered many unexpected findings, which led to the White Paper on Energy Use in Alaska's Public Facilities. This document reported the common energy efficiency measures recommended during the audits, highlighted informative case studies, and made a first attempt at creating a set of metrics that would allow those with a vested interest in the energy use and costs of public buildings to know how those buildings compare to similar structures throughout the state.

This paper builds upon the White Paper on Energy Use in Alaska's Public Facilities. It uses an expanded data set to increase the reliability of the energy comparison metrics, provides more detailed analysis on individual building usage types, and attempts to uncover the likely causes of differences in energy efficiency between buildings. The authors highly recommend that facility managers and building owners reading this document first calculate the energy cost and consumption metrics for their building(s) using the worksheet found in Appendix D.

Data Source Description

Several data sources were used in the creation of this report. While the data quality is high for all of these sources, it is important to note that they are not a random sampling, and so may not be representative of Alaska's public building stock as a whole. Additionally, as the audits provided much more detailed information than the benchmark data, some analyses were done using only audit data; these figures are listed with the subscript "A". Other analyses were done with the full data set; these figures are listed with the subscript "A+B". A few analyses were done only with ANTHC audits; these figures have the subscript "ANTHC".

[6] Improvements with a savings-to-investment ratio greater than 1.

AHFC Audits

AHFC technical service providers (TSPs) conducted investment grade audits (IGAs) from 2011 to 2012. The AkWarm© files that contain the specific information on these audited structures were used in this report.

AHFC Benchmarks

In 2011, CAEC and Nortech collected benchmark information from 1,200 public and municipal facilities around the state for AHFC. Some of this data was incomplete. Incomplete data arose for a number of factors including: lost records, no records, and untracked free waste heat from power plants. The benchmark records from the 2011 effort that were used in this report are those that, after review, were deemed complete in terms of their energy data.

In late 2011, State of Alaska personnel began entering benchmark data on state-owned and managed facilities, with different departments and divisions entering the process in a phased approach. Only facilities that had one year or more of benchmark energy data were used in this report.

ANTHC Audits

As part of the ARRA stimulus funds, ANTHC conducted audits on 68 of their facilities in rural Alaska in 2011 and 2012. Concentrating primarily on three building usage types, these audits look at water treatment plants and washaterias, health clinics, and tribal offices. With their permission, those 68 audits were also used in this report.

Other Major Data Sources

For calculations, notably those involving heating-degree-days (HDD), the climate data from the AkWarm energy library was used.

Public & Tribal Building Energy Consumption & Cost Metrics

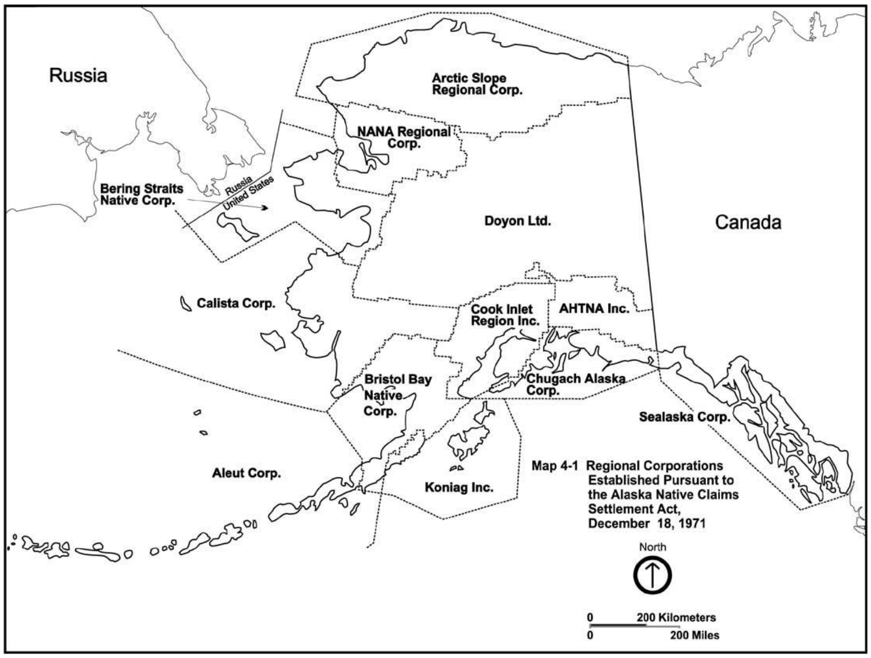
In the recent report "A White Paper on Energy Use in Alaskan Public Facilities", significant variation was found in both energy consumption and cost in public buildings across regions of the state as well as usage types. Energy use and costs metrics are vital to building owners and managers for comparing the energy use of current and planned structures to other buildings with a similar use and climate. Nationally, the Department of Energy conducts the Commercial Building Energy Consumption Survey (CBECS) to generate energy cost and consumption metrics for comparison purposes. However, this data is based on a limited number of surveys which then use a method of statistical extrapolation to represent buildings throughout the U.S. The coldest climate zone reported by CBECS has up to 7,000 heating degree days (HDD); in comparison, some areas of Alaska have over 20,000 HDD. This difference in HDD likely is the reason that the CBECS estimates differ so much from the values computed from the data used in this report. The coldest climate zone reported in CBECS has an average EUI estimate of 93 kBtu/SF, whereas the average and median values calculated in this report are 165 kBtu/SF and 113 kBtu/SF, respectively.[7] In order to produce a reliable set of comparable buildings, the Cold Climate Housing Research Center (CCHRC) has updated the data set used in the recent white paper to include additional data. The original data set included 327 investment grade audits (IGA) that were a part of an Alaskan Housing Finance Corporation (AHFC) program for public and municipal buildings. This study includes additional IGA data that were completed after the analysis for the white paper, data from 68 energy audits done by the Alaska Native Tribal Health Consortium (ANTHC), and limited data on 335 buildings that underwent a building energy benchmarking effort through AHFC and the State of Alaska. In total, data from 730 buildings were used, which is roughly 15% of the estimated 5,000 public buildings in Alaska. For a detailed description of the validity of this data, please see Appendix A.

The energy metrics are reported below based on three different divisions:

1. **Alaska Native Settlements Claim Act (ANCSA) Region:** The state is commonly divided into regions based on the geographic boundaries defined in the 1971 ANCSA decision. Since buildings in urban areas often have different energy characteristics, these have been further broken out of their geographic ANCSA region. See Figure 2 for map.

[7] Commercial Building Energy Consumption Survey. Energy Information Administration. 2003. http://www.eia.gov/consumption/commercial/data/2003/ Date Accessed: 5/9/2014

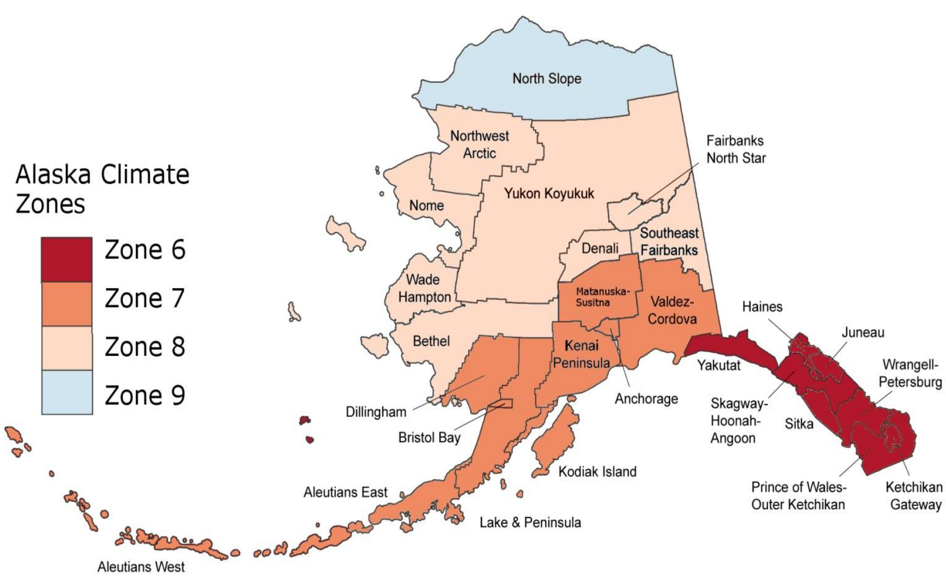
Figure 2: ANCSA Regions



2. **Usage Type:** During both the audit and benchmark efforts, buildings were assigned usage types from a preset list generated by the Cascadia Green Building Council under contract with AHFC. The level of analyses done on usage type in this report is dependent on the number of records available for that usage type, and the variability of the energy characteristics between the records. The records were aggregated or split to give the finest level of detail that was deemed reliable.

3. **Climate Zone:** The Alaska Building Energy Efficiency Standard (BEES) divides the state into 4 climate zones, based on the number of heating degree days found in each area (see Figure 3 for map).

Figure 3: BEES Climate Zone Map



All energy consumption and costs are reported on a per square foot basis, using the following nomenclature:

- **ECI**: Energy Cost Index. The total amount of money spent on energy in a year divided by the square footage of the building.
- **EUI**: Energy Use Intensity. The total amount of energy used annually by a building, including heating fuel, electricity, and any other energy source, divided by the square footage of the building.
- **HDD**: Heating Degree Days. A measure of the heating requirement for a geographic location that is calculated based on the time and distance that the temperature stays below a base temperature of 65-degrees Fahrenheit. The HDD used in this report are 30-year averages for the 1960 – 1990 period and come from the AkWarm energy library.
- **Electric EUI**: The total electrical use of a building in kilowatt-hours per year divided by the square footage of the building.
- **Thermal EUI / HDD**: The Energy Use Intensity for *space heating only* normalized by heating degree days. This measure normalizes the EUI by climate, allowing for comparisons across climate zones.

ANCSA Region

Energy Consumption and Cost by ANCSA Region

Analysis was conducted using ANCSA regions because they are typically climatically and culturally similar, and are familiar ways of dividing up the state. For the purposes of this analysis, large urban areas were also separated out from the rest of the ANCSA region, as they often have unique energy characteristics. Within the data available, regional sampling was more evenly distributed than the building usage type sampling. Energy cost, use, and general building characteristics by ANCSA region are summarized in Figure 4 and Figure 5. For the geographic locations of the ANCSA regions please refer back to Figure 2.

ANCSA regions are relatively well represented in this data set, with all but NANA having energy use and costs for over 15 buildings.

Figure 4: Square Footage and ECI by ANCSA Region

ANCSA Region:	# OF RECORDS	SQUARE FOOTAGE A+B				ECI A			
		AVG	MEDIAN	MAX	MIN	AVG	MED	MAX	MIN
Sealaska non-Juneau	58	21,198	16,230	190,290	500	$4.18	$3.25	$11.39	$1.31
Sealaska - Juneau	18	55,479	31,259	190,738	5,000	$4.80	$2.84	$15.71	$1.81
Ahtna-Chugach	21	40,684	20,000	205,952	2,876	$4.44	$4.12	$6.34	$3.13
BBNC	20	18,359	16,622	37,696	6,499	$7.27	$7.28	$11.50	$4.03
CIRI - Anchorage	152	61,131	52,038	361,698	2,500	$2.92	$2.28	$8.69	$1.24
CIRI - non-Anchorage	108	48,390	36,692	206,687	2,250	$2.95	$2.68	$6.33	$1.07
Koniag	38	18,206	8,011	175,587	747	$3.14	$2.84	$5.54	$2.09
Aleut	17	13,940	10,939	49,296	1,200	$4.27	$4.39	$6.05	$2.48
Calista	90	6,975	2,040	75,829	350	$10.73	$7.02	$108.27	$1.86
Doyon - FNSB	68	50,455	48,655	234,412	750	$2.90	$2.29	$8.05	$1.25
Doyon - non-FNSB	60	18,985	12,443	76,683	320	$5.18	$4.44	$14.09	$1.69
ASRC	51	15,807	10,680	55,545	960	$5.93	$5.43	$19.53	$0.68
NANA	2	29,775	29,775	48,225	11,325	$7.75	$7.75	$9.62	$5.88
Bering Straits	21	15,725	13,346	44,343	1,064	$6.97	$6.69	$11.16	$4.31

As might be expected, the more remote areas of the state tend to have smaller average building sizes. The ECI of different regions is not as straightforward. This number is affected by fuel prices, which is likely why regions in Western Alaska have some of the highest ECIs. ECI is also affected by energy efficiency, which may explain how energy conscious Fairbanks facilities have an average ECI that is lower than the CIRI region even though fuel costs in CIRI are significantly lower. Lastly, the distribution of different usage types affects these ECIs. For example, audits of energy intensive washateria and water treatment plant buildings are concentrated in the Calista region, driving the maximum and average ECI up.

As can be seen by the ranges below, EUI and Electric EUI vary significantly even within a region. This suggests that for many buildings there is a large potential for efficiency gains to be made through energy efficiency measures. Though climate may vary within a region, most of these areas have fairly similar numbers of heating degree days, so facility owners or operators can compare their EUIs with the median EUI for buildings in their region.

Figure 5: EUI and Electric EUI by ANCSA Region

ANCSA Region:	# OF RECORDS	EUI (thousands of BTU / YR / SQFT) A+B				ELECTRIC EUI (KWH / YR / SQFT) A+B			
		AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
Sealaska - non-Juneau	58	113.4	96.4	371.1	29.7	11.1	7.8	55.7	2.1
Sealaska - Juneau	18	291.7	94.9	1,334.3	17.6	27.2	10.1	142.9	2.1
Ahtna-Chugach	21	118.5	107.4	290.0	77.5	8.5	7.5	21.7	2.8
BBNC	20	105.1	99.9	229.1	30.9	5.9	5.0	11.7	3.0
CIRI - Anchorage	152	159.3	125.8	898.8	38.8	13.3	10.1	122.4	0.5
CIRI - non-Anchorage	108	141.1	103.7	1,109.9	42.3	13.2	8.7	247.4	1.1
Koniag	38	162.7	102.2	894.2	15.0	14.7	7.9	173.5	0.7
Aleut	17	90.5	83.4	198.0	59.1	4.8	4.6	9.4	2.1
Calista	90	197.7	126.1	2,176.1	34.0	14.2	6.9	310.3	1.1
Doyon - FNSB	68	124.3	81.9	1,164.1	14.8	13.8	8.0	207.6	1.1
Doyon - non-FNSB	60	145.1	108.9	1,016.6	33.1	7.7	6.4	46.5	1.4
ASRC	51	327.2	210.8	2,237.0	104.2	12.4	10.5	43.8	0.1
NANA	2	156.2	156.2	219.0	93.4	6.7	6.7	7.1	6.4
Bering Straits	21	143.6	134.4	325.7	74.0	8.1	6.9	17.8	4.7

Usage Type

Energy Consumption and Cost by Usage Type

Original classification of usage type was done by energy auditors by following the *General Guidelines for Public and Commercial Building Audit and Retrofit Strategies for Alaska*[8] that are embedded in the Alaska Retrofit Information System (ARIS) database. CCHRC then evaluated whether they were properly classified and recoded them, if necessary. Additionally, as there were a significant number of records for buildings that had unique energy use patterns which under the Cascadia definitions would have fallen into the "Other" category, CCHRC created the following new categories:

- Athletics Facility
- Maintenance/Shop
- Pool

[8] Available at http://www.ahfc.us/files/9813/5736/3277/building_type_audit_recomm_rpt.pdf

- Correctional Facility
- Terminals
- Washateria / Water Plant

Mean, median, maximum, and minimum metrics were calculated by usage type for several characteristics, shown in Figure 6 through Figure 8 on the following pages. These tables provide a baseline of energy usage and costs that can give owners and managers of similar buildings a comparable benchmark. The number of audits on which these metrics are based should also be considered, as the accuracy will be affected by the sample size.

The ranges between minimum and maximum values on a statewide level in Figure 7 and Figure 8 are large. The EUIs for all buildings range from 14.8 kBTU/SF per year to 2,237 kBTU/SF per year. Note that statewide, the highest average EUI is found in facilities in the Other, or miscellaneous, category at 522 kBTU/SF per year, while the lowest is found in education facilities at 107 kBTU/SF per year.

At the same time, the ECIs for all buildings range from $0.68/SF to $108.27/SF per year. The highest average ECI is found in Washaterias and Water Plants at $25.18/SF per year, while the lowest average ECI is found in the Other, or miscellaneous, category at $2.96/SF per year.

Figure 6: Building Age and Size by Usage TypeA+B

USAGE TYPE	# OF RECORDS	AVG AGE	SQUARE FOOTAGE			
			AVG	MED	MAX	MIN
Athletics Facility	23	32	43,311	31,536	151,470	1,373
Education - K - 12	313	33	55,834	49,550	361,698	2,320
Health Care - Hospitals	4	34	66,156	52,857	138,908	20,000
Health Care - Nursing/Residential Care	19	25	40,608	29,000	150,366	1,072
Health Clinic	24	13	2,451	2,255	13,541	520
Maintenance/Shop	37	29	15,485	8,281	107,846	650
Office	95	37	12,119	4,172	72,048	420
Other	17	26	14,782	8,364	48,075	320
Pool	12	27	24,743	21,666	40,112	17,362
POS - Correctional Facility	12	35	72,608	51,388	205,952	9,066
Public Assembly	25	31	40,338	8,250	200,000	1,158
Public Order and Safety	69	25	10,244	6,848	63,050	437
Terminals (Airport, Bus, Harbor, Train)	4	23	12,288	10,930	26,092	1,200
Warehousing and Wholesale	41	34	17,476	11,520	72,289	500
Washateria / Water Plant	23	23	2,155	1,280	18,390	350

Figure 7: ECI by Usage Type[A]

USAGE TYPE	ECI[A]			
	AVG	MED	MAX	MIN
Athletics Facility	$3.22	$3.14	$5.31	$1.49
Education - K - 12	$4.29	$3.19	$12.46	$1.60
Health Care - Hospitals	$5.37	$4.13	$8.76	$3.22
Health Care - Nursing/Residential Care	$1.36	$1.36	$1.64	$1.07
Health Clinic	$6.49	$5.64	$12.14	$3.39
Maintenance/Shop	$5.19	$3.97	$19.53	$0.68
Office	$5.09	$4.71	$10.39	$1.25
Other	$2.96	$2.96	$3.51	$2.40
Pool	$7.77	$6.48	$15.71	$4.35
Public Assembly	$3.99	$2.69	$9.69	$1.79
Public Order and Safety	$4.52	$3.94	$9.72	$1.48
Terminals (Airport, Bus, Harbor, Train)	$4.85	$4.85	$4.85	$4.85
Warehousing and Wholesale	$3.33	$3.27	$5.68	$1.15
Washeteria / Water Plant	$25.18	$18.60	$108.27	$7.05

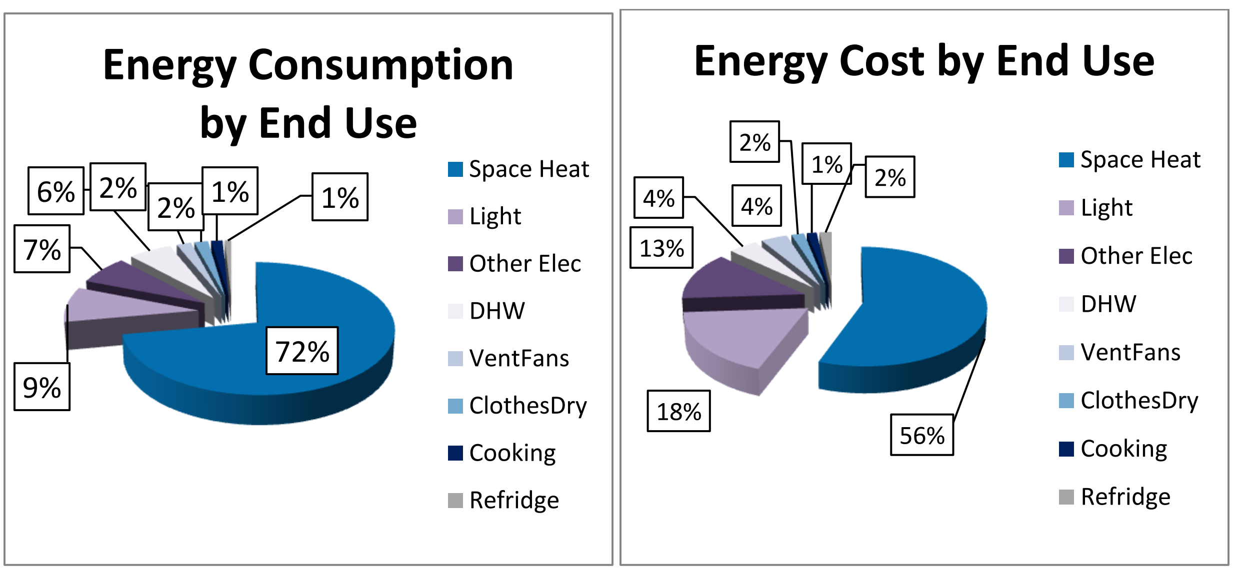
Figure 8: EUI & Electric EUI by Usage Type A+B

USAGE TYPE	# OF RECORDS	EUI (thousands of BTU / SQFT)				ELECTRIC EUI (kWh / SQFT)			
		AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
Athletics Facility	23	176.1	143.8	735.5	33.1	19.3	11.8	173.5	1.7
Education - K - 12	313	106.2	101.2	290.0	29.7	7.8	7.8	24.0	0.7
Health Care - Hospitals	4	343.9	191.9	898.8	93.1	26.6	25.3	44.6	11.1
Nursing/ Residential Care	19	183.4	143.8	745.4	17.6	13.0	10.1	25.1	2.1
Health Clinic	24	124.6	123.7	215.1	78.8	8.4	7.4	13.7	5.7
Maintenance/ Shop	37	402.5	249.7	1,973.3	57.0	26.3	12.2	207.6	0.5
Office	95	124.8	112.1	363.7	15.0	9.3	7.5	37.6	0.7
Other	17	522.3	269.4	2,237.0	14.8	46.8	27.8	247.4	2.2
Pool	12	284.7	297.4	478.2	171.2	24.7	19.7	55.7	12.2
Correctional Facility	12	176.6	105.0	840.2	34.0	10.4	8.4	26.2	4.6
Public Assembly	25	144.3	143.5	302.2	46.1	11.3	10.1	38.0	1.6
Public Order and Safety	69	160.0	134.3	945.4	28.1	12.1	10.9	38.5	1.1
Terminals (Air, Land, Sea)	4	174.7	163.3	277.6	94.7	17.4	19.2	25.1	6.2
Warehouse & Wholesale	41	130.5	119.1	414.2	35.2	7.6	7.4	18.2	0.1
Washateria / Water Plant	23	464.5	365.3	2,176.1	138.7	41.1	25.7	310.3	5.6

Energy End Uses and Costs

The majority of energy used in commercial sized public buildings in Alaska goes towards space heating, which on average accounts for 72% of total energy use, as can be seen in Figure 9. Since space heating efficiency is determined by ventilation rates, insulation values, and heating equipment, energy efficiency measures that change the performance of these three areas will likely have the biggest impacts. Lighting and other non-ventilation electrical use combined account for 16% of total energy use, although because of the higher relative cost of electricity, they account for a combined 31% of the total energy cost. User-behavior based energy reduction programs typically primarily target lighting and electrical use, so while still important, they have relatively less potential for reducing energy use and cost than energy efficiency measures that target space heating.

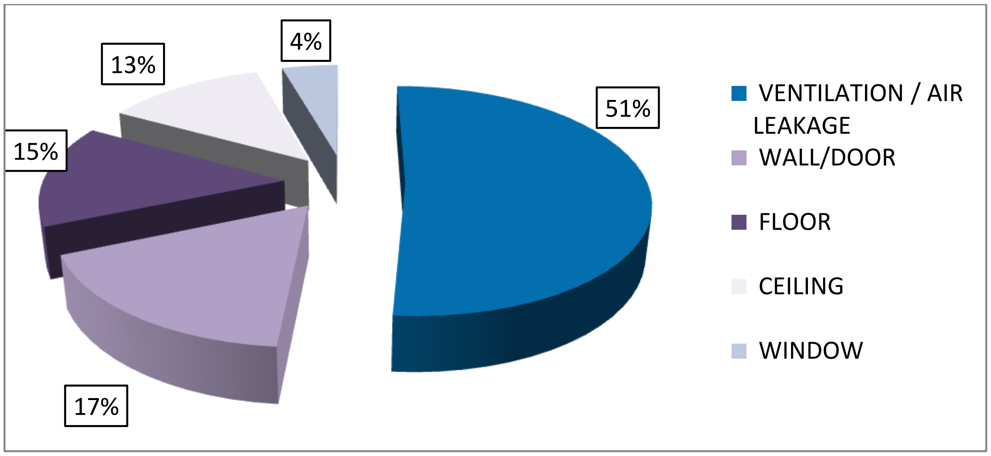
Figure 9: Energy Consumption and Cost by End UseA



Of the energy used for space heating, Figure 10 shows that the majority of it is lost through ventilation and air leakage. Research shows that typically ventilation rates in commercial scale buildings are significantly higher than the leakage rates[9], pointing to ventilation as the largest single energy use in a building, and consequently, an area that should be investigated for possible energy conservation measures. The White Paper on Energy Use in Public Facilities includes several common energy efficiency measure suggestions dealing with ventilation, including installing demand-controlled ventilation and remotely monitoring DDC systems.[10]

[10] Document available at: http://www.alaska.edu/files/facilities/public_facilities_whitepaper_102212.pdf

Figure 10: Space heat loss by component for all audited buildings[A]



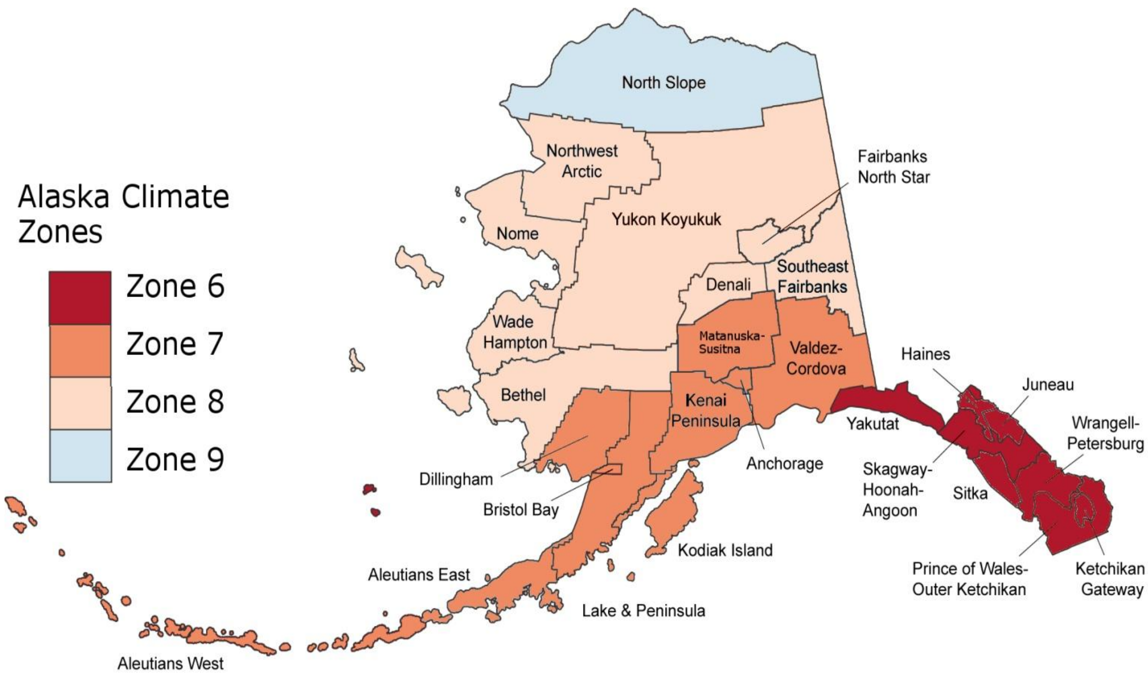
Non-correlated factors

There are significant differences in energy efficiency both within a climate zone and within a building usage type. Many factors were initially identified as possible contributors to these differences. CCHRC analyzed these factors to see if there were significant correlations with the Thermal EUI/HDD of buildings. Factors analyzed included building age, year of last major remodel, price of the primary fuel, window to wall ratio, and a geographic location factor that captures the relative cost of building commercial scale buildings in an area as compared to costs in Anchorage. All of these factors were found to have very little correlation with thermal EUI/HDD, with R squared values of less than 0.01[11], meaning that they are not good single predictors of energy efficiency. They could have some effect on thermal EUI/HDD, but it is likely to be relatively small.

[11] See Appendix B for scatter plots and linear regressions for these variables.

Climate Zone

Figure 11: BEES Climate Zone Map



Energy Consumption and Cost by Climate Zone

Data at the climate zone level allows high level regional differences to be examined. By examining the median square footages in Figure 12, a general trend of larger buildings in Zones 6 and 7 and smaller buildings in Zones 8 and 9 emerges. Zones 8 and 9 include many of the more remote areas of the state. At this regional level, ECIs have the lowest median values in Zone 7, where there is relatively inexpensive natural gas, and highest in Zone 8, where heating is generally done with fuel oil and wherein some areas are reachable for fuel delivery only by air.

Figure 12: Building Size and ECI by Climate Zone

ALL BUILDINGS		SQUARE FOOTAGE$_{A+B}$				ECI$_{A}$			
BEES Climate Zone	# OF RECORDS$_{A+B}$	AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
6	76	29,317	20,411	190,738	500	$4.44	$3.15	$15.71	$1.31
7	356	46,821	33,609	361,698	747	$3.54	$2.89	$11.50	$1.07
8	242	23,199	7,933	234,412	320	$7.37	$5.42	$108.27	$1.25
9	50	15,592	10,524	55,545	960	$5.86	$5.39	$19.53	$0.68

In both Figure 12 and Figure 13, the averages in each category are significantly higher than the medians, suggesting that a few buildings with very high energy consumption, or communities with very high costs, are driving these averages, and that the median is a better measure of the typical building in that particular climate zone. Looking at the median, EUI goes up as the climate zone gets colder, with the exception of Zone 8.

Figure 13: EUI & Electric EUI by Climate Zone$_{A+B}$

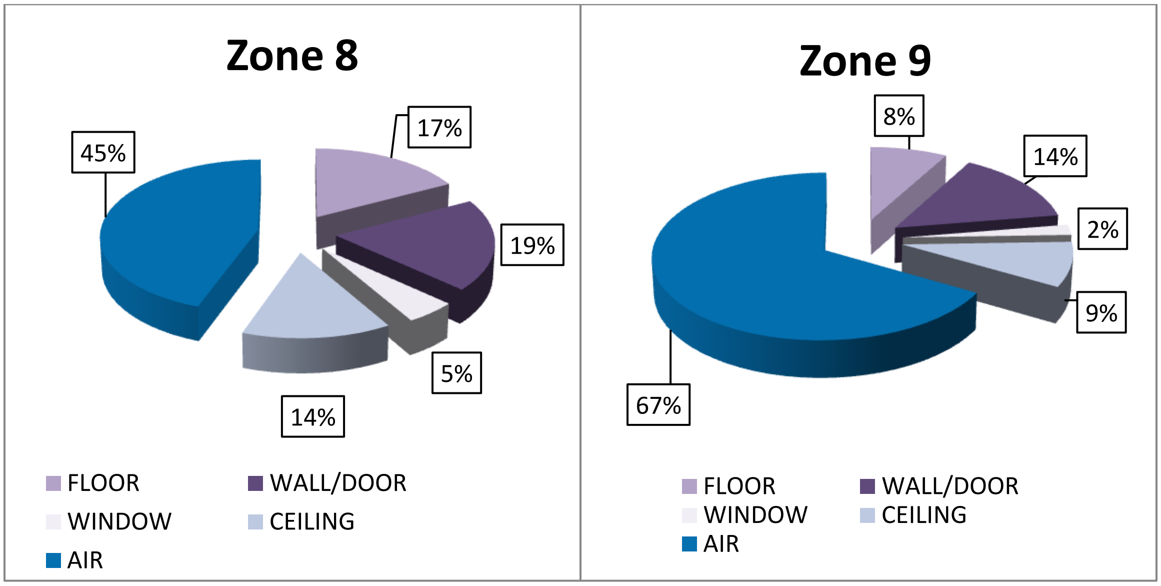
ALL BUILDINGS		EUI (thousands of BTU / SQFT)				ELECTRIC EUI (KWH / SQFT)			
BEES Climate Zone	# OF RECORDS	AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
6	76	155.6	96.4	1,334.3	17.6	14.9	8.2	142.9	2.1
7	356	145.4	112.4	1,109.9	15.0	12.3	8.8	247.4	0.5
8	242	158.7	112.0	2,176.1	14.5	11.9	7.1	310.3	1.1
9	50	330.9	213.0	2,237.0	104.2	12.4	10.5	43.8	0.1

For all climate zones heat loss happens primarily due to air leakage and ventilation. However, there are differences between climate zones. The public buildings in this study in Zone 9 lose 65% of their heat, on average, due to air movement, whereas in climate Zone 8 only roughly 45% of heat is lost through air movement. There are several possible causes of these differences, including leakier structures, oversized ventilation systems, and differences in operation of air handling systems.

Figure 14: Heat Loss by Component by Climate Zone$_{A}$

Climate Zone	# of Records	Med SQFT	Med Space Loss (kBTU)	% Loss Floor	% Loss Wall / Door	% Loss Window	% Loss Ceiling	% Loss Air
6	38	53,498	5,597,135	6%	17%	4%	10%	63%
7	140	46,243	4,302,625	13%	15%	4%	12%	56%
8	203	23,848	1,744,552	17%	19%	5%	14%	45%
9	29	17,947	4,686,200	8%	15%	2%	9%	65%

Figure 15: Heat Loss by Component - Climate Zones 8 and 9A



After accounting for heat loss due to air transport, the building envelope only accounts for between 35% and 55% of heat loss on average in a building. This suggests that improvements to ventilation and air leakage should be the first priorities when considering possible energy retrofits and evaluating energy efficiency options in new construction. However, with an average 72% of the energy for these public buildings being used for space heating, the building envelope is still the second largest source of energy consumption.

While detailed ventilation data at the climate zone level was not available for this report, air leakage data were collected or estimated for each of the audited buildings. Approximately 19% of the audits done included a blower door test. While common in residential energy audits, blower door tests are often not performed on commercial buildings because of several factors, including the complications caused by compartmentalization of commercial buildings and the fact that air exchange rates due to leakage are almost always lower than those caused by mechanical ventilation.[12] Other leakage rates were estimated by the engineers performing the audits. While the median leakage rates were similar between those with blower door tests and those with estimated leakage, the ranges in leakage rates between buildings of roughly similar size were large, as can be seen in Figure 16 and Figure 17.

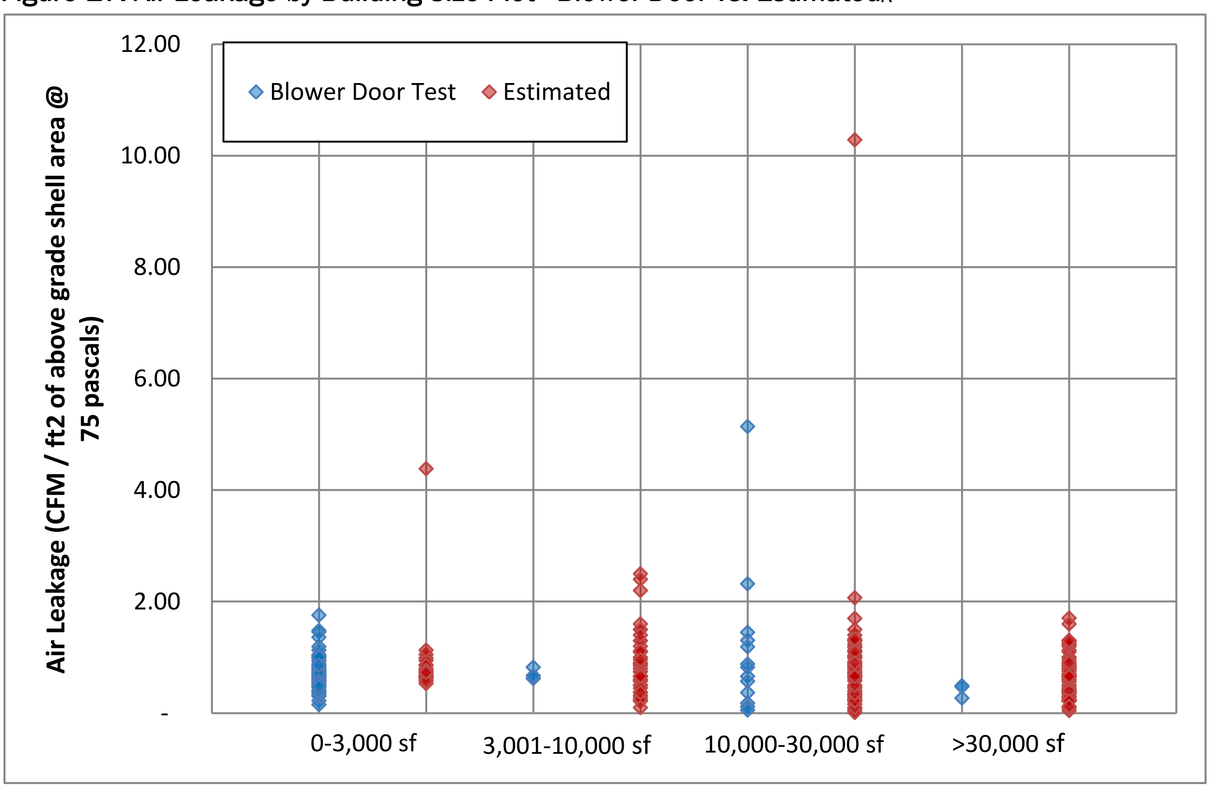
[12] Price, Phillip N., A. Shehabi, and R. Chan. 2006. *Indoor-Outdoor Air Leakage of Apartments and Commercial Buildings.* California Energy Commission, PIER Energy-Related Environmental Research Program. CEC-500-2006-111.

Figure 16: Air Leakage - Blower Door vs. Estimated[A]

Size (ft²)	# of Records	Air Leakage (CFM/ft2@75Pa)			
		AVG	MED	MAX	MIN
Blower Door Data					
All Buildings	78	0.78	0.68	5.14	0.05
0-3,000	58	0.73	0.69	1.76	0.15
3,001-10,000	4	0.69	0.65	0.82	0.62
10,001-30,000	13	1.16	0.82	5.14	0.05
>30,000	3	0.41	0.48	0.49	0.27
Estimated Data					
All Buildings	314	0.76	0.66	10.28	0.01
0-3,000	22	0.92	0.73	4.38	0.53
3,001-10,000	54	0.84	0.66	2.50	0.10
10,001-30,000	96	0.84	0.66	10.28	0.01
>30,000	142	0.64	0.66	1.70	0.05

*Note: 0.22 is considered tight, 0.66 average, and 1.3 leaky

Figure 17: Air Leakage by Building Size Plot - Blower Door vs. Estimated[A]

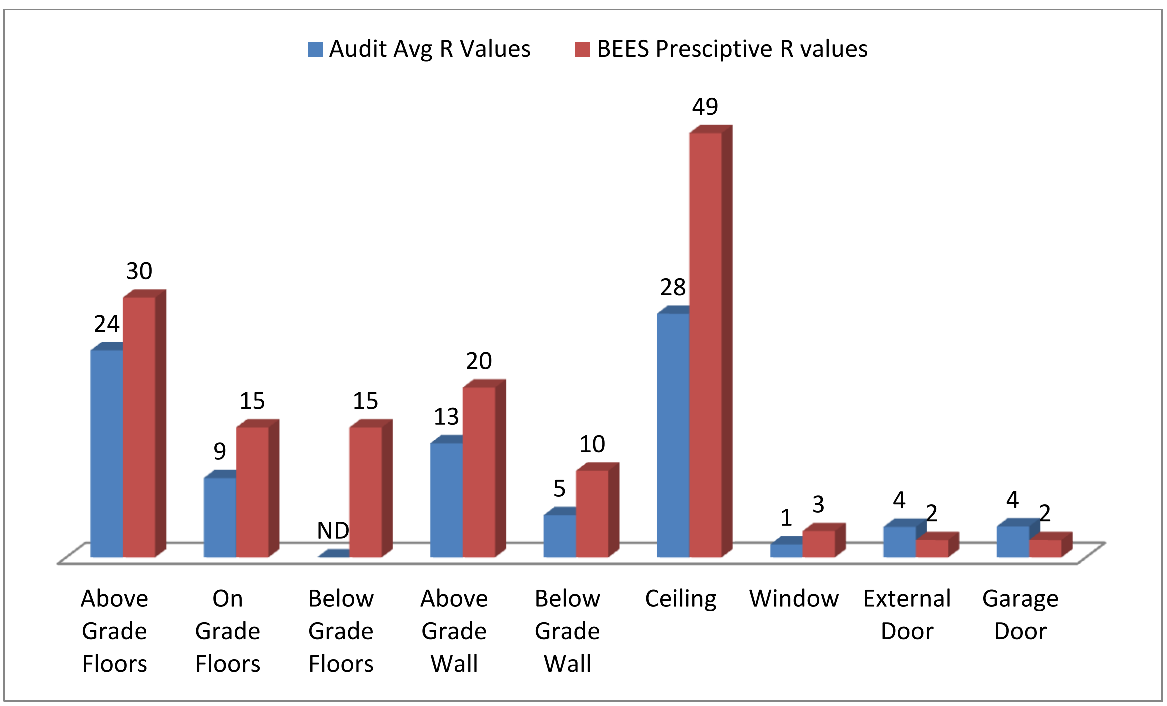


With the large range of leakage rates that were found, a blower door is highly recommended. Some buildings with blower door tests showed air leakage rates 10 times higher than those of other buildings, indicating an opportunity to capture "low-hanging fruit" in energy efficiency enhancements through air-sealing measures.

The following figures show the breakdown of average assembly R-values for each component by climate zone, and how these compare to the 2009 Alaska Building Energy Efficiency Standard (BEES) adopted by AHFC. The average age of buildings in the audit data set is 31 years old. Thus, the principal finding, that many of the shell components have R-values that are below the 2009 BEES standard irrespective of climate zone, is not surprising. However, these data do point to some components that are potential candidates for retrofits. For example, ceiling R-values are significantly lower than the current energy efficiency standard in all zones. When a roof reaches the end of its useful life, extra insulation can be added to the project for an additional cost that is typically much less than if it were to be undertaken as a stand-alone retrofit.

