Sample Municipal Portfolio Benchmarking Report

A Portfolio Analysis of Municipal Buildings in a Sample City

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Table of Contents

1.0 EXECUTIVE SUMMARY

The City of [REDACTED] has undertaken efforts to track energy performance across its portfolio of municipal buildings and to prioritize retrofits and other energy upgrades to City buildings. As part of that effort, the City of [REDACTED] has participated in the [REDACTED] Program. This program, funded by [REDACTED] and provided in cooperation with New Buildings Institute, [REDACTED] helps jurisdictions.

Building energy represents about 40% of emissions for [REDACTED]'s homes and businesses, mostly due to natural gas for heating. Building efficiency has the largest GHG emissions savings potential for the lowest cost, which reduces the need for new power plants and improves air quality. Cities can benefit from reduced operating costs, improved productivity, new jobs and improved quality of life for residents. Candidates for the [REDACTED] Program need to show a list of municipal buildings and a system for benchmarking the energy use as well as have a policy goal for reducing energy use.

[REDACTED] has an Environmental Action Plan with targets to reduce electricity use in City facilities, increase renewables, support better codes and hire staff to support these efforts. At the heart of every program are the people. People are responsible for collecting data, making decisions based on the stories that emerge from the data, and ultimately implementing policies that impact city sustainability. The [REDACTED] team has developed a proven framework for Strategic Energy Management (SEM) around the principle that people drive change. The framework guides teams on their path to reducing the environmental impact of their buildings.

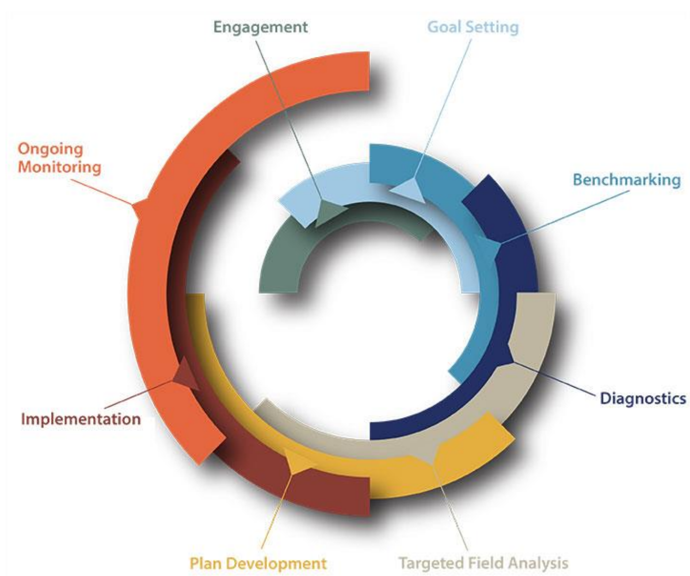

Figure 1: The Strategic Energy Management Framework

Gathering and organizing data on municipal building characteristics and energy consumption characteristics was the first step. City staff and [REDACTED] worked together to accurately align meters with buildings, update data in Portfolio Manager and make strides to streamline the download process for updating energy usage between the utility and the City.

The next step was to evaluate the energy performance of [REDACTED]'s buildings in order to provide a detailed Portfolio Analysis of the municipal facilities. This report provides that Portfolio Analysis: a snapshot of facility conditions and energy usage characteristics as of late 2016.

1.1 THE TEAM

New Buildings Institute (NBI): Founded in 1997, New Buildings Institute (NBI) is a nonprofit organization working to improve the energy performance of commercial buildings. NBI works collaboratively with commercial building market players—governments, utilities, energy efficiency advocates and building professionals—to remove barriers to energy efficiency, including promoting advanced design practices, improved technologies, public policies and programs that improve energy efficiency.

Northwest Energy Efficiency Alliance (NEEA): The Northwest Energy Efficiency Alliance (NEEA) is an alliance of more than 140 Northwest utilities and energy efficiency organizations working on behalf of more than 13 million energy consumers. Through collaboration and pooling of resources, the region's utilities and stakeholders have harnessed their collective influence to drive market adoption of energy efficiency products, services and practices for the benefit of utilities, consumers and the region.

This team worked with the City of [REDACTED] and [REDACTED] to cleanse data and provide guidance on streamlining the data management process before analyzing energy usage trends and running diagnostics using the FirstView® inverse energy modeling tool.

1.2 SUMMARY OF FIRSTVIEW RESULTS

This analysis provides an initial review of potential energy saving opportunities in municipal facilities located in [REDACTED]. NBI used the FirstView tool to analyze a total of 47 buildings: 17 fire stations, eight libraries, seven police stations, four offices, three senior care centers, two stadiums, and four other buildings of various types. Individual building FirstView analysis reports have been provided separately. The results are then used to recommend areas for further investigation and identify potential high-priority savings opportunities. This portfolio-level analysis includes energy end-use disaggregation, performance diagnostics and benchmark comparisons for each building. Except where noted otherwise, the values presented represent the most recent 12 consecutive months of available data. The analyzed consumption dates for each building are included in the individual building reports.

In some cases, the measured energy use for buildings was very low or very high. In these cases, the building was excluded from the portfolio analysis. Buildings with very low energy usage (EUI < 10) are likely missing data or secondary meters. Buildings with very high usage (EUI > 200) may not have data issues, but were still excluded from the portfolio analysis as outliers in order to focus on more typical buildings.

Overall, most [REDACTED] facilities have energy usage roughly similar to national benchmark values. Libraries generally perform better, while police stations use more energy than national benchmarks.

Table 1 shows [REDACTED] facility EUIs (in kBtu/ft^2/yr) and various national and climate zone specific benchmark values, including CBECS[1], CEUS[2], and ASHRAE 100[3].

Table 1: Average EUIs: [REDACTED] Facilities vs. National and Climate-Specific Benchmarks

Building Type	Count in Final Set	Average EUI in Final Set, kBtu/ft^2/yr	CBECS (2003) EUI	CBECS (2012) EUI	CEUS (2006) EUI	ASHRAE 100, Median EUI for CZ [R]	ASHRAE 100, 25th Percentile EUI for CZ [R]
Fire Station	18	55	88	58	-	94	66
Library	8	37	92	73	-	88	61
Office	5	55	67	61	73	72	50
Other	4	101	70	58	57	-	-
Police Station	7	67	88	59	-	94	66
Senior Care Community	3	89	79	-	-	120	84

Annual energy use across the portfolio ranges from 6 kBtu/ft^2 in the [REDACTED] to 504 kBtu/ft^2 at the [REDACTED] Building. Separating the EUI into specific end uses leads to additional observations, including:

- Electric Baseload is the largest end use at 57%
- Heating is the second largest end-use, accounting for 37% of total energy
- Cooling and Thermal Baseload together make up only 6% of the portfolio wide energy use

The large electric baseload provides an opportunity for the City to achieve their goal of reducing electricity use in City facilities by [REDACTED]. Heating is the second largest end-use, and accounts for most of the emissions for [REDACTED]'s homes and businesses. Implementing measures to reduce heating can have a direct effect on emissions.

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[1] The Commercial Building Energy Consumption Survey (CBECS), published in 2003, is commonly used to represent the energy use of typical existing building stock in the United States. CBECS is available at: http://www.energystar.gov/ia/business/tools_resources/new_bldg_design/2003_CBECSPerformanceTargetsTable.pdf.

[2] The California Commercial End Use Survey (CEUS), published in 2006, is a survey of energy use in existing building stock in California. CEUS is available at: http://www.energy.ca.gov/2006publications/CEC-400-2006-005/CEC-400-2006-005.PDF

[3] ASHRAE/ANSI/IES Standard 100-2015 (Energy Efficiency in Existing Buildings) defines EUI targets for existing buildings across various building types and climate zones.

Further investigation of energy end uses and FirstView diagnostics revealed a number of areas that warrant further investigation, including:

- **High total energy use**
    - [REDACTED]
    - [REDACTED] City Hall
    - Police Headquarters
    - [REDACTED] Warehouse
    - [REDACTED]
- **Shell & Ventilation Related Efficiency**
    - Municipal Services Center
    - Survey Building
    - Fire Station 12
    - Fire Station 3
    - Fire Station 5
- **High electric baseload**
    - [REDACTED]
    - [REDACTED] Police Station
    - [REDACTED] Police Station
    - Main Library
- **Unusually high summer gas use**
    - Admin Building
    - [REDACTED] Senior Center
    - Fire Station 4
    - Fire Station 8
    - [REDACTED] Senior Center

Certain buildings within the municipal portfolio, typically those with high overall energy consumption and varied opportunities for savings, are likely to be good candidates for whole-building deep energy retrofits. Other buildings, typically with low energy consumption, may be good candidates for zero net energy retrofits (assuming enough on-site renewable generation is possible given existing building constraints). These candidate buildings are:

- **Potential Retro-Commissioning and Retrofit Candidate Buildings**
    - Police Headquarters
    - [REDACTED]
    - Admin Building
    - [REDACTED] Senior Center
- **Potential Zero Net Energy Retrofit Candidate Buildings**
    - [REDACTED] Library
    - [REDACTED] Senior Center
    - [REDACTED] Library
    - [REDACTED] Library

2.0 METHODOLOGY

FirstView® is a software tool that enables users to extract targeted and insightful energy performance information from monthly billing data. FirstView works by automatically creating a simplified building energy model that is auto-calibrated to match the building's measured energy use. The auto-calibration matches the weather-normalized model to the measured energy use with an iterative inverse modeling approach which tracks several key operational variables, including set points, equipment efficiencies, and other building characteristics. More information on the FirstView model is available on the New Buildings Institute webpage[4]. The calibrated model is then used to disaggregate energy end uses, provide energy use diagnostics, and develop benchmarks for comparison.

FirstView uses an Energy Signature plot to analyze performance patterns of the building. An Energy Signature is a graph of energy use (vertical axis) in relation to outside temperatures (horizontal axis) for the same period. This reveals key performance indicators as an algebraic function, for example the slope of the heating curve or the height of the electric baseload. The Energy Signature plot enables FirstView to conduct comparisons, such as automated diagnostics and advanced benchmarking.

- ***Automated Diagnostics***. FirstView automatically compares mathematic parameters revealed in the Energy Signature to thresholds in eight areas: heating and ventilation efficiency, cooling efficiency, controls, reheat, thermal baseload, light and plug loads, external/process loads, and data consistency. NBI sets diagnostic thresholds based on past experience and comparisons of a particular group of buildings. This enables the tool to quickly and automatically identify poor, average or high energy performance and directs attention to specific areas that warrant more attention. Each of the automated thresholds is specifically designed based on NBI's past experience drawing from a growing database of previously analyzed buildings.
- ***Advanced Benchmarking****.* FirstView goes beyond an Energy Use Intensity (EUI) commonly used in benchmarking to graphically illustrate how a building compares to its peers. For this project, NBI developed a custom spectrum based on the building set for this project. This carefully defined spectrum represents the 25th and 75th percentile of building performance and serves as a comparison for all of the buildings to each other. Other spectra for specific building types are also included. These building type specific spectra are generated from a combination of previously analyzed buildings and buildings within this portfolio to compare the portfolio on a national scale. Additional high-performance benchmarks are included in the report to give broader context and aid in target setting.

2.1 FirstView End Uses

FirstView breaks down the total energy use into four end use categories, as described below:

- ***Electric Baseload.*** If there is a period during the year where no heating or cooling is utilized, the only energy use in a building is electric baseload. In FirstView, Electric Baseload is calculated as the sum of lighting, plug loads, year round fans/pumps, consistent process loads and electric water heating. FirstView recognizes that these elements of a building's electricity consumption are relatively constant throughout the year and are independent of outside temperature.
- ***Heating.*** Heating energy is derived in FirstView by analyzing the estimated internal gains, overall heat transfer coefficient, and modeled equipment efficiencies of a building. Using this

[4] More information on FirstView is available here: http://newbuildings.org/product/firstview/

information, FirstView calculates the energy used for heating (including estimated electricity consumption for fan and pump operation).

- ***Cooling.*** Cooling energy is derived in FirstView by analyzing the estimated internal heat gains, overall heat transfer coefficient and modeled equipment efficiencies of a building. Using this information FirstView calculates the electrical energy used for cooling (including estimated fan and pump energy use).
- ***Thermal Baseload*.** Thermal Baseload is derived in FirstView by analyzing a building's summer thermal fuels (natural gas, district steam, or district hot water) use. Typically, this is gas that is used for service water heating. However, some buildings may have additional year-round thermal demand in the form of gas process loads (such as kitchen or laundry equipment).

2.2 FirstView Diagnostics

FirstView can provide automated diagnostics for specific building types (offices and buildings broadly similar to office buildings in their usage) in seven categories. For non-office building types, the model outputs are interpreted on a case-by-case basis to diagnose the building. The various diagnostics are described below:

- **Shell and Ventilation Efficiency.** The shell and ventilation efficiency are represented by an aggregate U-value, referred to as UA, which describes how efficiently a building responds to changes to outdoor air temperature. A higher UA value means that as the temperature drops, more energy will be needed for heating. Under the same conditions, a building with a lower UA value would use less energy for heating. Previous analysis of office buildings has shown that buildings with a UA value greater than 0.3 Btu/(°F*hr*ft^2) may have inefficiencies in their shell and ventilation, including excess infiltration. In this portfolio analysis, most buildings (34 of 47) were found to have a UA value in excess of 0.3. A total of 8 buildings have a UA above 1.0; these buildings are highlighted in this report as retrofit opportunities.

- **Lighting and Plug Loads.** The magnitude of a building's electric baseload is estimated by FirstView's inverse energy model, which includes a calculation of internal heat gain, represented by Q_{in}. This is the estimated watts per square foot that are used inside the thermal envelope of the building, typically composed of lighting and plug loads. For this custom portfolio analysis, NBI analyzed the statistical distribution of Q_{in}. Buildings with a Q_{in} value greater than 1 standard deviation above the mean are flagged as having a "high electric baseload". Q_{in} values more than 1 standard deviation below the mean are flagged as "low electric baseload."

- **Thermal Baseload.** Thermal baseload is also estimated by the FirstView inverse energy model. This calculation examines thermal fuel use during the two warmest months of the year (summer). During the warmest months of the year, gas consumption for space heating is typically minimal or zero. Summer gas consumption is attributed to water heating. Calculated thermal baseload energy is converted to an estimate of domestic hot water use (DHW), expressed in gallons/(day*ft^2). This estimated DHW use is independent of the actual metered water usage at the building. Extensive previous analysis of office buildings has shown that DHW in excess of 0.015 gal/(day*ft^2) is unusual.

- **Controls.** The controls indicator compares the amount of heating and cooling that is used in a building to the amount that would be expected for that building, given the calculated occupant loads, shell and ventilation characteristics, envelope, and equipment efficiencies. A large discrepancy between the used and expected values suggests that control errors are creating inefficiencies.

- **Reheat.** At the monthly data level, most buildings will show a slight level of overlapping heating and cooling use in the 50°F – 65°F average monthly temperature range. Excessive reheat is suggested by overlaps covering a wider temperature range, high levels of both heating and cooling, and high summer gas use.
- **External Process Loads.** All electrical loads which cannot be associated with heating, cooling, or internal lighting and plug loads are attributed to external process loads. These external process loads may indicate such loads as pumps, data centers or other relatively demanding electrical loads.
- **Cooling efficiency.** In FirstView, the cooling efficiency is calculated through the inverse energy modeling process as a cooling coefficient of performance (COP). This COP is not directly analogous to the rated efficiency of equipment; rather, it is a measure of an entire building's response to increased outdoor air temperature. Buildings with a calculated COP greater than 3 are considered to have "good cooling efficiency". A COP of less than 2 is classified as "poor cooling efficiency".
- **Data consistency.** FirstView analyzes data consistency by measuring the goodness of fit between the FirstView inverse energy model and the measured monthly energy use data. This is expressed as an R^2 value. Most buildings show a consistent relationship between outdoor air temperature and energy use, which can be accurately modeled by FirstView with an R^2 of 0.9 or better. R^2 values below 0.9 are classified as having irregular or "noisy" data. Overall, 13 out of the 47 building analyses had an R^2 value less than 0.9; five of which had fits with an R^2 less than 0.85. These buildings are noted in Table 4 in Section 2.3. Irregular data may be caused by changes in a building, erratic controls, erroneous data, or a building with significant fluctuations in the number of occupants, occupant density, schedule of occupancy, or process loads that are not well correlated with temperature. Buildings with irregular or noisy data may still have valid analyses from FirstView, depending on the model fit and overall data pattern.

2.3 Peer Building Comparison

For this portfolio analysis, NBI created a custom [REDACTED] Municipal Facilities Spectrum to benchmark each building's energy relative to others in the portfolio. In order to create the spectrum, NBI examined the statistical distribution of the underlying FirstView parameters for each building. The lower boundary of the custom spectrum represents the 25^{th} percentile, and the upper boundary the 75^{th} percentile, of these parameters. NBI also created custom comparison spectrums for specific building types (fire stations, libraries, police stations, and office buildings) including buildings in [REDACTED] as well as other cities nationwide.

2.4 Data Received and Pre-Screening

NBI analyzed and included data selected from 47 buildings in the City of [REDACTED] Municipal Buildings Portfolio for this report. Due to unresolved data issues, several buildings from the original full list of 58 buildings could not be analyzed. Six buildings were considered outliers due to very high or low energy usage and were excluded from this report. These are called out in Table 2, below.

Table 2: Facility Summary

Building Name	Building Type	Included in Study?	Size (sf)	Consumption (MMBtu)	EUI (kBtu/ft^2/yr)
Admin Building	Office	Yes	32,500	2,802	88
[REDACTED] Building	Other	No	4,700	31	6
[REDACTED] Senior Center	Senior Care Community	Yes	12,122	1,862	143
[REDACTED]	Office	Yes	52,200	4,352	85
Central [REDACTED]	Other	No	3,530	1,790	504
[REDACTED] Wastewater Treatment Plant	Wastewater Treatment Plant	No	194,528	69,159	319
[REDACTED] Stadium	Stadium	Yes	7,350	117	16
[REDACTED] Library	Library	Yes	7,996	354	47
[REDACTED] Fire Department	Fire Station	Yes	9,450	503	51
Fire Prevention Center	Fire Station	Yes	4,649	306	66
Fire Station [REDACTED]	Fire Station	Yes	16,600	944	55
Fire Station [REDACTED]	Fire Station	Yes	1,963	247	127
Fire Station [REDACTED]	Fire Station	Yes	5,121	127	25