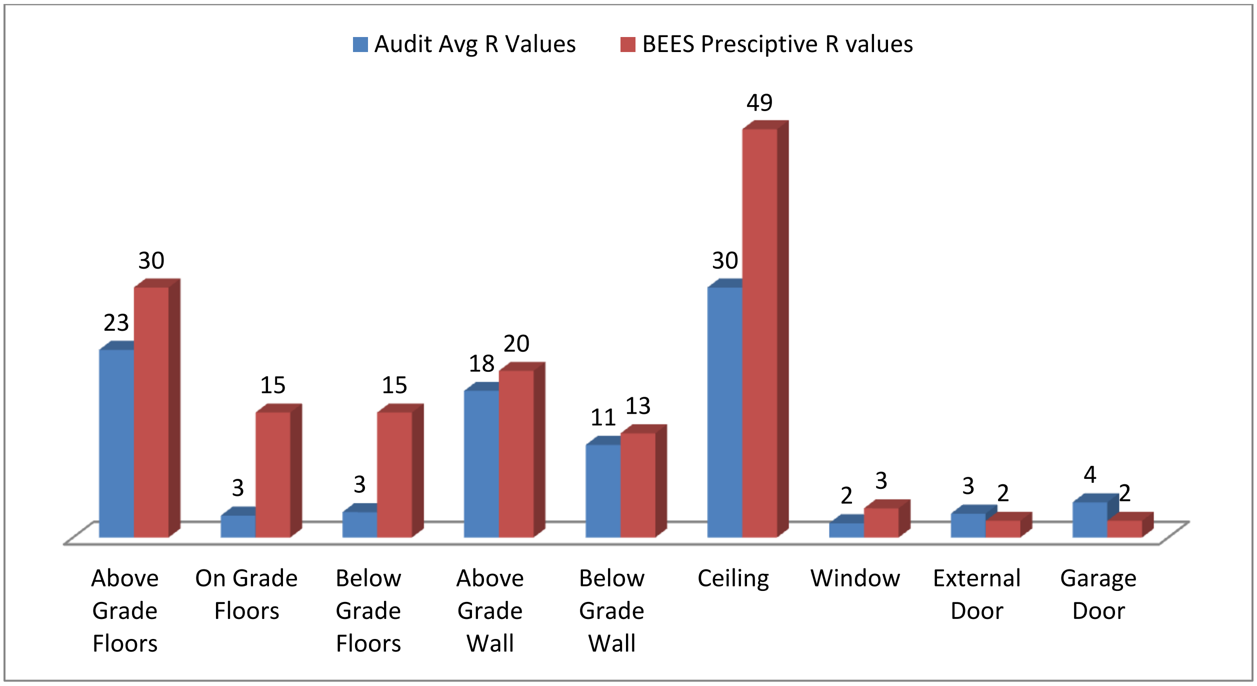
In Climate Zone 6, we see that buildings have a tendency to be under-insulated for all major shell components relative to the 2009 BEES, with wall and ceiling R-values average about half of the recommended levels. Further, where a structure has on-grade floors, they tend to be under-insulated as well. While it can be difficult and costly to retrofit insulation in the floor system, bringing up the wall and ceiling insulation can have definite positive paybacks. Depending on the system adopted, air tightening of the structure can also be accomplished simultaneously.

Figure 18: Zone 6 R-values - BEES vs. Audited BuildingsA



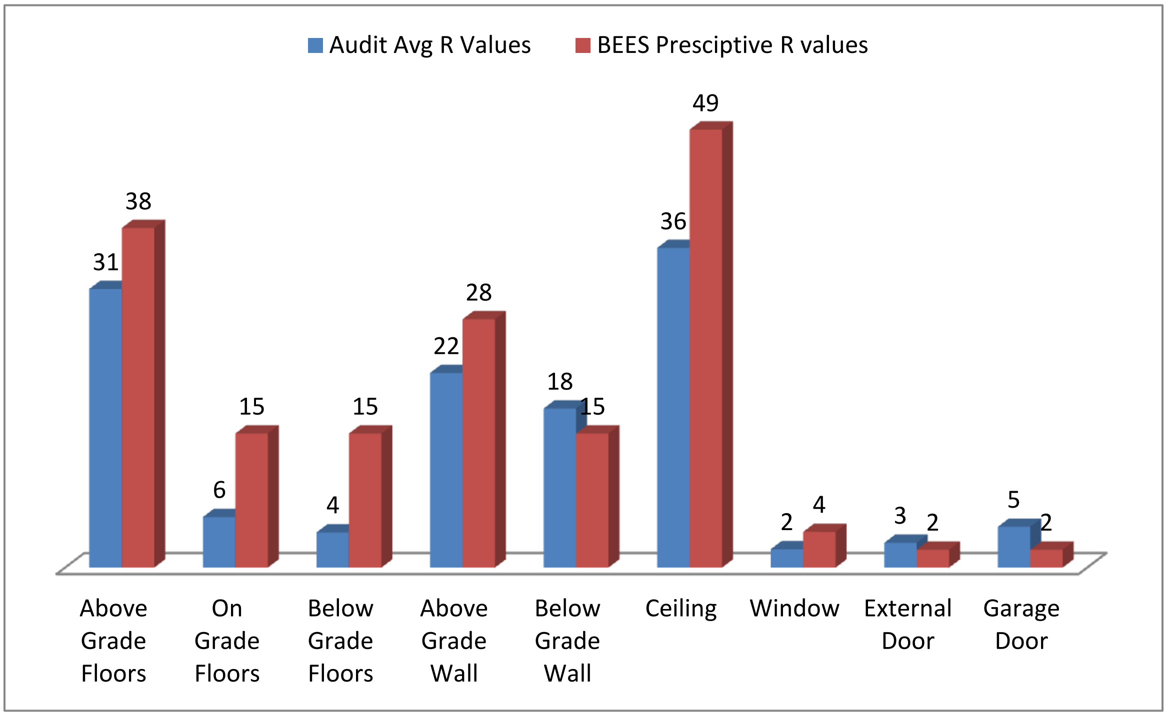
In Climate Zone 7, Ceilings are averaging about 60% of the recommended values. On and Below grade floors are 20% of the recommended values. On average, walls and above grade floors are near the recommended 2009 levels. Some areas of climate zone 7 have issues with discontinuous permafrost and with ice lens formation. It is always wise to consult a geotechnical expert about a sites subsurface conditions. If no such issues pertain to a site, then insulating the floor to BEES levels is a recommended course of action.

Figure 19: Zone 7 R-values - BEES vs. Audited BuildingsA



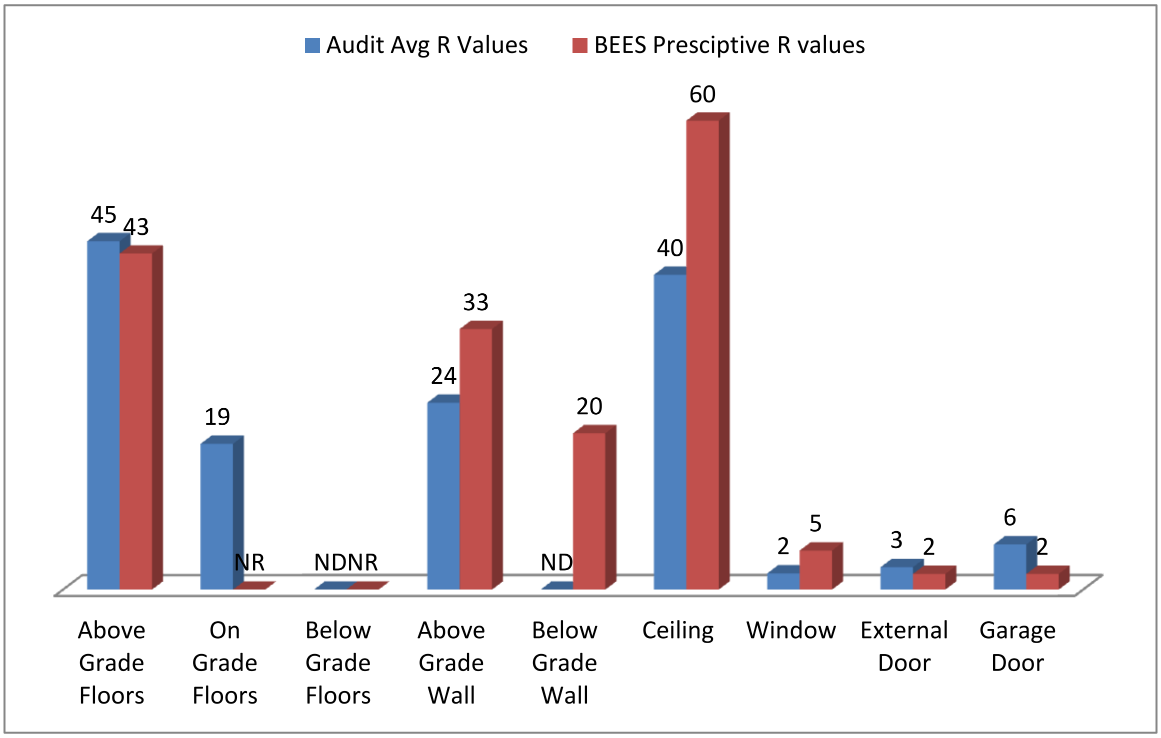
Commercial buildings in climate zone 8 have ceiling insulation levels that are on average about 30% below BEES recommended values. On and below grade floors are significantly under-insulated relative to the AHFC standard of R-15 of continuous sheathing, and windows are not far behind. These low floor insulation levels are likely part of why buildings in Zone 8 on average lose a larger percentage of total space heat through the floor, at 17%.

Figure 20: Zone 8 R-values - BEES vs. Audited Buildings[A]



Public buildings in climate zone 9 are actually exceeding the recommended insulation values in above grade floor on average. However, ceiling and above grade wall insulation levels are about 1/3 lower than the recommendations. This information can help inform future designs and deep energy retrofit programs throughout the region.

Figure 21: Zone 9 R-Values - BEES vs. Audited Buildings[A]



ND = No data, or insufficient data

NR = Not recommended

Thermal envelope retrofits are often the most costly to implement. For this reason, it is important that the initial design include as many energy efficiency upgrades as can be fit into the project budget. The difficulty in increasing envelope insulation post-construction and the significantly lower current R-values in public buildings both point to the need for a mandatory statewide energy efficiency code to minimize the long term costs to Alaska for energy expenditures.

Case Study - Rural Retrofits

One of the strongest cases for energy efficiency is that it produces jobs[13]. Money spent on energy efficiency retrofits involves a significant amount of labor, including construction, maintenance, and engineering. With a properly trained workforce, much of this labor can be provided locally, whereas typically money spent on fuels goes primarily to distant resource extraction companies. Additionally, reduced spending on energy can allow organizations to potentially spend more money on program staffing. Residential energy efficiency programs in Alaska are estimated to have already created 2,700 short-term jobs and 300 permanent jobs, with potential to create an additional 30,000 short-term jobs and 2,600 permanent jobs.[14]

Energy efficiency has the potential to be particularly beneficial to rural Alaskan economies. The economy in rural western and northern Alaska is unique in that it is based not only on cash, but also networks of subsistence, sharing, and trading. Approximately 71% of the cash portion of this economy and 36% of the jobs comes from government sources, according to research done by the Institute of Social and Economic Research.[15] These jobs include positions in schools, tribal offices, health clinics and more. The cost for the energy required to maintain a comfortable environment in these rural public buildings is often high—for example, the average annual energy cost of the 10 schools that received an energy audit in the Bering Strait region was over $200,000. As heating fuel prices have already risen by more than 50% in western and northwestern Alaska since 2005[16] and are projected to increase by 41% by 2040[17], reducing energy consumption is a crucial part of maintaining economically viable rural communities.

In an effort to understand the possible effects of energy efficiency retrofits in rural Alaska, the Cold Climate Housing Research Center analyzed the types of retrofits recommended in Alaska Native Tribal Health Consortium (ANTHC) energy audits. These energy audits were completed on 68 tribal buildings located primarily in Western Alaskan villages, which fell into one of the following 3 categories: Water Systems, Tribal Buildings, and Health Clinics. Preliminary analysis indicates that the average potential energy cost savings of 31% found for these buildings are comparable to those found through the Alaska Housing Finance Corporation public building audits. The data from these audits was stored in the Alaska Retrofit Information System (ARIS) which is owned and operated by AHFC. A further review showed the audit data to be of a similar level of quality.

After conducting the audits, ANTHC staff classified each of the 517 recommended retrofits by the type of retrofit and whether it can be performed solely by local village personnel, by a combination of village personnel and technicians from outside the village, or whether the retrofit would largely be conducted by engineers and professionals who reside out of the village.

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13 For a detailed discussion of the jobs benefits from energy efficiency, see Bell, Casey. "Energy Efficiency Job Creation: Real World Experiences. October 2012. American Council for an Energy Efficient Economy. Available at: http://www.aceee.org/files/pdf/white-paper/energy-efficiency-job-creation.pdf

14 Colt, Steve, Fay, Ginny, Berman, Matt, Pathan, Sohrab. *Energy Policy Recommendations.* (January 25, 2013). Institute of Social and Economic Research.

15 Goldsmith, Scott. January 2008. "Understanding Alaska's Remote Rural Economy." Institute of Social and Economic Research.

16 "Current Community Conditions Alaska Fuel Price Report." July 2012. Department of Commerce, Community, and Economic Development.

17 U.S. Energy Information Administration, "Annual Energy Outlook 2014", website: http://www.eia.gov/forecasts/aeo/er/pdf/0383er(2014).pdf

Figure 22 defines these different retrofit types, and gives common examples that were found during the audits.

Figure 22: ANTHC Retrofit Types

Retrofit Types	Description	Example
Operations	Simple projects that require little time or money to accomplish. Local village fully capable of doing.	Shut off heat tape, setback thermostat, shut off pumps, reduce temperature in loop
Maintenance	Projects that may require a specialized person from the village, but the village has most necessary supplies. May need some funding.	Clean boilers, reduce air transfer, clean and adjust floats in lift station
Local Retrofit	Projects that may require significant funding, but local village has all necessary skills and capabilities. Village may or may not have supplies for the job.	New thermostats, new lights, Replace aquastats, insulation additions
Minor Project	Larger scale projects that require outside assistance. Project may require technicians to assist and/or very significant funding.	Controls retrofitting, new boiler installation, resizing and replacing pumps
Major Project	Largest scale projects that will require significant outside assistance. Projects may potentially need an engineer, superintendant, or other professionals. Technical experts and very significant funding required.	Waste heat projects, Outfall replacement

Figure 23 shows that a significant portion of savings can potentially be done by local labor. Of the approximately $525,000 of annual energy savings found in the audits, roughly half can be achieved by trained local people. This is significant, as the audits were done in the rural areas with some of the highest average unemployment rates in the state (Figure 24) and currently approximately 41% of workers in rural Alaska are non-local[18]. Figure 23 also shows that on average, the costs for these local projects are lower so they can be done with only minimal capital investments.

[18] Goldsmith, Scott. January 2008. "Understanding Alaska's Remote Rural Economy." Institute of Social and Economic Research.

Figure 23: ANTHC Retrofit Savings & Costs by Project Type

ANTHC RETROFITS BY PROJECT TYPE			Annual Energy Savings (in $ thousands)			One-time Retrofit Costs (in $ thousands)		
		#	Total	AVG	MED	Total	AVG	MED
Totals		517	$525	$1.02	$0.27	$2,451	$4.74	$0.50
Project Type	Local	438	$203	$0.50	$0.21	$539	$1,231	$500
	Outside Help /Local	36	$95.9	$2.66	$1.30	$482	$13.4	$3.01
	Outside Help	43	$227	$5,279	$1.99	$1,430	$33.3	$5.00

Figure 24: ANTHC Retrofits vs. Unemployment Rates

ANTHC RETROFITS BY CENSUS AREA	# of Retrofits	Percent of retrofits with local labor	Regional Unemployment Rate[19]
State of Alaska	n/a	n/a	6.5%
Municipality of Anchorage	n/a	n/a	5.2%
Bethel Census Area	396	86%	14.8%
Nome Census Area	39	74%	10.1%
Wade Hampton Census Area	51	84%	20.8%
Yukon-Koyukuk Census Area	31	87%	15.1%

In addition to having the lowest capital costs, the retrofits identified as local projects also tend to have the quickest payback periods, as can be seen in Figure 25. Both the average payback period and the median payback for local projects are significantly shorter than for those projects that were identified as requiring some outside help or those that would be almost totally dependent upon outside engineers and specialists.

Figure 25: ANTHC Simple Paybacks by Project Type

ANTHC RETROFITS BY PROJECT TYPE		# of Retrofits	Paybacks (yrs)	
			AVG	MED
Totals		517	5.0	2.3
Project Type	Local	438	4.8	1.8
	Outside Help/Local	36	5.2	4.4
	Outside Help	43	6.8	4.0

[19] *December 2013 Preliminary Unemployment Rate.* State of Alaska Department of Labor and Workforce Development. Retrieved February 24th, 2014 from Live.laborstats.alaska.gov/labforce/index.cfm

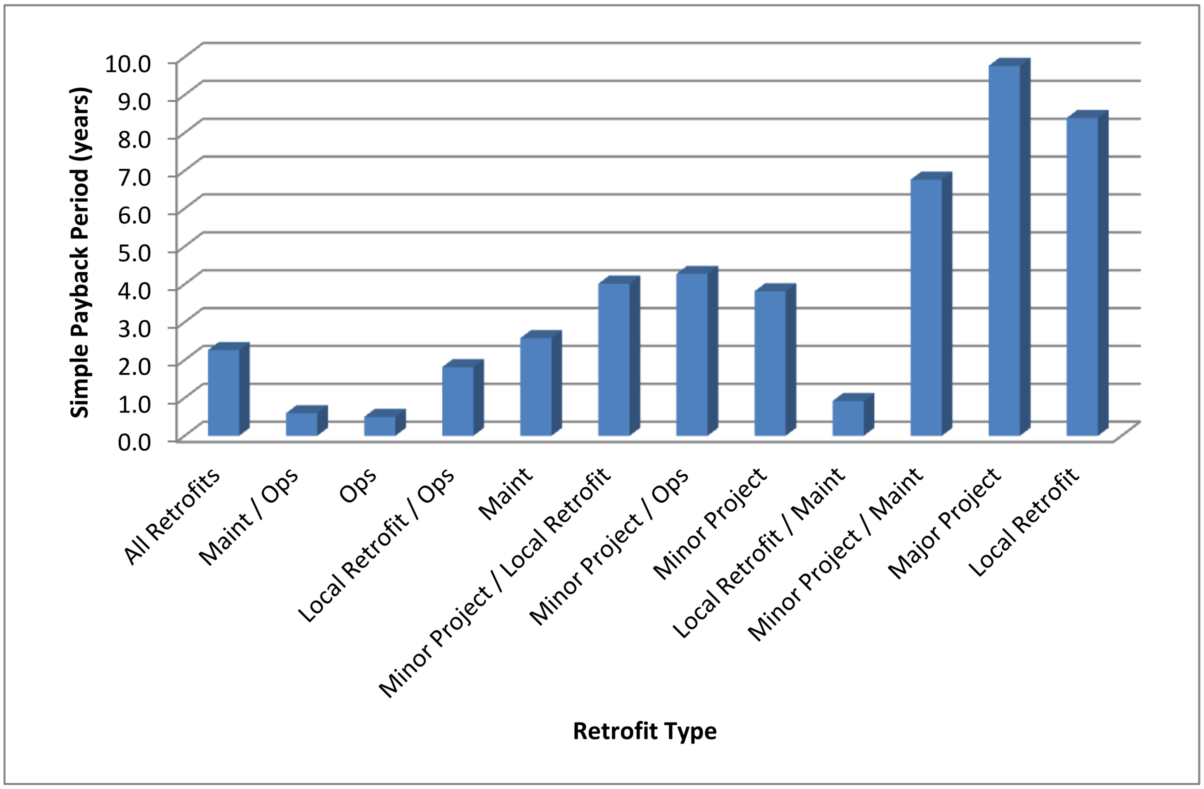
Analyzing the data by retrofit type shows that there are significant opportunities for energy savings through changing operational practices and by doing regular maintenance on buildings and mechanical systems. Figure 26 shows the annual savings and one-time costs for the different retrofit types. Because the average capital costs on operations and maintenance retrofits are typically much lower than other retrofits, paybacks are often very quick, as can be seen in Figure 27. While major and minor projects account for approximately 43% of the total potential annual energy savings, because of their significant costs, they tend to have longer payback periods. These findings are in line with the recommendations made by energy auditors in the *White Paper on Energy Use in Public Facilities*.[20]

Figure 26: ANTHC Retrofit Savings & Costs by Retrofit Type

ANTHC RETROFITS BY RETROFIT TYPE		Annual Energy Savings (in $ thousands)			One-time Retrofit Costs (in $ thousands)		
	#	Total	AVG	MED	Total	AVG	MED
All Retrofits	517	$525	$1.02	$0.27	$2,451	$4.74	$0.50
Maint / Ops	2	$4.70	$2.40	$2.40	$0.90	$0.45	$0.45
Ops	118	$22.0	$0.19	$0.05	$14.5	$0.12	$0.03
Local Retrofit / Ops	166	$106	$0.64	$0.36	$146	$0.88	$0.50
Maint	65	$25.90	$0.40	$0.21	$69.3	$1.07	$0.50
Minor Project / Local Retrofit	21	$40.70	$1.03	$1.47	$158	$7.53	$3.01
Minor Project / Ops	7	$10.10	$1.45	$0.87	$26	$3.71	$2.00
Minor Project	33	$89.20	$2.70	$1.30	$333	$10.1	$3.20
Local Retrofit / Maint	3	$5.67	$1.90	$2.18	$6.81	$2.27	$2.00
Minor Project / Maint	8	$45.10	$5.64	$2.24	$298	$37.2	$8.00
Major Project	10	$137	$13.78	$7.44	$1,098	$110	$82.5
Local Retrofit	84	$37.90	$0.45	$0.27	$301	$3.58	$1.98

[20] Armstrong, Richard, Luhrs, Rebekah, Diemer, James, Rehfeldt, Jim, Herring, Jerry, Beardsley, Peter, et. al. (2012). *A White Paper on Energy Use in Alaska's Public Facilities*. Alaska Housing Finance Corporation. Available online at: http://www.ahfc.us/iceimages/loans/public_facilities_whitepaper_102212.pdf

Figure 27: Median Simple Payback by Retrofit Type



Information from ANTHC staff, interviewed public school energy conservation and facilities managers, and Alaskan energy auditors all pointed to inadequate training for operations and maintenance staff as one of the reasons that these energy saving operations and maintenance measures have not been performed.[7,21,22] Considering the large potential for monetary savings on energy expenditures in public buildings in Alaska that can be accomplished with routine operations and maintenance procedures, this lack of training represents a large untapped resource.

Recommendations:

Energy prices in rural Alaska are high and likely to increase over time, and so inefficient buildings require increasingly larger amounts of public funding to be diverted from meeting program goals to cover energy costs. Additionally, the cash economy is limited in these areas and is largely dependent upon government funding, which is at risk given projected declines in the state revenues.[23] Energy efficiency measures in public buildings can reduce energy costs and free up funding for public

[21] Dixon, Gavin, Reitz, Daniel, personal communication, March 2013.
[22] Wiltse, Nathan, Madden, Dustin. *Energy Efficiency in Public Buildings: Schools.* (2014). Cold Climate Housing Research Center.
[23] *Revenue Sources Book: Fall 2013.* Alaska Department of Revenue - Tax Division. Available at: http://www.tax.alaska.gov/programs/documentviewer/viewer.aspx?1022r

organizations to hire new employees or perform more services. As roughly half of the energy efficiency measures recommended in audits were identified as being able to be performed with local labor, funding to increase efficiency in buildings also has the potential to boost employment in local economies. Based on our analysis, we believe that the following recommendations will help improve the long term economic viability of rural Alaska:

- **Conduct energy audits and retrofits on all public buildings in rural Alaska.** Identifying energy cost savings and undertaking local retrofits and maintenance/operations projects will help rural Alaska cope with dwindling government funding and predicted long-term energy price increases.

- **Incorporate energy efficiency training into all major retrofit projects in rural areas**. Training and hiring local workers keeps more of the economic benefits of the energy efficiency measures in remote communities.

- **Track energy use.** Operations and maintenance changes were some of the most cost-effective energy efficiency measures identified in rural Alaska. Installing building monitoring systems and benchmarking buildings using AHFC's ARIS software allows trained local staff to identify areas of excessive energy use and change operation and maintenance procedures to reduce it.

Schools

Findings Summary:

- $49 million public dollars per year are spent on energy in the 67% of schools that have available data.
- On average, audited schools in Fairbanks used less than half the amount of energy for space heating per square foot than audited schools in other urban school districts when climate has been factored out.
    - Incentive systems for energy management appear to be one of the biggest factors in this difference.
    - The level to which valuing energy efficiency has been institutionalized and operational efficiencies have been maximized also are likely contributing factors to differences in school energy efficiency.
- Schools in rural areas of the state tend to have lower electric use per square foot than those in urban areas.
- Ventilation and air leakage are often the largest source of thermal energy loss for schools.
- There is often significant variation in energy use and costs even within a school district, meaning there are likely many cost effective opportunities for energy retrofits.
- There is little correlation of building energy efficiency with the age of the building, local fuel price, the additional costs of construction in remote areas, or available fuel type. This means that older buildings and buildings in remote areas are not necessarily less energy efficient, and schools in areas with high fuel prices are not necessarily more energy efficient.

Of all the public buildings in this study, schools have the most data to support analysis; about 38% of all schools in Alaska received an IGA, and when benchmark data is included, about 67% of all schools in Alaska are represented. Additionally, interviews were conducted with energy conservation or facilities managers from 6 different school districts to supplement the quantitative data collected. The total energy use for these 67% of schools is approximately 1.85 trillion BTUs of energy per year, at a total cost of just under $49 million dollars annually. The cost of energy for schools can be a burden to communities throughout the state. These energy costs are likely to rise with the price of oil predicted to increase 41% by 2040[24] and Southcentral Alaska facing potential natural gas shortfalls without significant new developments.[25]

Each year schools are required to spend at least 70% of their budget on direct instruction, or obtain a waiver from the Alaska Department of Education and Early Development (DEED). Between 2001 and 2011, on average about half of the 53 school districts in Alaska have had to obtain a waiver for

[24] U.S. Energy Information Administration, "Annual Energy Outlook 2014", website: http://www.eia.gov/forecasts/aeo/er/pdf/0383er(2014).pdf
[25] Stokes, Peter J. "Cook Inlet Natural Gas Supply: 2014 and Beyond". RDC Annual Meeting. Available at: http://www.akrdc.org/membership/events/conference/2013/presentations/stokes.pdf

this requirement.[26] DEED has found that typically schools with operations and maintenance costs over 20% need this waiver, and money spent on energy is a significant component of these costs.[27] Reducing the energy costs required to maintain a comfortable school environment would free up more funding to be spent where it is needed most—on direct student instruction.

An analysis of 156 energy audits conducted by the Alaska Housing Finance Corporation (AHFC) on public schools throughout Alaska showed that on average, schools could save approximately $33,300 per year on energy by implementing the cost-effective energy efficiency retrofits identified by the auditors. The upfront capital cost of these retrofits averaged approximately $125,000, which would lead to an annual return on investment of 26%, paying itself off in a period of just under four years. Reducing energy costs has the potential to increase the funding available for education and provides a measure of long-term fiscal security in the face of uncertain future energy costs.

This paper investigates the differences in energy use and costs using audit and benchmark data from 67% of the schools as well as interviews with energy conservation and facilities managers in school districts throughout the state. CCHRC analyzed the factors affecting the energy efficiency of schools in order to identify the most cost-effective ways for buildings to reduce their long-term energy needs.

Variability of Energy Use and Costs in Alaska

Figure 28 and Figure 29 below show the differences in energy efficiency of schools in the four different BEES climate zones. While slight differences between climate zones can be seen, the large variability in energy efficiency and energy costs that occurs even within the same climate zone is evident in these two tables. For example, Zones 6, 7, and 8 all have similar ranges from approximately $2 per square foot to $12 per square foot—meaning some schools in the same general climate are spending six times as much on energy. Similarly, EUIs in these regions all have a range that is around seven times as much as the minimum.

Figure 28: Building Size and ECI of Schools by Climate Zone

SCHOOLS		SQUARE FOOTAGE$_{A+B}$				ECI$_{A}$			
BEES Climate Zone	# OF RECORDS$_{A+B}$	AVG	MEDIAN	MAX	MIN	AVG	MEDIAN	MAX	MIN
6	26	45,820	23,082	190,738	2,320	$4.01	$2.98	$11.39	$1.81
7	196	60,968	50,986	361,698	5,405	$3.49	$2.53	$11.50	$1.60
8	85	47,980	40,081	234,412	3,796	$4.91	$4.33	$12.46	$1.67
9	6	42,745	38,796	55,545	35,558	$7.03	$7.33	$9.08	$4.12

[26] October 29th 2012 State Board of Education Information Packet
[27] Ibid.

Figure 29: EUI and Electric EUI of Schools by Climate Zone A+B

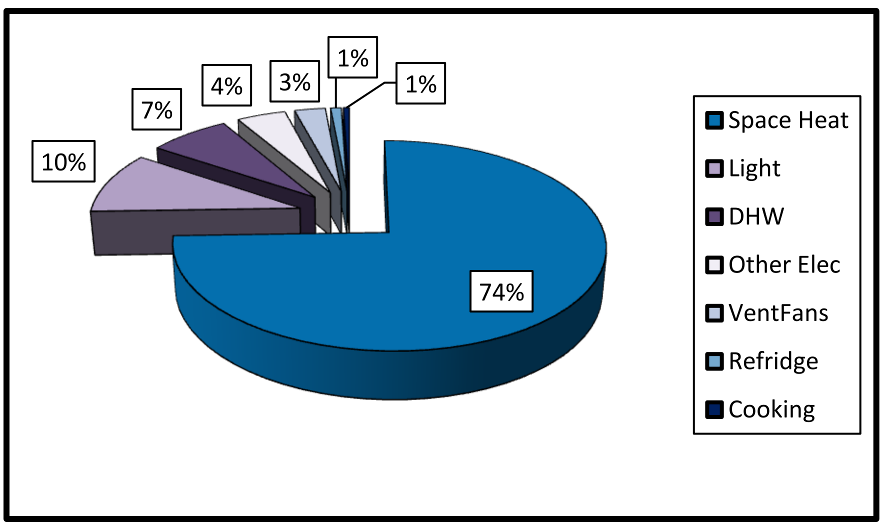
SCHOOLS		EUI (thousands of BTU / SQFT)				ELECTRIC EUI (KWH / SQFT)			
BEES Climate Zone	# OF RECORDS	AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
6	26	88.3	78.6	224.9	29.7	7.0	6.3	17.0	3.3
7	196	107.6	102.4	290.0	30.9	8.3	8.2	24.0	0.7
8	85	102.0	92.5	245.8	36.7	6.8	6.9	11.5	1.4
9	6	195.1	195.0	278.1	116.4	11.3	9.9	18.2	7.4

Energy End Uses – Space Heating

CCHRC analyzed energy end uses in an attempt to determine what is driving the high variability in energy use and costs in schools. Figure 30 shows that on average nearly three-quarters of the energy used in a public school building is for space heating. As space heating constitutes the majority of the energy use, it is also the area with the most potential for energy savings. There are several programs and initiatives in school districts in Alaska to increase energy efficiency by incentivizing user behavior.

While energy for lighting and electrical plug loads can typically be reduced by changing user behavior, space heating is not likely to be significantly affected.

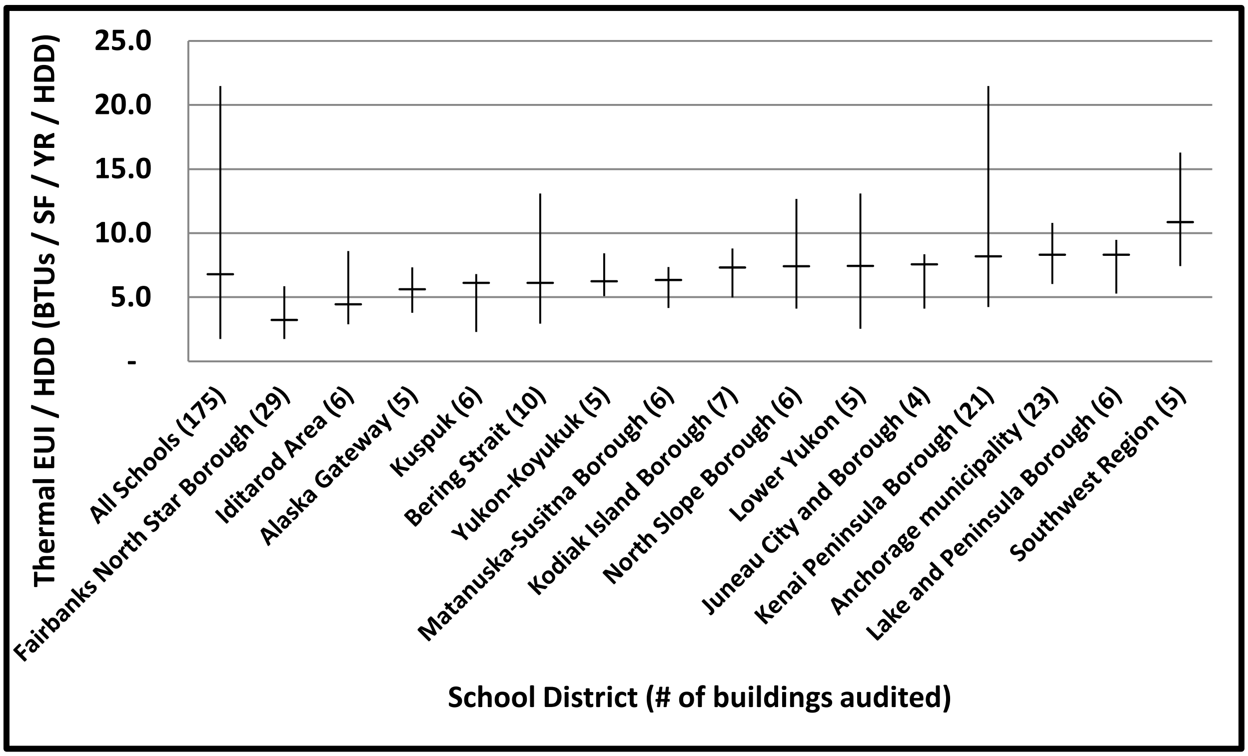
Figure 30: Schools - Energy Consumption by End Use A



Since space heating is typically the largest energy use in a school building, and different climates will have different heating loads, the best metric for comparing the energy efficiency of schools across the state is Thermal EUI/HDD. By normalizing the space heating load by the heating degree days and the square footage of a building, one can more reasonably compare both large and small schools and schools located in the Arctic versus those in more temperate regions of Alaska.

Figure 31 shows the Thermal EUI/HDD for school districts that had four or more energy audits performed. It should be noted that these schools were not randomly selected; AHFC's investment grade audit program typically chose the least energy efficient buildings in each district, as potential energy cost savings would be higher. As these audits were not evenly distributed, some districts received audits for a much higher percentage of their buildings than others. The central bar in this figure represents the median, and the vertical line represents the maximum and minimum usage in each district. The range highlights how variable energy efficiency is even within a school district. A large range likely indicates that there is one or more very poorly performing school in that district which probably has significant opportunities for cost effective retrofits or operational changes. Small ranges, on the other hand, may indicate that the district is closely watching energy use and focusing resources on the low-hanging fruit for energy efficiency measures. Gains are still possible in such cases, but often require greater capital investment.

Figure 31: Median Thermal EUI/HDD by School District[A]

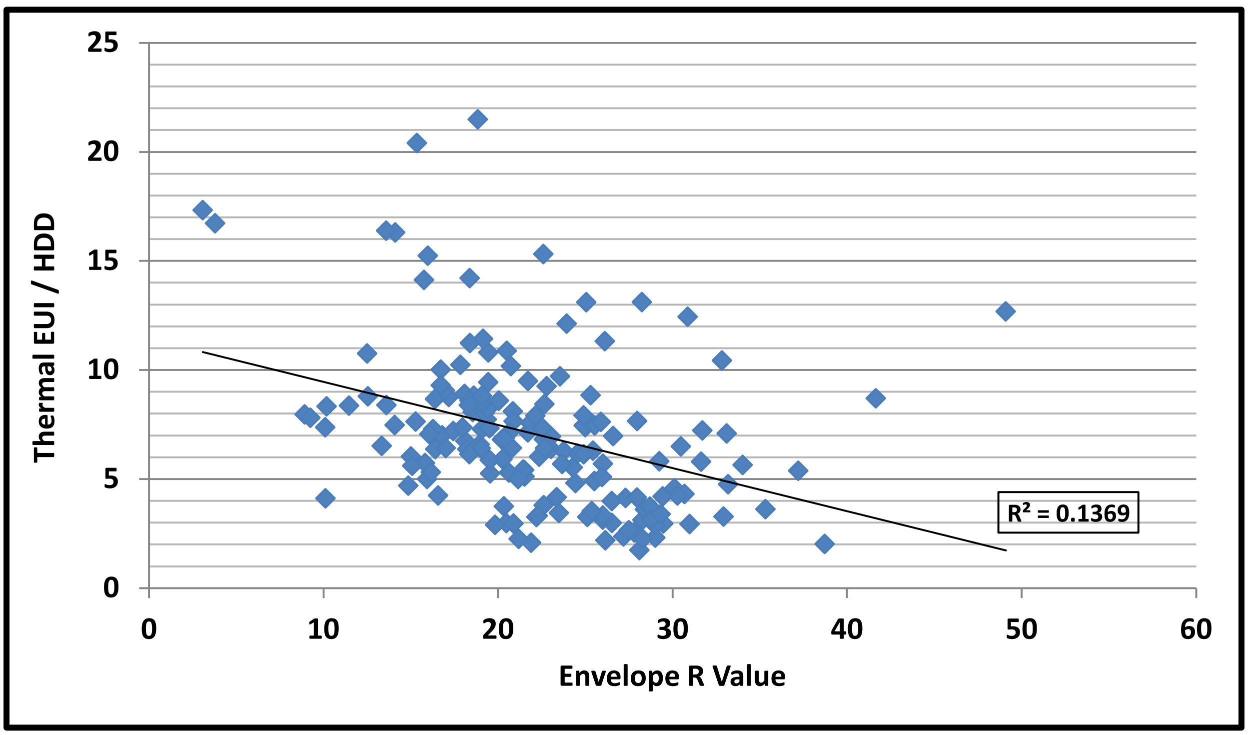


Of the school districts with at least four audited buildings, the Fairbanks North Star Borough district uses significantly less energy than other districts with access to the road or ferry system (Figure 31). In fact, districts in Anchorage, Juneau, and the Kenai Peninsula use more than two times the energy per square foot on average for an equivalent amount of heating as Fairbanks schools.

A variety of factors were analyzed to investigate the cause of the significant variation in energy use between school districts. CCHRC performed regression analyses looking for correlation between thermal EUI / HDD and: building age, years since the last remodel, the current geographic area construction cost factors for building a facility in remote locations[28], primary fuel type, building size, and the price of fuel. For all school buildings, there was no significant correlation found between any of these variables[29]. This means that the primary driver of energy efficiency is not age of buildings, construction cost, or energy prices.

One variable that did show some correlation to Thermal EUI / HDD is building insulation level, measured by R value. The R values for the entire envelope assembly were calculated and compared to the Thermal EUI / HDD values on a school-by-school basis. As one would expect, Figure 32 shows a general trend of buildings with higher insulation values having a lower thermal EUI / HDD. There is also significant variation within this trend, and there are many outliers.

Figure 32: Schools - Thermal EUI/HDD vs. Envelope R-value[A]



Envelope R value does not account for most of the variation in thermal EUI / HDD for school buildings. Of the 74% of energy used for space heating in schools, between 55% and 58% is lost through air transport from ventilation and leakage (Figure 33). In commercial buildings, the rate of air exchange due to mechanical ventilation is almost always higher than the air infiltration rates[30]. Indeed, when the total annual amount of ventilation was compared to the annual thermal energy per

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[28] Cost factors come from the Program Demand Cost Model for Alaskan Schools published by the Alaska Department of Education and Early Development available at https://www.eed.state.ak.us/facilities/pdf/cost_model_instructions.pdf

[29] See Appendix A for details.

[30] Price, Phillip N., A. Shehabi, and R. Chan. 2006. *Indoor-Outdoor Air Leakage of Apartments and Commercial Buildings.* California Energy Commission, PIER Energy-Related Environmental Research Program. CEC-500-2006-111.

HDD for school buildings, a much more significant correlation was found (Figure 34). While envelope insulation values are an important part of the energy efficiency picture, accounting for 42-45% of heat loss, the tight correlation between ventilation and thermal energy per HDD points to ventilation rates as being the single biggest driver of energy usage in schools. Additional factors that play a role in the variation of energy use include different indoor temperature setpoints and setbacks and different hours of operation.

Figure 33: Space heating loss by component for large & small schoolsA

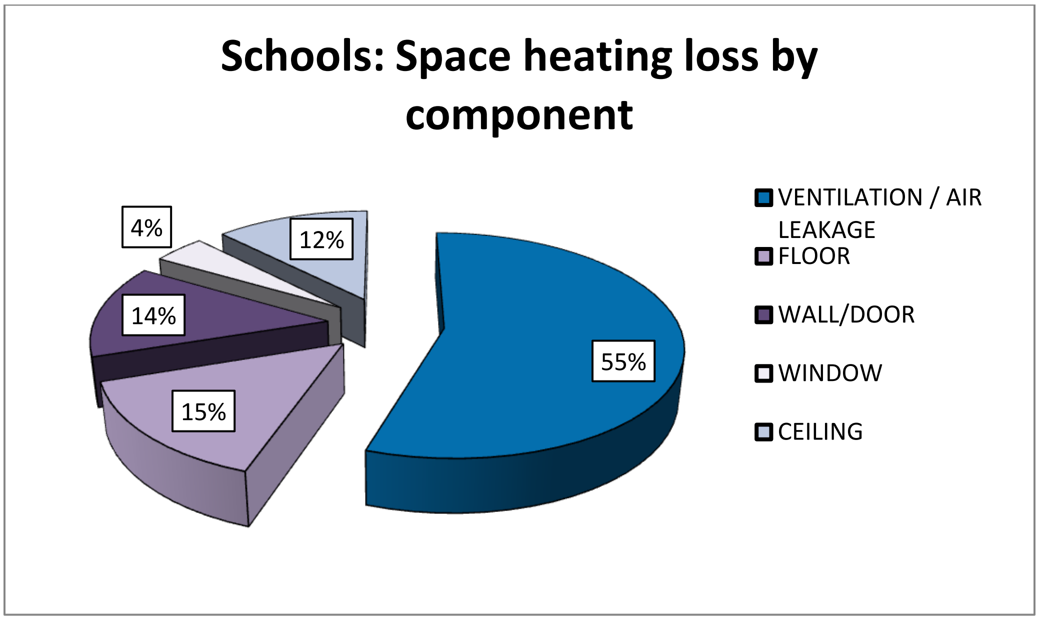


Figure 34: Schools: Annual thermal energy / HDD vs. Total Annual Ventilation

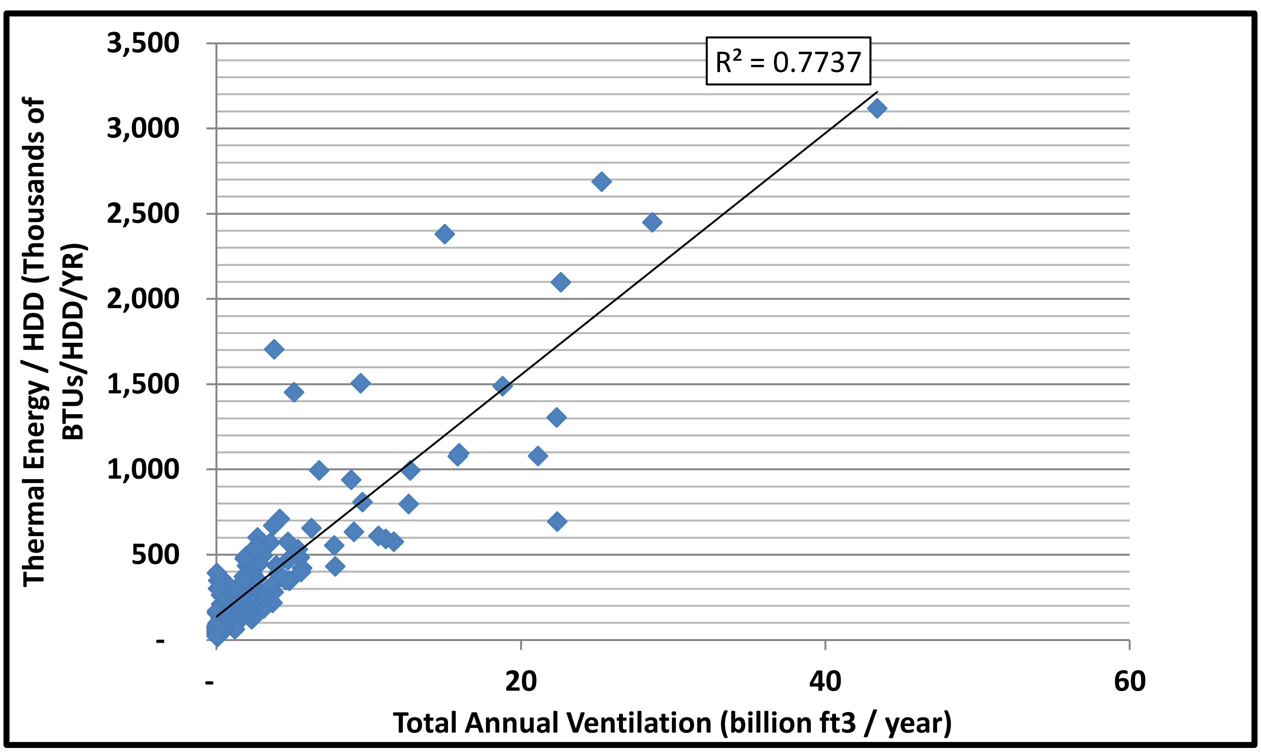


Figure 35 and Figure 36 highlight the variation found in thermal EUI/HDD. Figure 35 compares the thermal EUI/HDD of the three urban school districts with the most available data. Similarly, Figure 36 compares the thermal EUI/HDD of three rural school districts with very different energy performance characteristics.

Figure 35: Comparison of Urban School Districts - Envelope R-value vs. Thermal EUI/HDD[A]

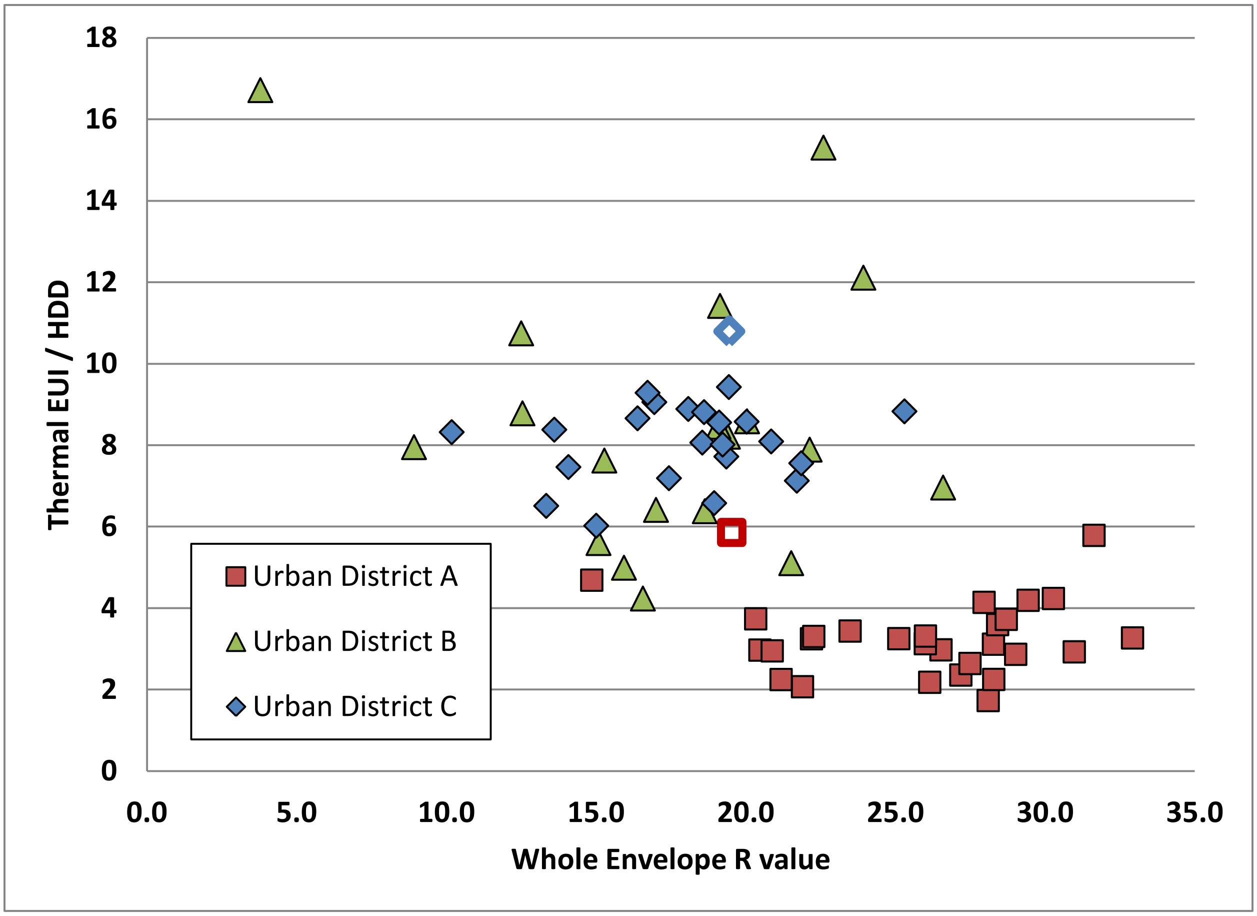
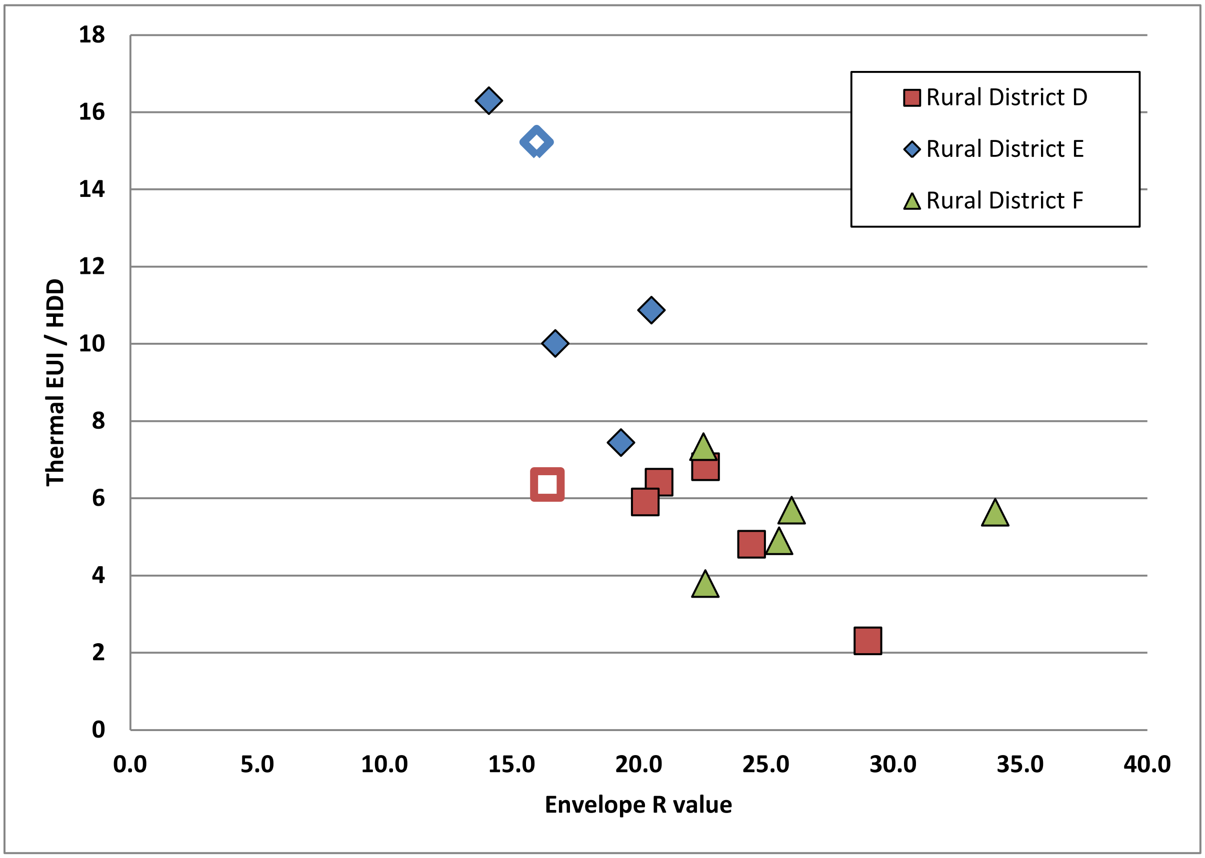


Figure 36: Comparison of Rural School Districts: Envelope R-values vs. Thermal EUI/HDDA

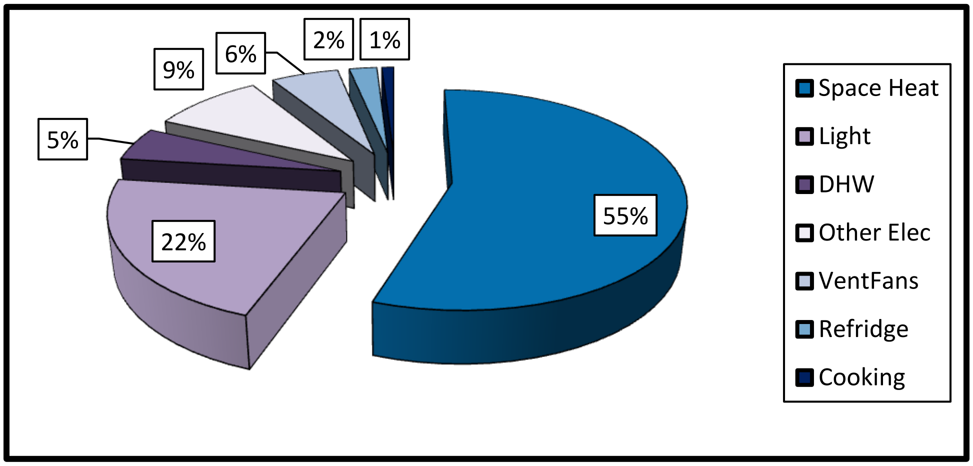


In both of these comparisons, the highest-performing district is offset horizontally to the right, meaning they have better insulation values. A more energy efficient district having better insulation values is to be expected. More interesting is that the higher-performing districts are also offset vertically, meaning that a building with the *same* levels of insulation in the better performing district are actually using significantly less energy per heating degree day than the buildings in the lower-performing districts. This is highlighted by the hollow points in the above graphs. In each case, the two buildings being compared have roughly the same whole envelope R value, but the school in the higher-performing district is using almost half the energy per heating degree day to heat each square foot of building space. The strong correlation found in Figure 34 and the information from the interviews suggest that the primary cause of this discrepancy is differences in ventilation strategies. Other contributing factors are air leakage and operation of the buildings. A more detailed discussion of these differences can be found in the case study on school energy conservation below.

Energy End Uses - Electricity

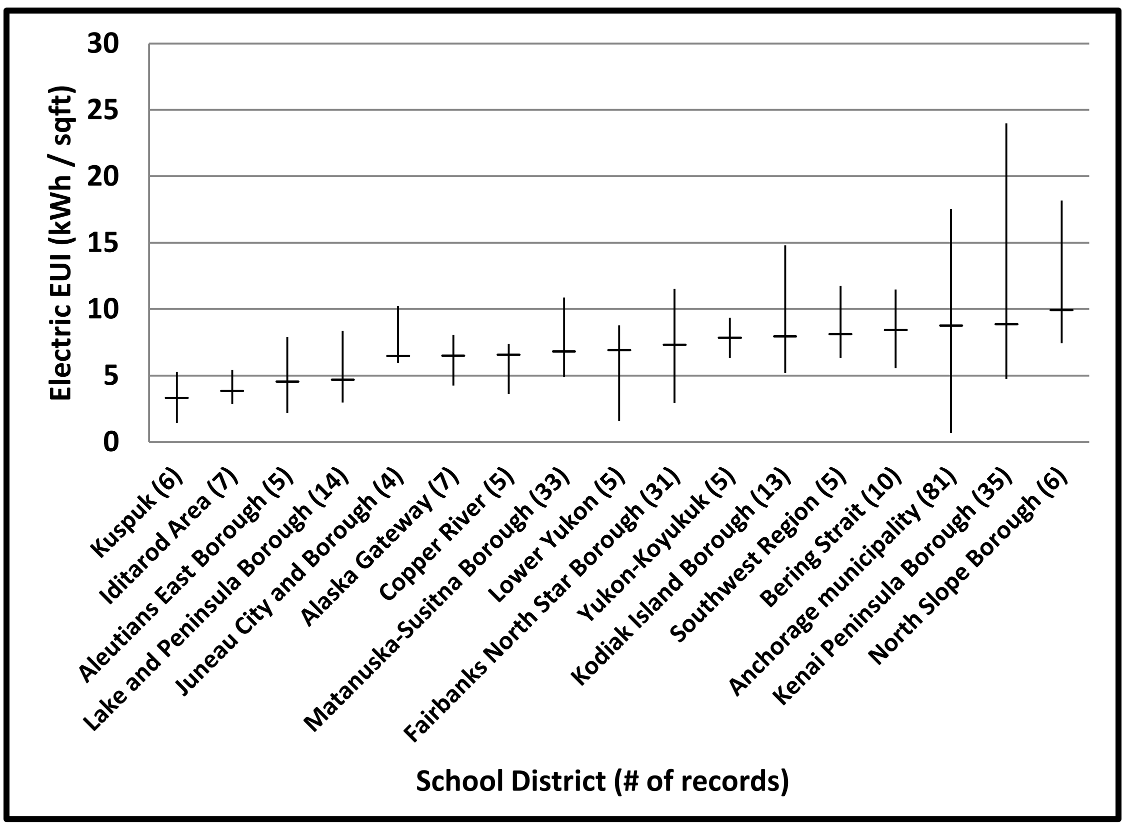
Due to Alaska's cold climate, space heating is by far the largest energy use and cost in the state's public buildings. The next largest energy use is lighting. Due to the higher cost of electricity, lighting accounts for over 20% of energy costs, even though it is only 10% of energy use of the average school. Figure 37 shows the average breakdown in energy costs by end use for schools.

Figure 37: Schools–Energy Cost by End Use[A]



The electricity use between school districts varies significantly (Figure 38). The horizontal bars represent the median for each school district, and the vertical lines represent the ranges found in different schools.

Figure 38: Median Electric Utilization Index by School District[A+B]



Interestingly, this data appears to show that the districts with the least electrical use are all located in rural areas. In fact, when comparing the Electric EUI across districts, the four most efficient electricity users are all located in rural areas. CCHRC recommends further research to determine the underlying cause of this electricity conservation and determine if it could be replicated in other areas.

Case Study - School Energy Conservation

In an attempt to better understand the underlying reasons behind the differences in thermal EUI/HDD among school districts, CCHRC conducted in-depth interviews with Facility Department personnel and Energy Conservation Managers in six school districts[31] throughout the state. Interviews were designed to look at the institutional policies and practices that may partially account for the differences in energy usage between districts.

Figure 39 provides an overview of key factors in the way school districts manage energy consumption and costs in their district.

[31] Information from one of the school districts is not presented here because of data collection anomalies

Figure 39: Incentives & Staffing of Selected School Districts

School District	# Audits / # Benchmarks / # Schools in district	Average thermal EUI / HDD (Btu/SF/ HDD)	Electric EUI (kWh / SF)	Year Energy Focus Started	Incentives	Personnel
Alaska Gateway	5 / 2 / 7	5.5	6.5		Money saved through EEMs more likely to be approved for use for future facilities / maintenance projects	Small staff; well-trained
Anchorage	23 / 58 / 94	8.2	9	2007	25% of money saved through energy efficiency goes to budget of individual school; no incentive for facilities and maintenance	High turnover due to funding cuts; insufficient number of DDC[32] programmers
FNSB	29 / 2 / 34	3.3	7.5	~15 years ago	Positive feedback loop: money saved through EEMs[33] goes back into facilities / maintenance budget	Well-trained; sufficient number of DDC programmers
Mat-Su	6 / 27 / 42	6.3	7	2005	All money saved through energy conservation goes back into district general fund	Well-trained; insufficient number of DDC programmers
Southwest Region	5/ 0 / 8	12	8.3	2005/ 2006	Money saved through EEMs more likely to be approved for use for future facilities / maintenance projects	Insufficient number of community-based trained professionals

During the course of these interviews, CCHRC identified four common factors that appear to play major roles in the energy efficiency of the different school districts: the type of incentive system (if any) that was in place, the existence of systems and staff to maximize operational efficiency, equipment standardization, and whether or not energy efficiency had been institutionalized.

[32] Direct Digital Control (DDC) systems are automated controls for building components such as HVAC and lighting, and typically entail controllers, logic, time schedules, set-backs, timers, alarms, and possibly trend logs. These systems can potentially save significant amounts of energy, but must be programmed and readjusted to meet changing occupancy schedules.
[33] Energy efficiency measures; these include any change to equipment, control systems, or practices which reduce the amount of energy used to provide the same level of comfort or utility.

Incentive System

While each district operates under different conditions, including differences in climate, the interviews suggest that the biggest driving forces behind the differences in energy efficiency are the incentive systems. For example, based on the data available, Fairbanks has the lowest thermal EUI/HDD of any district in the state. While this may be due to several factors, the most significant difference between Fairbanks and other school districts found in the interviews is that every dollar saved through energy efficiency measures goes back into the facilities and maintenance budget, creating a strong incentive to reduce energy use. This system provides an incentive for all levels in the organization—in times of tough budget cuts around the state, saving money spent on energy has meant that in general facilities and maintenance positions have been retained in the FNSB school district. This system also allows for energy efficiency measures to continue to be implemented with a limited budget, as facility managers are motivated to implement measures that will quickly pay for themselves, freeing up more money to be spent on personnel and projects rather than on fuel over time. This combination of utility and facility budgets also allows for long-term planning as to how best to implement energy efficiency over time.

In contrast, when money is saved in the Southwest Region, Alaska Gateway, or the Mat-Su school districts, it first goes back into the general fund. In Anchorage, if money is saved on energy, 25% of those funds go to the school where energy was reduced, and the rest goes back into the district general fund. This type of incentive system tends to spur school principals and district managers to implement programs to change user behavior and reduce plug loads in schools. In a commercial-scale building, changing plug loads and user behavior has less potential for energy reduction than optimizing operational controls and implementing mechanical retrofits. Thus, while this type of incentive system is a good second phase to reducing energy use, it has the potential to reduce already limited funding for more cost-effective energy saving measures if it is implemented before operational efficiencies and the low-hanging fruit of energy efficiency measures have been maximized.

Operational Efficiency

Operational efficiency involves attention to the function of the building's systems. This can include tuning heating and ventilation rates and schedules to occupancy and needs, establishing off-use setbacks, adjusting lighting use, identifying waste and leakage, and training staff on proper operation. As discussed earlier, space heating provides the largest avenue for energy savings, with ventilation controls being a key factor in the differences in thermal EUI/HDD for schools (Figure 33 and Figure 34). There is considerable research showing the need to adequately ventilate enclosed spaces in order to maintain proper indoor air quality[34], and interviewees indicated that schools were designed to meet these standards. In Alaska's climate, this often means that air is being brought in at temperatures below zero and warmed to 70 degrees at a significant energy cost. It is essential that operations staff ventilate to meet the needs of students when the building is occupied, but minimize the amount of ventilation during periods of low/no occupancy.

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[34] American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (2010). ASHRAE Standard 62.1. Atlanta, GA.

One common remark from every interview was that schools in Alaska are heavily used by the community. Many schools have some level of occupancy until late into the evening on a regular basis, although often only a small number of people and only certain sections of the school. One of the key factors that all interviewees pointed out was the importance of controlling ventilation so that during these periods of low-occupancy only the area directly occupied is being ventilated. This requires that buildings have well-partitioned HVAC zones, adequate control systems, and the staff to properly operate these systems. A common complaint among school districts with higher thermal EUI/HDD numbers was that they had either a large number of different Direct Digital Control (DDC) systems, or inadequate levels of trained DDC system[35] staffing in each community of their district to achieve optimized ventilation rates for ever-changing school occupancy schedules. Additionally, more than one interviewee pointed to poor zoning as the cause of one of their inefficient buildings and, conversely, well-partitioned zones as responsible for high performing buildings. For example, one recently constructed large high school had a minimum number of zones, so when the dutiful administration member arrives two hours before students, the HVAC system starts operating for the offices, gym, and cafeteria as if they were at full occupancy. This leads to a constant exchange of a huge volume of outside air that needs to be heated when only one person is in the office.

Analysis of historical energy data is beyond the scope of this paper. However, interviewees in districts with energy conservation managers all pointed to significant energy cost savings in the past several years relative to a base year. Since operational efficiency appears to play such a large role in energy consumption and costs for schools, having a position dedicated to tracking energy data and detecting inefficiencies for remediation is integral to lowering overall energy use. Several energy conservation managers pointed to a case in which they saved significant amounts of money simply by identifying cases of overbilling by the utilities.

Institutionalized Energy Efficiency

Another key difference between districts was the level to which energy efficiency had been institutionalized, or integrated into organizational culture and policy. For example, the FNSB school district requires that energy efficiency opportunities be examined during any maintenance project. This policy tends to reduce the cost of energy retrofits as they may be integrated into regularly scheduled repair or replacement projects. For example, when a roof or siding has reached the end of its life cycle, more insulation can be added before installing the new component. Other districts did their energy retrofits primarily on an ad hoc basis, when grant funding or bond money was available. This policy difference may be part of the reason that FNSB buildings have much higher envelope R values than those in other urban school districts (Figure 35), even though all of these districts have buildings of a similar average age.

Including energy conservation staff in the design process for new buildings is also essential to institutionalizing energy efficiency. When these staff are not an integral part of the process, relatively new buildings have been found to be less energy efficient than schools that are over 30 years old. For example, both the Southwest Region and Mat-Su school districts have built a school

[35] DDC systems are simply automated controls for building components such as HVAC and lighting, and typically entail controllers, logic, time schedules, set-backs, timers, alarms, and possibly trend logs.

within the past 10 years that has proven to be one of the biggest energy users in their district, and in each case there was little to no involvement of energy conservation staff in the design.

Retro-commissioning

Finally, more than one of the interviewees indicated that because of budget constraints leading to significant deferred maintenance, some buildings were in need of retro-commissioning. Retro-commissioning is a commissioning process for existing buildings whose performance, appliances, or characteristics may have changed or been altered over time. It ensures that the HVAC system and other building components are working as intended to meet the building occupants' needs in the most efficient manner and that staff are trained to operate and maintain the building correctly. According to a meta-analysis by the Lawrence Berkeley National Laboratory, the median payback on retro-commissioning an existing building is 1.1 years, with a median energy savings of 16% and a commissioning cost of $0.30 per square foot.[36] The non-energy benefits of retro-commissioning are also estimated to be quite high—in one example from the Lawrence Berkeley study, four elementary schools avoided an estimated $100,000 in repair costs by correcting problems in a retro-commissioning effort[37]. An earlier case study found that buildings with annual energy costs greater than $2 per square foot and those with deferred maintenance are the best candidates for saving money.[38] Since every school district except Anchorage[39] has an average ECI of greater than $2 per square foot and some schools have issues with deferred maintenance, retro-commissioning is likely to be very cost effective.

Equipment Standardization

Due to the limited maintenance budgets and staffing that many school districts face, it appears that equipment standardization likely plays both a direct and indirect role in affecting energy efficiency. Directly, both interviews and the results in the "White Paper on Energy Use in Public Facilities"[40] indicate that more complex energy-saving technologies are sometimes overridden or improperly used because operations and maintenance staff are not familiar with them, cancelling out the benefits of the systems. Examples include direct digital control systems being switched to manual mode, negating the energy savings of setting back temperatures and ventilation rates at night, and maintenance workers bypassing motion sensors for lighting because of a lack of time to learn how to fix a new system. Indirectly, if maintenance staff can do their jobs more quickly due to familiarity

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36 Mills, Evan. 2009. *Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions*. Lawrence Berkeley National Laboratory. Retrieved November 20, 2012 from http://escholarship.org/uc/item/7dq5k3fp

37 Ibid.

38 Gregorson, Joan. (1997). Commissioning Existing Buildings. *ESource Tech Update.* Retrieved November 19, 2012 from http://www.cecer.army.mil/kdsites/hvac/commissionpedia/publications/Papers/Tu9703%20ES%20Commissioning%20Existing%20Buildings.pdf

39 Anchorage has an average ECI of $1.96 per square foot

40 Armstrong, Richard, Luhrs, Rebekah, Diemer, James, Rehfeldt, Jim, Herring, Jerry, Beardsley, Peter, et. al. (2012). *A White Paper on Energy Use in Alaska's Public Facilities*. Alaska Housing Finance Corporation. Available online at: http://www.ahfc.us/iceimages/loans/public_facilities_whitepaper_102212.pdf

with equipment, more time is available to implement energy efficiency measures. A long-term effort to standardize equipment likely contributes to the ability of the Alaska Gateway School District to perform so well even with only three maintenance personnel for seven schools.

Because DDC systems are particularly important in optimizing the operational efficiency of ventilation and heating systems, CCHRC recommends that these be standardized as much as possible within a school district or even within a region. Several interviewees pointed to the difficulty of having multiple systems and not necessarily having sufficient numbers of staff trained to operate each system.

Interview Highlights

The following are interesting additional insights obtained through the interviews:

- A LEED Silver certified[41] school in one district was one of the highest energy users in the district due to a lack of separate zones and design flaws.
- One school with high electricity costs had a full LED lighting retrofit done, which paid back in less than one year. Money for this project was taken straight out of the annual budget for utilities at the start of the fiscal year.
- An energy conservation manager saved approximately $250,000 per year by uncovering a billing oversight.
- Exterior LED retrofits in one school district saved 1,800 man-hours annually by reducing the amount of labor needed to replace lamps.
- One school district has an internal standard of R-75 for any future roof retrofits and new construction.

[41] Leadership in Energy & Environmental Design (LEED) is a third-party certification program verifying buildings as "green" to different levels. See http://www.usgbc.org/leed for more details.

Recommendations

The availability of large amounts of data on schools in conjunction with the interviews allows for detailed recommendations. Energy costs can comprise a significant portion of school budgets. As energy costs rise, schools will need to find ways to cost-effectively reduce energy consumption to avoid reducing the instructional budget even further. If done efficiently, energy management has the potential to increase the funding available for instruction in the near-term. Based on the analyses in this report, the authors feel that these recommendations will help schools reduce their energy costs in a targeted, effective manner.

Short Term:

- **Get an energy audit for all buildings.** On average schools can save $33,300 per year on energy costs through making cost effective changes.
- **Implement the cost-effective energy efficiency measures recommended by the auditors.** The average return on investment is 26%, or a less than 4-year simple payback.
- **Create a district-wide energy policy.** This policy should direct staff to pay attention to energy use and look for means to cut costs. It should also provide a means of recognizing staff members that have been successful in reducing energy costs.
- **Consider retro-commissioning buildings with energy costs greater than $2 per square foot.** This is a good way to ensure that building systems are working properly, and typically energy cost savings quickly overtake the initial expenditure
- **Install a building monitoring system.** These systems allow staff to track energy usage of different building systems and diagnose inefficiencies before they cause equipment maintenance problems. AHFC has developed an inexpensive building monitoring package that has already allowed them to find significant energy cost savings.

Long Term:

- **Focus energy reduction efforts on space heating.** The majority of energy consumption and costs in a school are for space heating.
    - **Aggressively manage ventilation.** Ventilation is the largest component of space heating.
        - **Ensure there are sufficient staff trained to properly operate DDC systems.** These systems allow ventilation to be properly matched to occupancy of the building so cold air is not excessively brought into the building.
        - **Install Demand Controlled Ventilation systems in new construction.** These systems automatically adjust the ventilation rates based on building occupancy.
        - **Where feasible, include well-partitioned and independently controlled HVAC zones to account for different occupancy or scheduling in various building areas.**

- **Incentivize Energy Efficiency**
    - **Combine the utility budget with the maintenance and operations budget.** This provides an incentive for all maintenance and operations staff to find the most cost-effective way to reduce energy use. Often facilities and maintenance departments that save energy costs do not see any of the savings and receive little recognition for their efforts. Combining budgets allows maintenance and operations staff to implement energy efficiency measures in combination with facility upgrades and routine maintenance, making them more cost effective.
    - **Track monthly energy consumption and costs.** Energy patterns cannot be seen with the naked eye. Keeping a database of monthly energy use and cost by fuel type allows anomalies to be detected and the effectiveness of energy reduction efforts to be verified. An incentive system only works if people can see the results of their efforts. AHFC provides an online energy tracking tool in the ARIS database free of charge for public facilities in Alaska.
    - **Ensure that operations and maintenance staff are properly trained in energy efficient operation of lighting and HVAC systems.**
- **Include operations and maintenance staff trained in energy efficiency in design decisions.** These people will be responsible for the energy costs of the building, and thus should be part of design for new construction.
- **Standardize Equipment.** This will allow operations and maintenance staff to effectively use energy-saving equipment and reduce maintenance time. Of particular importance is standardizing DDC systems as much as possible, as these are complex systems that can reduce energy costs significantly if properly used.
- **Energy Management.** Consider hiring an energy conservation manager to track energy use, to benchmark buildings and create a plan to reduce energy costs starting with the most poorly performing buildings first. This benchmark data can be compared to other public buildings in Alaska using AHFC's ARIS database, allowing schools to see how their energy performance compares to districts around the state.

Offices

Findings Summary:

- There is a very large range in energy use even for offices in the same ANCSA region or of the same size class, meaning there is a lot of room for low-performing buildings to make energy efficiency improvements
- Buildings in rural Alaska have lower electric use per square foot on average than buildings in urban Alaska. For example, offices in the Calista region on average use less than one quarter the amount of electricity per square foot as office buildings in Anchorage.
- Building size appears to play a larger role in energy use for offices than for other building usage types, with larger buildings having lower average thermal EUI/HDDs and at the same time higher average electricity use per square foot

Figure 40 shows that of the 59 office buildings that had in-depth energy audits done, on average 78% of the buildings energy use was for space heating. This is higher than the average of 72% for all buildings audited. The difference can likely be attributed to the fact that the data is skewed, with 41 of 59 audited buildings being located in climate zone 8, which has a larger number of heating degree days and thus would require more energy for space heating.

Figure 40: Offices - Energy consumption by end useA

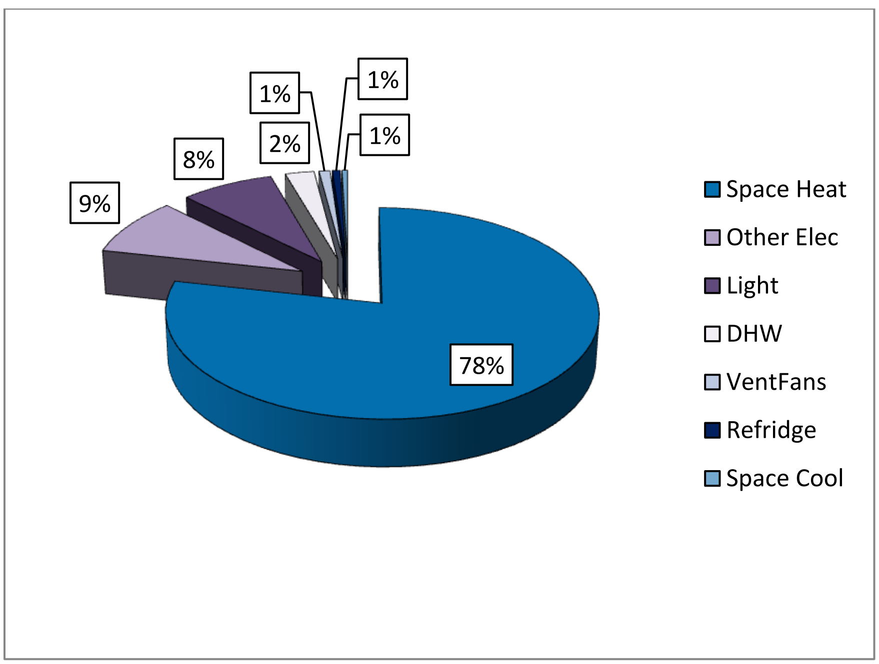
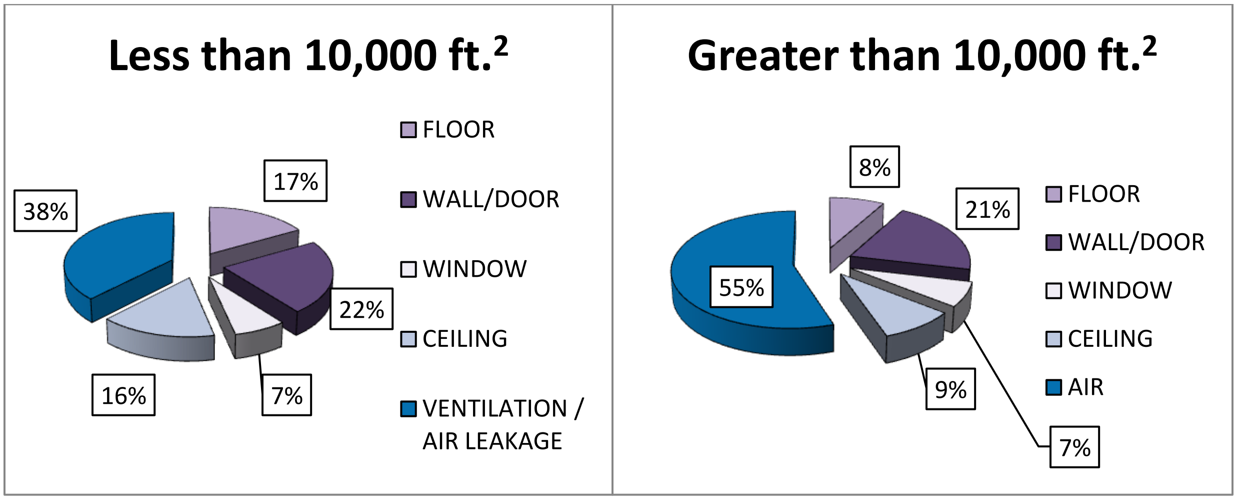


Figure 41 shows the breakdown of where this space heating energy is lost. For smaller buildings, 66% of the energy is lost through the building envelope, which is significantly higher than the 45% of energy lost in office buildings larger than 10,000 square feet. This could be due to higher ventilation rates in larger buildings, to higher surface area to volume ratios in smaller offices, or other potential factors.

Figure 41: Offices by Size - Space Heating Loss by ComponentA

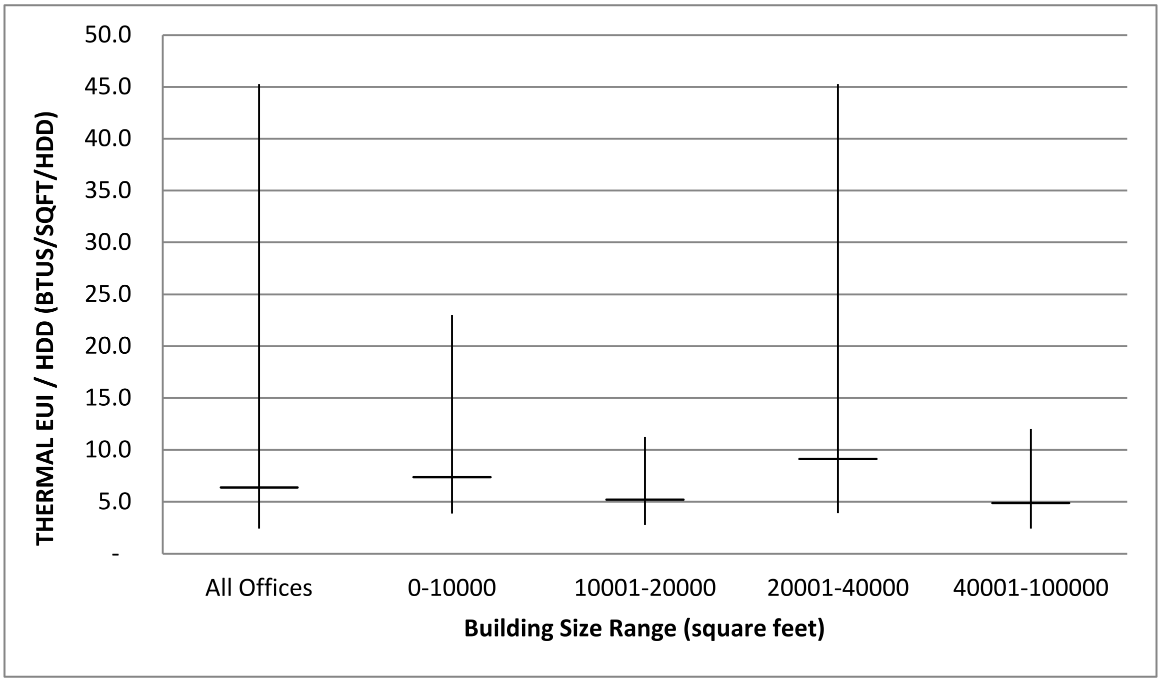


Since space heating loss is the largest energy end use of offices, this difference in *where* the heat is lost between large and small office buildings suggests that building size is an important factor. Indeed, Figure 42 and Figure 43 show that there appears to be a trend of a slight decrease in energy use on a per square foot basis for larger buildings. However, there is a wide range in the data, and buildings sized between 20,000 and 40,000 square feet differ significantly from this pattern.

Figure 42: Thermal EUI/HDD for Offices by Building SizeA

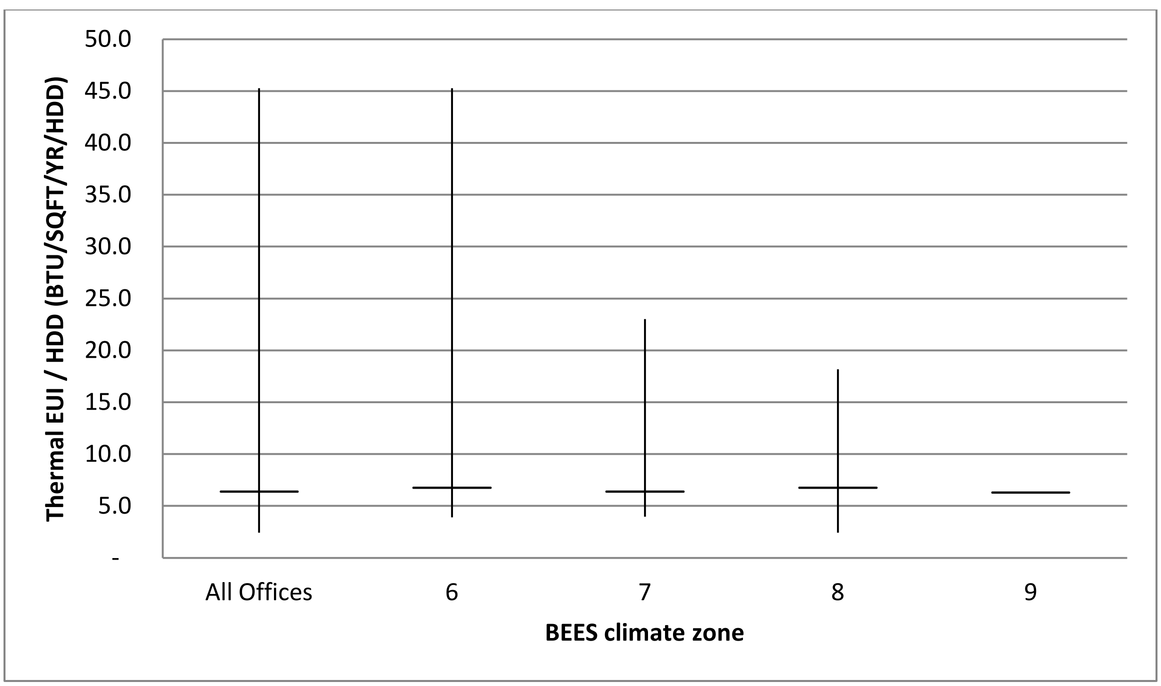
OFFICES			THERMAL EUI / HDD (BTUS/SQFT/HDD) A			
SIZE RANGE		# OF RECORDSA	AVG	MED	MAX	MIN
ALL OFFICES		59	8.3	6.4	45.3	2.4
0	10,000	38	8.2	7.4	23.0	3.9
10,001	20,000	9	6.3	5.2	11.2	2.8
20,001	40,000	6	14.5	9.1	45.3	3.9
40,001	100,000	6	5.6	4.9	12.0	2.4

Figure 43: Median Thermal EUI/HDD for Offices by Building SizeA



As can be seen in Figure 44, there is very little difference between the median thermal EUI/HDD across climate zones. This is further evidence that size is a more important factor for office buildings than for other usage types.

Figure 44: Median Thermal EUI/HDD by Climate Zone for OfficesA



While the buildings between 20,000 and 40,000 square feet remain somewhat of an outlier, there also appears to be a downward trend in ECI as the buildings get larger and larger, as can be seen in Figure 45. This downward trend in cost comes in spite of the fact that average electric EUI trends upwards as buildings get larger, as can be seen in Figure 46.

Figure 45: ECI of Offices by Building Size

OFFICES BY SIZE			ECI$_A$			
SIZE RANGE		# OF RECORDS$_A$	AVG	MED	MAX	MIN
0	10,000	38	$5.64	$5.41	$10.38	$1.25
10,001	20,000	9	$4.20	$4.36	$7.58	$2.12
20,001	40,000	6	$4.86	$3.21	$10.39	$1.31
40,001	100,000	6	$3.11	$2.93	$4.71	$1.69

Figure 46: EUI & Electric EUI of Offices by Building Size$_{A+B}$

OFFICES BY SIZE			EUI (thousands of BTU / SQFT)				ELECTRIC EUI (KWH / SQFT)			
SIZE RANGE		# OF RECORDS	AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
0	10,000	61	123.8	104.8	346.6	15.0	7.4	5.8	37.6	0.7
10,001	20,000	15	116.1	110.0	219.4	42.8	10.8	10.6	34.3	1.1
20,001	40,000	11	144.1	152.9	363.7	38.0	13.4	14.7	27.2	2.1
40,001	100,000	7	122.6	132.1	213.2	64.2	15.4	13.6	23.2	5.1

As in other building types, lighting and other electric costs are relatively higher than the energy they consume, in this case accounting for roughly 33% of the energy costs for the average office building. The end use cost breakdown for offices is similar to other building types, with the exception that offices have other electrical uses that cost more for energy than lighting, as can be seen in Figure 47.