Building Name	Building Type	Included in Study?	Size (sf)	Consumption (MMBtu)	EUI (kBtu/ft^2/yr)
Fire Station [REDACTED]	Fire Station	Yes	9,970	578	60
Fire Station [REDACTED]	Fire Station	Yes	9,900	104	10
Fire Station [REDACTED]	Fire Station	Yes	1,963	158	76
Fire Station [REDACTED]	Fire Station	Yes	3,360	219	61
Fire Station [REDACTED]	Fire Station	Yes	8,994	486	51
Fire Station [REDACTED]	Fire Station	Yes	1,752	33	19
Fire Station [REDACTED]	Fire Station	Yes	16,380	464	28
Fire Station [REDACTED]	Fire Station	Yes	2,816	229	77
Fire Station [REDACTED]	Fire Station	Yes	6,115	336	52
Fire Station [REDACTED]	Fire Station	Yes	4,200	196	50
Fire Station [REDACTED]	Fire Station	Yes	2,081	127	61
Fire Station [REDACTED]	Fire Station	Yes	17,400	976	57
Fire Station [REDACTED]	Fire Station	Yes	11,000	347	31
Maintenance [REDACTED]	Other	Yes	28,600	953	29
[REDACTED] Library	Library	Yes	5,000	233	46
[REDACTED] Senior Center	Senior Care Community	Yes	8,777	748	85
[REDACTED] Library	Library	Yes	95,727	2,805	29
Fire Station [REDACTED]	Fire Station	Yes	1,900	82	41
[REDACTED] Library	Library	Yes	15,487	396	26
[REDACTED] Library	Library	Yes	5,025	166	33
Municipal Services Center	Other	Yes	6,857	893	130
Parking Services Office	Office	No	8,000	51	6

Building Name	Building Type	Included in Study?	Size (sf)	Consumption (MMBtu)	EUI (kBtu/ft^2/yr)
[REDACTED] Senior Center	Senior Care Community	Yes	3,806	103	27
Police Headquarters	Police Station	Yes	73,000	6,494	93
[REDACTED] Warehouse	Police Station	Yes	120,535	4,965	42
[REDACTED] Library	Library	Yes	7,475	231	31
[REDACTED] Building	Other	Yes	1,080	189	170
[REDACTED] Library	Library	Yes	9,586	318	32
[REDACTED]	Stadium	Yes	250,000	14,195	55
[REDACTED] City Hall	Office	Yes	207,020	8,347	39
[REDACTED] City Hall 2	Office	Yes	41,400	1,784	42
[REDACTED] Police Station	Police Station	Yes	3,500	256	72
[REDACTED] Police Station	Police Station	Yes	3,500	216	61
[REDACTED] Police Station	Police Station	Yes	3,500	233	66
[REDACTED] Police Station	Police Station	Yes	3,500	249	71
[REDACTED] Police Station	Police Station	Yes	3,500	235	68
Traffic Signal Shop	Other	Yes	12,000	773	62
[REDACTED] Library	Library	Yes	16,932	844	48

To help visualize this data, Figure 2 summarizes the portfolio energy usage, calling out those buildings with high total energy consumption. The data reported is the most recent 12 months of full consecutive energy data for each building. In most cases, the data is from 2015-2016.

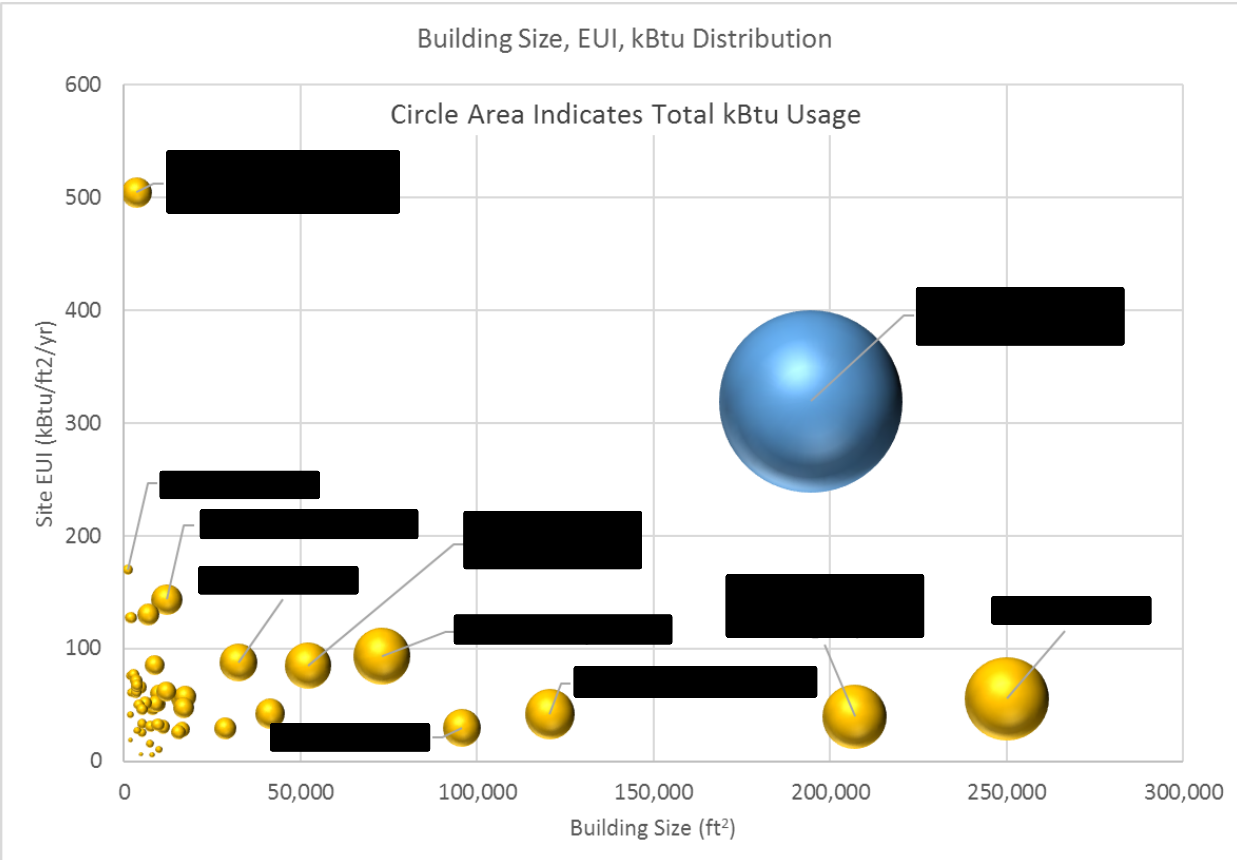

Figure 2: Map of Building EUI by Building Size for all analyzed buildings. Data Labels Highlight Selected Special Interest Buildings. The [REDACTED] is included in this figure for comparison but excluded throughout the remainder of this report.

It is clear from Figure 2 that a small number of buildings use a substantial portion of the total energy consumption in this data set based on size and EUI. In particular, [REDACTED] consumes 52% of the total energy usage of all analyzed buildings. Excluding [REDACTED] brings the remainder of the buildings into better focus, as seen in Figure 3.

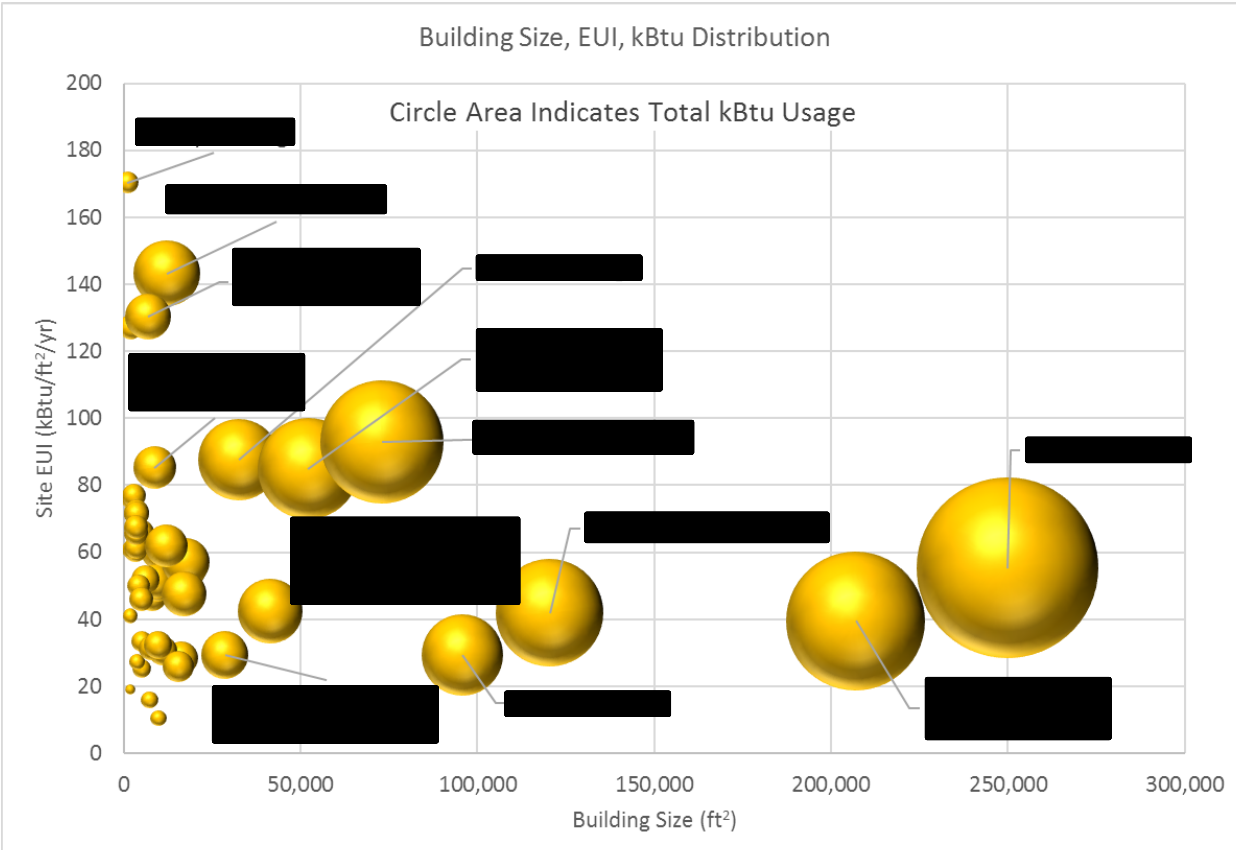

Figure 3: Map of Building EUI by Building Size for all analyzed buildings, excluding outliers. Data Callouts Highlight Special Interest Buildings.