Figure 47: Offices - Energy Cost by End Use[A]

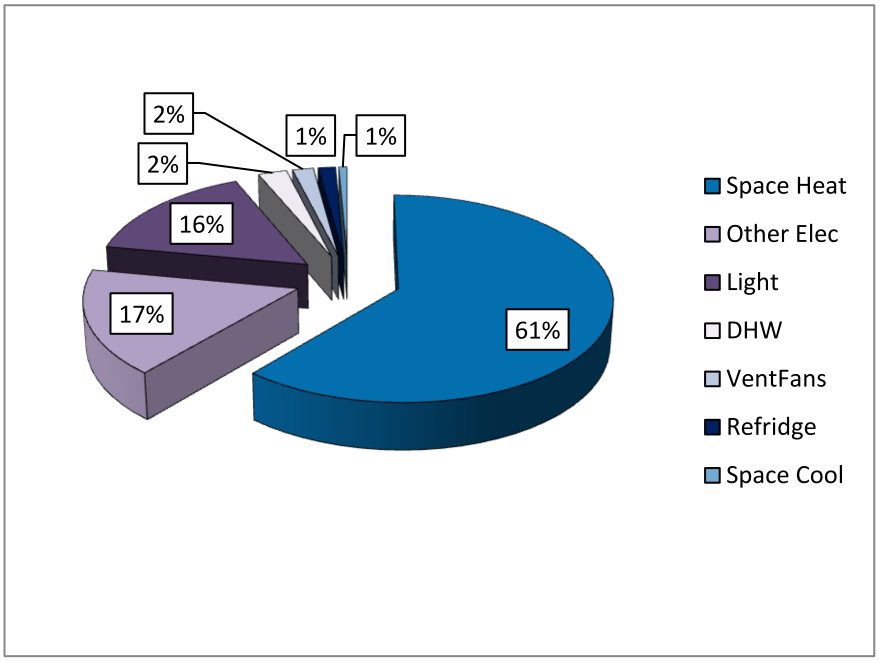
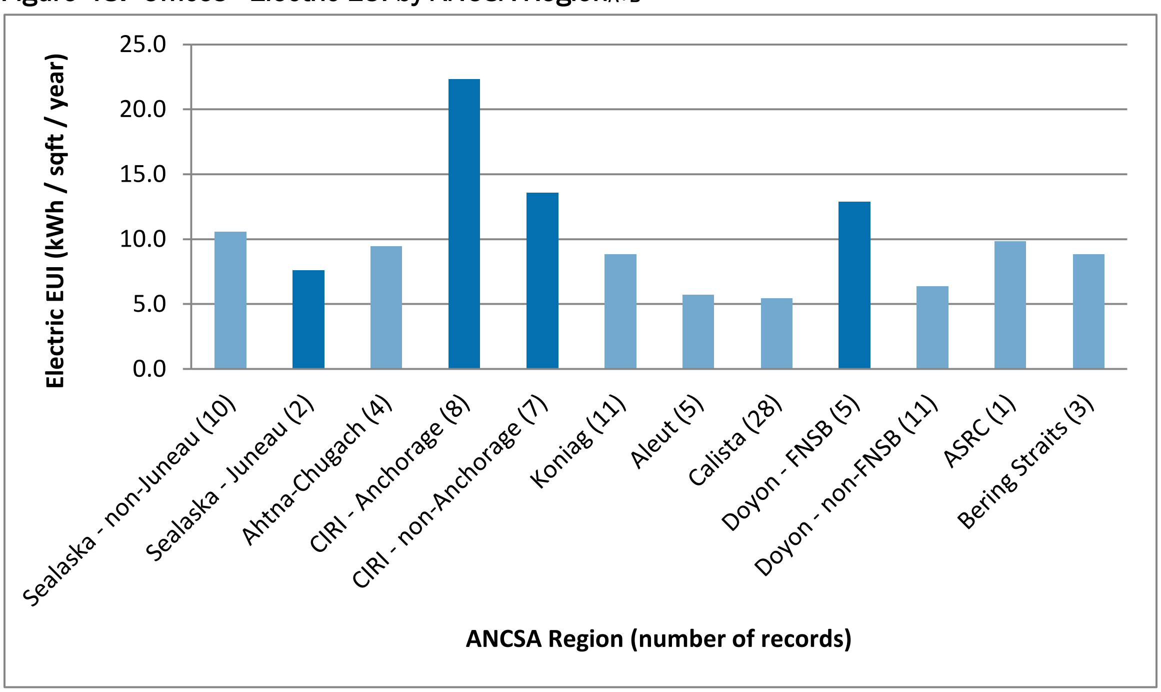


Figure 48 shows the differences between ANCSA regions in electric EUI. Similar to schools, it appears that office buildings in rural Alaska (in blue) use less electricity on a square footage basis than do buildings in urban Alaska (in purple). Offices in Anchorage top the list of electricity consumption by using over 4 times as many kilowatt-hours per square foot on average than buildings in the Calista region. This may be due to a variety of factors, but one possibility is that size is also correlated with electric utilization index, and offices in rural areas tend to be significantly smaller than those in urban areas.

Figure 48: Offices - Electric EUI by ANCSA Region[A+B]



CCHRC summarized the data on office buildings at both the climate zone level and the ANCSA region level. As there are significant differences between rural and urban areas that are lost when doing a climate zone level analysis, only ANCSA region is shown below in Figure 49 and Figure 50. These differences include size, with rural regions typically having smaller buildings on average than urban regions, electric use, and to some extent ECI. ECIs tend to be higher for the rural portion of a particular ANCSA region, likely due to higher fuel costs. A notable exception is Anchorage, which has an average ECI that is over $2 more per square foot than offices outside of the city in the CIRI region, which is likely due to its much higher electricity usage.

Figure 49: Offices - Building Size and ECI by ANCSA Region

OFFICES BY ANCSA REGION		SQUARE FOOTAGE A+B				ECI A			
ANCSA Region:	# BLDG.	AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
Sealaska - non-Juneau	10	13,290	4,308	36,218	840	$5.85	$5.85	$10.39	$1.31
Sealaska - Juneau	2	23,256	23,256	24,111	22,400	$2.69	$2.69	$2.69	$2.69
Ahtna-Chugach	4	14,782	17,604	20,000	3,920	$3.59	$3.59	$3.59	$3.59
CIRI - Anchorage	8	28,046	17,361	72,048	3,061	$5.15	$4.71	$6.39	$4.36
CIRI - non-Anchorage	7	23,489	12,464	65,363	8,276	$2.84	$2.34	$4.34	$1.72
Koniag	11	8,660	4,172	28,567	747	$3.74	$3.74	$3.74	$3.74
Aleut	5	5,191	3,567	13,500	2,448	$4.13	$3.99	$6.05	$2.51
Calista	28	4,080	1,233	28,820	420	$6.46	$6.57	$10.38	$2.12
Doyon - FNSB	5	39,533	45,510	70,531	4,200	$2.47	$1.99	$4.65	$1.25
Doyon - non-FNSB	11	4,788	3,550	12,536	2,320	$4.03	$3.18	$6.89	$2.47
ASRC	1	22,704	22,704	22,704	22,704	$1.50	$1.50	$1.50	$1.50
Bering Straits	3	5,158	1,064	13,346	1,064	$6.01	$5.34	$7.58	$5.13

Figure 50: Offices - EUI & Electric EUI by ANCSA Region A+B

OFFICES BY ANCSA REGION		EUI (thousands of BTU / SQFT)				ELECTRIC EUI (KWH / SQFT)			
ANCSA Region:	# BLDG	AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
Sealaska - non-Juneau	10	127.8	98,.9	363.7	38.0	10.6	9.3	19.3	2.1
Sealaska - Juneau	2	77.0	77.0	82.6	71.5	7.6	7.6	7.7	7.5
Ahtna-Chugach	4	97.2	93.5	120.4	81.3	9.5	9.8	14.4	3.8
CIRI - Anchorage	8	177.1	174.4	219.4	135.4	22.3	22.2	37.6	10.3
CIRI - non-Anchorage	7	156.8	145.6	346.6	81.3	13.6	11.3	22.7	10.2
Koniag	11	136.9	148.1	263.7	15.0	8.8	6.4	16.7	0.7
Aleut	5	80.0	82.9	98.7	59.1	5.7	6.5	9.4	2.1
Calista	28	118.0	113.6	249.1	42.8	5.4	5.1	12.0	1.1
Doyon - FNSB	5	105.6	73.6	189.7	64.2	12.9	13.6	22.3	2.9
Doyon - non-FNSB	11	104.7	96.3	225.0	62.8	6.4	6.6	12.9	1.4
ASRC	1	163.2	163.2	163.2	163.2	9.8	9.8	9.8	9.8
Bering Straits	3	155.6	165.9	173.9	126.9	8.8	6.6	13.3	6.6

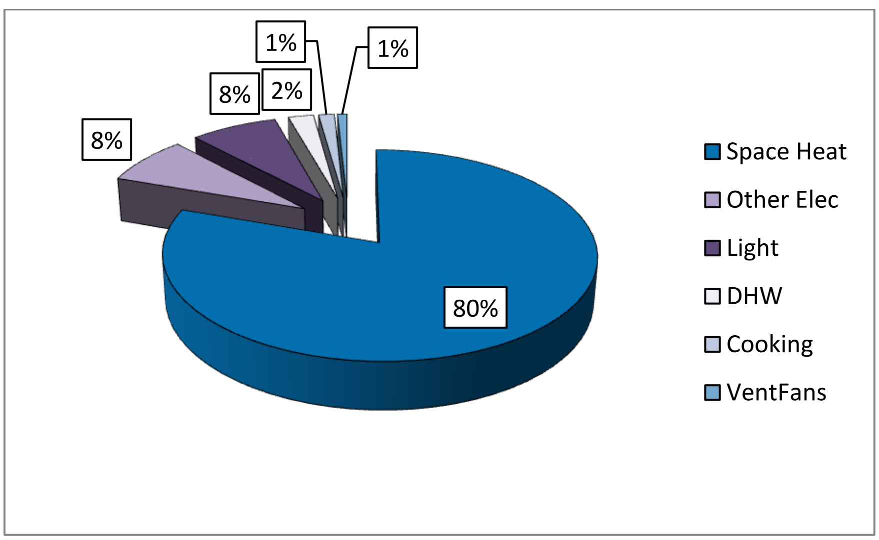
Maintenance & Shop Buildings

Findings Summary:

- Ventilation and air leakage account for 50% of the total energy use for the average maintenance / shop building in Alaska.
- Maintenance / shop buildings tend to be significantly leakier than other building usage types.
- Even after normalizing by climate, maintenance / shop buildings in climate zone 9 use significantly more energy per square foot for space heating and spend more money on energy per square foot than buildings in other climate zones.
- Buildings in this category use more energy per square foot than the majority of other usage types.
- Electric EUIs vary significantly within and between climate zones.

The AHFC audit program resulted in 22 structures that were classified as shops or maintenance buildings getting energy audits, and an additional 16 buildings provided benchmark data. Based on the audit data, the main energy use for these buildings is for space heating, as can be seen in Figure 51. At 80% on average, these types of buildings use a larger percentage of energy on space heating than almost any other use type. Two factors that may be influencing this are the slightly higher ratio of buildings audited in the colder climate zones (8 and 9), and the anecdotal evidence that many of these buildings have large bay doors that are left open for long periods of time, allowing massive quantities of cold outside air into the building.[42]

Figure 51: Maintenance / Shop - Energy Consumption by End Use[A]



[42] Armstrong, Dick. White Paper Planning session 4/18/2012

Notable differences from other building types in Figure 52 include a much lower percentage of heat loss through windows, which is likely due to fewer windows, and a higher percentage of heat loss through ventilation and air leakage. This increased heat loss relative to other building types may be due to the aforementioned bay doors, to high ventilation rates, or to other potential hidden factors. Generally, in commercial scale buildings the total amount of air movement from ventilation tends to be significantly higher than that from air leakage.[43] When the amount of heat lost through ventilation and air leakage is combined with the percentage of energy used for space heating, roughly 50% of the energy consumed by a maintenance / shop building can be attributed to air movement; this is a strong incentive to ensure that ventilation rates are not above recommended levels and that leakage is minimized.

Figure 52: Maintenance / Shop - Space heating loss by component[A]

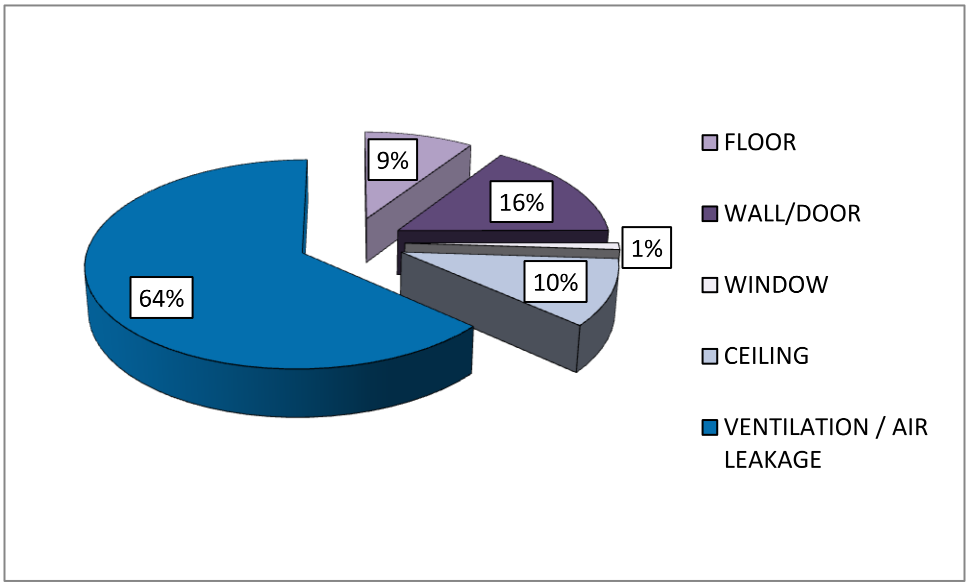
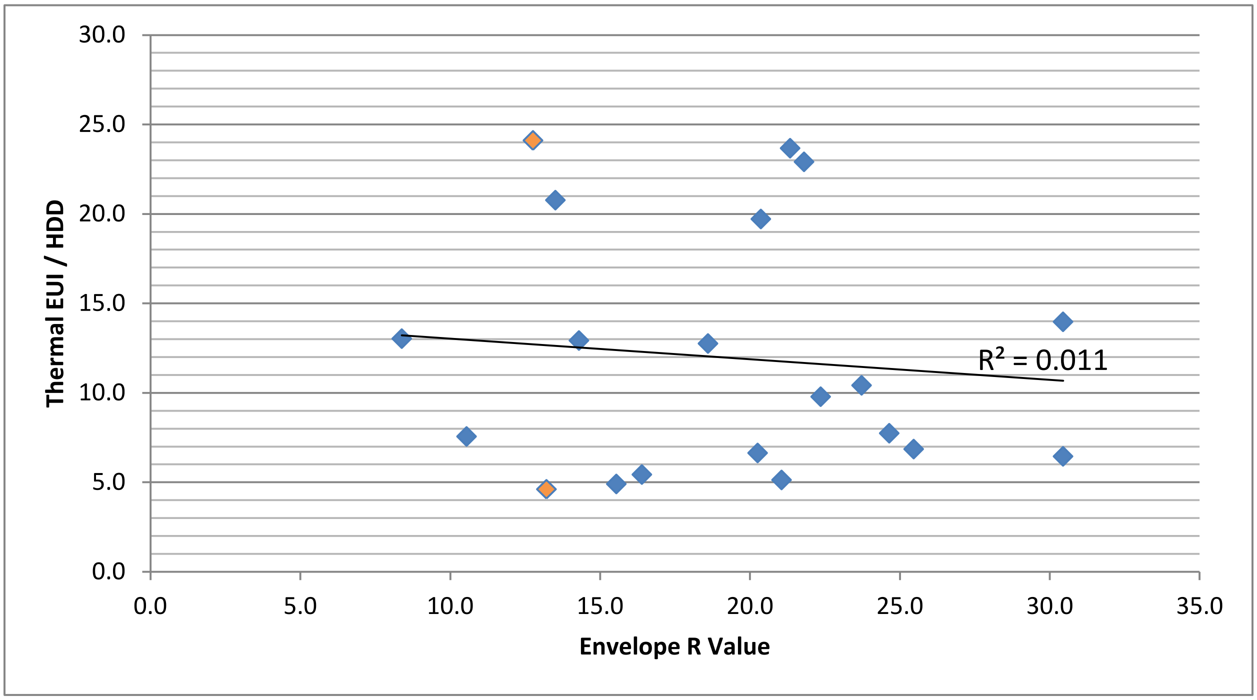


Figure 53 is further evidence that air movement due to ventilation and leakage is the primary factor driving energy use in maintenance / shop buildings. The low correlation between envelope R value and thermal EUI/HDD suggests that air movement outweighs the insulation values of a maintenance/shop building in determining energy efficiency. The buildings displayed in orange below highlight the fact that even with roughly the same envelope insulation values, there is variation in thermal EUI/HDD. It should be noted that while the R^2 value is fairly low for these buildings, it does not mean that insulation values have no effect; rather, it signifies that envelope insulation values are not a good *single predictor* of energy use for maintenance / shop buildings.

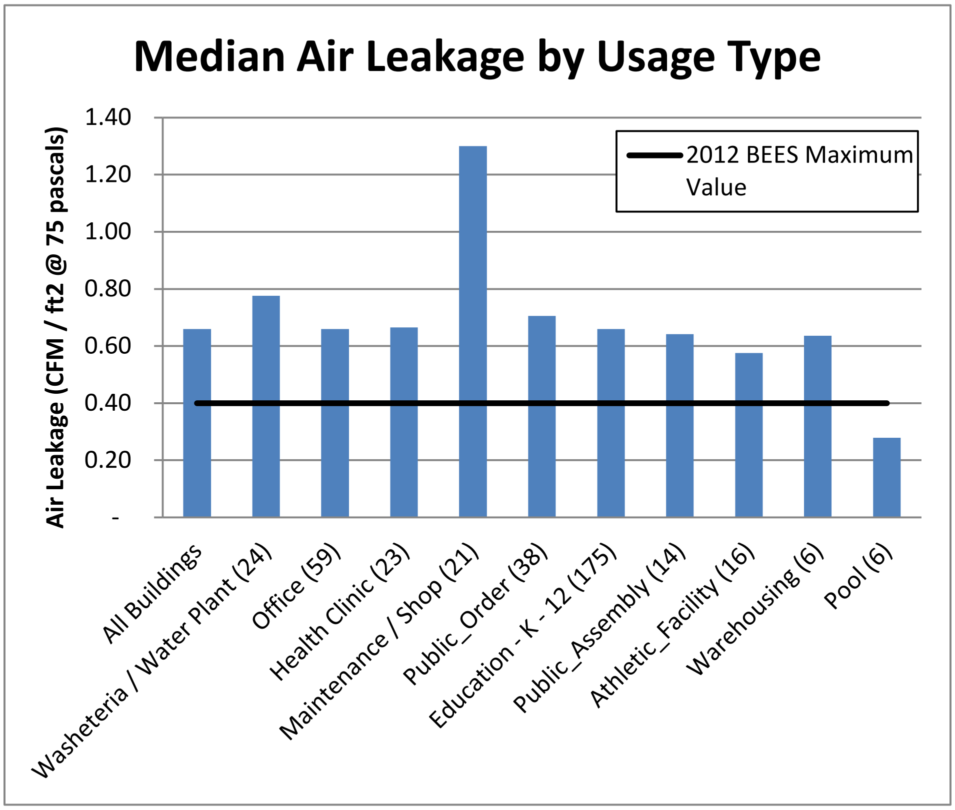
43 Price, Phillip N., A. Shehabi, and R. Chan. 2006. *Indoor-Outdoor Air Leakage of Apartments and Commercial Buildings.* California Energy Commission, PIER Energy-Related Environmental Research Program. CEC-500-2006-111.

Figure 53: Maintenance / Shop - Thermal EUI/HDD vs. Envelope R-valueA



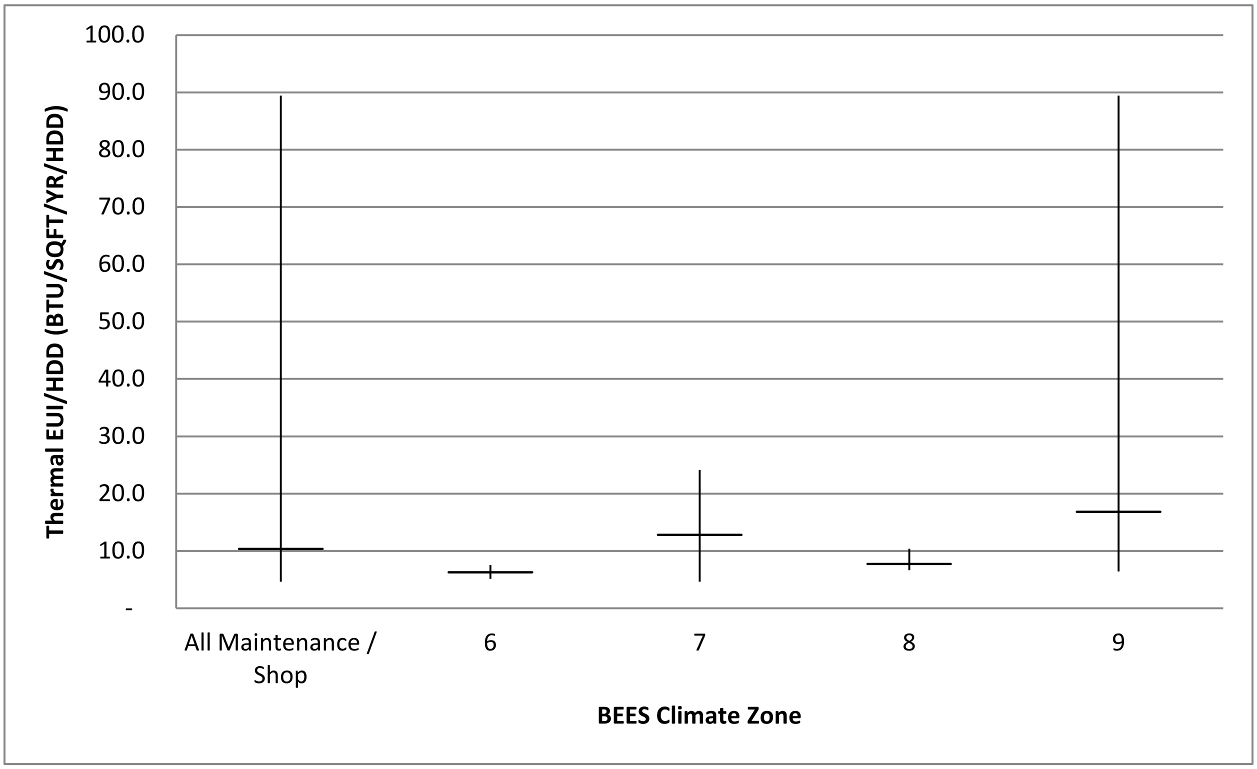
One of the reasons that maintenance / shop buildings lose such a large amount of energy through air movement is that they are significantly leakier than buildings of other usage types, as can be seen in Figure 54. While the majority of building usage types have leakage rates within 10-20% of each other, maintenance / shop buildings have leakage rates that are twice that of many others. This graph also shows that with the exception of pools, the median air leakage value of all building usage types is significantly higher than the 0.40 cfm/ft2 at 75 pascals measurement required by the 2012 International Energy Conservation Code.

Figure 54: Median Air Leakage by Usage Type[A]



Even when energy used for space heating is normalized by climate, buildings in climate zone 9 use significantly more than other climate zones, as can be seen in Figure 55. Additionally, the range of thermal EUI/HDD values in climate zone 9 shows that there are maintenance / shop buildings that are using huge quantities of energy for space heating.

Figure 55: Maintenance / Shop - Median Thermal EUI/HDD by Climate ZoneA



This much higher amount of energy use in climate zone 9 also causes the average and median ECI for the region to be noticeably higher than other climate zones, even though typically fuel prices are much lower and/or subsidized in the Arctic Slope region. Figure 56 shows how maintenance / shop buildings compare to each other on a square footage and cost of energy basis.

Figure 56: Maintenance / Shop - Building Size & ECI by Climate Zone

MAINTENANCE & SHOP BUILDINGS BY CLIMATE ZONE									
BEES Climate Zone	# OF RECORDS	SQUARE FOOTAGEA+B				ECIA			
		AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
6	4	10,665	7,174	23,310	5,000	$2.29	$2.29	$2.73	$1.85
7	15	23,697	12,246	107,846	2,500	$4.23	$3.87	$8.69	$2.52
8	7	8,258	4,550	29,940	650	$4.85	$4.53	$5.68	$4.35
9	11	10,637	8,281	23,754	1,824	$7.01	$4.36	$19.53	$0.68

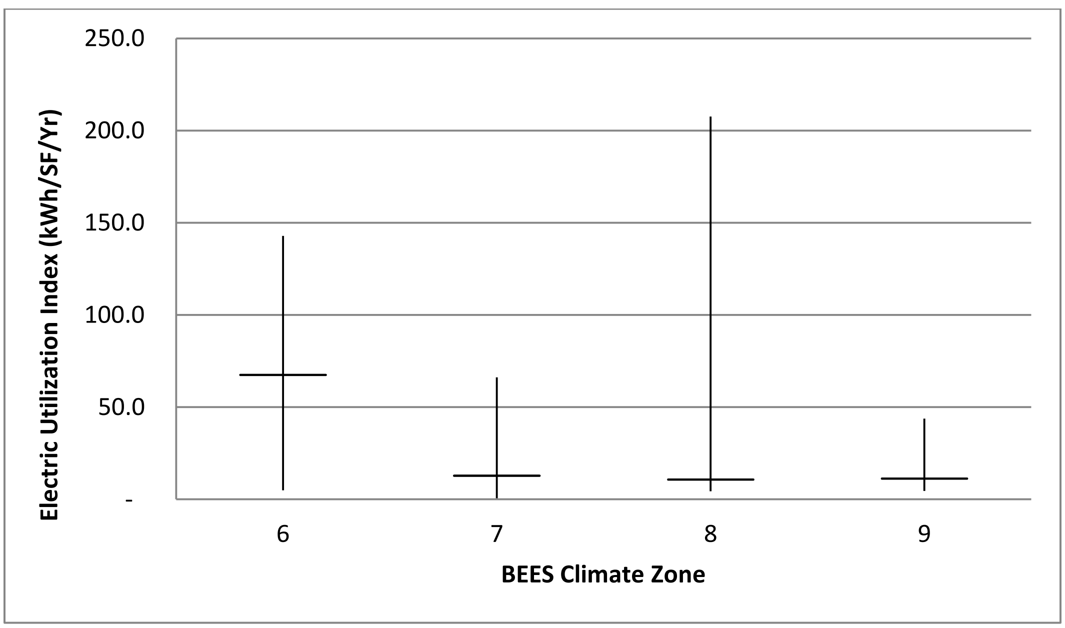
Figure 57 shows the differences in EUI and Electric EUI for maintenance / shop buildings between climate zones. These buildings use significantly more energy on average than other than usage types; on the extreme end of the spectrum, a shop in climate zone 6 uses on average over 6 times the energy per square foot as the average school in the same climate zone.

Figure 57: Maintenance / Shop - EUI & Electric EUI by Climate Zone A+B

MAINTENANCE & SHOP BUILDINGS BY CLIMATE ZONE									
BEES Climate Zone	# OF RECORDS	EUI (thousands of BTU / SQFT)				ELECTRIC EUI (KWH / SQFT)			
		AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
6	4	496.2	477.4	973.0	57.0	70.7	67.5	142.9	5.0
7	15	280.1	227.2	706.5	67.1	15.8	12.9	66.2	0.5
8	7	260.0	223.9	672.1	116.6	40.9	10.9	207.6	4.4
9	11	525.1	400.8	1,973.3	150.9	15.0	10.3	43.8	4.6

Figure 58 displays the differences in Electric EUI between climate zones. The horizontal bar represents the median and the vertical line the range. The extremely large ranges likely are a factor of the amount of variation in the usage of buildings in the maintenance / shop category; some shops have large amounts of heavy equipment, do a significant amount of vehicle maintenance, and include electric head-bolt heaters for many vehicles, whereas others are wood shops with some office space, or small vehicle maintenance shops that have relatively low usage.

Figure 58: Maintenance / Shop - Median & Range Electric EUI by Climate Zone A+B



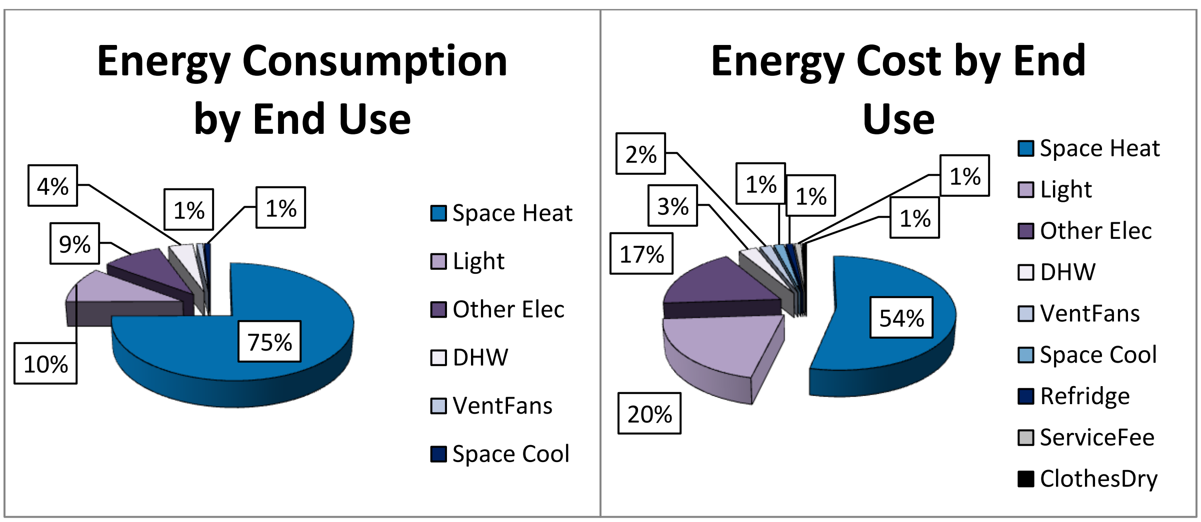
Public Order & Safety

Findings Summary:

- Buildings in climate zone 8 use significantly less energy per square foot annually than do buildings in other climate zones
- There appears to be little variation in thermal EUI/HDD between different climate zones.
- Public Order and Safety buildings in the Arctic Slope climate zone 9 have a considerably wider range of energy use and costs relative to other climate zones.
- Fire Stations and Correctional Facilities use less energy per square foot than other Public Order and Safety Buildings (such as police departments, search and rescue buildings, etc.)
- Electric use per square foot varies significantly between buildings, with some buildings using over 10 times more electricity than others.

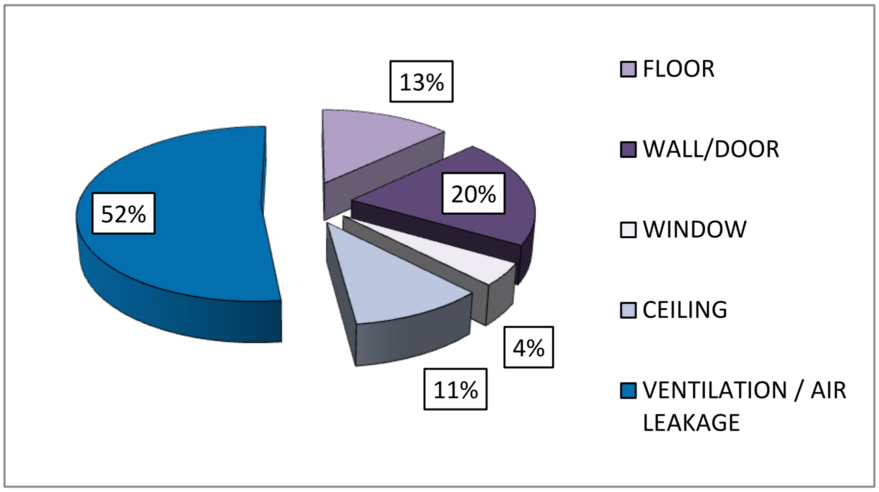
38 public order and safety buildings received energy audits through AHFC, and an additional 31 buildings reported adequate benchmark data. Examples of buildings in this category include fire departments, police stations, and search and rescue buildings, etc. The breakdown of end-uses and costs of energy for these types of buildings is similar to that of other audited buildings, as can be seen in Figure 59. The only differences are that on average Public Order and Safety buildings use slightly more energy for space heating, slightly less energy for heating hot water, and spend more on lighting and other electrical applications than the average for all audited buildings.

Figure 59: Public Order & Safety - Energy Cost & Consumption by End UseA



Space heating is the number one energy end use and cost for all audited buildings in Alaska, including Public Order and Safety Buildings. Similar to other types of buildings, the majority of this heat is lost through a combination of bringing in outside air to ventilate the building and air leakage. The breakdown of where this heat is lost can be seen in Figure 60.

Figure 60: Public Order & Safety - Space Heating Loss by Component[A]



Since the vast majority of the energy used in Public Order and Safety buildings is for space heating, the best way to compare energy use across regions is to look at the thermal EUI, normalized by heating degree days. The thermal EUI/HDD of these types of buildings is shown in Figure 61. As can be seen in this graph, there is somewhat less variation in thermal EUI/HDD for buildings within a climate zone than was seen with other building usage types, except in the Arctic Slope climate zone, which has a very large range of thermal efficiency.

Figure 61: Public Order & Safety - Median Thermal EUI/HDD by Climate Zone[A]

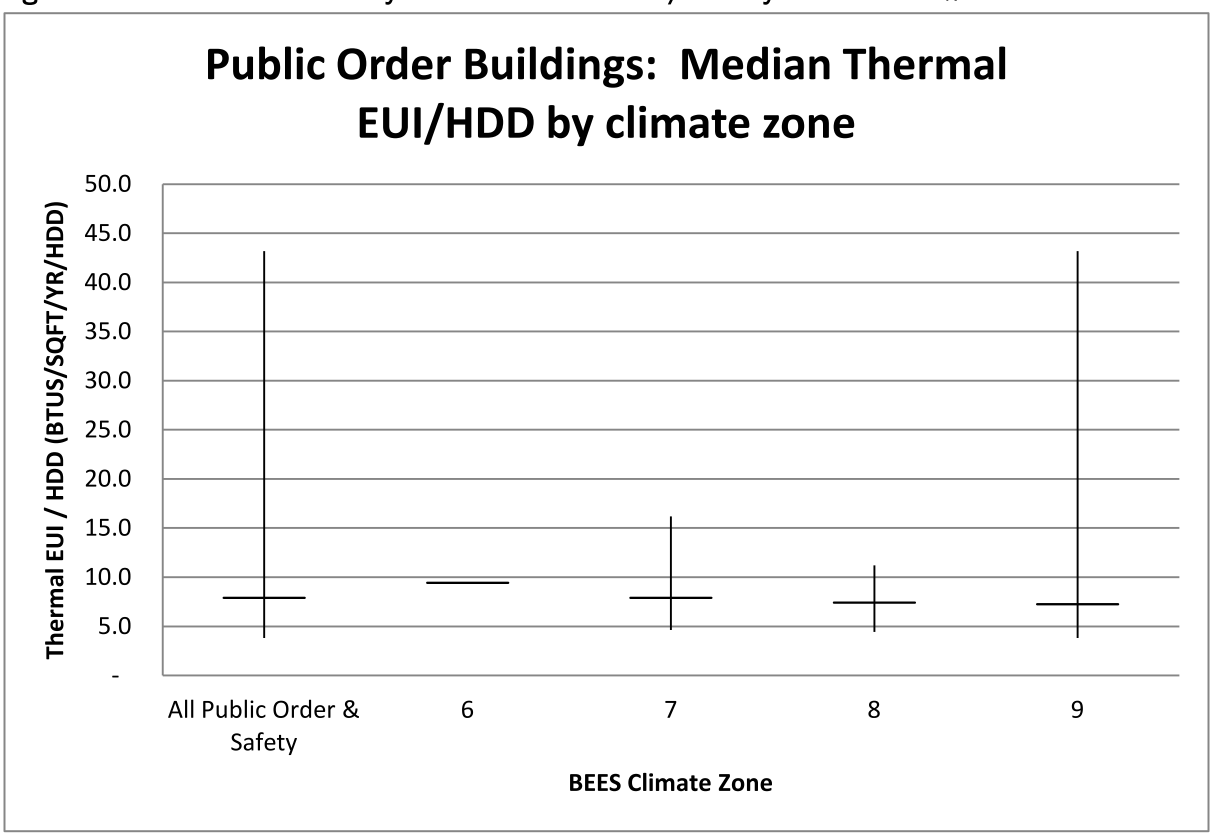


Figure 62 also shows that there is a tighter correlation between the whole envelope R value and the thermal EUI/HDD than for other building usage types. This relatively tight correlation combined with the smaller range in thermal EUI/HDD values for Public Order and Safety buildings suggests that ventilation and building operations for these buildings vary somewhat less than other building usage types.

Figure 62: Public Order & Safety - Thermal EUI/HDD vs. Envelope R-value[A]

Similarly, Figure 63 shows that the ranges of ECIs within a climate zone are also smaller than for many other building usage types. The median and average ECIs are also quite close, which is further evidence that the majority of Public Order and Safety buildings have similar energy cost characteristics within a climate zone.

Figure 63: Public Order & Safety - Building Size & ECI by Climate Zone$_A$

PUBLIC ORDER & SAFETY BUILDINGS BY CLIMATE ZONE		SQUARE FOOTAGE$_{A+B}$				ECI$_A$			
BEES Climate Zone	# OF RECORDS	AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
6	3	16,931	14,530	34,822	1,440	$3.58	$3.58	$3.83	$3.33
7	35	11,726	8,064	63,050	3,126	$3.33	$3.13	$5.44	$1.87
8	20	8,309	5,270	40,666	437	$5.01	$5.03	$9.72	$2.31
9	11	7,221	4,608	14,496	2,695	$5.86	$5.85	$9.39	$1.48

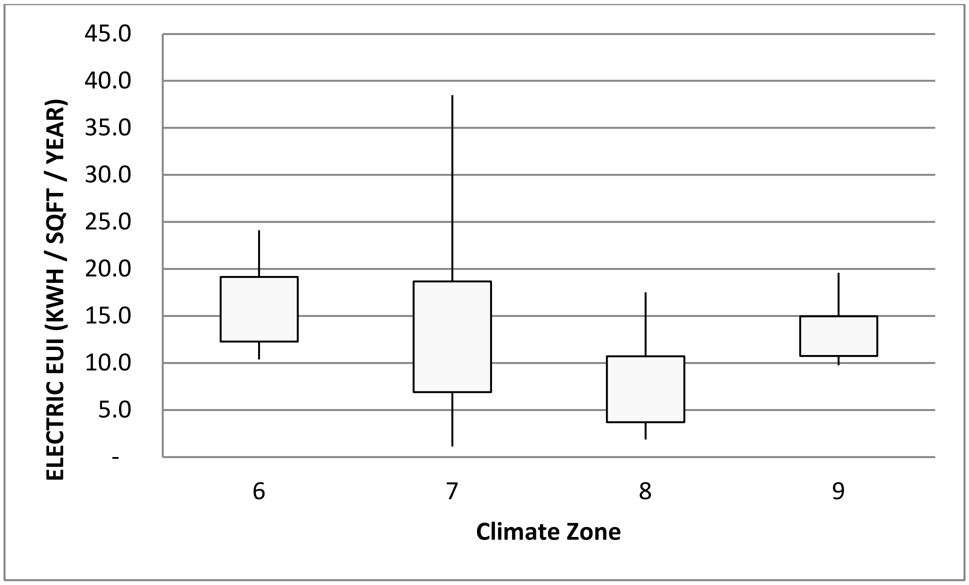
In contrast, the EUIs of Public Order and Safety buildings within a climate zone have much larger ranges relative to ECIs, as can be seen in Figure 64. Electric use per square foot also shows significant variation between the maximum and minimum values, especially in climate Zone 7, where the maximum value is 35 times as high as the minimum. Interestingly, climate zones 6, 7, and 9 all have relatively similar average and median electric use, whereas Public Order and Safety buildings in zone 8 use significantly less electricity per square foot.

Figure 64: Public Order & Safety - EUI & Electric EUI by Climate Zone$_{A+B}$

PUBLIC ORDER & SAFETY BUILDINGS BY CLIMATE ZONE		EUI (thousands of BTU / SQFT)				ELECTRIC EUI (KWH / SQFT)			
BEES Climate Zone	# OF RECORDS	AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
6	3	118.4	122.1	124.4	108.7	16.2	14.2	24.1	10.4
7	35	159.9	134.0	386.2	58.1	14.1	11.3	38.5	1.1
8	20	116.0	118.0	196.0	28.1	7.4	5.9	17.5	1.9
9	11	251.5	189.4	945.4	112.6	13.3	14.4	19.6	9.8

Figure 65 highlights these differences in electric utilization indices between climate zones. The box represents the central 50% of the buildings in that climate zone, and the tails on either end represent the overall range of the data. The large box in climate zone 7 highlights the variability in electric use between buildings—even the buildings in the middle of the range vary by a factor of more than 2.

Figure 65: Public Order & Safety - Electric EUI by Climate ZoneA+B



To determine whether there are different energy usage patterns within the broad category of Public Order and Safety buildings, CCHRC divided them into three sub-types: Fire Stations, Correctional Facilities, and Other buildings. The vast majority of audited and benchmarked buildings were fire stations, with 47 audited or benchmarked throughout the state. Figure 66 shows how these three types differ in energy characteristics.

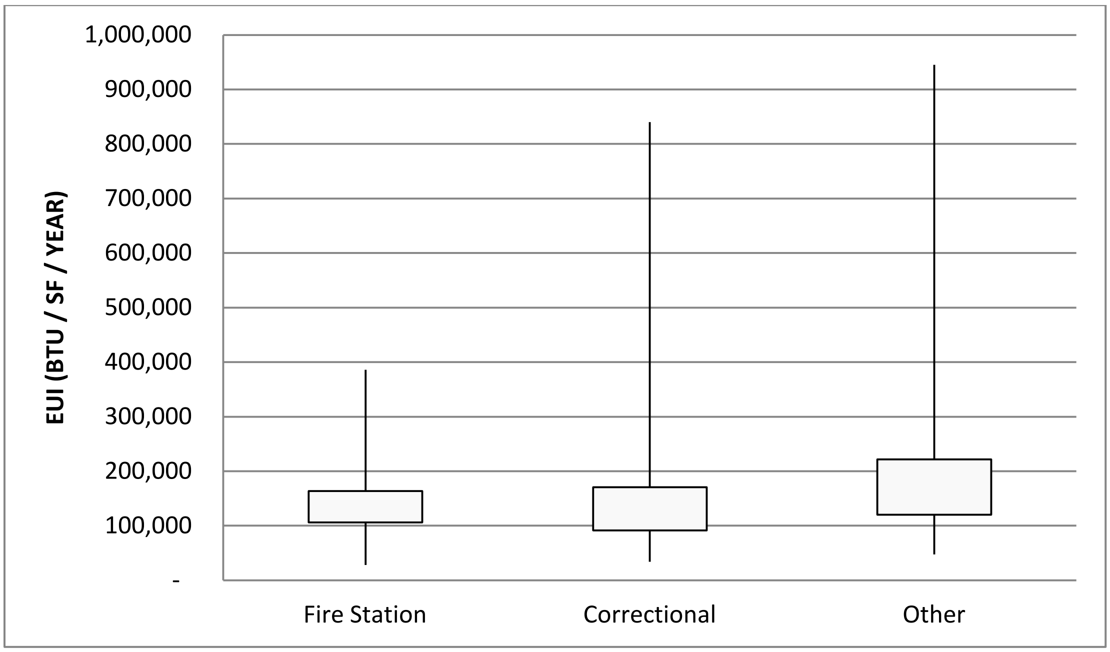
Figure 66: Public Order & Safety - EUI & Electric EUI by Building Sub-typeA+B

PUBLIC ORDER AND SAFETY	# OF RECORDS	EUI (thousands of BTU/SF)				ELECTRIC EUI (KWH/SF)			
		AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
Fire Station	47	140.7	130.3	386.2	28.1	10.3	9.8	33.7	1.1
Correctional	12	176.6	105.0	840.2	34.0	10.4	8.4	26.2	4.6
Other	22	201.2	138.8	945.4	47.4	16.1	14.3	38.5	1.9

There are significant differences between average and median EUIs by building sub-type, which means that outliers are skewing the data.

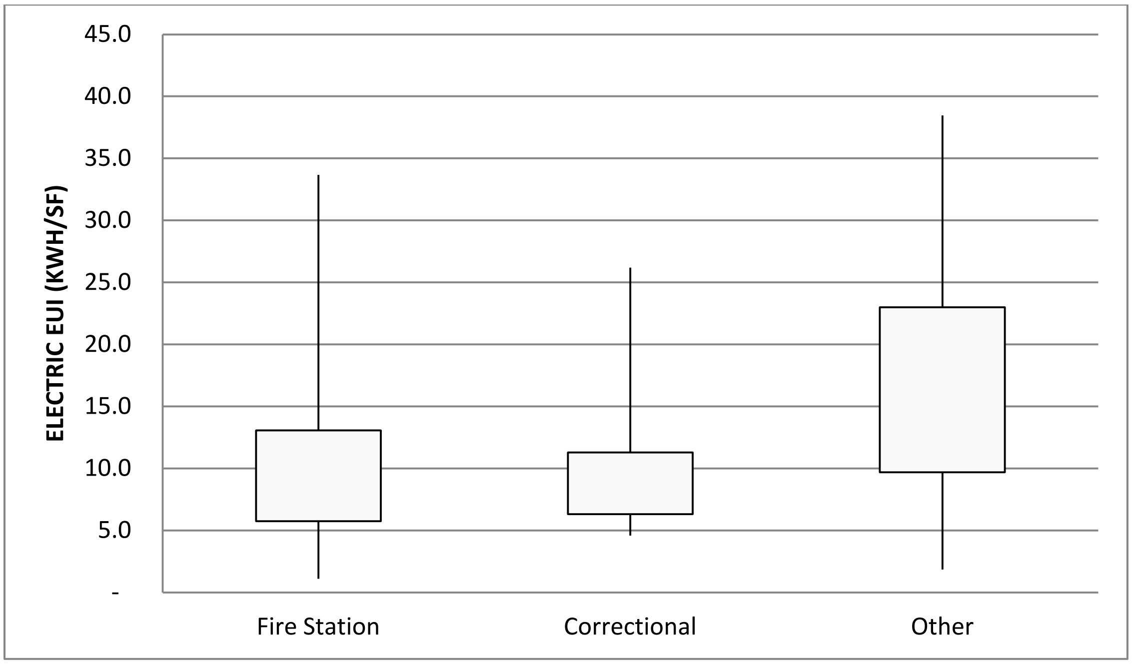
Figure 67 allows these differences to be examined more closely; as before, the boxes represent the distribution of the middle 50% of the data and the tails on either end represent the maximum and minimum values. Viewed in this way, the extreme outliers in Correctional Facilities and Other buildings become more apparent, as does the relatively smaller amount of variation in energy use per square foot for Fire Stations.

Figure 67: Public Order & Safety - EUI by Sub-type$_{A+B}$



When electric use is examined in the same way in Figure 68, the significant range in Other buildings is very apparent. In comparison, while Fire Stations and Correctional Facilities both have significant outliers, the difference between the 1st and 3rd quartile is much less. While the quartile range is smaller, the upper quartile being roughly double the lower quartile in both cases is still significant; using twice the amount of electricity for the same amount of square footage implies that there are significant possibilities for savings.

Figure 68: Public Order & Safety - Electric EUI by Sub-type A+B



Health Clinics

Findings Summary:

- **Energy and cost characteristics are reliable for comparing health clinics in Western Alaska, but there is insufficient data to reliably compare health clinics in other climate zones.**
- **On average, health clinics are much smaller than most other building usage types, averaging around 2,000 square feet.**
- **Health clinics lose a much smaller portion of energy to ventilation and air leakage than other public building types.**

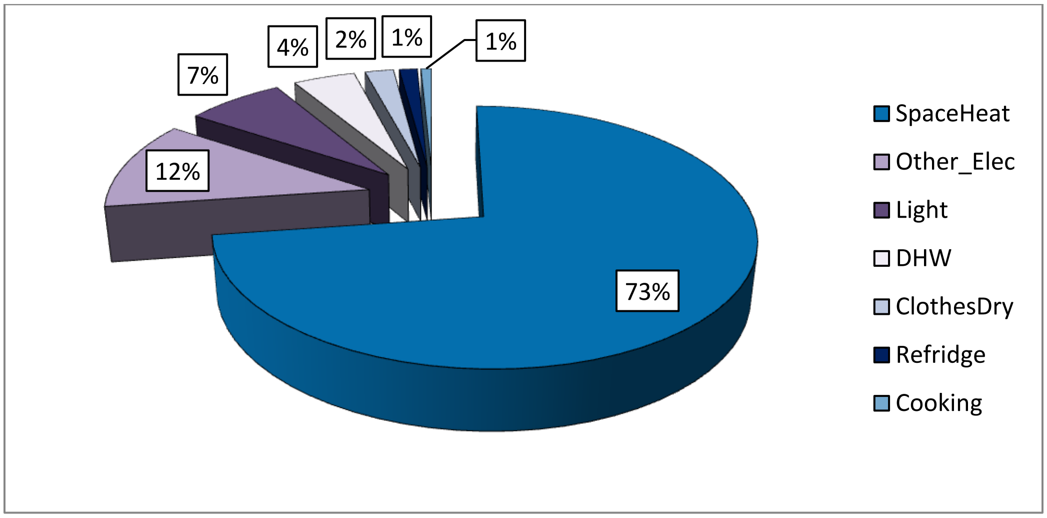
For this report data on 25 health clinics were examined, 80% of which were audited by ANTHC. All but one of these clinics is located climate zone 8, and the majority of these are located in the Calista region. While there is variation in energy consumption and costs between clinics, it is not as extreme as many usage types, as can be seen in Figure 69. This similarity suggests that these summary metrics are reliable for health clinics in Western Alaska, but it is unknown how applicable they are to buildings in other climate zones.

Figure 69: Health Clinics in Climate Zone 8: Energy Metrics[A]

HEALTH CLINICS (23)				
	AVG	MED	MAX	MIN
SIZE (SQFT)	1,969	2,214	2,615	520
EUI (BTU/SF/YR)	126,334	124,313	215,128	78,821
ECI ($/SF/YR)	$6.49	$5.64	$12.14	$3.39
Thermal EUI/HDD (BTU/SF/YR/HDD)	7.1	6.4	14.8	3.8
ELECTRIC EUI (KWH/SF/YR)	8.5	7.3	13.7	5.7

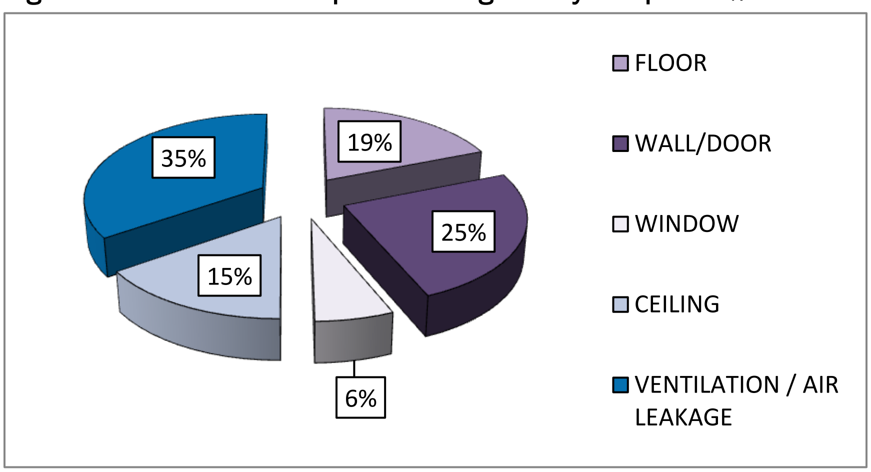
The average size of these buildings is significantly smaller than the majority of the other building usage types. However, the energy consumption by end use for health clinics is very similar to the average for all buildings, as can be seen in Figure 70. There are two slight but notable differences: health clinics use a higher percentage of energy on plug loads, and on average, have less than 1% of energy being used for ventilation fans.

Figure 70: Health Clinic - Energy Consumption by End UseA



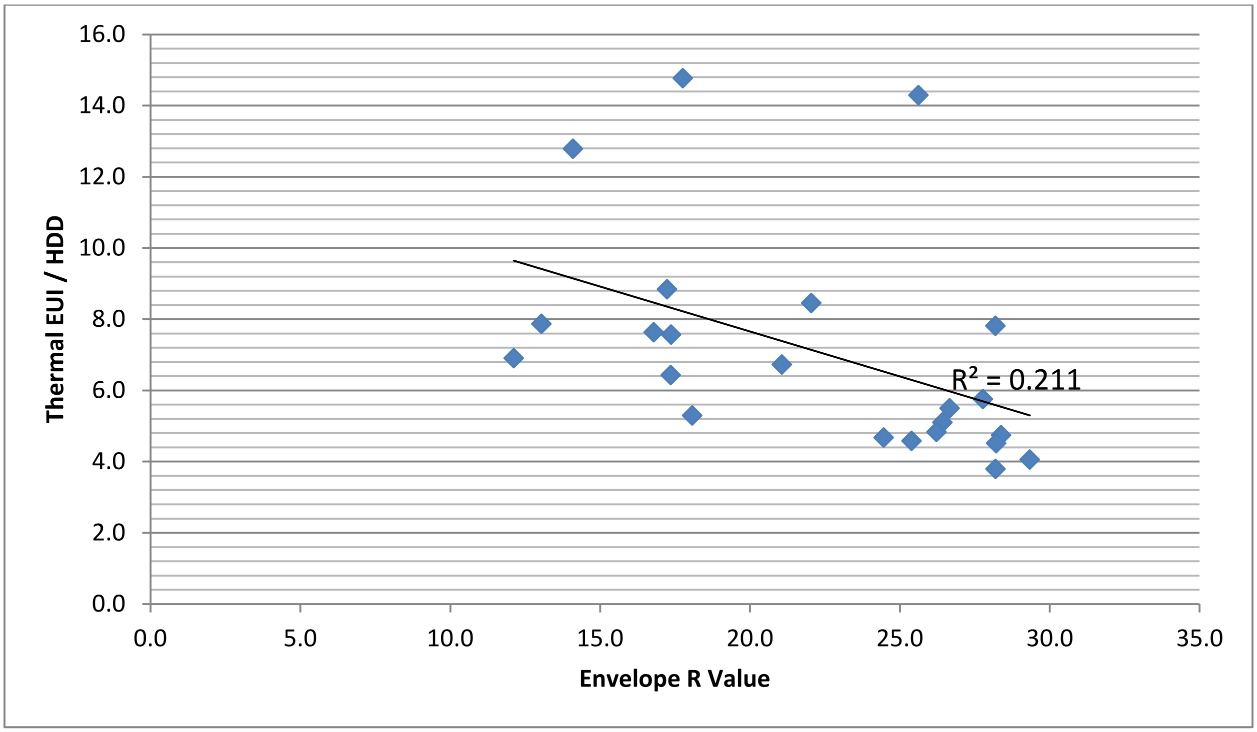
Having a negligible amount of energy devoted to ventilation fans likely stems from a combination of small building size and low levels of ventilation in health clinics. Figure 71 supports this hypothesis, showing that 35% of space heat is lost through air leakage and ventilation, which is significantly less than the 52% average found in all building usage types.

Figure 71: Health Clinic - Space heating loss by componentA



Since air leakage and ventilation are a lower percentage of space heating loss than other usage types, the envelope insulation value should play a larger relative role in energy loss. Figure 72 shows that buildings with higher insulation levels generally use less energy per square foot on space heating. While there are outliers, the significance of the correlation between thermal EUI/HDD and total envelope R-value is higher for health clinics than for other building usage types.

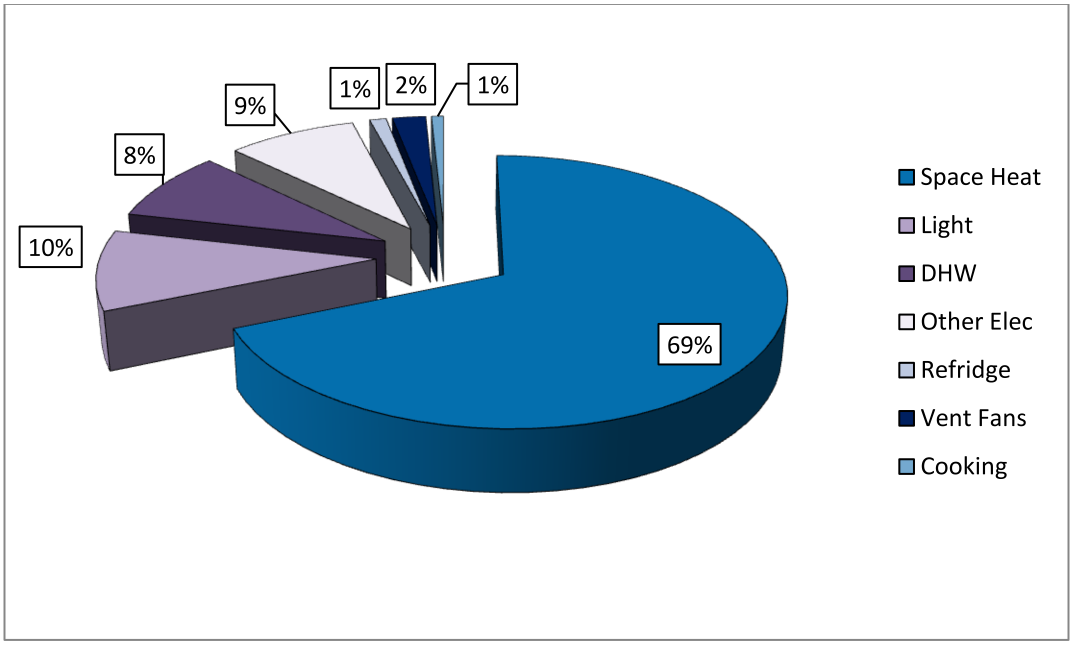
Figure 72: Health Clinic - Thermal EUI/HDD vs. Envelope R-valueA



Athletic Facilities

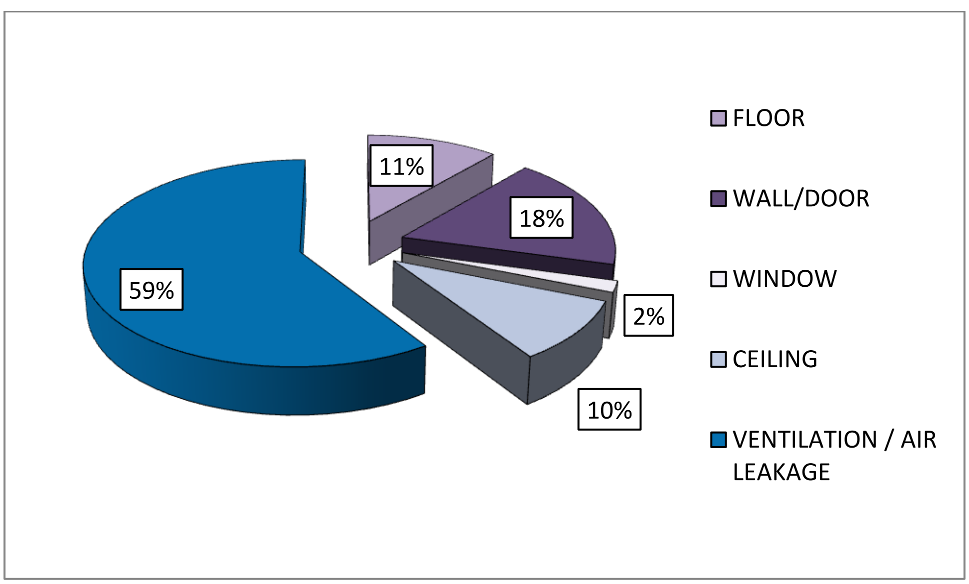
19 athletic facilities in Alaska received investment grade audits from AHFC, and an additional 7 facilities provided adequate benchmark data for this report. Figure 73 shows that these buildings have a fairly typical end use breakdown when compared to the average of all buildings analyzed, with the only notable difference being the 3% of energy that is used in refrigeration.

Figure 73: Athletic Facilities - Energy consumption by end useA



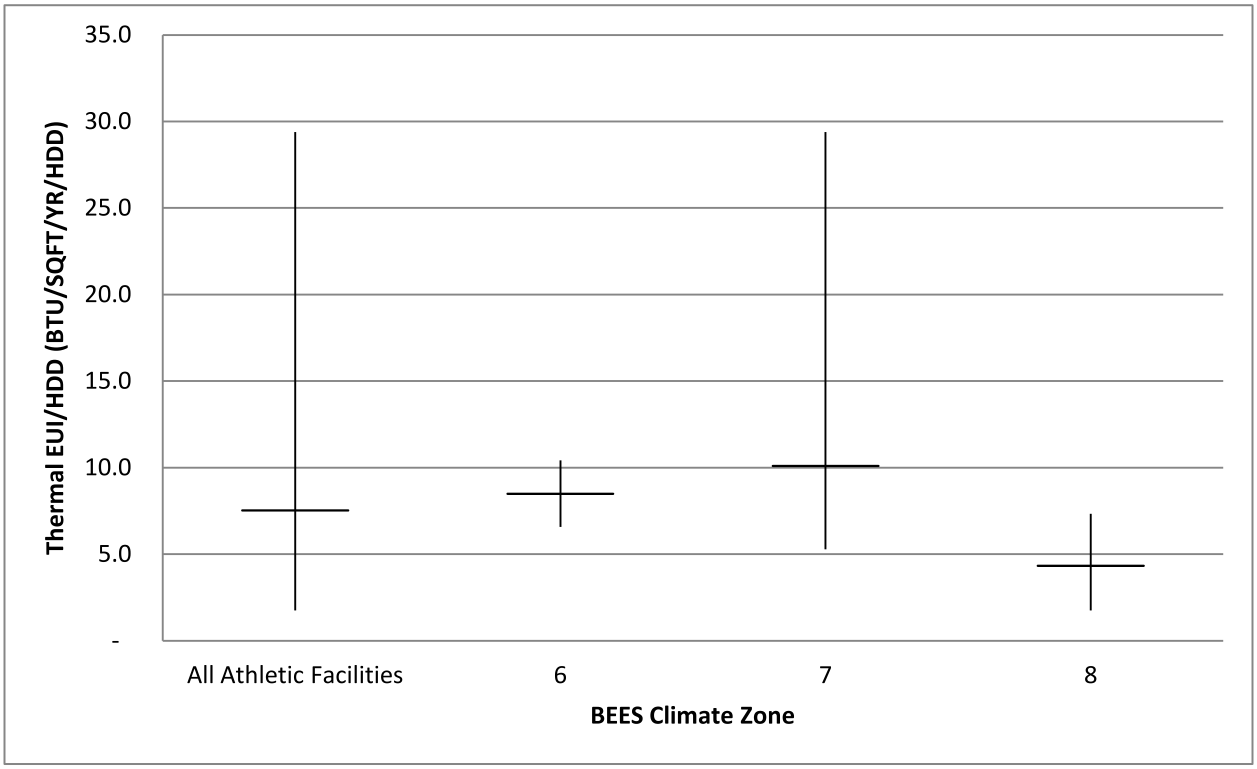
On average, athletic facilities also have a relatively similar space heat loss breakdown, except that they have higher loss through ventilation/air leakage, and relatively less loss through windows.

Figure 74: Athletic Facilities - Space heat loss by componentA



As the majority of energy use in athletic facilities goes to space heating, thermal EUI/HDD is a useful metric to compare buildings across climate zones. Athletic facilities in climate zone 8 use significantly less energy to heat their buildings given climate demands, as can be seen in Figure 75. Median energy use for facilities in zone 7 is more than that of those in zones 6 or 8, but it is also apparent in Figure 75 that there are significant outliers in climate zone 7, which use 3 times as much energy as the median building. Climate zone 9 is not included in this graph because of a lack of data.

Figure 75: Athletic Facilities - Median thermal EUI/HDD by climate zone[A]



In addition to using significantly more energy for space heating, athletic buildings in climate zone 7 also use at least twice the amount of electricity per square foot as buildings in climate zones 6 and 8, as can be seen in Figure 76. At over 10 times the median, the maximum electricity usage in climate zone 7 highlights the potential for large amounts of electricity that could be saved with effective retrofit and energy management programs.

Figure 76: Athletic Facilities - EUI & Electric EUI by Climate Zone$_{A+B}$

ATHLETIC FACILITY BUILDINGS BY CLIMATE ZONE									
		EUI (THOUSAND BTU / SQFT)				ELECTRIC EUI (KWH / SQFT)			
BEES Climate Zone	# OF RECORDS	AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
6	2	91	91	112	70	12.3	12.3	17.3	7.4
7	14	212	161	736	61	25.6	14.8	173.5	4.1
8	6	99	96	173	33	8.2	7.0	19.1	1.7
9	1	301	301	301	301	11.8	11.8	11.8	11.8

Despite the much higher energy usage by athletic facilities in climate zone 7, the average annual energy cost per square foot in these buildings is actually *lower* than costs in climate zone 8, as can be seen in Figure 77. One possible explanation is that most of climate zone 8 uses fuel oil for space heating, whereas the majority of zone 7 uses relatively less expensive natural gas for space heating and electrical production.

Figure 77: Athletic Facilities - Building Size & ECI by Climate Zone

ATHLETIC FACILITY BUILDINGS BY CLIMATE ZONE									
		SQUARE FOOTAGE$_{A+B}$				ECI$_A$			
BEES Climate Zone	# OF RECORDS	AVG	MED	MAX	MIN	AVG	MED	MAX	MIN
6	2	43,974	43,974	53,826	34,121	$2.68	$2.68	$3.28	$2.08
7	14	43,645	33,368	151,470	1,373	$3.17	$3.05	$5.20	$1.49
8	6	48,869	30,463	135,431	11,175	$3.51	$3.38	$5.31	$1.69
9	1	3,972	3,972	3,972	3,972	No Data	No Data	No Data	No Data

Washateria / Water Plant

Twenty three Washateria / Water Plant buildings received audits from ANTHC, and CCHRC built upon and added to the analyses done by their Department of Environmental Health and Engineering for this study. These buildings ranged from simple washateria facilities with shower, laundry, and water dispensing facilities to water and/or wastewater treatment plants with vacuum sewers which heat water in above ground pipes throughout the community to keep them from freezing. The audited facilities were all located in Climate Zone 8, mostly in communities that are very remote.

Because these remote communities often have relatively small populations and cash economies, the burden of energy costs to run these facilities can be significant. Depending on the type of water system, the average total annual energy cost per household ranges from $316 for conventional systems to $1,494 for an aboveground circulating water system with a vacuum sewer.[44] In extreme cases, energy costs to run these water plants were found as high as $3,860 per household per year, or roughly 12% of household median income.[45] The situation in Kivalina in October of 2012 highlights the burden of energy costs on communities. Essentially, the city did not have the money to buy the fuel necessary to run the water plant for the community, delaying the filling of water tanks. When sufficient funds were found, weather and equipment problems conspired to limit the water that could be treated, delaying school opening and leaving the community without enough clean water.[46]

Investments in energy efficiency can reduce the long-term financial burden on a community for providing clean water. While state and federal governments provide significant support for the capital costs of water and sewer treatment buildings, there is little support for operations and maintenance costs,[47] so money spent on energy likely comes primarily from local governments and water users. To determine the fiscal impacts on these communities, the current energy costs and the amount of money that could be saved if all of the proposed energy efficiency measures were done were calculated on a per household basis. Figure 78 shows the significant energy cost savings that some communities could achieve in the long term if energy efficiency measures are implemented. These household savings will not be realized immediately due to the initial costs of the retrofit, but with a median simple payback of only 3 years, community members would generally see the benefits fairly quickly.

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[44] Reitz, Daniel, Ronimus, Art, Remley, Carl, Black, Emily. (2011). *Energy Use and Costs For Operating Sanitation Facilities in Rural Alaska: A survey.* Alaska Native Tribal Health Consortium. Retrieved Novemeber 28, 2012 from http://www.anthctoday.org/dehe/documents/Latest%20Energy_Use_and_Costs_for_Rural_Alaska_Sanitation_Facilities__A_Survey.pdf

[45] Ibid.

[46] Kivalina school year postponed by storms. (2012, September 2). *Anchorage Daily News.* Retrieved November 27, 2012 from http://www.adn.com/2012/09/02/2609253/school-in-kivalina-postponed-by.html

[47] Colt, Steve, Goldsmith, Scott, Wiita, Amy. (2003). *Sustainable Utilities in Rural Alaska: Effective Management, Maintenance, and Operation of Electric, Water, Sewer, Bulk Fuel, Solid Waste.* Institute of Social and Economic Research. Retrieved November 27, 2012 from http://www.iser.uaa.alaska.edu/Publications/sustainA.pdf

Figure 78: Energy Costs and potential savings per household for clean water

WASHATERIA / WATER PLANT		Annual Energy Cost Household ($ / Year / hhld)			
Community	# occupied housing units	Current	Post-Retrofit	Total Savings	% savings
Average	**80**	**$503**	**$307**	**$196**	**37%**
Selawik	163	$1,571	$833	$737	47%
Shaktoolik	61	$856	$152	$704	82%
Tuntutuliak	87	$603	$127	$476	79%
Chuathbaluk	33	$668	$308	$360	54%
Sleetmute	37	$516	$193	$323	63%
Napaskiak	85	$845	$588	$256	30%
Marshall	91	$425	$187	$239	56%
Tuluksak	86	$533	$359	$174	33%
Chefornak	77	$371	$199	$172	46%
Kongiginak	75	$807	$638	$170	21%
Nulato	87	$795	$629	$166	21%
Nunapitchuk	96	$356	$242	$114	32%
Eek	75	$589	$477	$113	19%
Toksook Bay	133	$286	$204	$82	29%
Teller	75	$744	$665	$78	11%
Lower Kalskag	69	$281	$213	$68	24%
Tununak	77	$292	$236	$56	19%
Upper Kalskag	53	$81	$26	$55	68%
Akiak	94	$393	$339	$54	14%
Goodnews Bay	83	$258	$212	$45	18%
Russian Mission	73	$174	$146	$28	16%
Nightmute	61	$52	$25	$27	52%
Newtok	64	$82	$70	$12	15%

Recent research suggests that increasing the availability of water may lead to better health outcomes due to increased hand-washing and other hygiene practices.[48] Additionally, ISER research has found that many water haul system users have cut down their consumption in an effort to conserve money[49]. If reducing energy costs results in lower prices for consumers and further

[48] Hennessy, Tom, Ritter, Troy, Holman, Robert, Bruden, Dana, Yorita, Krista, Bulkow, Lisa, et al. (2008). The Relationship Between In-Home Water Service and the Risk of Respiratory Tract, Skin, and Gastrointestinal Tract Infections Among Rural Alaska Natives. *American Journal of Public Health, 98.*
[49] Colt, Steve, Goldsmith, Scott, Wiita, Amy. (2003). *Sustainable Utilities in Rural Alaska: Effective Management, Maintenance, and Operation of Electric, Water, Sewer, Bulk Fuel, Solid Waste.* Institute of Social and Economic Research. Retrieved November 27, 2012 from http://www.iser.uaa.alaska.edu/Publications/sustainA.pdf

research proves a causal relationship between more water consumption and better health outcomes, then energy efficiency measures also have the potential to increase the health of local communities.

In addition to direct savings from reduced energy use, local communities may also stand to benefit from increased local hire since the majority of these energy efficiency measures can be performed locally, as was noted in the case study on types of retrofits earlier in this paper. The potential for more local jobs and a reduced energy cost burden in remote communities highlights the possible benefits of energy efficiency measures in washaterias and water plants throughout rural Alaska.

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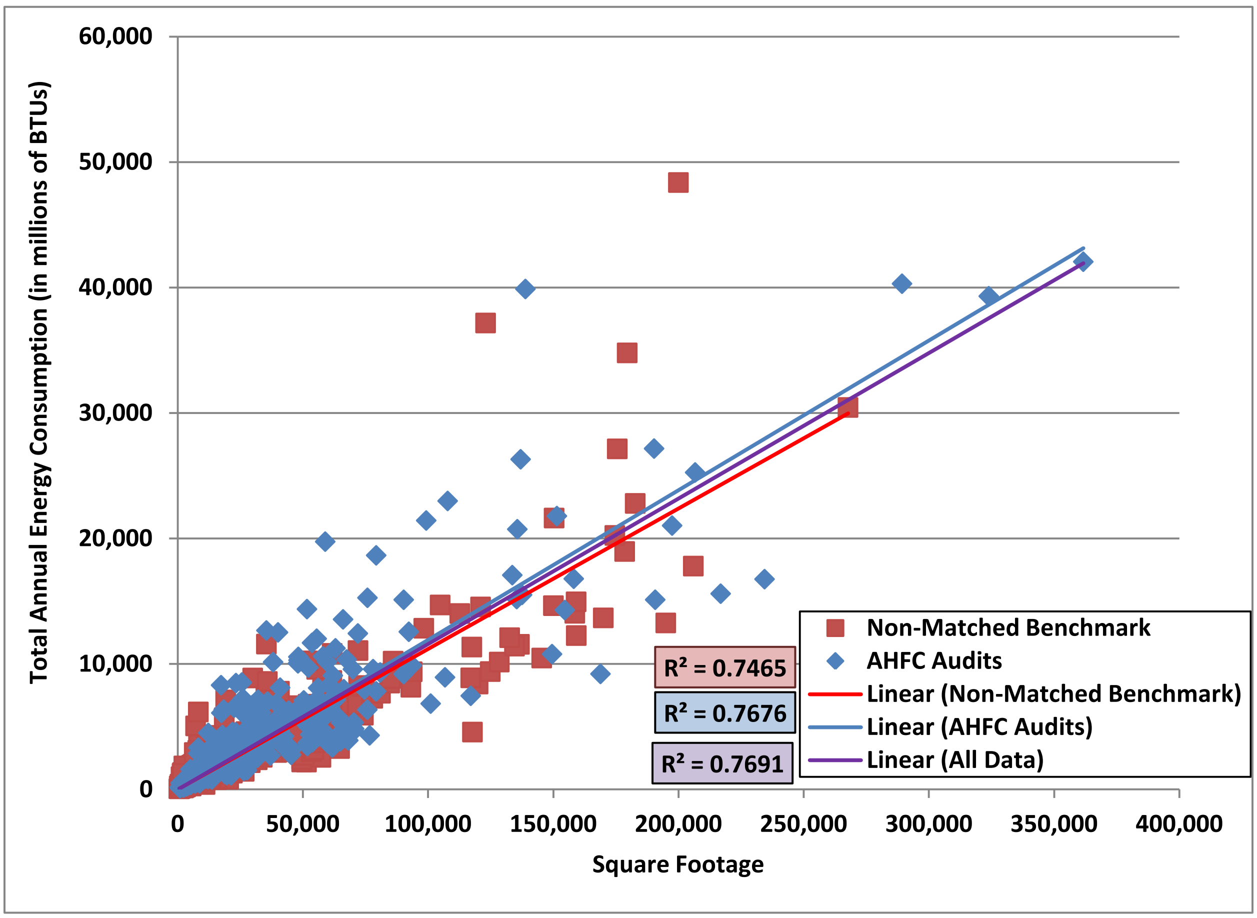
Appendix A: Comparison of Data Sets

AHFC Benchmark + AHFC Audits: Energy vs. SQFT

This report utilizes several sets of data collected by different organizations. In an effort to determine the usability of the data sets in a unified whole, we ran several comparisons between the data sets. For all comparisons in this section, the top 2.5% and bottom 2.5% of records as determined by their EUI were removed as outliers. Data were tested for statistically significant differences. These results are referenced where appropriate. N-values given in this section are for the reduced data after the outliers are removed.

Figure A contains all the records from the recent AHFC audit effort for public and municipal buildings (n=326).[50] Most audits (n=267) were done on buildings that had already submitted benchmark data. Figure A shows the similarity of the AHFC audits and the unmatched benchmark records (n=318). There was no statistical difference between the means of these data sets.

Figure A: Comparison of All Non-matched Benchmark vs. AHFC Audit Data



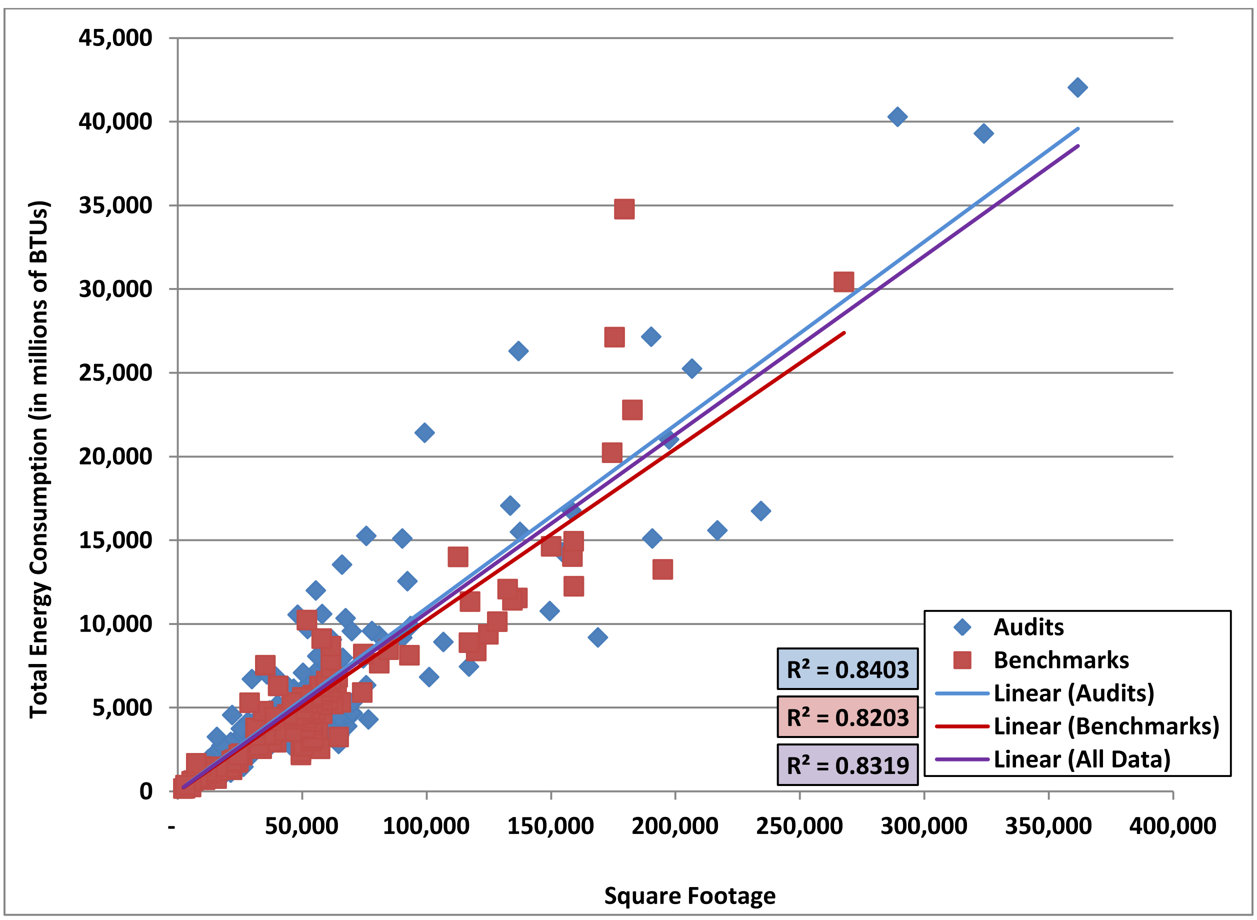
[50] Note that some anomalous data was removed for this analysis.

Note there is a reasonably strong correlation (0.75 – 0.77) for each dataset between total energy and square footage. As has been previously noted in the recent AHFC white paper and elsewhere, there is generally a difference in how different building usage types use energy. Therefore, the data was examined further by building usage type. The following comparisons are by descending number of records.

All Data - Comparisons by Building Usage Type

Figure B highlights the audit (n=176) and benchmark (n=129) records for schools. Elementary, Middle, and High Schools are all present in the dataset. Note the similarities in the AHFC audit and benchmark data sets. Note that the data sets in Figure B also have similar, and strong, correlations (0.82 – 0.84) between energy and square footage. When determining which buildings to audit within a community, AHFC and the TSPs typically chose the building that had reported higher energy usage. We believe that this selection bias is the reason that the means of these two populations are different by a statistically significant amount.

Figure B: Comparison of School Benchmark and AHFC Audit Data



Offices came from three data sources as can be seen in Figure C. AHFC audits and unmatched benchmarks represent the majority of records (n=34 and n=35 respectively), while a smaller number (n=21) came from ANTHC's audit efforts. Note the similarities between the AHFC and ANTHC audits. ANTHC's tend to be for much smaller structures, but have a very similar trend to AHFC's. Statistically, there was no significant difference in the means of any of these data sets.

Figure C: Comparison of Office Benchmark, AHFC Audit, and ANTHC Audit Data

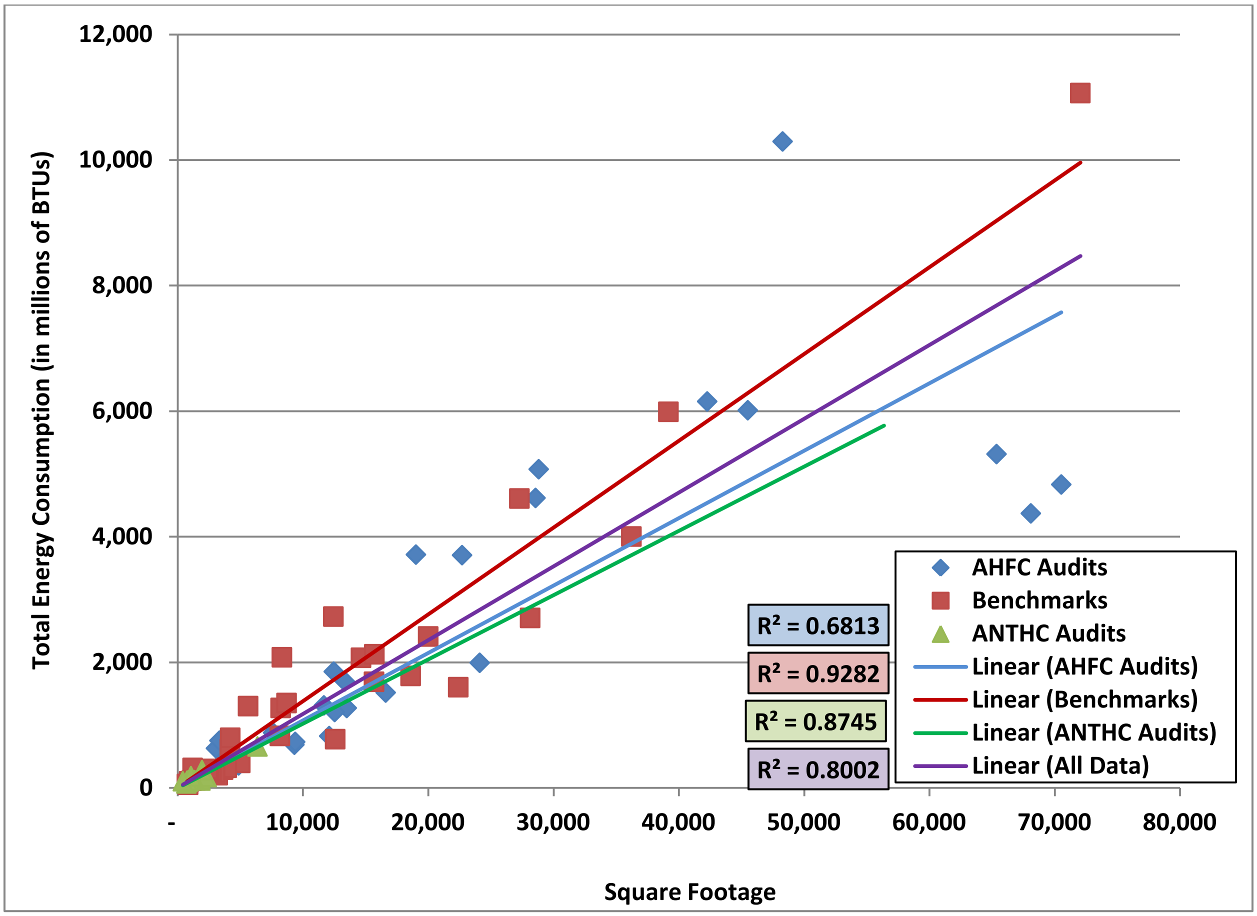
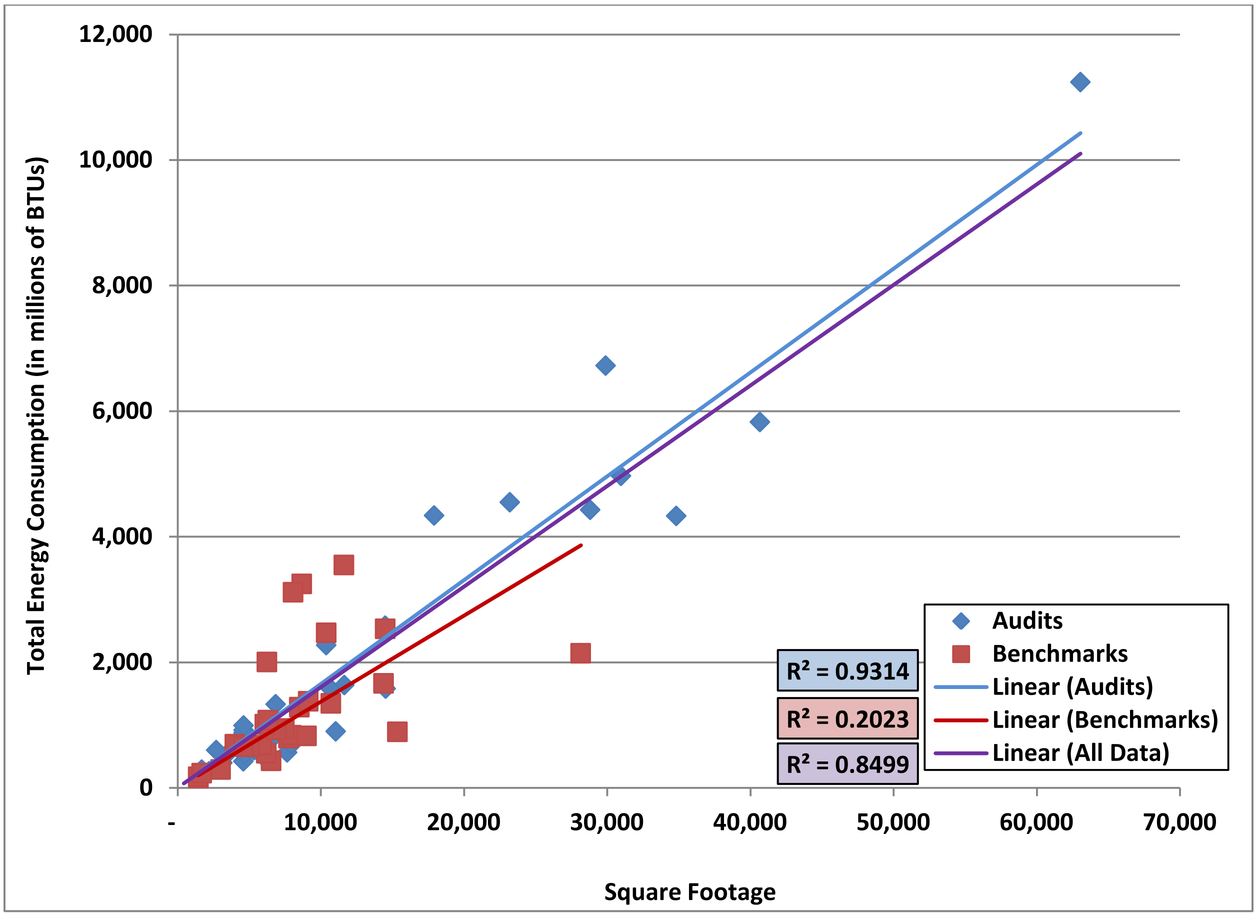


Figure D examines the data for Public Order and Safety buildings. Note that the correlation for the benchmark data is quite low (0.20), a fact that is driven by a number of records in the 10,000 to 15,000 square footage size range with highly variable energy consumption. When these records are combined with the audits, the resulting correlation is strong (0.85). Statistically, there is no significant difference in the means of these data sets.

Figure D: Comparison of Public Order and Safety Building Benchmark and AHFC Audit Data



In Figure E are the data for Warehousing and Wholesale buildings. Note that the correlation for the audit data is lower (0.44) than that of the benchmarks (0.89). This is driven by the one record with a square footage of approximately 60,000. When these records are combined with the audits, the resulting correlation of is strong (0.83). Statistically, there is no significant difference in the means of these data sets.