To clearly show the magnitude of the contribution these buildings make to the total energy use of the studied buildings, Figure 4 provides the visual breakdown and percentages of portfolio energy use. The top five buildings consume 62% of total energy use and make up about 60% of the total square footage.

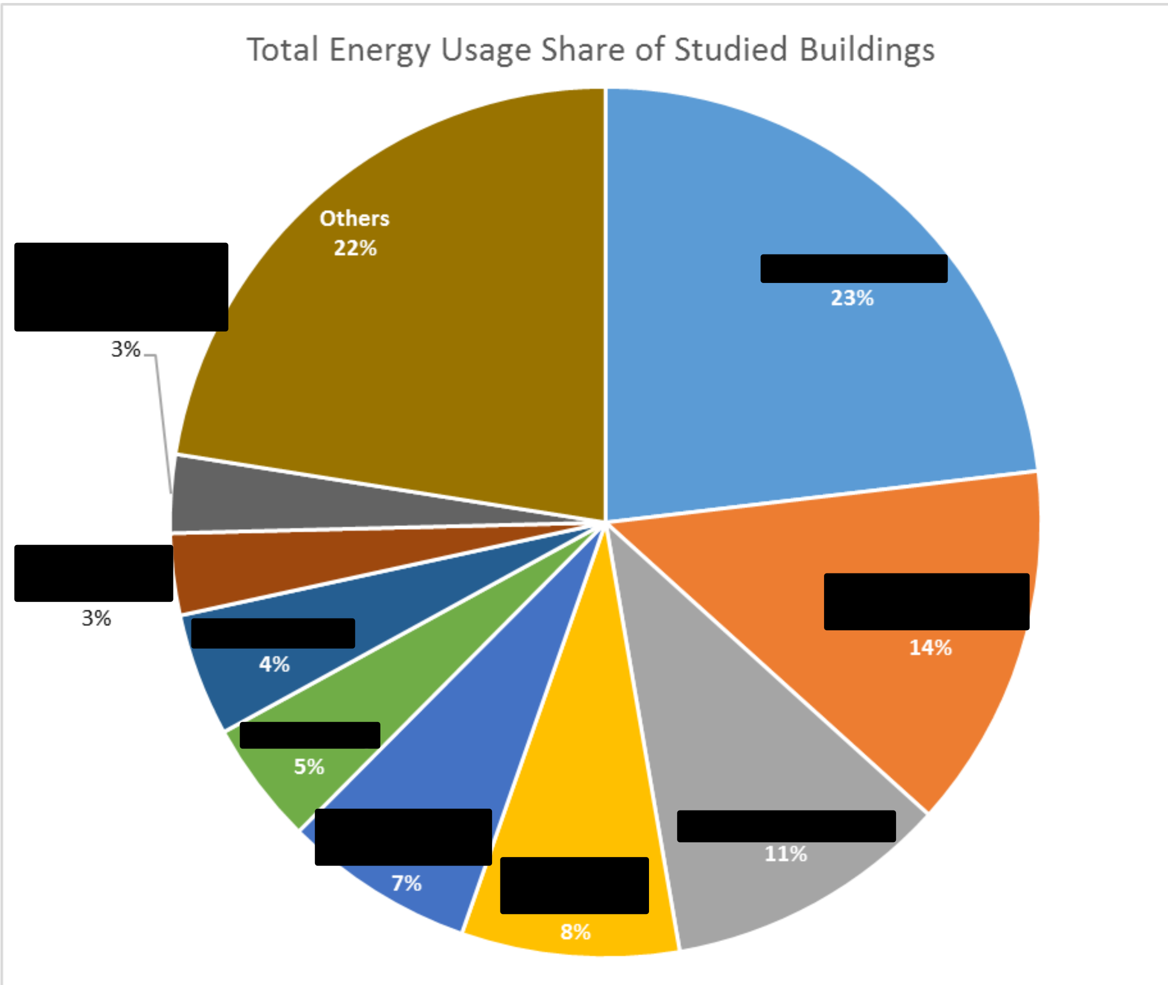

Figure 4: Individual Building Contributions to the Studied Building Portfolio Total Energy Use.

2.5 Input Data and Assumptions

For this report, NBI used the most recent 12 months of complete data for the primary FirstView analysis. In most cases, the data spans from 2015 to 2016. FirstView automatically collects the average temperature for each billing period from a database of historic weather data from the [REDACTED] International Airport weather station. The detailed FirstView data tables also include a calculation of weather normalized EUI. The normalized EUI is calculated using typical meteorological year data (TMY3) from the same weather station.

Some buildings showed signs of having a larger uptick in winter electric use than is typically found in buildings with gas heating. In some cases, FirstView assumes that electric heating is greater than zero in buildings with gas heat. This can be attributed to reasons including electric resistance reheat, space heater usage, plug loads, or waste heat. NBI accounted for this in the FirstView inverse energy model by adjusting the assumption for "Gas Heating Percent" (X_{space_g}).

Table 3 summarizes these assumptions for all buildings with gas heating percentage between 0% and 100%; buildings with zero gas heating percentage do not use any natural gas at all. This factor is used to allow the FirstView model to deal with increasing electric use as temperature drops into and through the heating zone. If a building has a hybrid electric/gas heating system, this factor can be used to capture the usage trends of that system. For buildings without a permanent electric heating source the factor is sometimes still needed, and could be explained by factors such as: electric space heater use, increasing lighting load in response to reduced daylight availability, or temperature correlated process loads.

Table 3: Assumed Heating Fuel Percentages

Building Name	Gas Heating Percent Assumption
Admin Building	99%
Fire Station [REDACTED]	99%
Fire Station [REDACTED]	98%
[REDACTED] Warehouse	97%
[REDACTED] Center	96%
Fire Station [REDACTED]	96%
Police Headquarters	89%
Fire Station [REDACTED]	80%
Fire Station [REDACTED]	80%
[REDACTED] Senior Center	74%
[REDACTED] Shop	70%
[REDACTED]	61%
[REDACTED] City Hall 2	61%
Fire Department [REDACTED]	30%
Remaining facilities	*100% (gas heated) or 0% (electric heated)*

3.0 BENCHMARKING RESULTS AND DISCUSSION

3.1 Portfolio Benchmarking

NBI successfully conducted FirstView analyses for 51 buildings. After removing outliers, 47 buildings are included in this report. The following energy signature chart, Figure 5, shows a quick snapshot of the performance variation seen in this portfolio. A wide range of performance is evident. Generally, fire and police stations use more energy than other building types in this portfolio, while the libraries are strong performers as compared to the portfolio comparison spectrum. To view each facility relative to the spectrum, see the attached individual building reports.

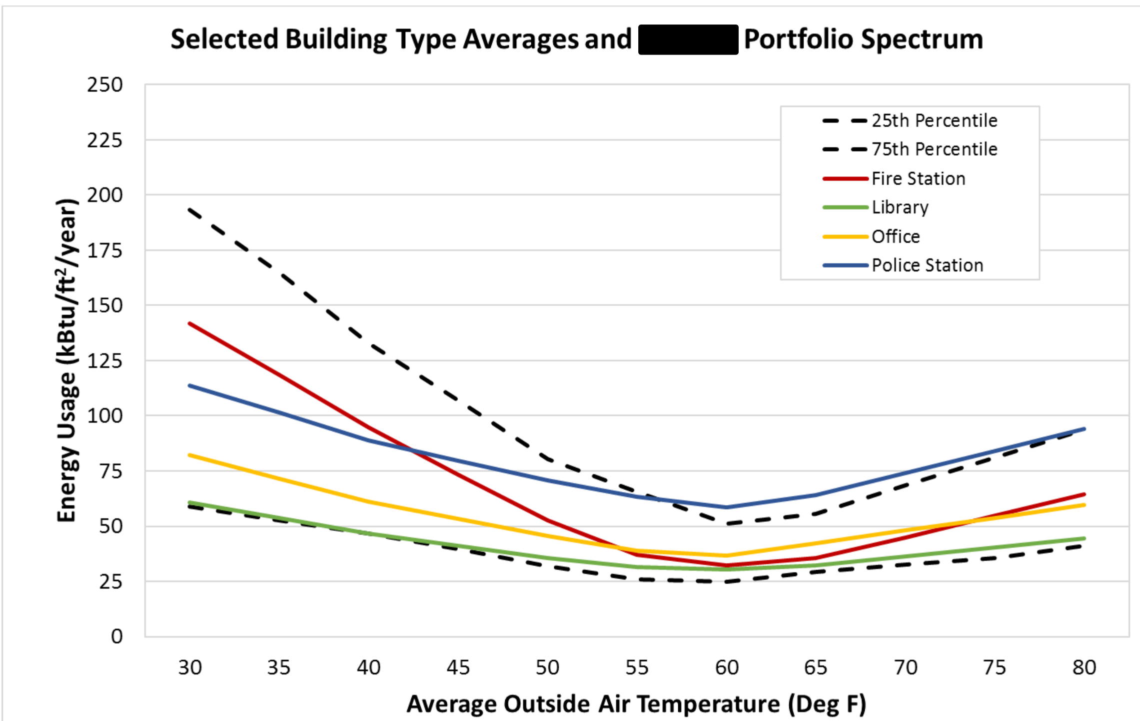

Figure 5: Energy Signature with Customized City of [REDACTED] Spectrum – Building Types

The next chart, Figure 6, shows an end use breakdown for the total portfolio. 37% of total energy use is used for heating (including both gas and electric usage); electric baseload accounts for 57% of energy usage. This suggests that there may be substantial savings opportunities for replicable programs that address these end uses and can be rolled out city-wide. As expected in the [REDACTED] climate, the cooling energy use is relatively small.

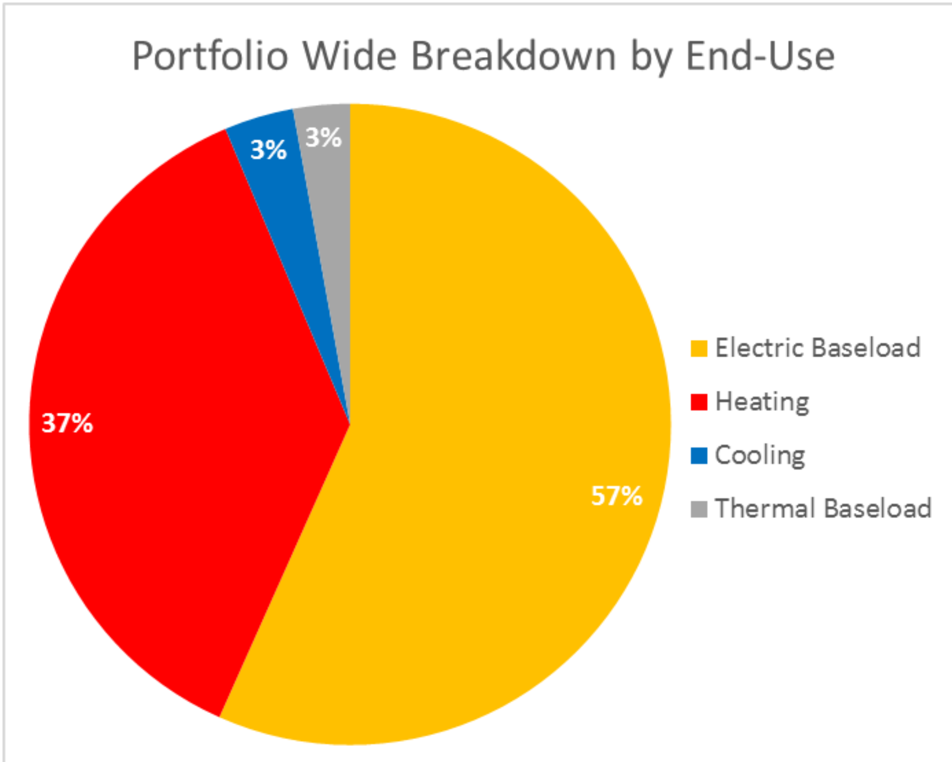

Figure 6: Portfolio Wide End Use Breakdown

Considering total annual energy use (per square foot) relative to peers gives some high-level perspective on the performance of this portfolio. Figure 7 shows the portfolio average site energy for common building types in this portfolio relative to national and climate specific benchmarks, including CBECS[5] and ASHRAE 100[6]. Overall, the municipal buildings within this portfolio have a median EUI of 55 kBtu/ft^2.

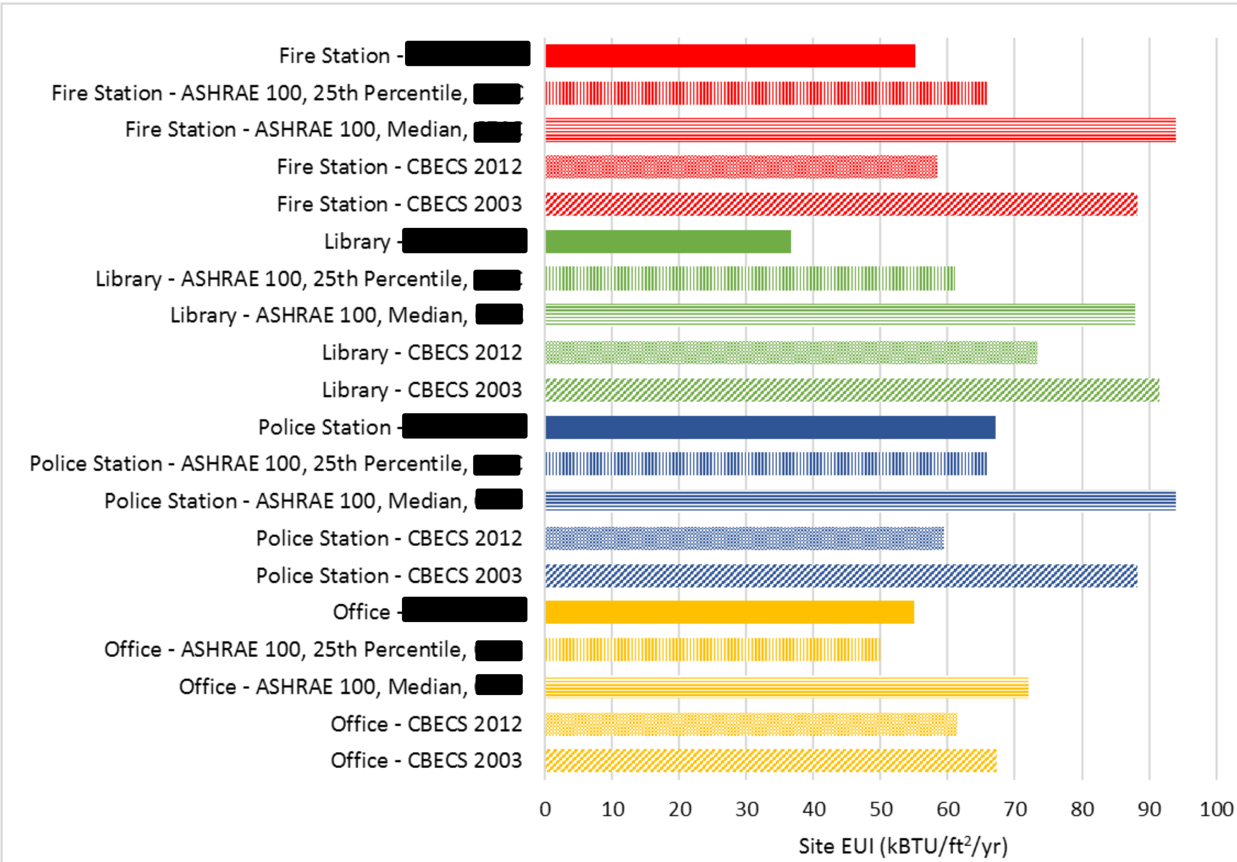

Figure 7: Annual Site Energy Use Intensity Benchmarks

Often, older buildings are thought to be higher users of energy than newer buildings. The modern advantages of more efficient equipment, advanced controls, and sophisticated materials and building methods generally increase building performance. However, stylistic changes and cost constraints may be working against that trend. Further, renovations, retrofits, or general modernization of older buildings often improves their energy performance, making it more difficult to compare buildings by age only.

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[5] The Commercial Building Energy Consumption Survey (CBECS), published in 2003, is commonly used to represent the energy use of typical existing building stock in the United States. CBECS is available at: http://www.energystar.gov/ia/business/tools_resources/new_bldg_design/2003_CBECSPerformanceTargetsTable.pdf.

[6] ASHRAE/ANSI/IES Standard 100-2015 (Energy Efficiency in Existing Buildings) defines EUI targets for existing buildings across various building types and climate zones.

Looking at Figure 8, below, the energy usage of [REDACTED] municipal buildings is weakly correlated with the age of the building. This suggests that the intuitive sense that older buildings should be the first to receive energy retrofits may not hold for this building set. The best candidates for energy retrofits may in many cases be more recently constructed buildings.