Figure E: Comparison of Warehousing and Wholesale Benchmark and AHFC Audit Data

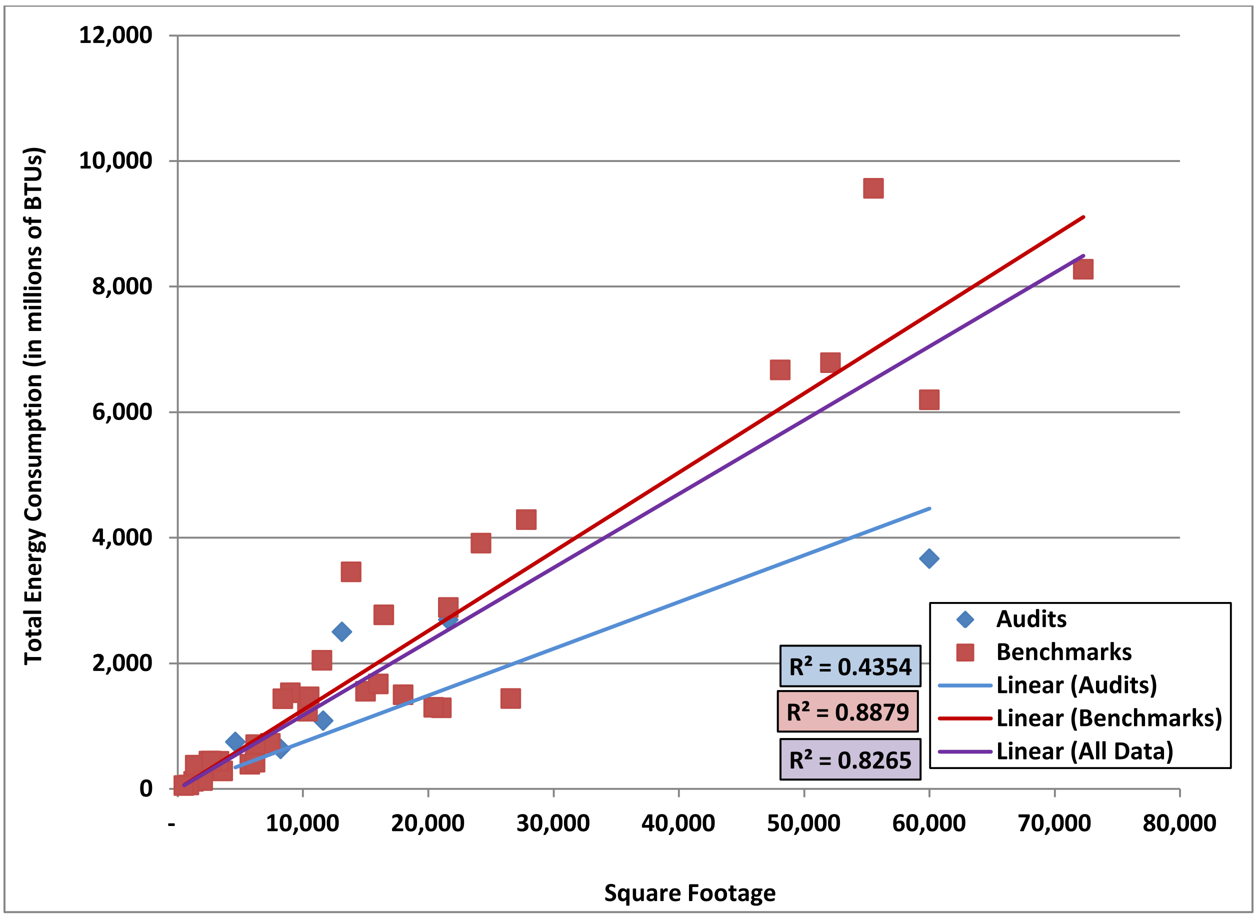
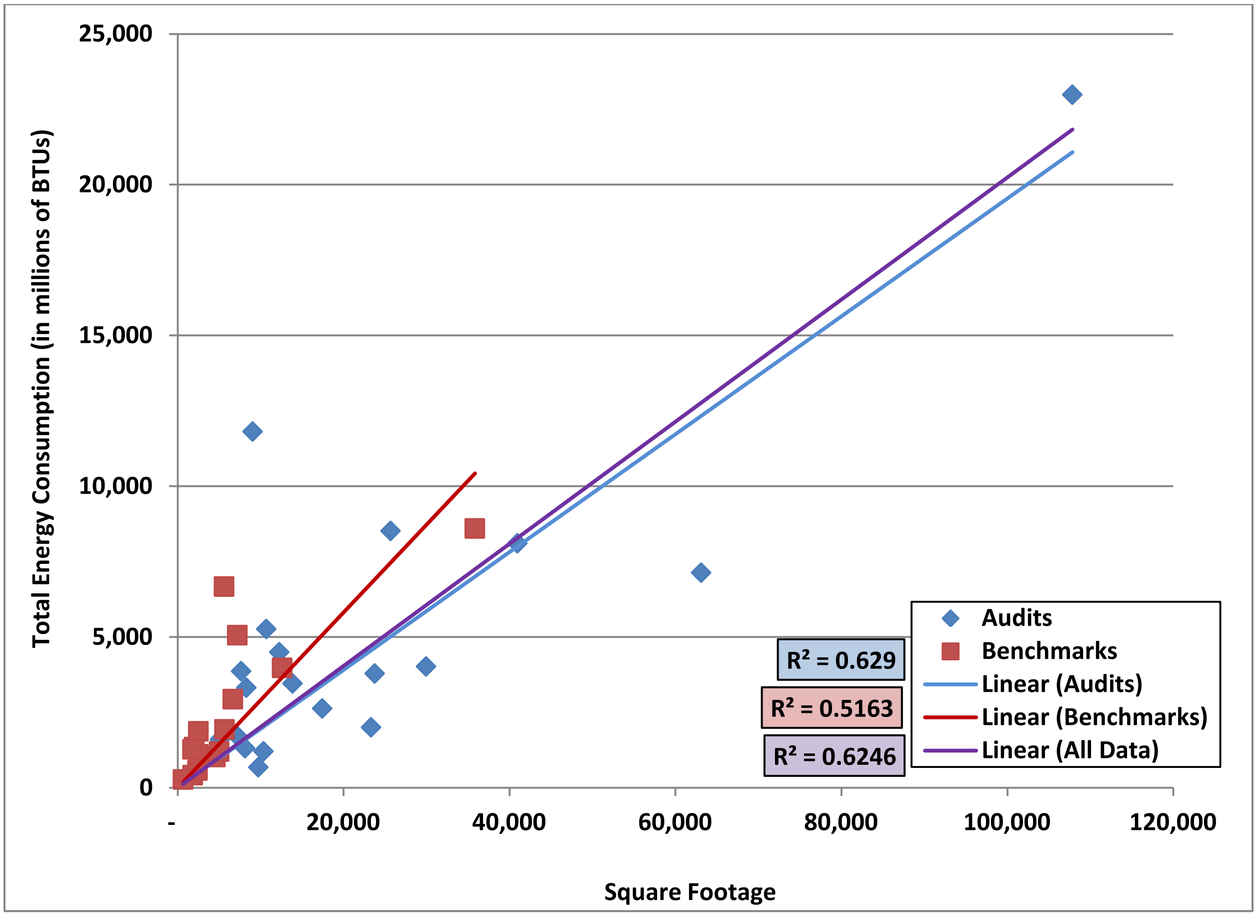


Figure F shows data from the maintenance facilities and shop buildings. This data had some of the largest variations in EUI of any building usage type. Originally included in several buildings usage types, including "Warehousing and Wholesale" and "Other" in the audit and benchmark records, the energy characteristics of maintenance and shop buildings were different enough that they were isolated for this report. While the correlations are not exceptionally strong for either of the data sets (0.63 and 0.52 respectively), the data sets are largely similar. There is no significant difference in the means at a 99% confidence interval.

Figure F: Comparison of Maintenance and Shop Building Benchmark and AHFC Audit Data



Data for Athletics Facilities can be seen in Figure G. AHFC audits represent the majority of records (n=18) with unmatched benchmarks representing the remainder (n=6). Note the wide variation in energy consumption for facilities of approximately 60,000 square feet. This leads to the lower (0.65) correlation for the audit data. Statistically, there was no significant difference in the means of these data sets.

Figure G: Comparison of Athletic Facility Benchmark and AHFC Audit Data

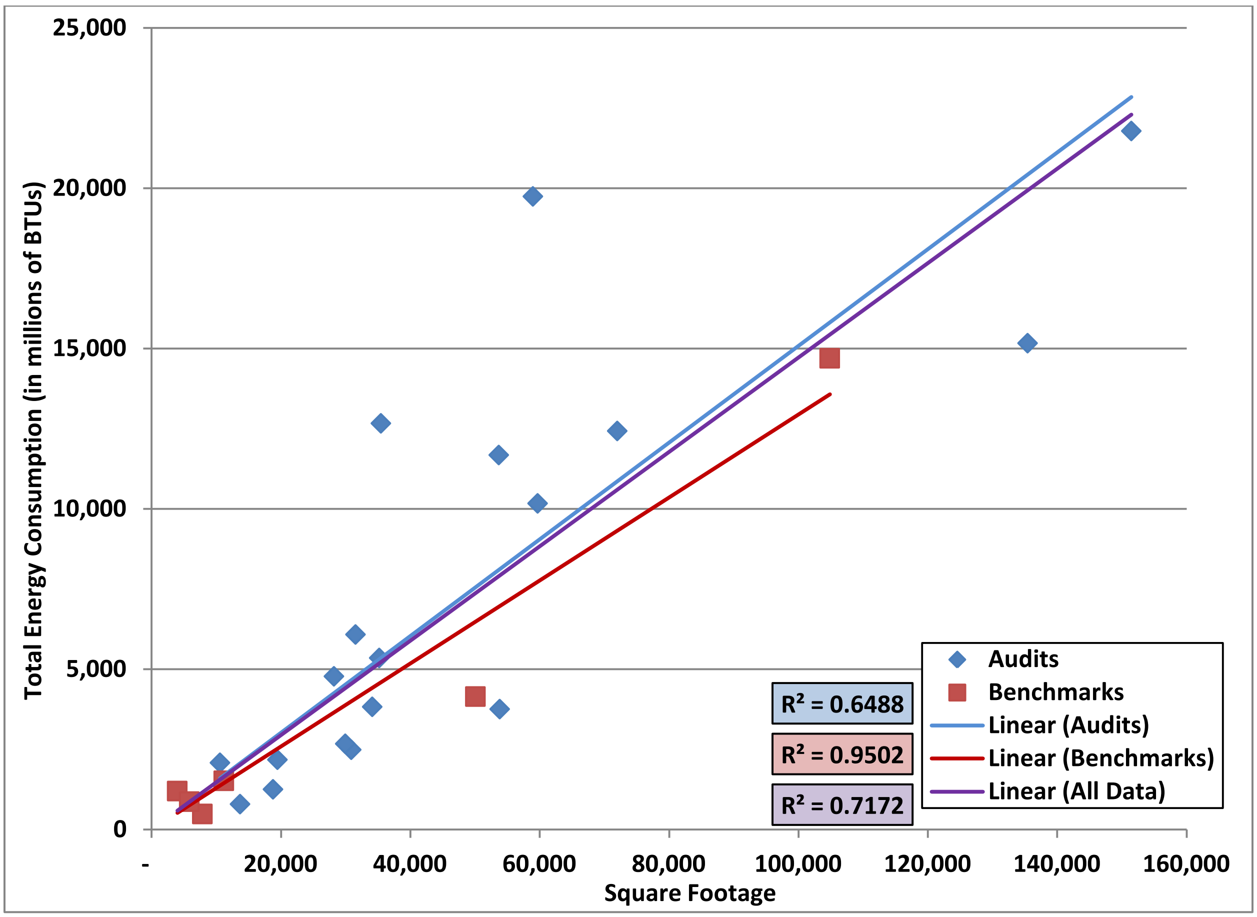
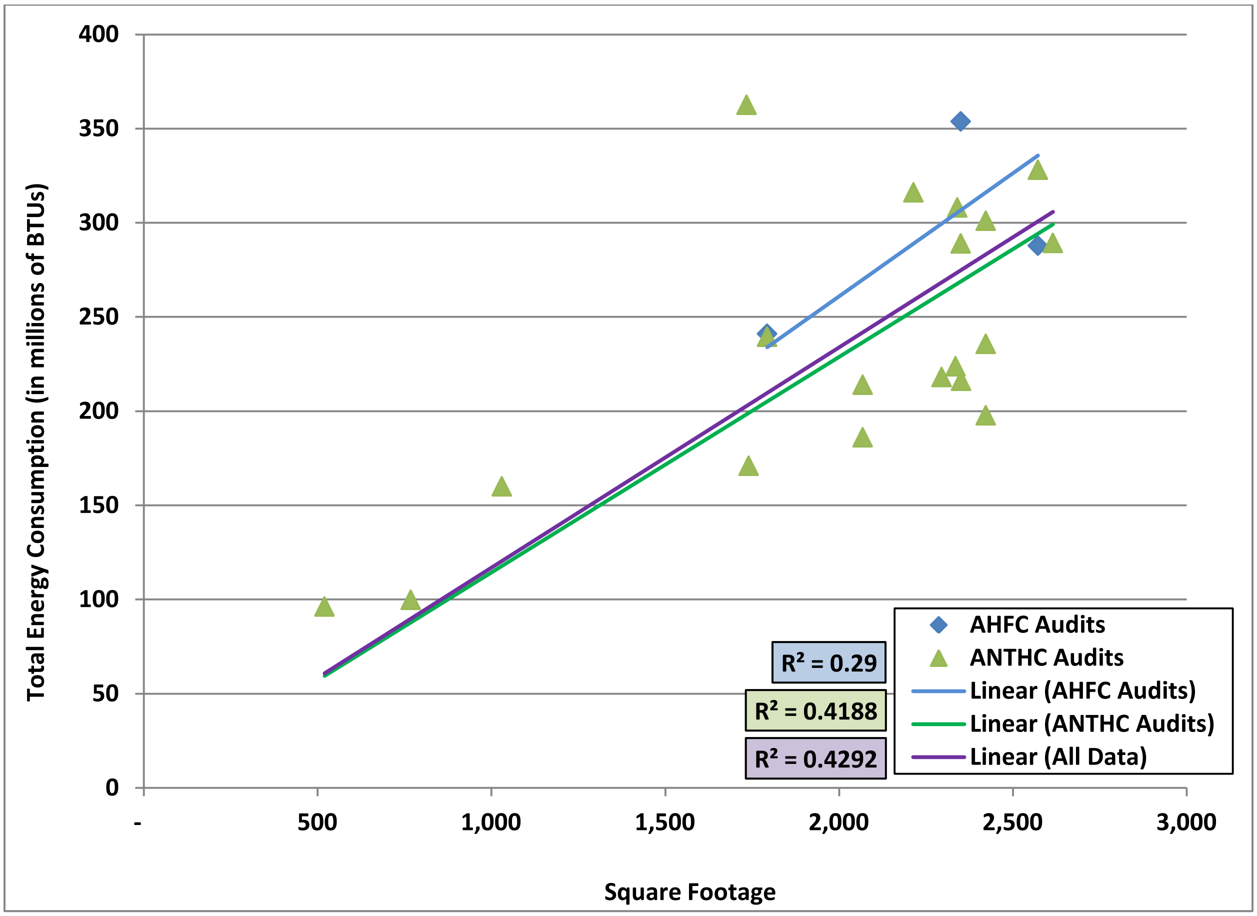


Figure H shows data for audited health clinics. These buildings tended to be very small square footage-wise. The audits show a large variability in the energy consumption for those buildings that are around 2,000 square feet in size. While the correlations are not exceptionally strong for either of the data sets (0.29 and 0.42 respectively), the data sets are largely similar. There is no significant difference in the means at a 90% confidence interval.

Figure H: Comparison of Health Clinic AHFC and ANTHC audit Data



The data for Public Assembly buildings is displayed in Figure I. Note that the data sets have strong correlations (0.76 – 0.99). Variability in energy consumption for the benchmark records of buildings greater than 175,000 square feet cause a lower r-squared value here. When these records are combined with the audits, the resulting correlation is strong (0.81). Statistically, there is no significant difference in the means of these data sets.

Figure I: Comparison of Public Assembly Building Benchmark and AHFC Audit Data

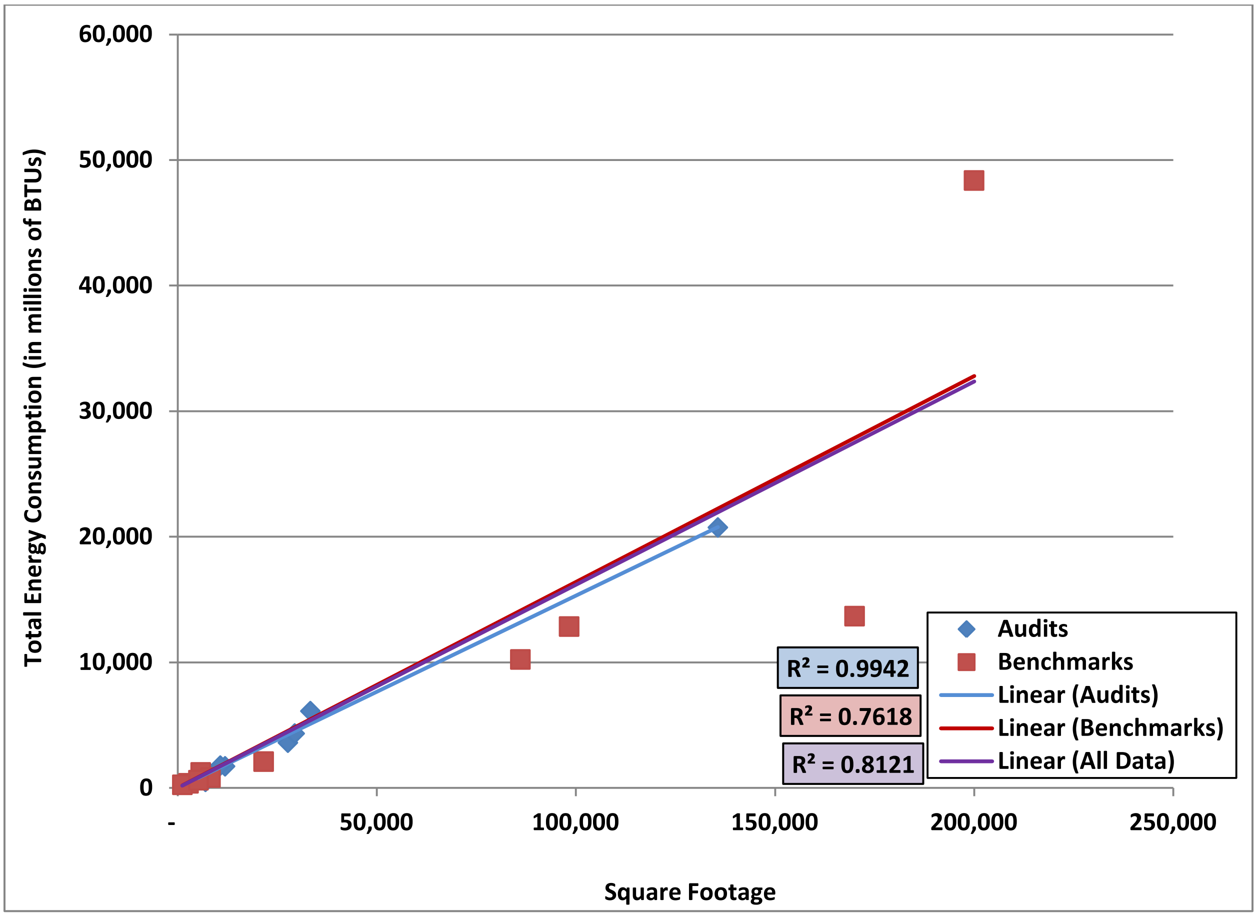


Figure J displays the data for Washaterias. Note that the AHFC audit data has a strong correlation (0.99) while the ANTHC audit data has a lower correlation (0.65). When these data are combined the resulting correlation is strong (0.97). Statistically, there is no significant difference in the means of these data sets.

Figure J: Comparison of Washateria and Water Plant AHFC and ANTHC Audit Data

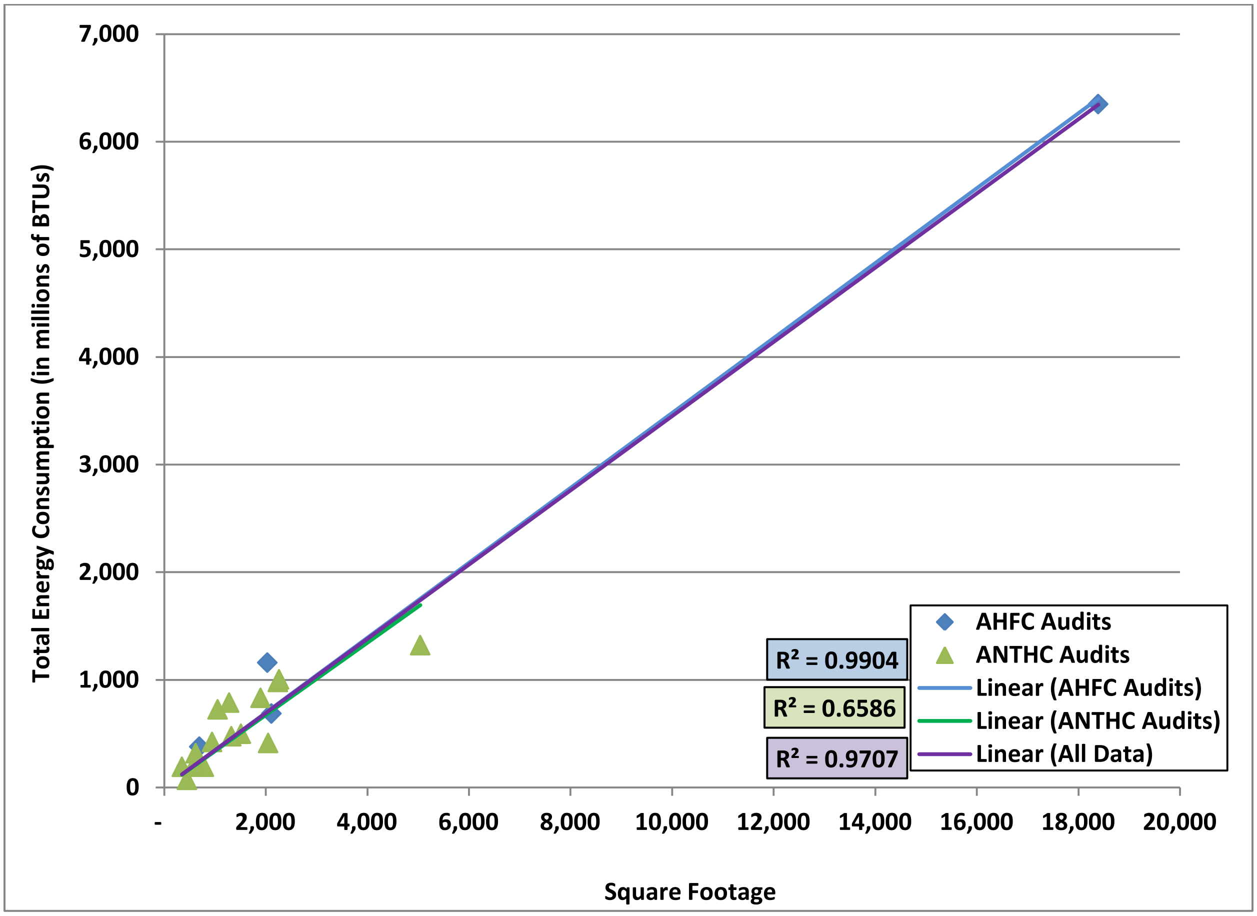


Figure K: Comparison of Benchmark and AHFC Audit Building Sizes

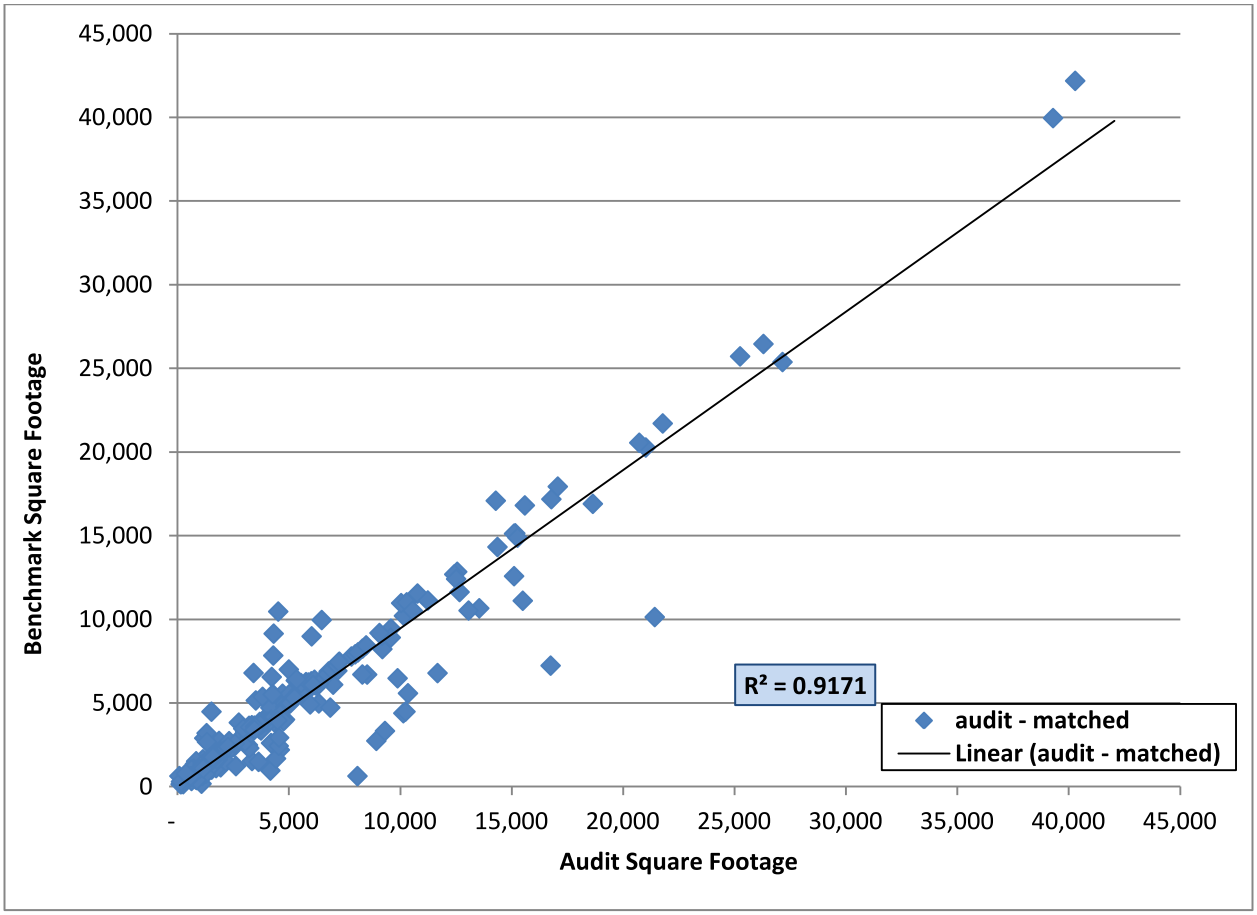


Figure L: Comparison of Building Age and Total Energy Consumption for All Buildings

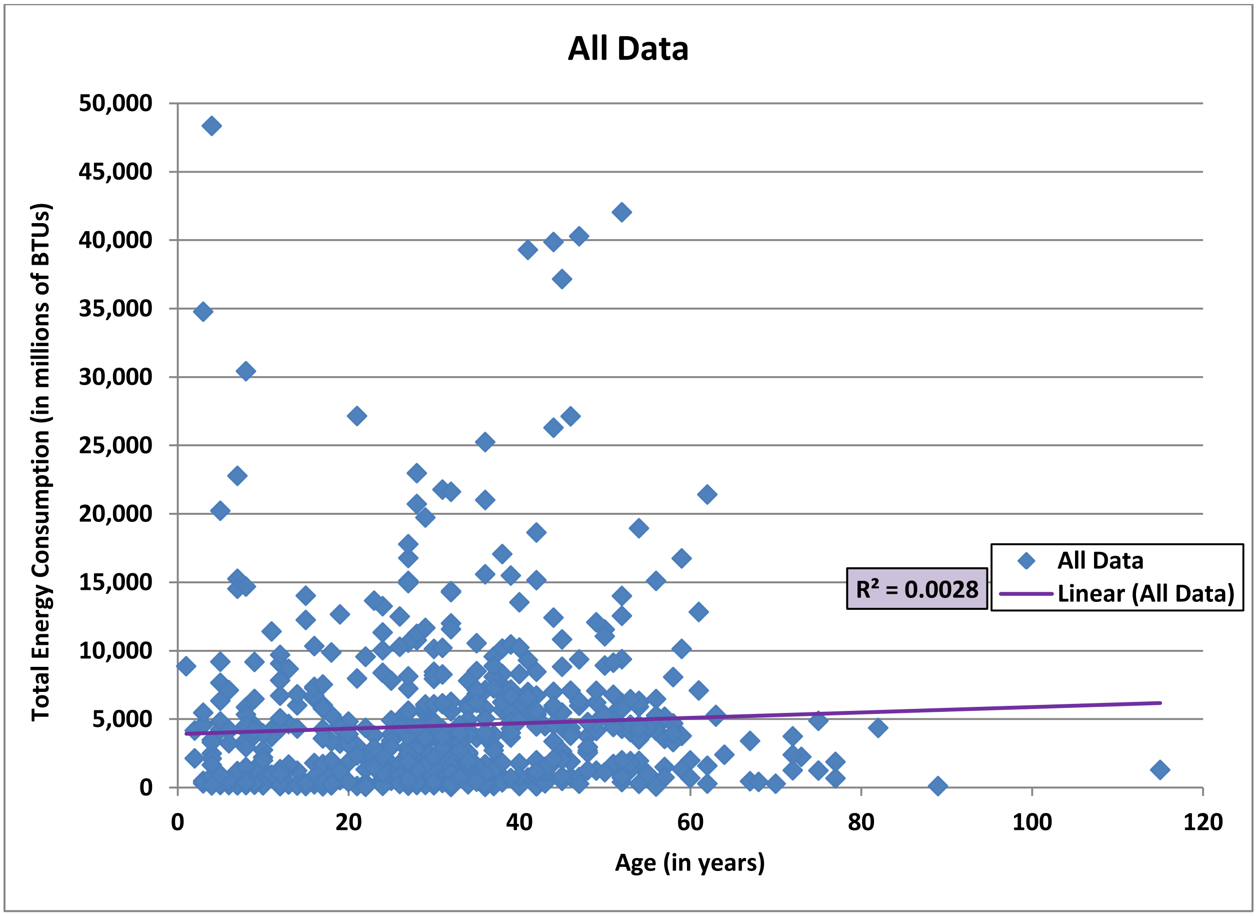


Figure M: Comparison of Building Age and Total Energy Consumption for Schools

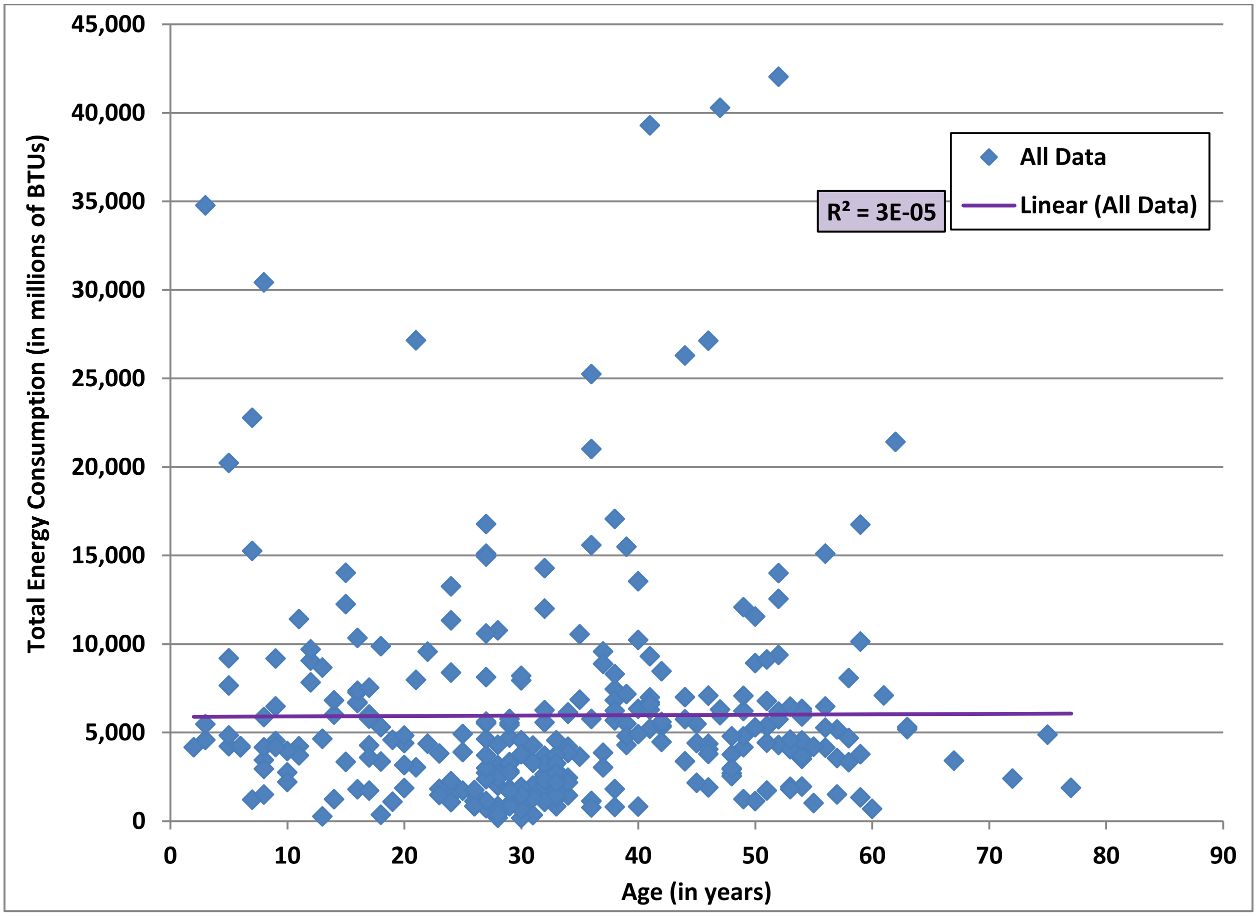


Figure N: Comparison of Building Age and Total Energy Consumption for Offices

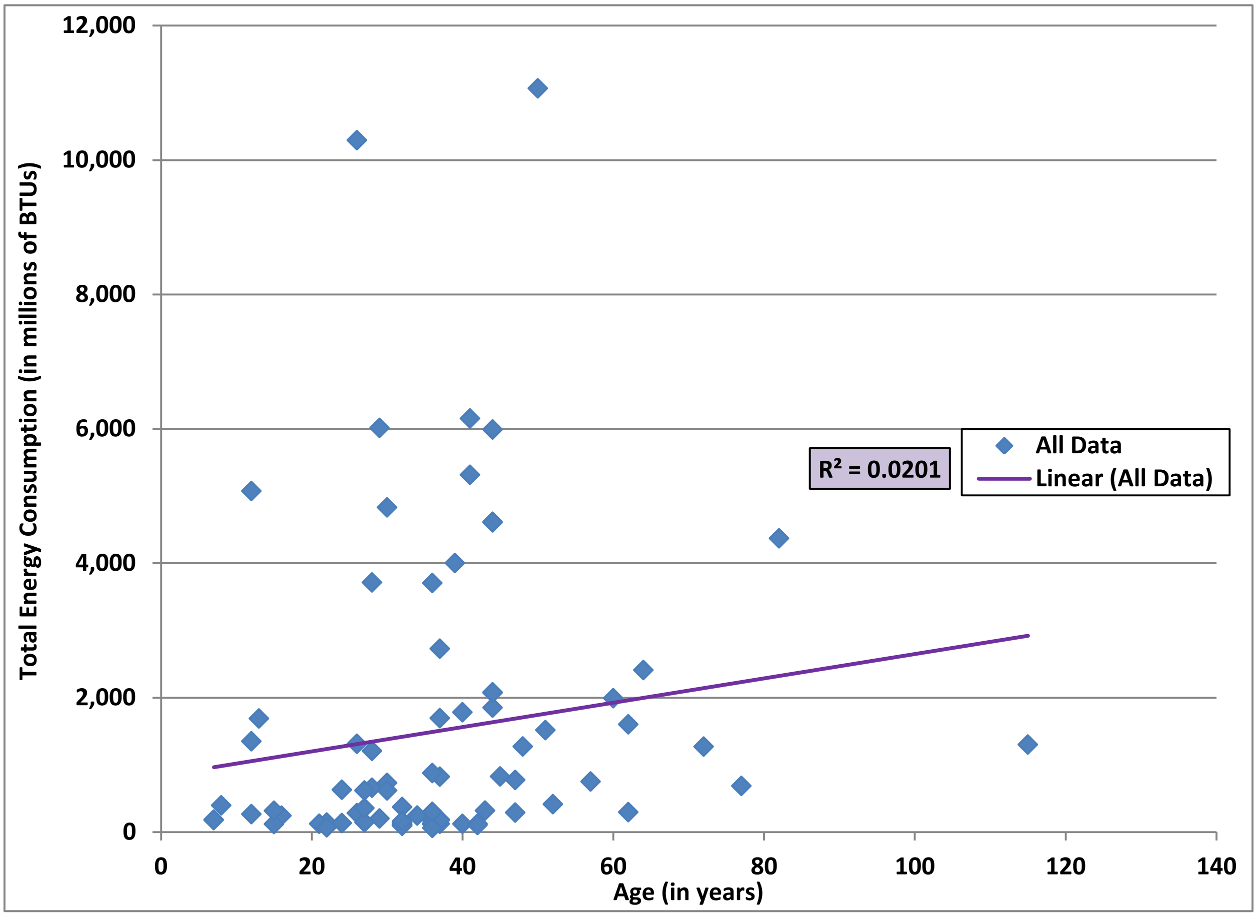


Figure O: Comparison of Building Age and Total Energy Consumption for Public Order and Safety Buildings

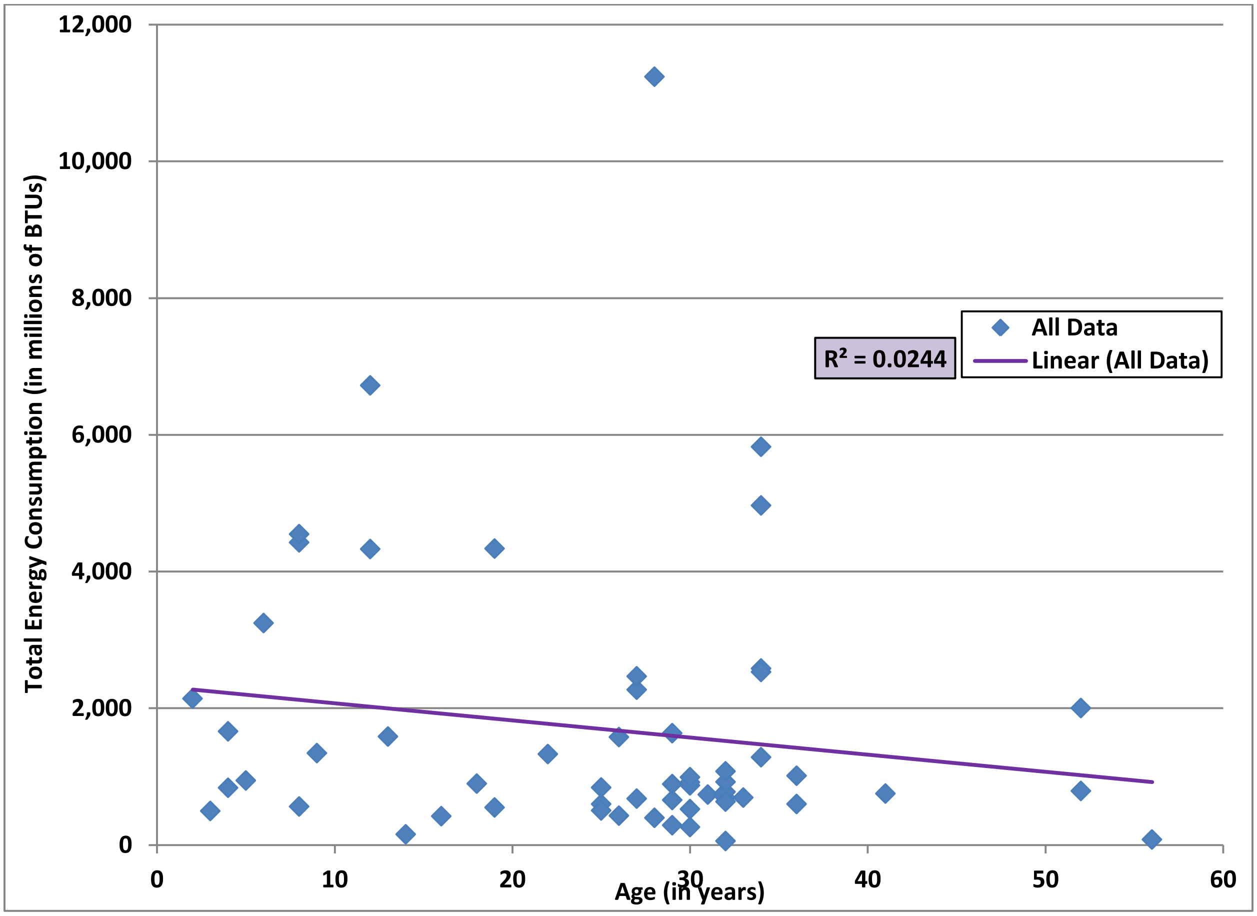


Figure P: Comparison of Building Age and Total Energy Consumption for Health Clinics

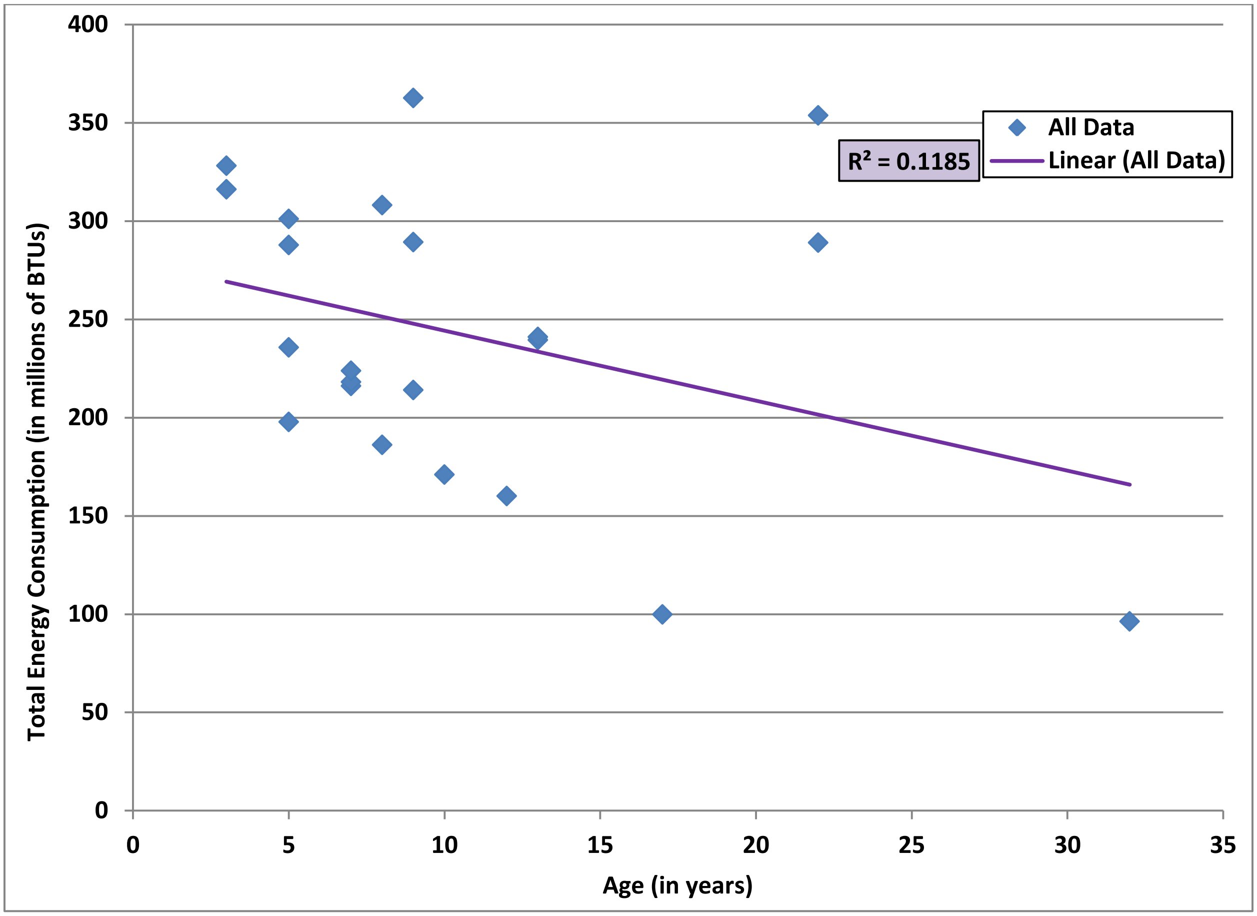


Figure Q: Comparison of Building Age and Total Energy Consumption for Washaterias