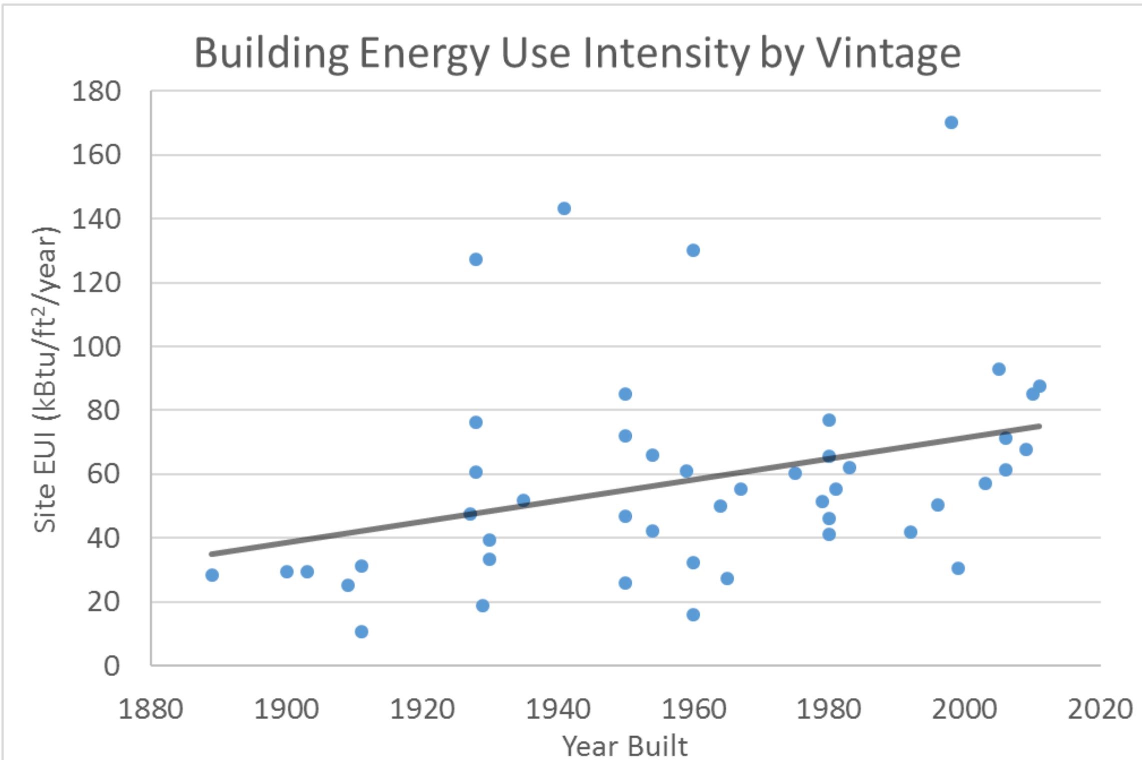

Figure 8: Comparison of Individual Building EUI to Building Age

3.2 Building Type Benchmarking

In order break down the entire portfolio into more manageable information, NBI has created additional figures looking specifically at common building types throughout the portfolio. The most common building types are Fire Stations, Libraries, Police Stations, and Offices. Each of these sub-categories are discussed in detail in the following sections.

3.2.1 Fire Stations

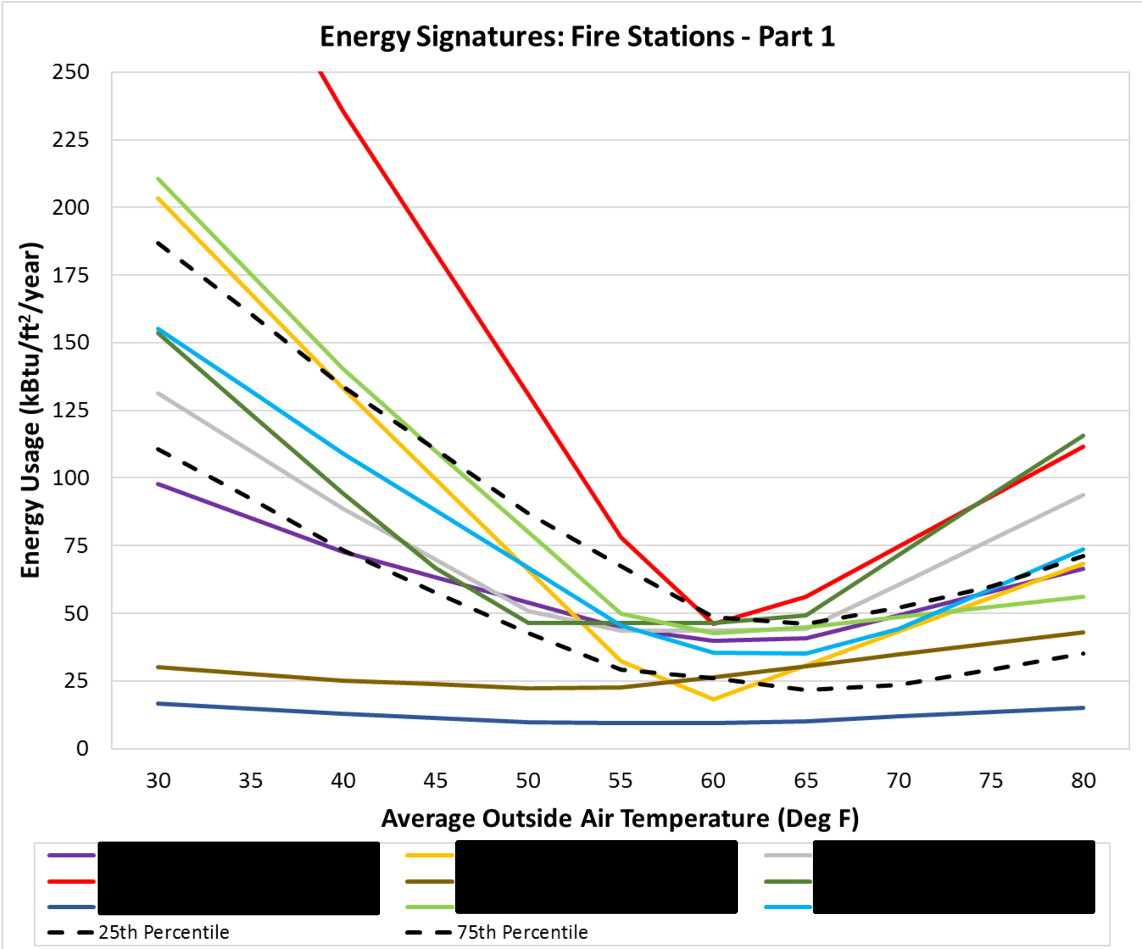

Figure 9: Energy Signatures for the First Set of Fire Stations

Figure 9, above, shows the specific energy signature for half the [REDACTED] fire stations at various outside air temperatures compared to a customized fire station-specific spectrum. Only half of the fire stations are plotted in order to more clearly distinguish individual building signatures. The remaining signatures are plotted below in Figure 10. This spectrum was generated by combining the energy signatures of 70 fire stations in various locations across North America, including the [REDACTED] fire stations in this portfolio. The [REDACTED] fire stations use a similar amount of energy when compared to their national peers. Some buildings do have a steep slope in the colder temperatures, including **[REDACTED]**, **[REDACTED]**, **[REDACTED]**, and **[REDACTED]**. This suggests that these buildings may have some heating, shell, or ventilation issues, and would be good candidates to investigate further. In the warmer temperatures, **[REDACTED], [REDACTED],** and **[REDACTED]** have relatively high energy use and slopes. This is likely due to increased cooling loads and/or process loads associated with the summer season.

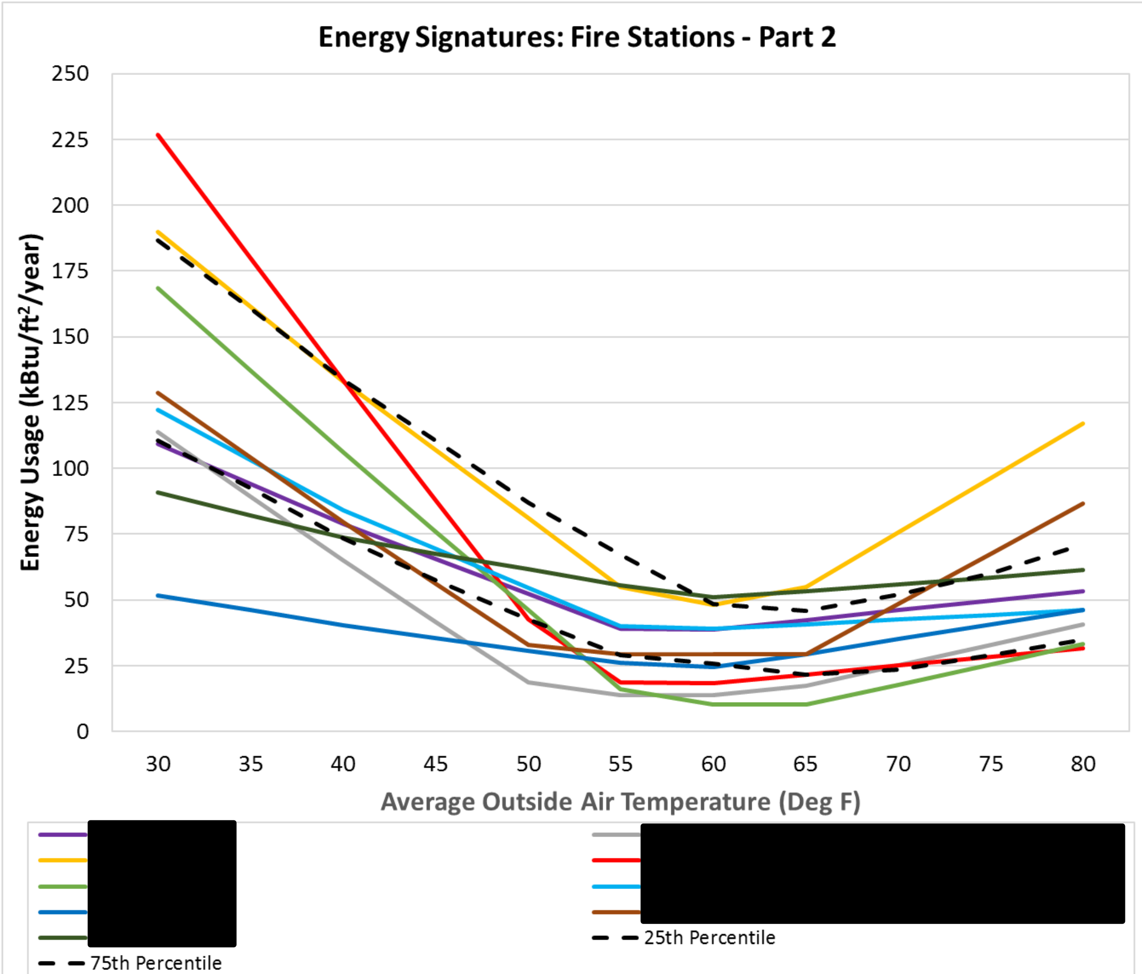

Figure 10: Energy Signatures for the Second Set of Fire Stations

Figure 10, above, shows the specific energy signature for the remainder of the [REDACTED] fire stations. In this set, **[REDACTED]**, **[REDACTED]**, and **[REDACTED]**stand out for their steep slopes in the cooler temperatures, which suggests these buildings may have some heating, shell, or ventilation issues, and would be good candidates to investigate further. In the warmer temperatures, **[REDACTED]** and **[REDACTED]** have steep slopes, which is likely due to cooling loads and/or process loads associated with the summer season. Other fire stations with lower slopes can serve as examples for those fire stations with high slopes on both the warmer and cooler temperature ends of the [REDACTED] climate and should also be investigated to determine which component will result in lower energy consumption.

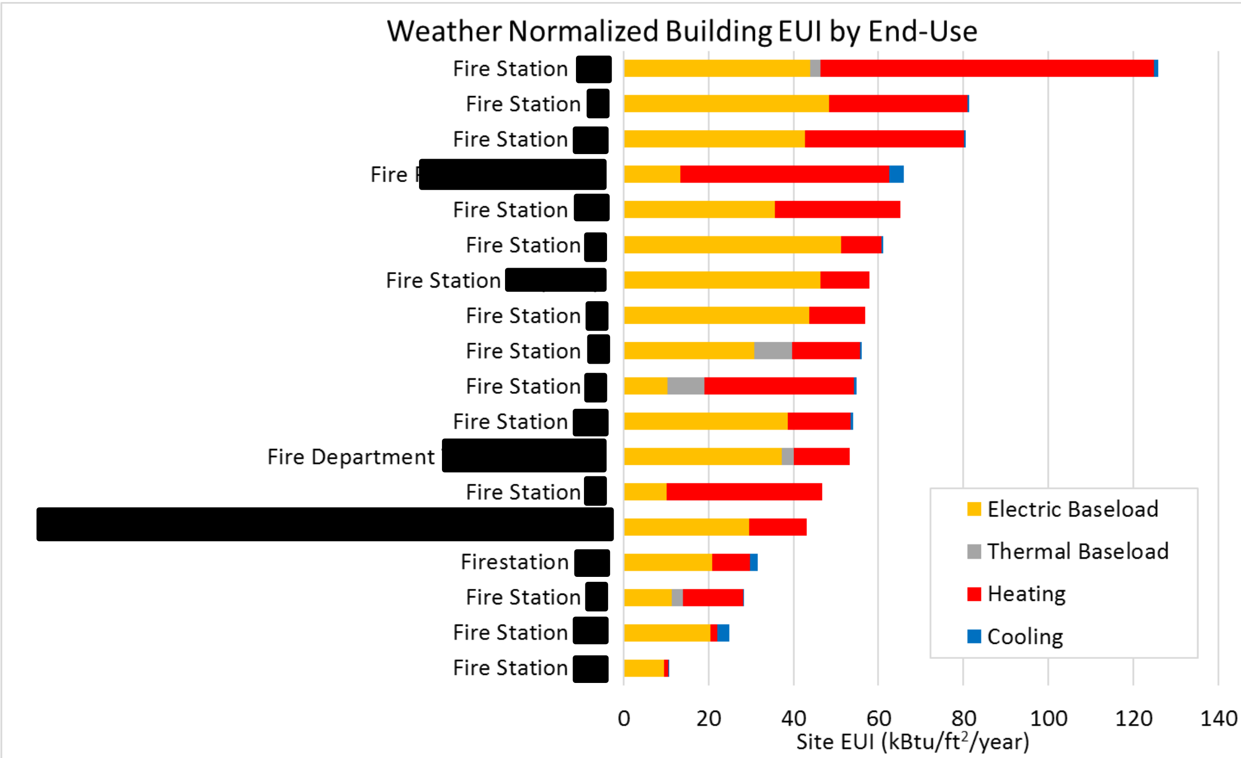

Figure 11: Breakdown of End-Use EUI for All Fire Stations

Looking now at the end-use EUI for the fire stations in Figure 11, the elevated usage and slope of **[REDACTED]** in the colder months, attributed to heating, is shown in red at the bottom of the chart. The relatively high thermal baseloads of the **[REDACTED]** and **[REDACTED]** is worthy of note in this figure. These high thermal baseloads should be validated by confirming that the buildings have a justifiably high hot water demand (domestic hot water heating, washing vehicles and equipment, laundry, cooking, etc.), and these buildings should be checked for hot water recirculation issues, reheat, and other issues that can contribute to year-round gas use.

Generally, the fire stations are smaller than the median building size and use less energy than the portfolio-wide median. While there are clear areas for further investigation to improve these buildings, they will not provide the greatest energy and emissions savings due to their small contribution to portfolio's total energy use.

3.2.2 Libraries

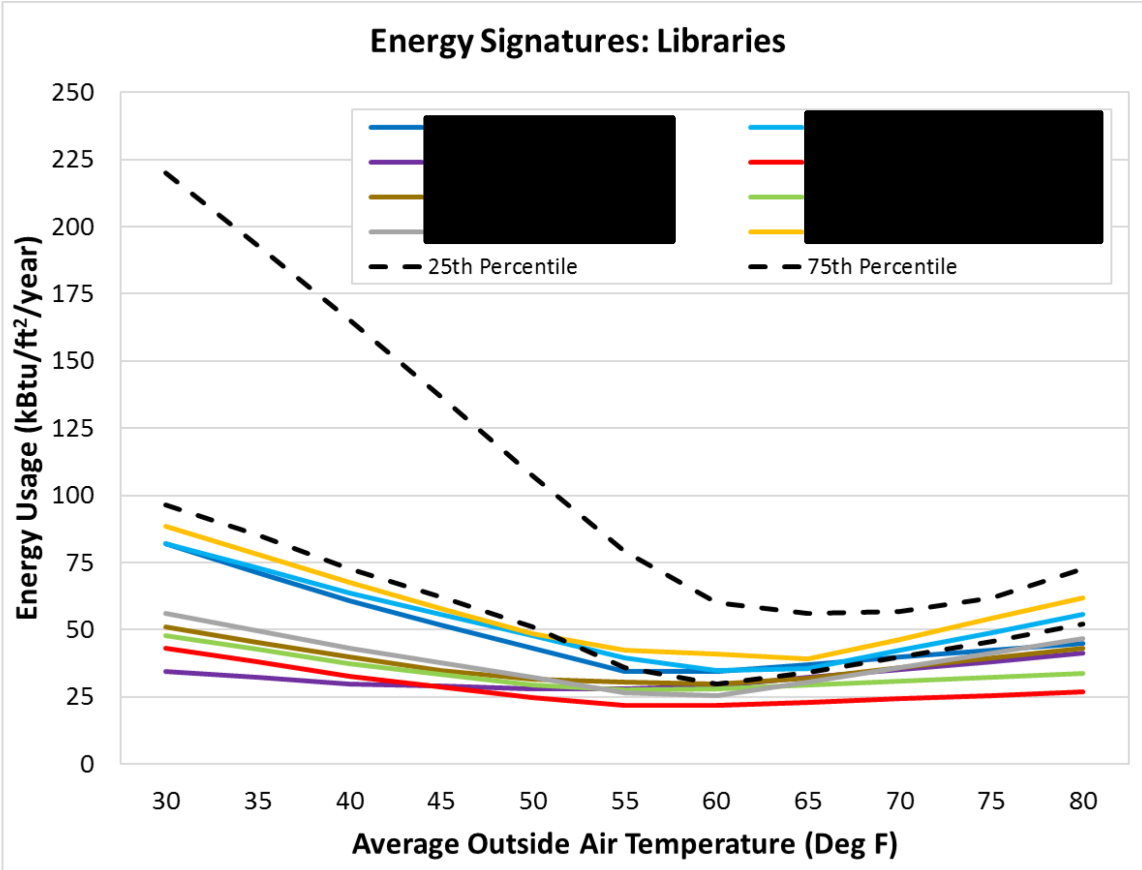

Figure 12: Energy Signatures of All Libraries

Figure 12 shows the individual energy signatures for the libraries in the portfolio compared to a customized library-specific spectrum. This spectrum was generated by combining the energy signatures of 39 libraries in various locations across North America, including the [REDACTED] libraries in this portfolio. The libraries as a whole are very good performers. Nearly all buildings are below the national spectrum. The **[REDACTED]**, while a strong performer, is a large building and one of the highest energy consumers of the portfolio. Improvements here to lower the electric baseload can lead to large total savings.