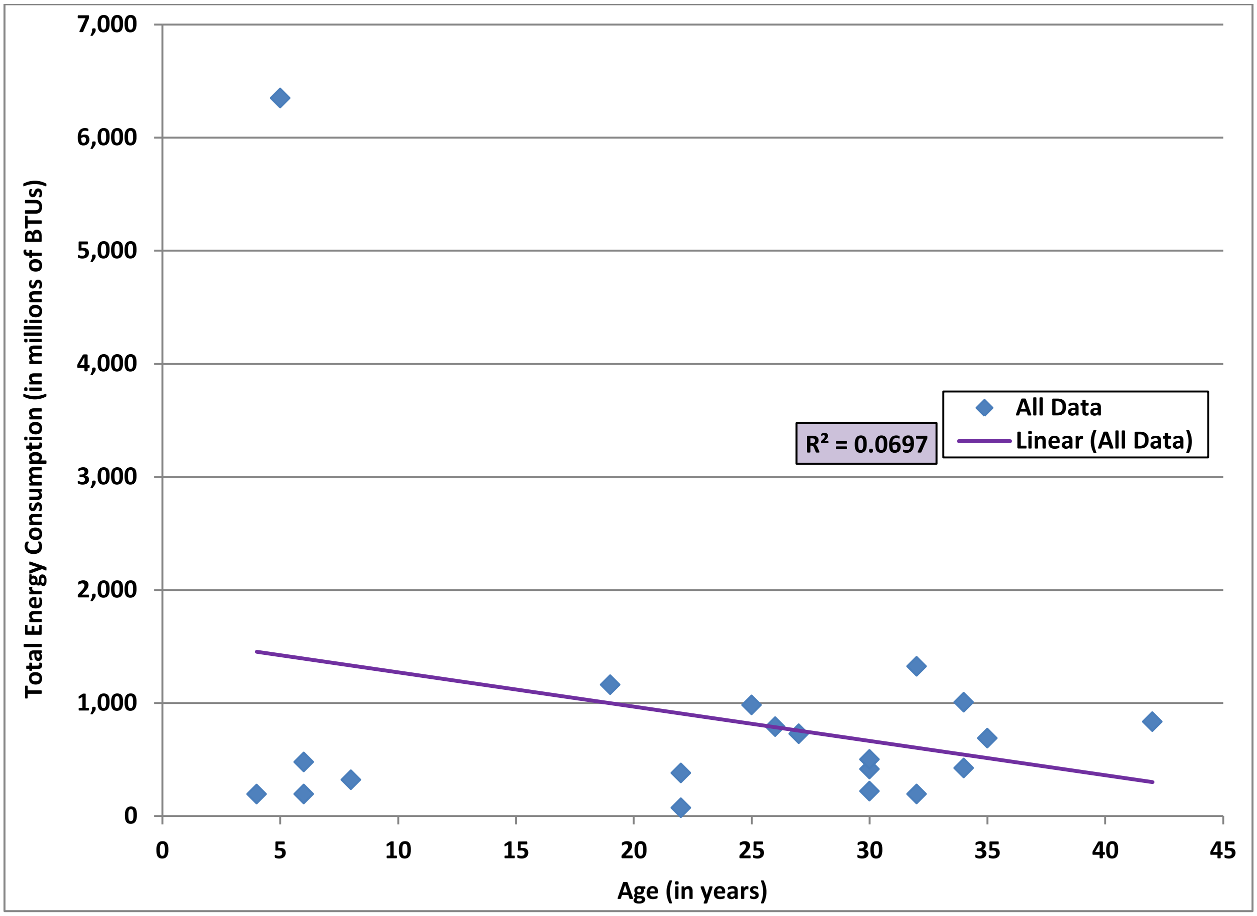


Figure R: Comparison of Age and Square Footage for All Buildings

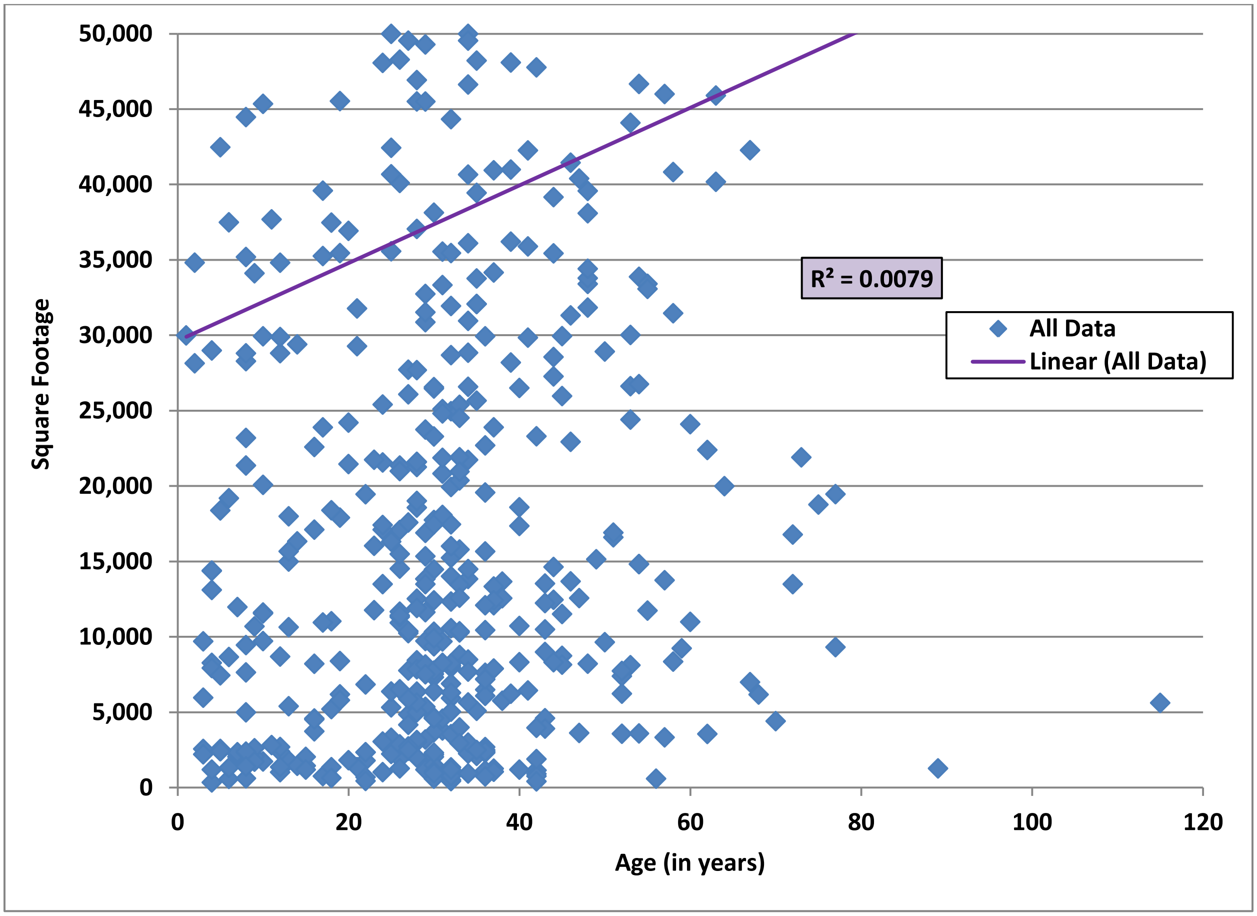


Figure S: Comparison of Building Age and Square Footage for Schools

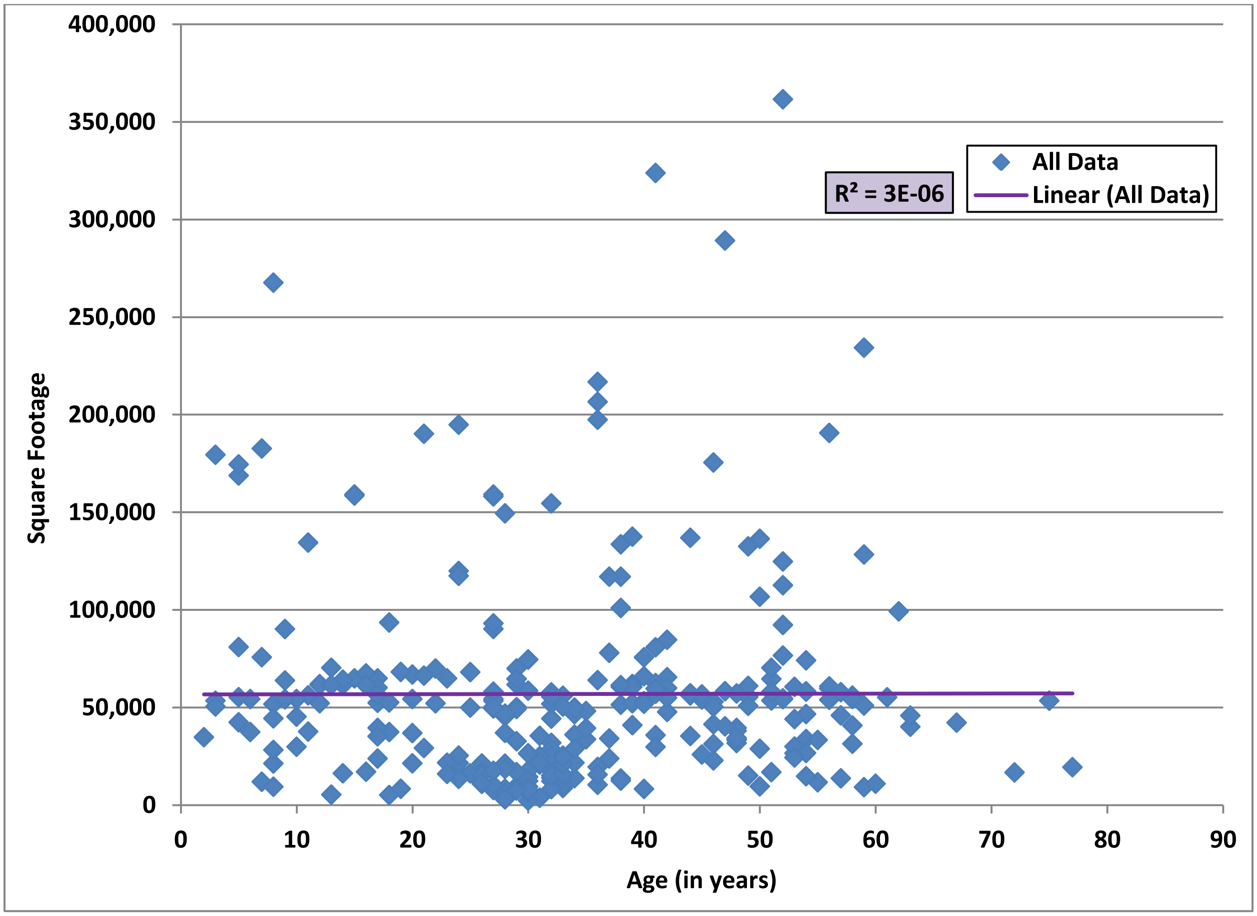


Figure T: Comparison of Building Age and Square Footage for Offices

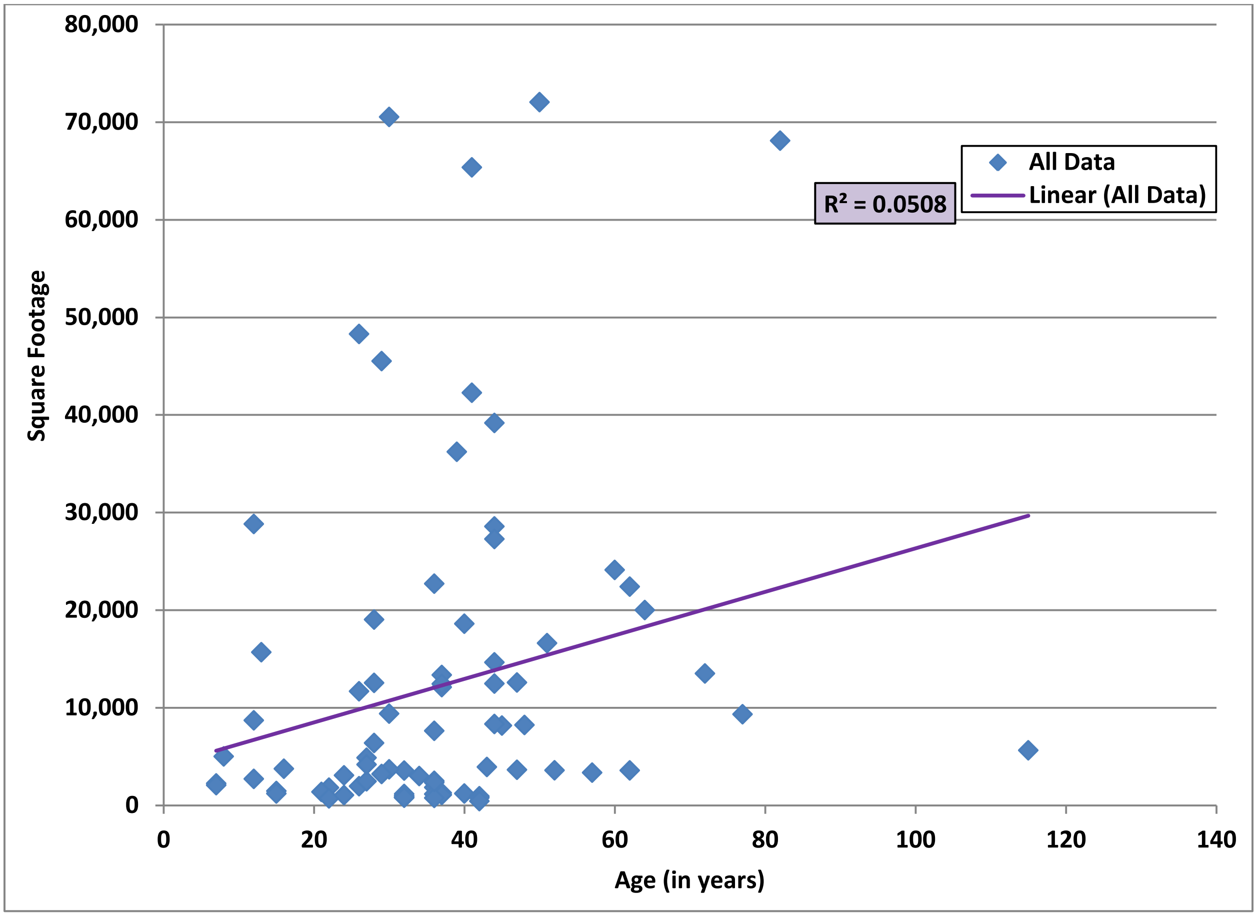


Figure U: Comparison of Age and Square Footage for Public Order and Safety Buildings

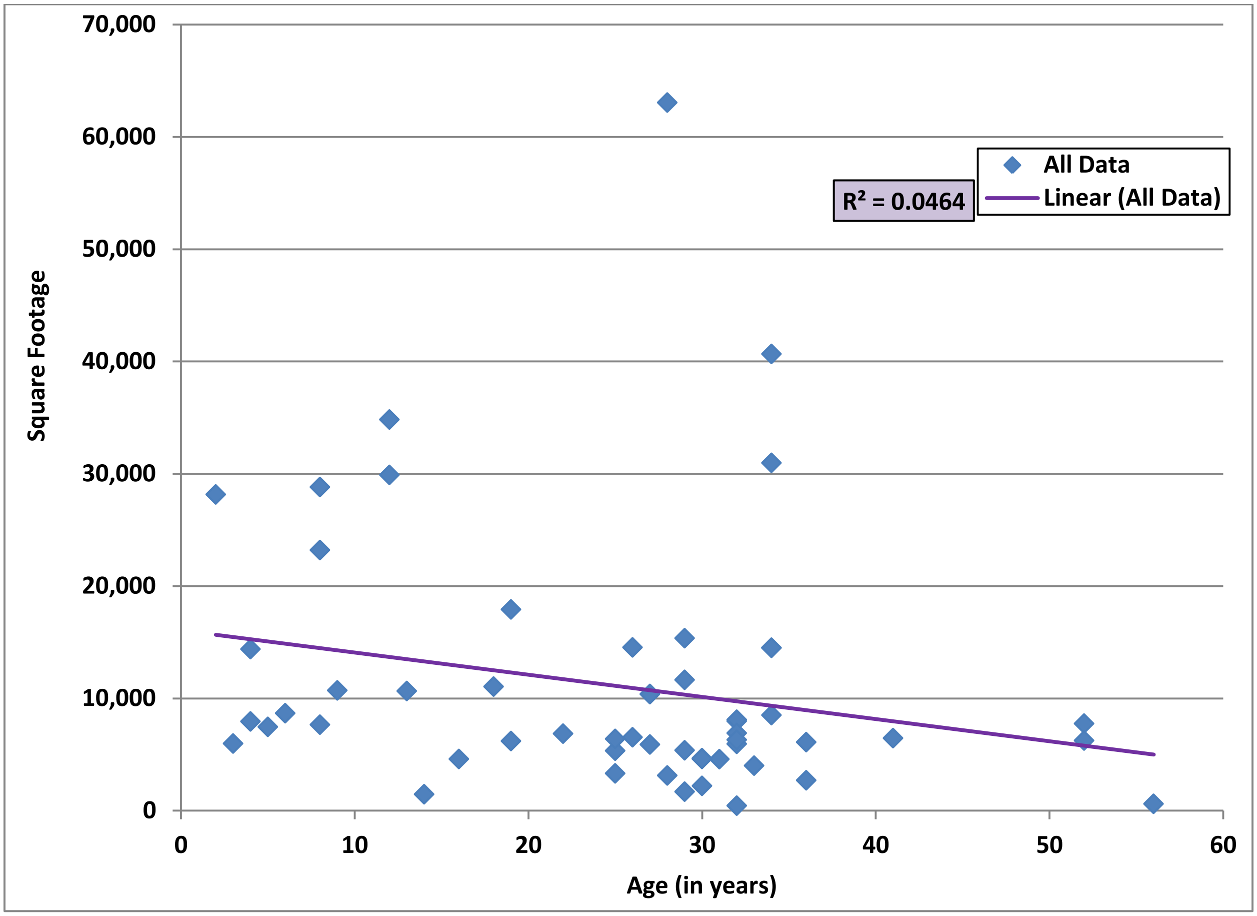
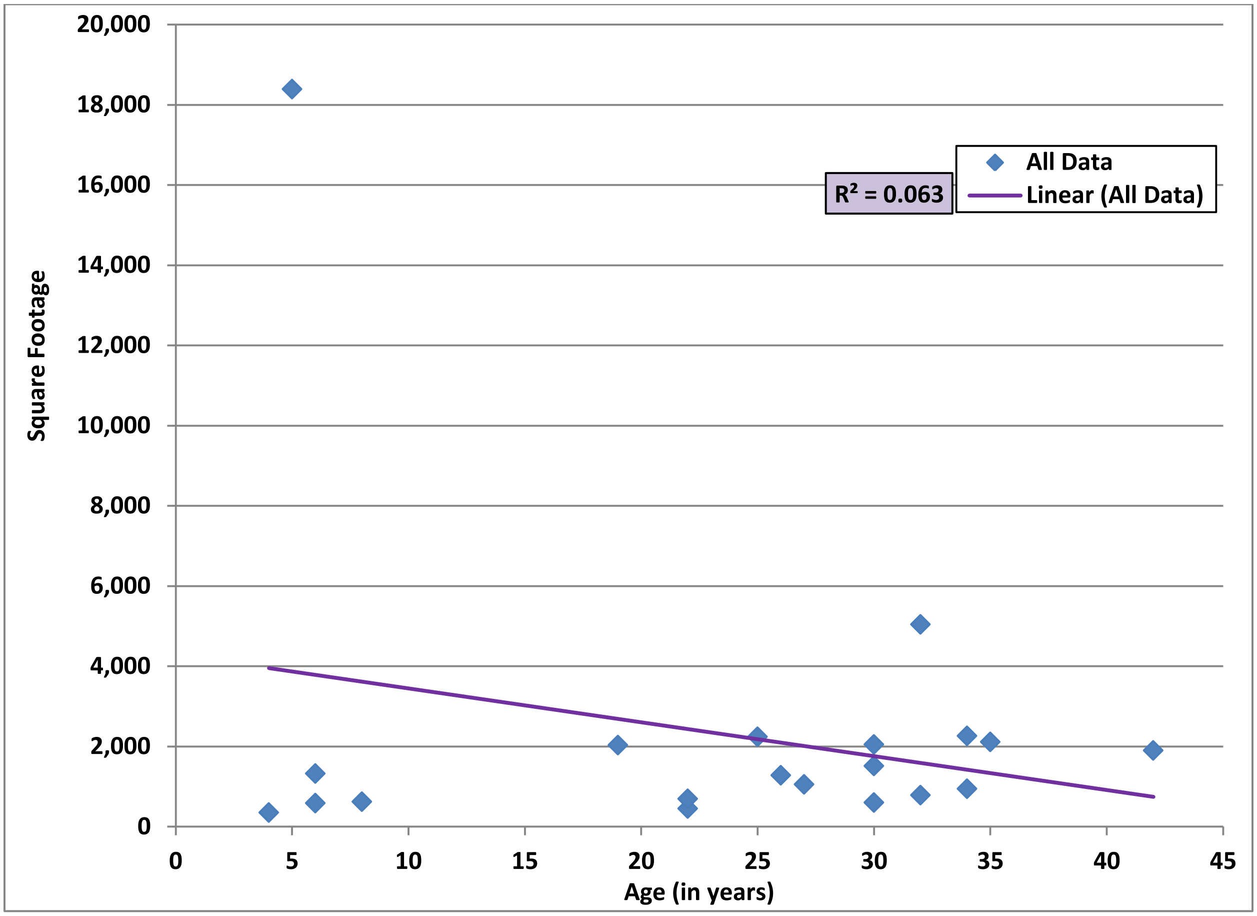


Figure V: Comparison of Age and Square Footage for Washaterias



Appendix B: Regression Analyses

Figure W: Thermal EUI/HDD vs. Primary Fuel Price for All Buildings

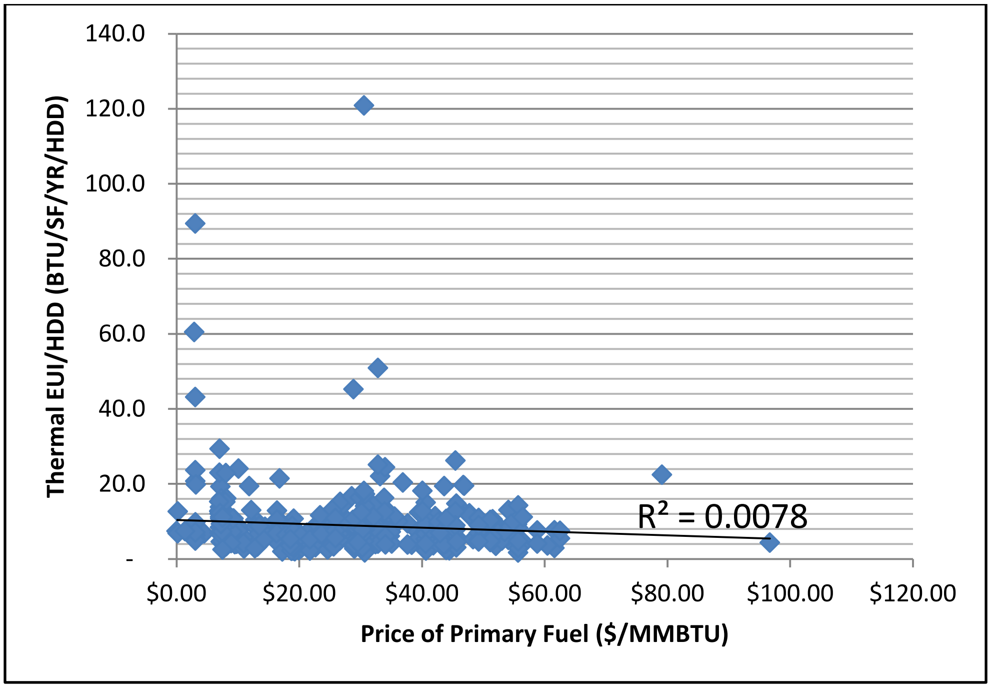


Figure X: Thermal EUI/HDD vs. Geographic Area Cost Factor for All Buildings

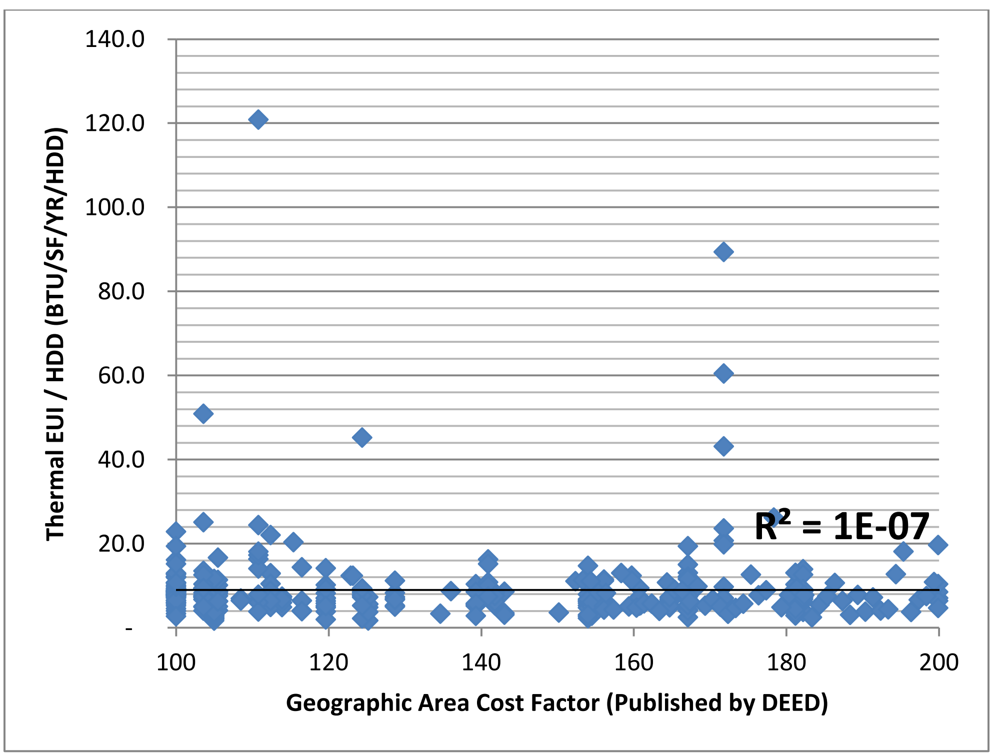


Figure Y: Thermal EUI/HDD vs. Building Age

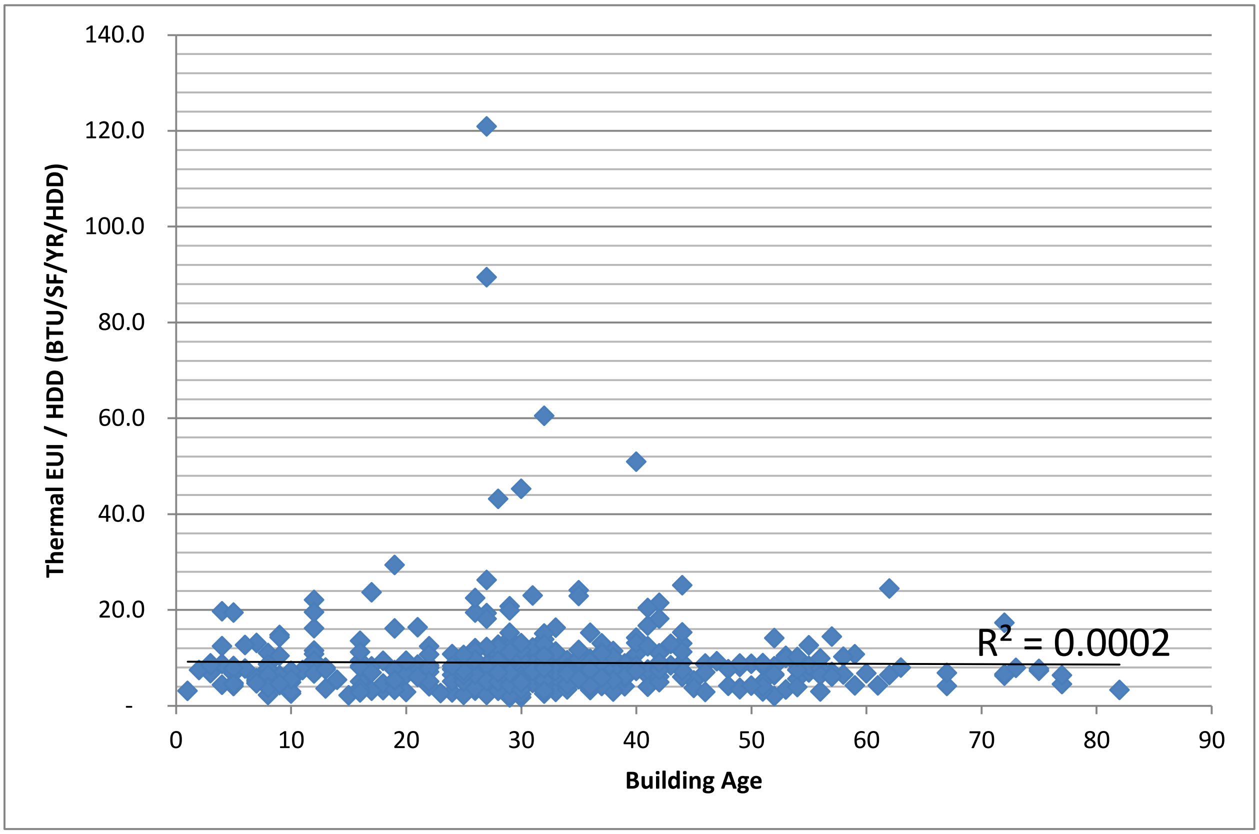


Figure Z: Thermal EUI/HDD vs. Year Remodeled for All Buildings Reporting Remodel.

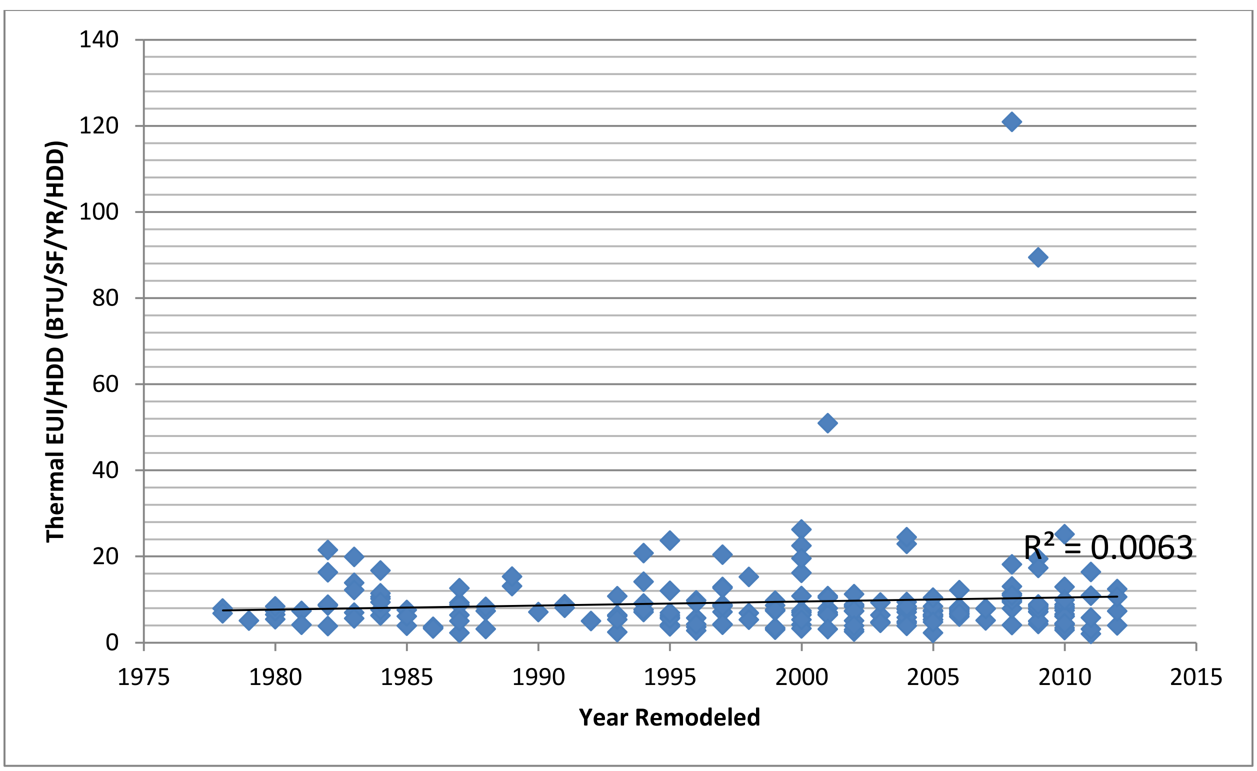


Figure AA: Thermal EUI/HDD vs. Window to Wall Ratio

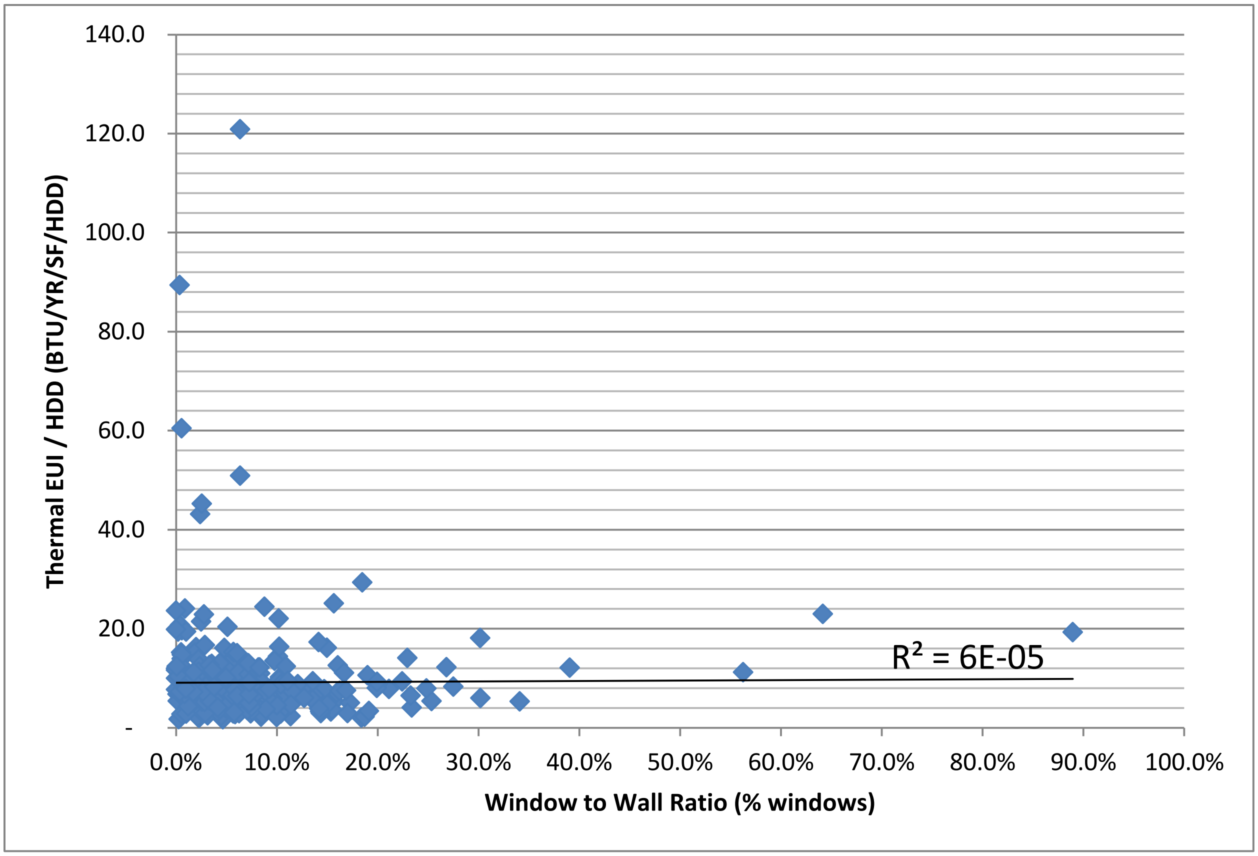


Figure AB: Thermal EUI/HDD vs. Primary Fuel Price for Schools

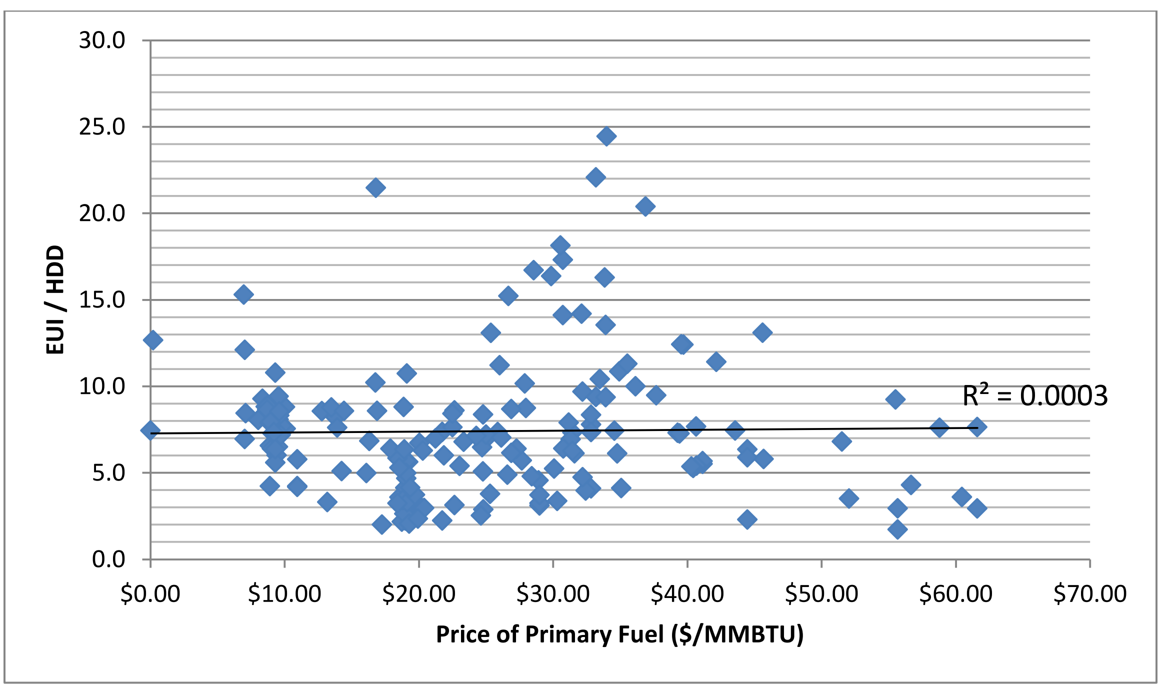


Figure AC: Thermal EUI/HDD vs. Geographic Area Cost Factor for Schools

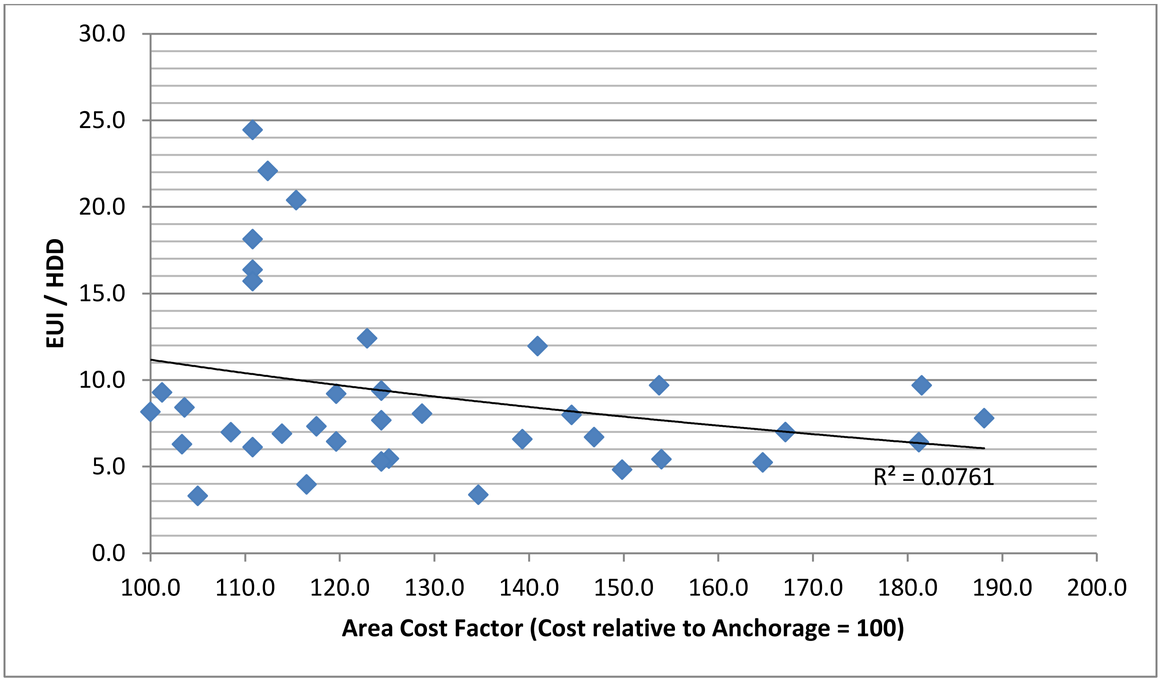


Figure AD: Thermal EUI/HDD vs. Envelope R-Value for Whole Building

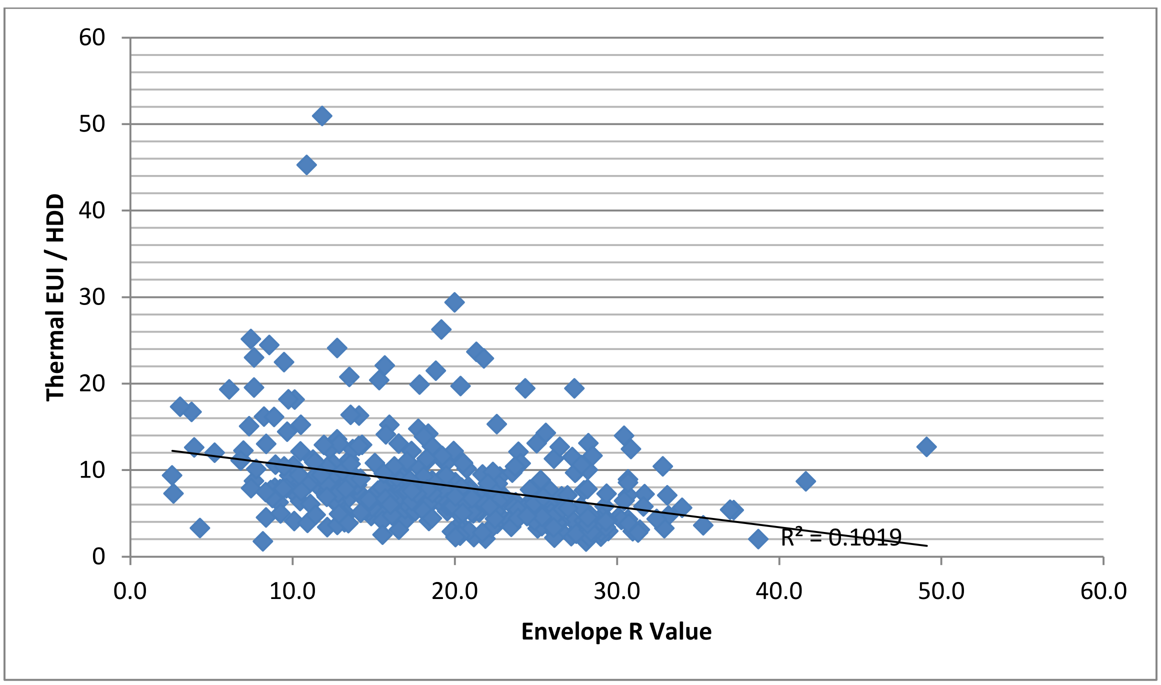
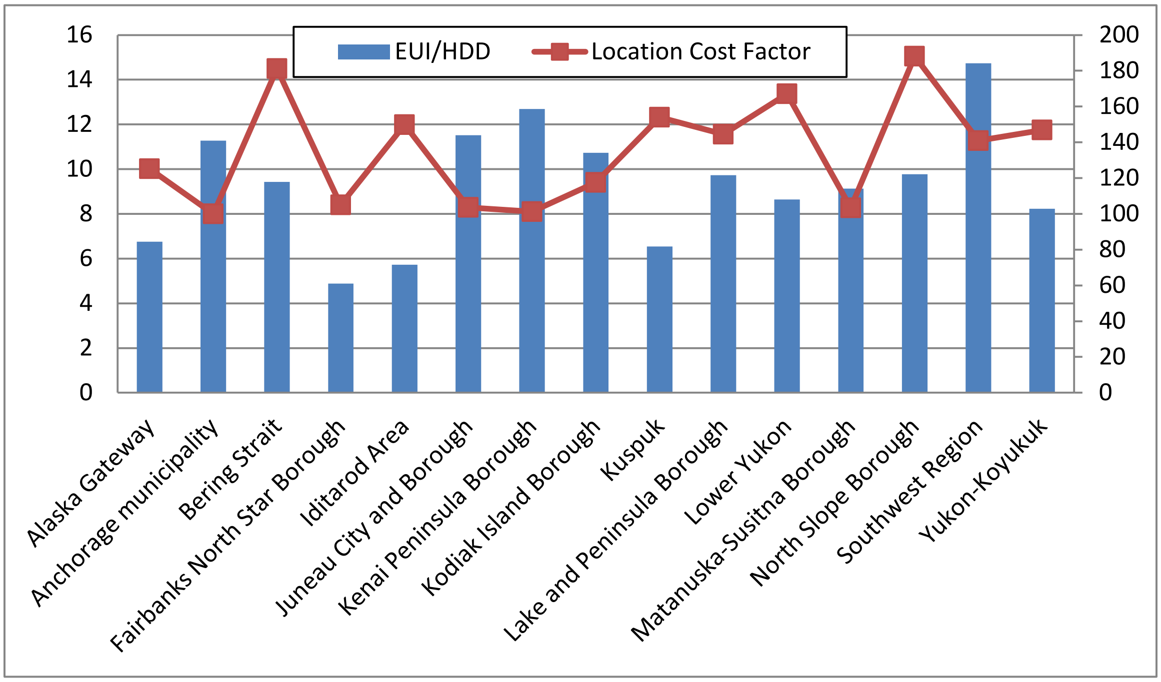


Figure AE: EUI/HDD vs. Geographic Area Cost Factor by School District



Appendix C: Design Heat Load

The design heat load is a valuable tool for comparing the energy use of planned new construction to the average public building in a particular climate zone in Alaska. The design heat load is the number of Btus per hour that a building is expected to lose during the coldest period of the year in a particular area. This figure can be calculated either by following the procedures outlined in ANSI/ASHRAE Standard 183 or by using energy modeling software, such as AkWarm-C, and typically is done by engineers to size heating systems. Figures 79-81 show the line of best fit for the data on audited public buildings; these charts allow facility and design personnel to determine how an existing or proposed building compares to the audited buildings in ARIS. It should be noted that these buildings are on average 31 years old, so this line should be considered a maximum design heat load for a structure in that climate zone.

Zones 6, 7, and 8 all have fairly tight correlations between square footage and design heat load. There are several outliers in these zones; however, designers and facilities personnel should consider comparing their buildings to the line or to buildings below it only; structures falling above the line are likely in need of retrofit.

Zone 9 is not included in this section, as there is insufficient data, and there is very little correlation between square footage and design heat load for buildings. This may be due to a number of factors, including the fact that some buildings in the region have access to inexpensive natural gas whereas others must use fuel oil and other energy sources for space heating, likely influencing the emphasis on energy efficiency between areas.

Figure 79: Zone 6 Design Heat Load for All Buildings

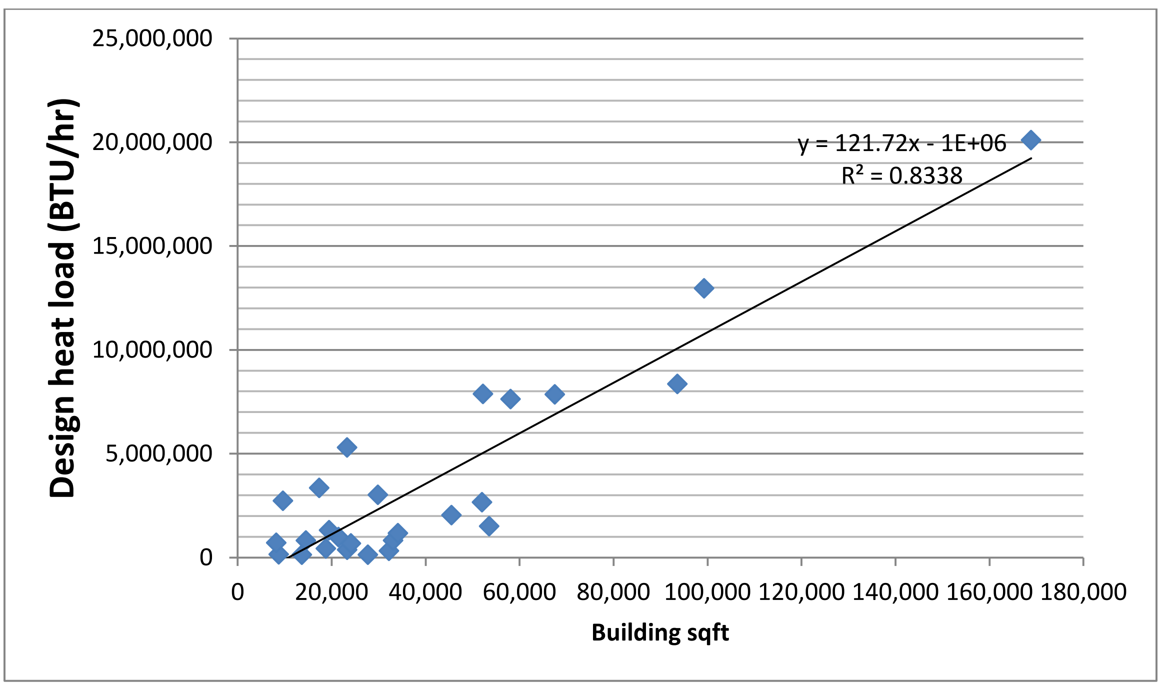


Figure 80: Zone 7 Design Heat Load for All Buildings

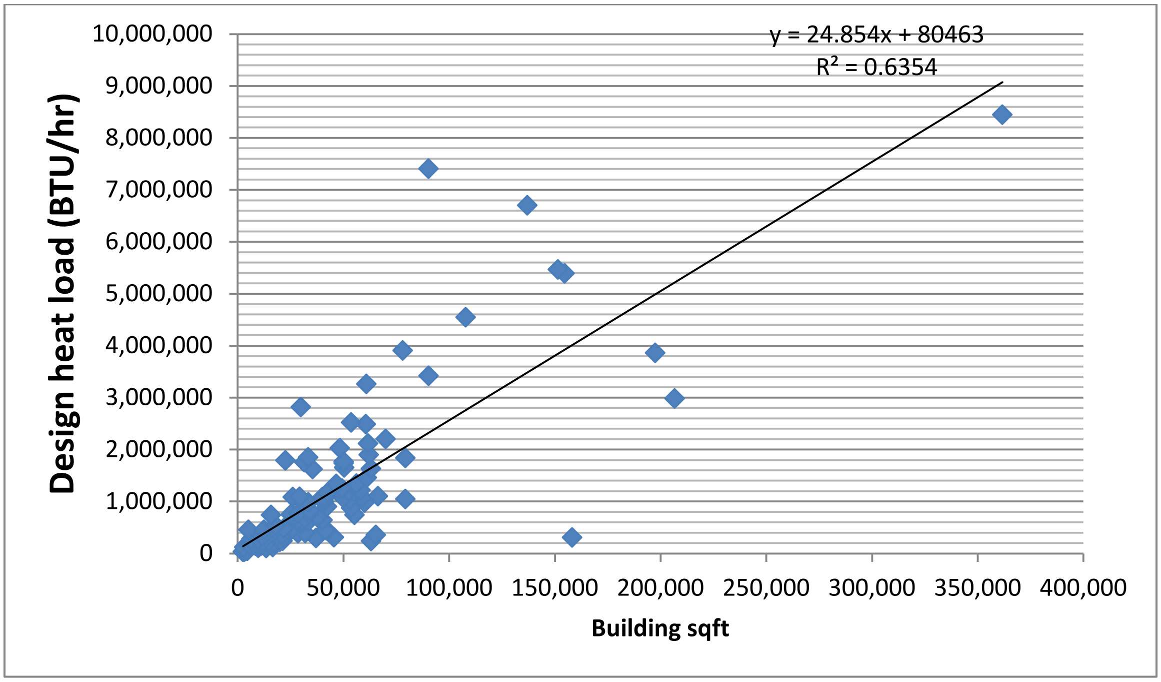


Figure 81: Zone 8 Design Heat Load for All Buildings

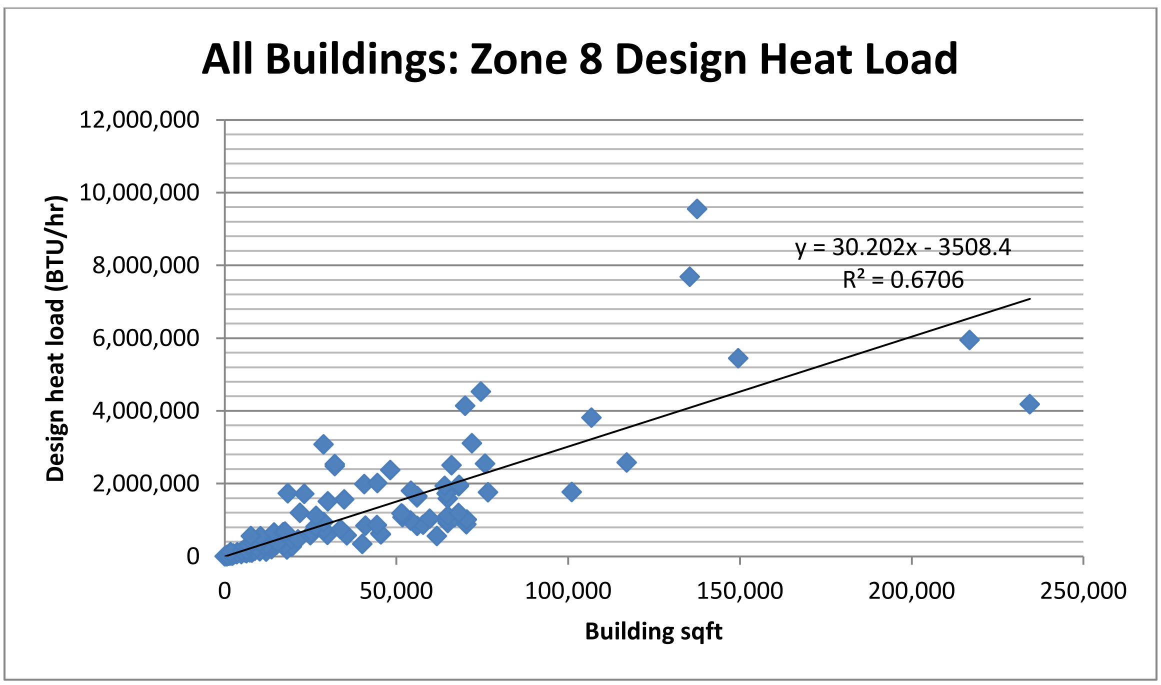


Figure 82: Design Heat Loss vs. Building Size for All Schools

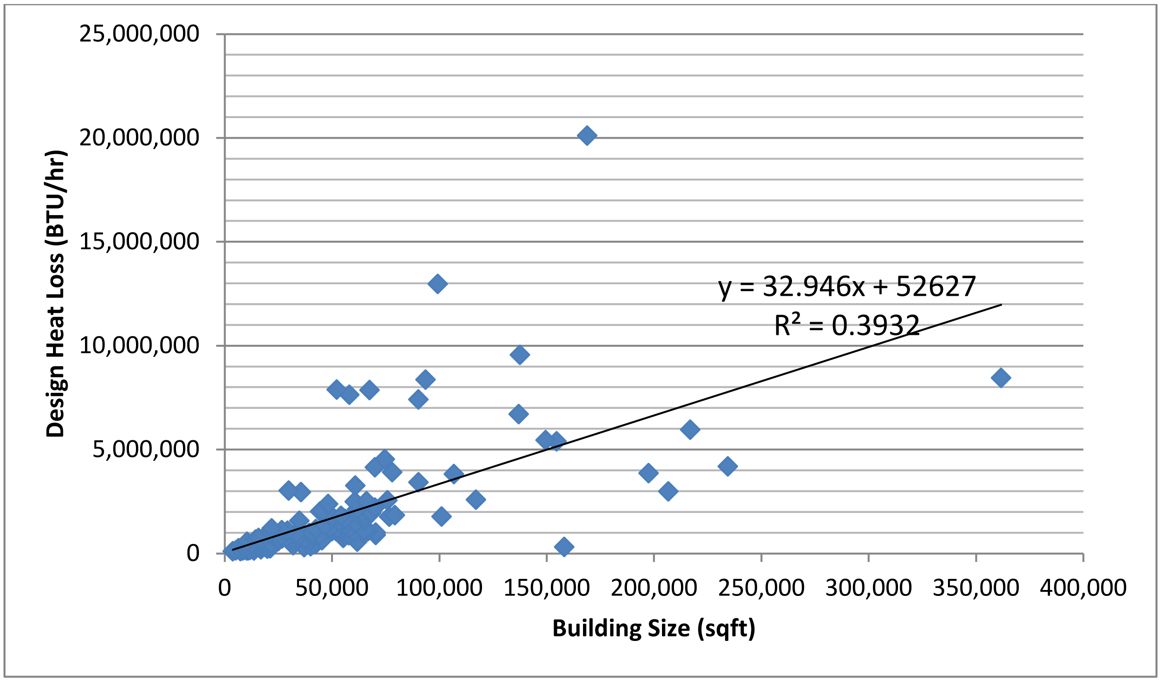


Figure 83: Design Heat Loss vs. Square Feet in Zone 6 Schools

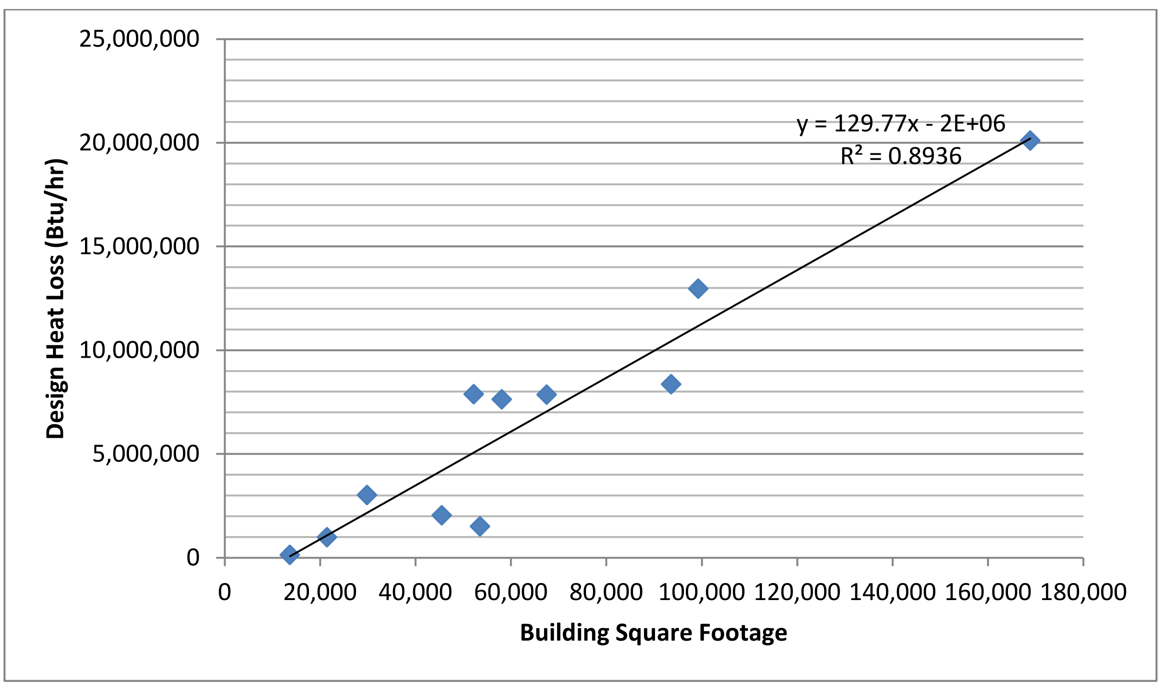


Figure 84: Design Heat Loss vs. Square Feet in Climate Zone 7 Schools

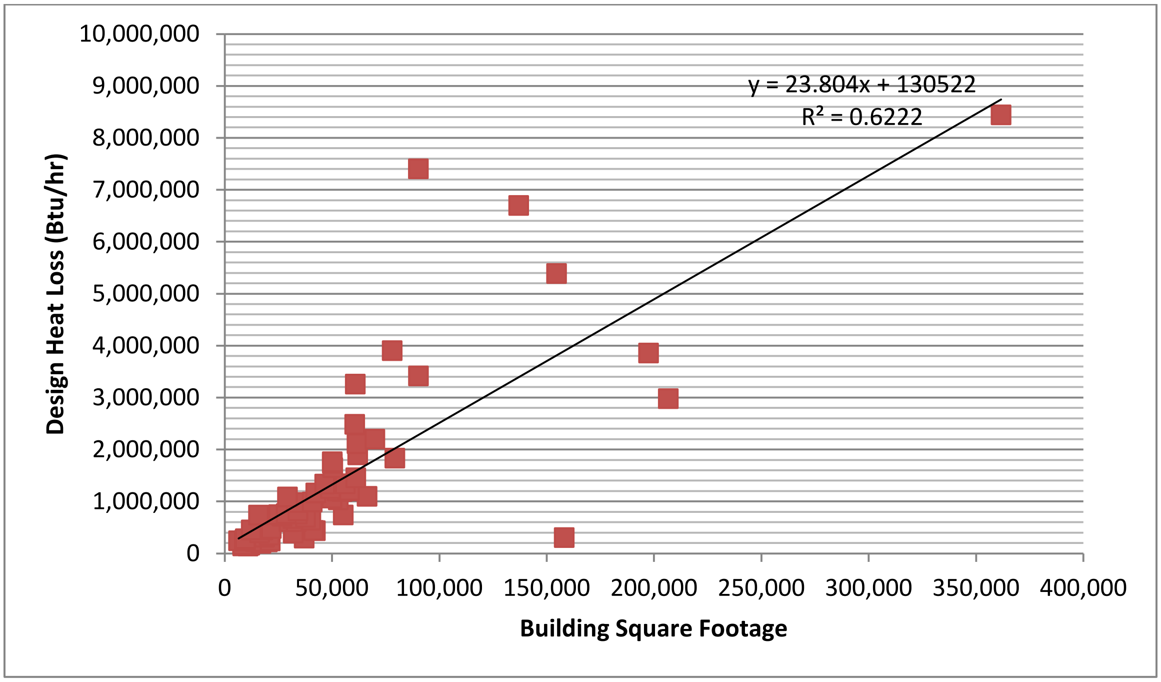


Figure 85: Design Heat Loss vs. Square Feet in Climate Zone 8 Schools

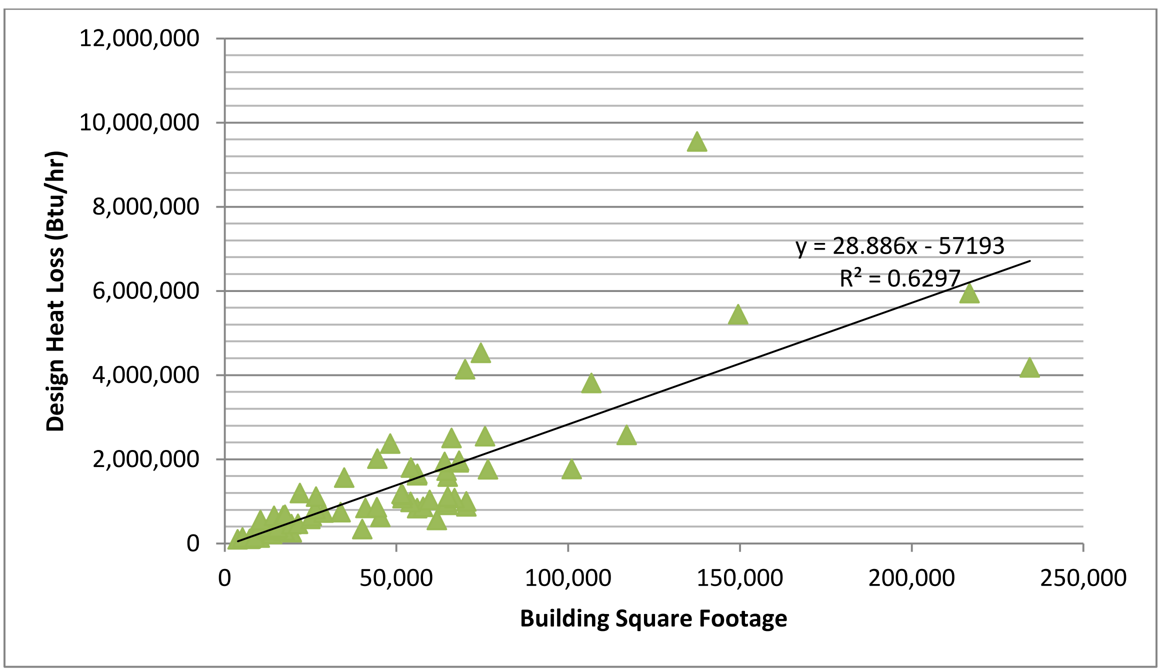


Figure 86: Design Heat Loss vs. Building Size in Offices

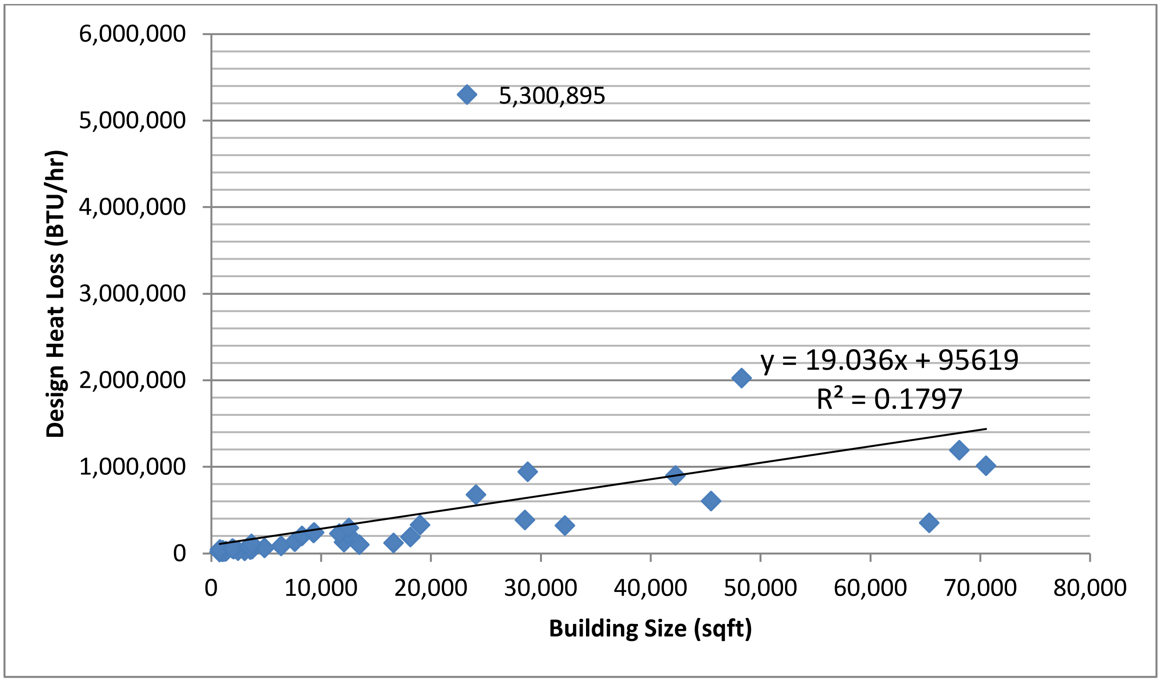


Figure 87: Design Heat Loss vs. Building Size in Maintenance/Shop Buildings

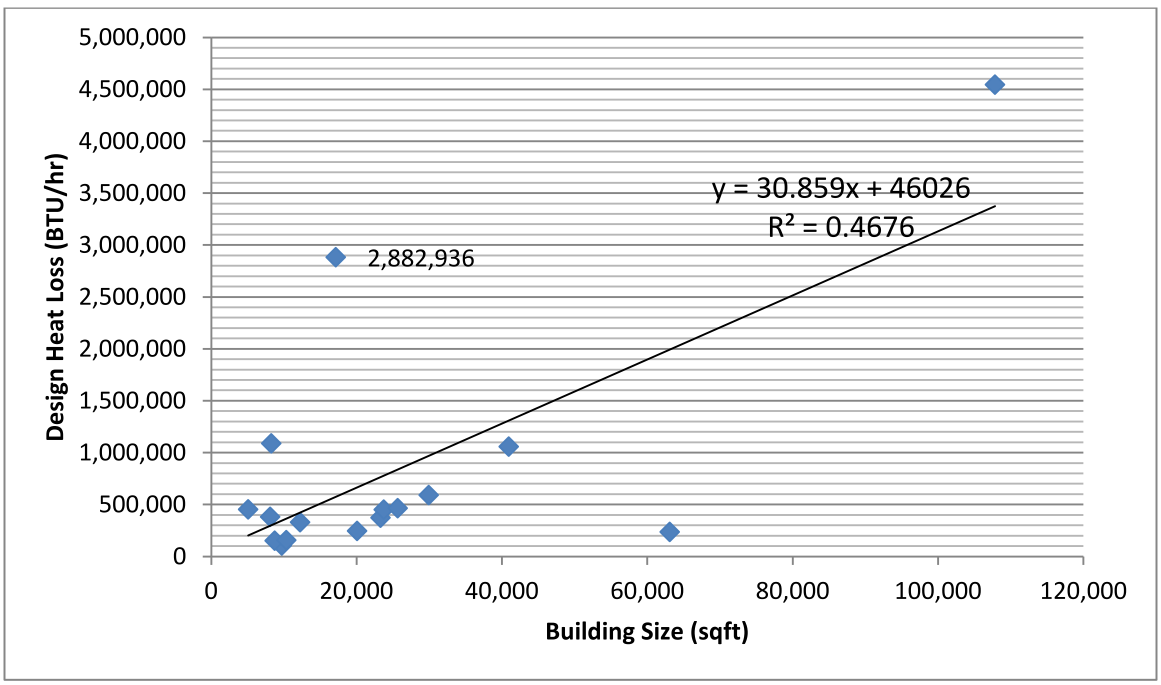


Figure 88: Design Heat Loss vs. Building Size in Athletic Facilities

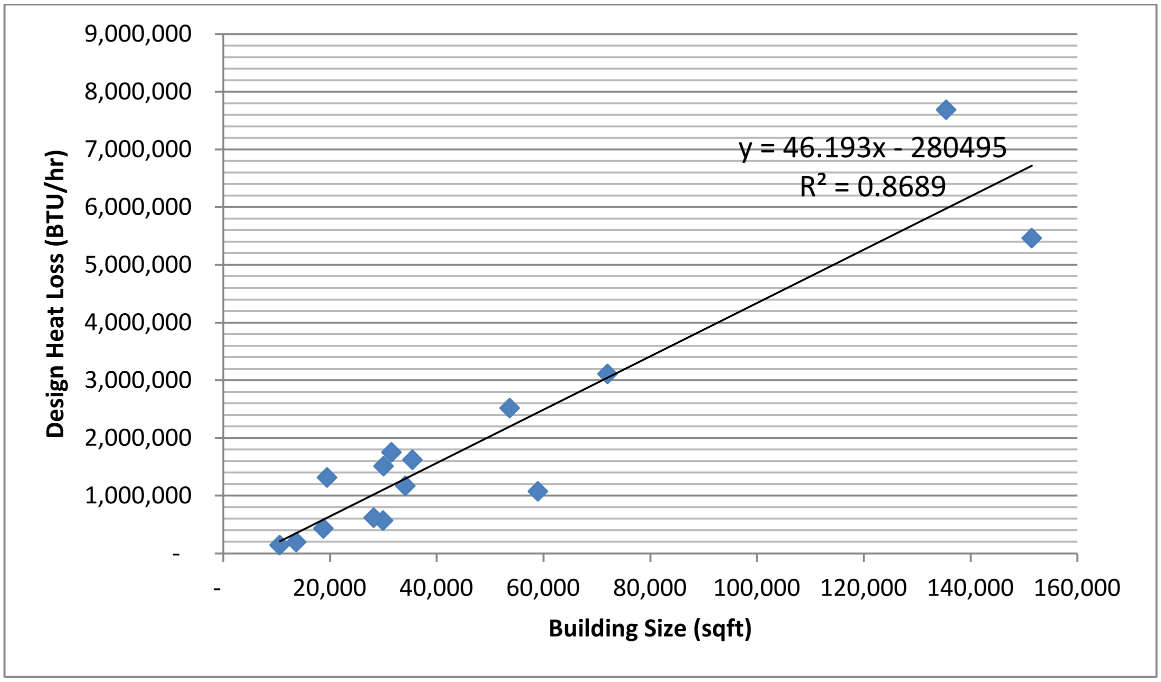
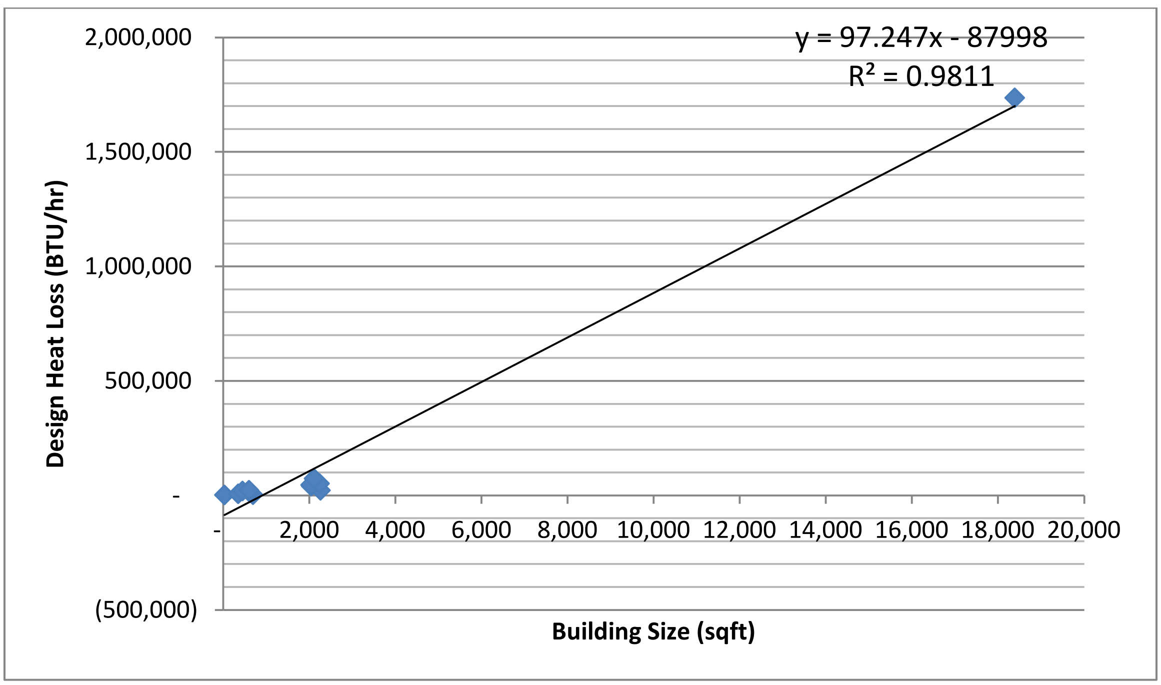


Figure 89: Design Heat Loss vs. Building Size in Washateria/Water Plants



Appendix D: Energy Consumption Metrics Worksheet

Step 1: Gather 12 consecutive months of fuel bills for each fuel type
Step 2: Enter your annual fuel use and costs for each fuel in the blue boxes below.
Step 3: Multiply the annual fuel use by the multiplier. Add all of the annual energy uses together to find the total
Step 4: Enter 1 if the fuel is used for space heating only, 0 if it is not used for space heating at all, or a decimal representing the percentage of that fuel that is used for space heating

Step 5: Multiply the annual energy use by the amount used for space heating to determine annual thermal energy use. Add all thermal energy uses together to determine the total thermal energy use annually

Fuel Type	Annual Fuel Cost ($)	Annual fuel use	Units		Multiplier		Annual energy use (kBtu/yr):		Amount for space heating:		Thermal energy use (kBtu/yr):
Electricity			kWh	x	3.4	=		x		=	
Natural gas			MCF	x	1000	=		x		=	
Natural gas			CCF	x	100	=		x		=	
Natural gas			MMBtu[1]	x	1000	=		x		=	
Natural gas			therms	x	100	=		x		=	
Fuel oil #1			gallons	x	136	=		x		=	
Fuel oil #2			gallons	x	138	=		x		=	
Propane			gallons	x	91	=		x		=	
Coal[2]			tons	x	15600	=		x		=	
District steam			lbs	x	1.194	=		x		=	
District steam			klbs	x	1194	=		x		=	
District steam			kBtu	x	1	=		x		=	
District steam			MMBtu[1]	x	1000	=		x		=	
District hot water				x		=		x		=	
Total annual energy cost:		Total annual energy use (kBtu)				=			Total thermal energy:	=	

[1]MMBtu = 1,000,000 Btu. [2]The coal multiplier varies significantly; ask the supplier for specific value

ENERGY CONSUMPTION METRICS WORKSHEET (continued)

Alaska Housing FINANCE CORPORATION

Step 4: Enter your building's floor area		square feet
Step 5: Enter the number of heating degree days (HDD) for your location: (This information can be found in the table on the following pages)		heating degree days
Step 6: Divide the total annual energy use by the square footage	EUI	kBtu/sqft/year
Step 7: Multiply the total thermal energy by 1,000 to convert to Btus. **Then divide this number by the square footage and by the HDD.**	Thermal EUI/HDD	Btu/sqft/year/HDD
Step 8: Divide the kWh of electricity entered in step 2 by the square footage.	Electric EUI:	kWh/sqft/year
Step 9: Divide the total annual energy cost by the square footage.	ECI:	$ /sqft/year

Name (A-D)	Heating Degree Days
Adak	9,046
Akhiok	9,102
Akiachak	13,213
Akiak	13,105
Akutan	8,554
Alakanuk	13,339
Alatna	16,625
Aleknagik	11,751
Allakaket	16,625
Ambler	15,675
Anaktuvuk Pass	18,873
Anchor Point	10,115
Anchorage	10,816
Anderson	14,375
Angoon	8,450
Aniak	13,356
Anvik	13,462
Arctic Village	17,356
Atka	9,054
Atmautluak	13,106
Atqasuk	20,370
Attu	9,490
Auke Bay	8,461
Barrow	20,370
Beaver	15,788
Bethel	13,334
Bettles	15,959
Big Lake	11,796
Birch Creek	16,326

Name (E-K)	Heating Degree Days
Eagle	14,891
Eagle River	10,816
Eek	11,548
Egegik	11,836
Ekwok	11,306
Elfin Cove	8,140
Elim	13,943
Emmonak	13,467
English Bay	10,136
Ester	14,274
Evansville	15,788
Eyak	9,778
Fairbanks	14,274
False Pass	9,733
Fort Yukon	16,326
Gakona	13,534
Galena	14,847
Gambell	14,572
Girdwood	10,336
Glennallen	14,067
Golovin	13,943
Goodnews Bay	12,107
Grayling	13,462
Gulkana	14,004
Gustavus	8,858
Haines	8,505
Halibut Cove	10,349
Healy	12,582
Hollis	7,802

Name (L-R)	Heating Degree Days
Larsen Bay	9,065
Levelock	11,306
Lime Village	13,339
Lower Kalskag	13,382
Manley Hot Springs	14,593
Manokotak	11,306
Marshall	12,785
McCarthy	13,053
McGrath	14,574
Mekoryok	13,575
Mentasta Lake	15,400
Metlakatla	7,000
Meyers Chuck	7,165
Minchumina	13,858
Minto	15,528
Moose Pass	11,126
Mountain Village	13,448
Napaimute	13,356
Napakiak	13,106
Napaskiak	13,106
Naukati	8,104
Nelson Lagoon	8,865
Nenana	14,539
New Stuyahok	11,306
Newhalen	11,130
Newtok	13,048
Nightmute	13,048
Nikiski	10,899
Nikolaevsk	11,155

Name (S-Y)	Heating Degree Days
Saint George	10,242
Saint Mary's	12,785
Saint Michael	14,272
Saint Paul	11,178
Salcha	15,403
Sand Point	8,865
Savoonga	14,971
Saxman	7,165
Scammon Bay	13,048
Selawik	16,827
Seldovia	10,136
Seward	9,188
Shageluk	13,462
Shaktoolik	13,919
Shemya	9,555
Shishmaref	15,790
Shungnak	15,586
Sitka	8,011
Skagway	8,666
Skwentna	11,873
Slana	13,534
Sleetmute	13,339
Soldotna	11,775
South Naknek	11,772
Stebbins	14,272
Sterling	12,006
Stevens Village	15,528
Stony River	12,633
Sutton	10,451

Name (A-D)	Heating Degree Days
Boundary	15,412
Brevig Mission	14,138
Buckland	16,462
Candle	16,462
Cantwell	13,893
Central	16,315
Chalkyitsik	16,326
Chandalar Lake	17,241
Chefornak	12,990
Chena Hot Springs	15,381
Chenega	9,350
Chevak	13,339
Chickaloon	11,790
Chicken	14,891
Chignik	9,612
Chignik Lake	9,612
Chiniak	8,539
Chistochina	13,534
Chitina	13,200
Chuathbaluk	13,356
Chugiak	10,816
Circle	16,349
Circle Hot Springs	15,763
Clam Gulch	11,375
Clark's Point	11,306
Clear	14,375
Coffman Cove	8,104
Cold Bay	9,877

Name (E-K)	Heating Degree Days
Holy Cross	13,462
Homer	10,349
Hoonah	8,858
Hooper Bay	13,106
Hope	10,100
Houston	10,810
Hughes	14,942
Huslia	14,942
Hydaburg	7,487
Hyder	7,165
Igiugig	11,306
Iliamna	11,130
Indian	10,604
Ivanof Bay	9,612
Jakolof Bay	10,349
Juneau, Airport	8,897
Juneau	8,021
Kake	8,527
Kaktovik	20,370
Kalifonsky	11,395
Kaltag	14,847
Karluk	8,539
Kasaan	7,802
Kasigluk	13,106
Kasilof	11,337
Kenai	11,395
Kenny Lake	14,036
Ketchikan	7,165

Name (L-R)	Heating Degree Days
Nikolai	15,214
Nikolski	9,555
Ninilchik	11,155
Noatak	16,758
Nome	14,371
Nondalton	11,130
Noorvik	15,675
North Pole	15,403
Northway	15,763
Nuiqsut	20,370
Nulato	14,847
Nunapitchuk	13,106
Nunum Iqua	13,467
Old Harbor	8,614
Oscarville	13,106
Ouzinkie	8,539
Palmer	10,868
Paxson	14,182
Pedro Bay	11,130
Pelican	8,529
Perryville	9,612
Petersburg	8,134
Pilot Point	10,415
Pitkas Point	12,785
Platinum	12,107
Point Hope	16,501
Point Lay	19,109
Port Alexander	7,513

Name (S-Y)	Heating Degree Days
Takotna	14,424
Talkeetna	13,113
Tanacross	15,479
Tanana	15,024
Tatitlek	9,778
Tazlina	14,067
Teller	15,142
Tenakee Springs	8,180
Tetlin	15,400
Thorne Bay	7,802
Togiak	11,306
Tok	15,400
Toksook Bay	12,990
Tonsina	13,928
Trapper Creek	11,863
Tuluksak	13,106
Tuntutuliak	13,106
Tununak	13,106
Twin Hills	11,306
Tyonek	9,742
Ugashik	10,415
Unalakleet	13,919
Unalaska	9,014
Upper Kalskag	13,356
Valdez	9,711
Venetie	16,465
Wainwright	19,824
Wales	15,939

Name (A-D)	Heating Degree Days
Coldfoot	16,589
Cooper Landing	10,527
Copper Center	14,101
Cordova	9,004
Craig	7,487
Crooked Creek	13,552
Deering	16,462
Delta Junction	13,549
Denali Nat'l Park	14,152
Dillingham	11,306
Diomede	15,939
Dot Lake	14,829
Douglas	8,075
Dry Creek	14,829
Dutch Harbor	9,197

Name (E-K)	Heating Degree Days
Kiana	15,675
King Cove	9,733
King Salmon	11,716
Kipnuk	12,990
Kivalina	16,758
Klawock	7,487
Klukwan	10,476
Kobuk	15,716
Kodiak	8,539
Kokhanok	11,610
Koliganek	11,306
Kongiganak	11,306
Kotlik	13,467
Kotzebue	16,032
Koyuk	13,943
Kwethluk	13,106
Kwigillingok	12,990

Name (L-R)	Heating Degree Days
Port Alsworth	11,206
Port Graham	10,136
Port Heiden	10,415
Port Lions	8,539
Quinhagak	12,107
Rampart	15,528
Red Devil	13,339
Ruby	13,858
Russian Mission	13,382

Name (S-Y)	Heating Degree Days
Ward Cove	7,165
Wasilla	10,810
White Mountain	13,578
Whittier	9,348
Willow	12,332
Wrangell	7,968
Yakutat	9,605