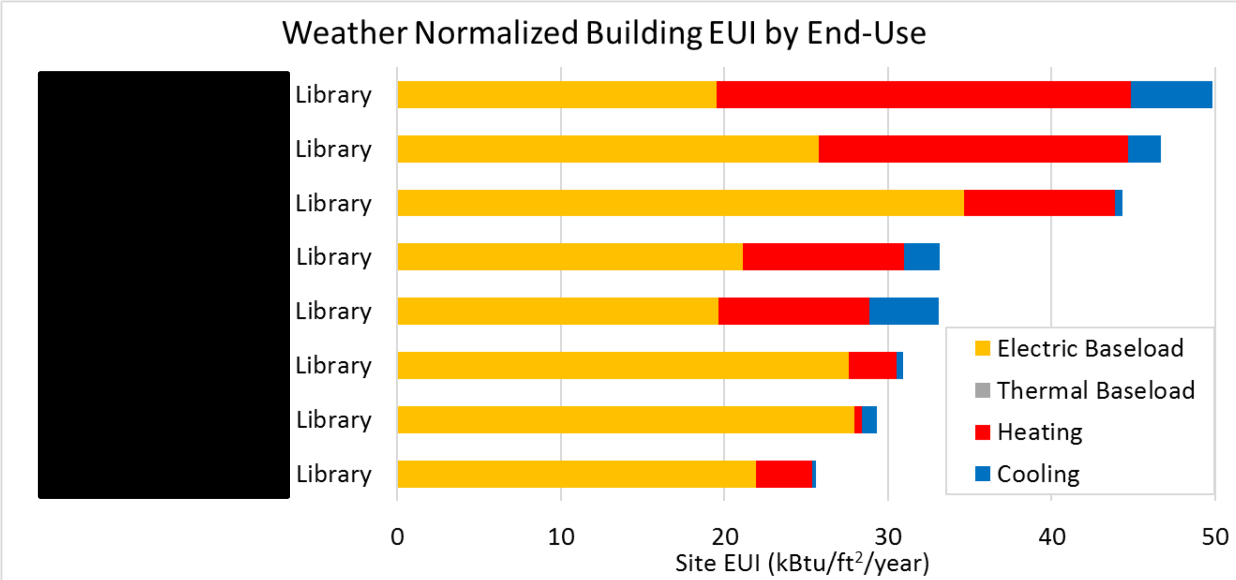

Figure 13: Breakdown of End-Use EUI for All Libraries

The trends in from Figure 12 are seen again here, in Figure 13. The EUIs for all libraries are relatively low. The **[REDACTED], [REDACTED],** and **[REDACTED]** libraries are strong potential candidates for zero net energy retrofits given their low energy usage, small floor area ratios, available roof space for PV, and electric baseload dominated energy signatures which allow for targeting savings in areas such as lighting and plug loads. As a very public building and overall high performer, the **[REDACTED]** may be a good candidate for a zero net energy retrofit, however, the limited roof space constrains the onsite solar potential. To get to zero, this building would require a different approach such as purchasing renewable energy from a community solar system.

3.2.3 Offices

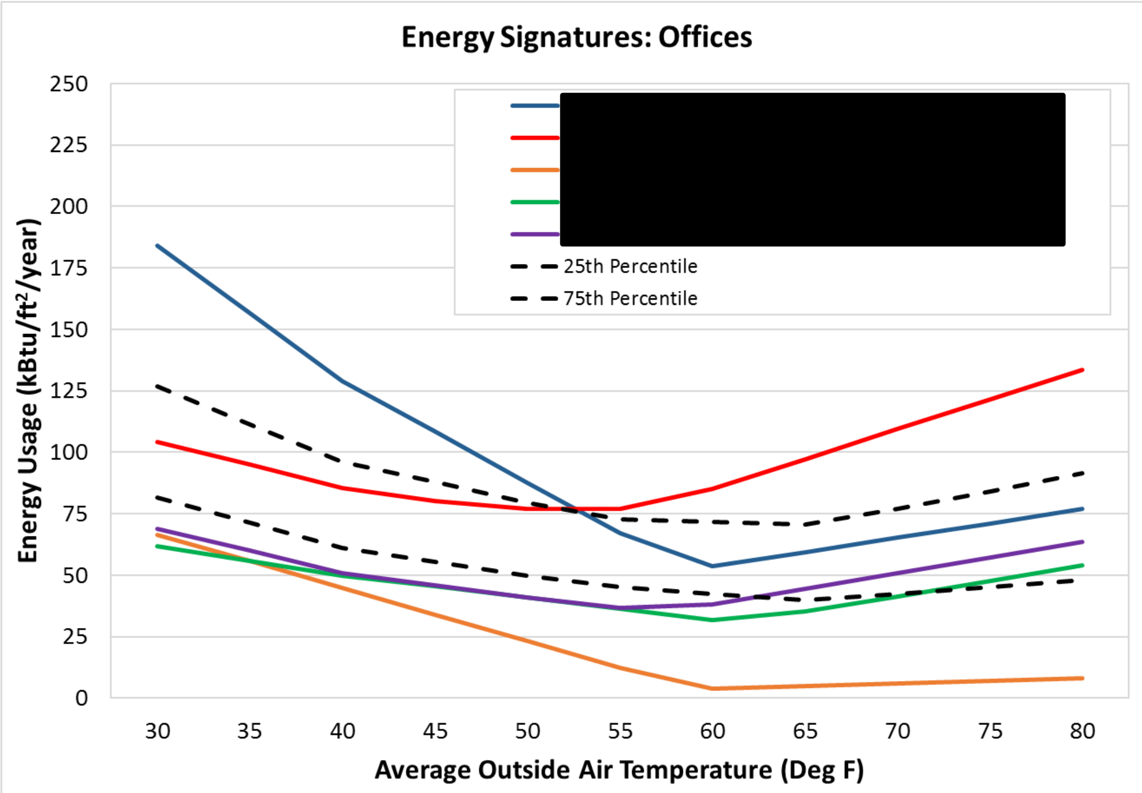

Figure 14: Energy Signatures of All Office Buildings

The office building energy signatures in Figure 14 reveal the relative performance of each building. The plotted spectrum represents the energy usage of 200 office buildings found throughout the country. The figure shows that **[REDACTED]** uses a lot more energy than average during the warmer season, which suggests poor cooling system efficiency and/or summer seasonal process loads (e.g. lab activity during the summer)[7]. In addition, the energy signature base level is much higher than peer buildings. **[REDACTED]** has very low energy usage in the warmer months, suggesting that the building used little to no cooling and may have minimal occupancy. The **[REDACTED]** is a poor performer during the colder months, using two to three times as much energy during the winter as peer buildings. Poor shell and ventilation performance tied to infiltration and low insulation levels, as well as poor heating system efficiency may be the cause and should be a primary focus for further investigation. Other factors such as occupancy and hours of operation should be taken into consideration when evaluating these energy signatures against one another; these factors can greatly impact the energy usage in office buildings.

[7] NBI has worked with the City of [REDACTED] to ensure we have accurate data for this building. Although this building is [REDACTED] and was carefully designed to minimize energy usage, the results from our analysis concur with the energy usage patterns seen in Portfolio Manager. The EnergyStar score for this building is 44, which further supports the energy performance conclusions for this building. Process loads, high ventilation, or other lab-driven energy usage may be responsible for the high energy consumption.

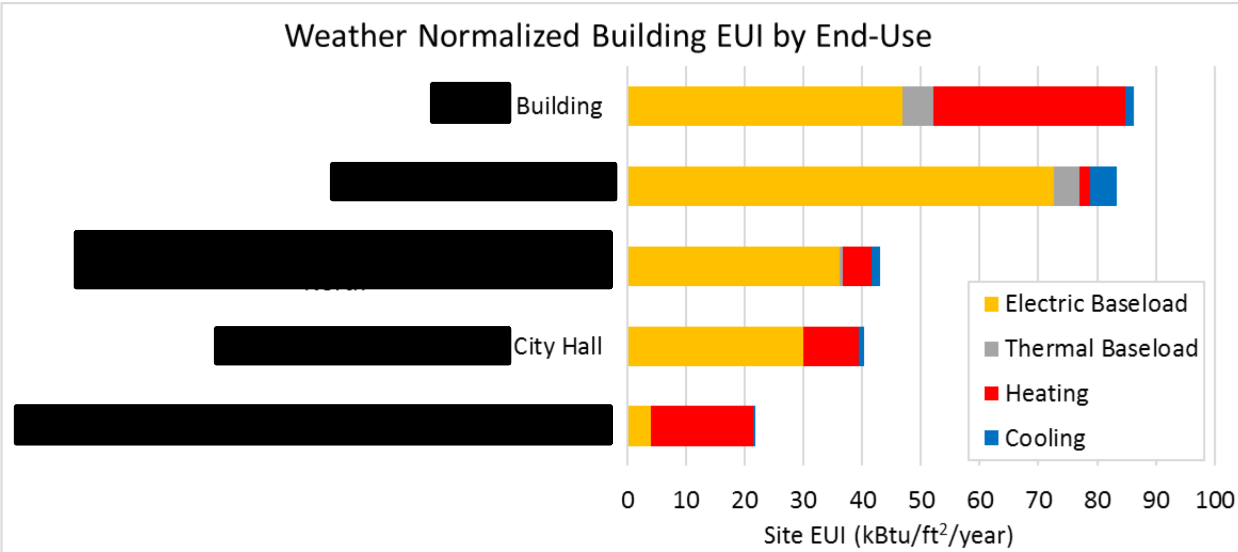

Figure 15: Breakdown of End-Use EUI for All Office Buildings

As suggested from the previous figure, Figure 15 shows that the **[REDACTED]** uses more energy per square foot than the other offices, particularly for heating. In addition, the **[REDACTED]** uses a lot of electricity throughout the year, which may be tied to laboratory use, but can also be due to poor lighting and controls. **[REDACTED]**, despite its strong performance, uses the most energy due to its size, and should not be ignored. Aside from **[REDACTED]**, the office buildings are among the highest energy consumers of the portfolio, and should therefore be prioritized for an ASHRAE level 2 audit as well as retro-commissioning and retrofits, as they have the greatest potential for savings.

3.2.4 Police Stations

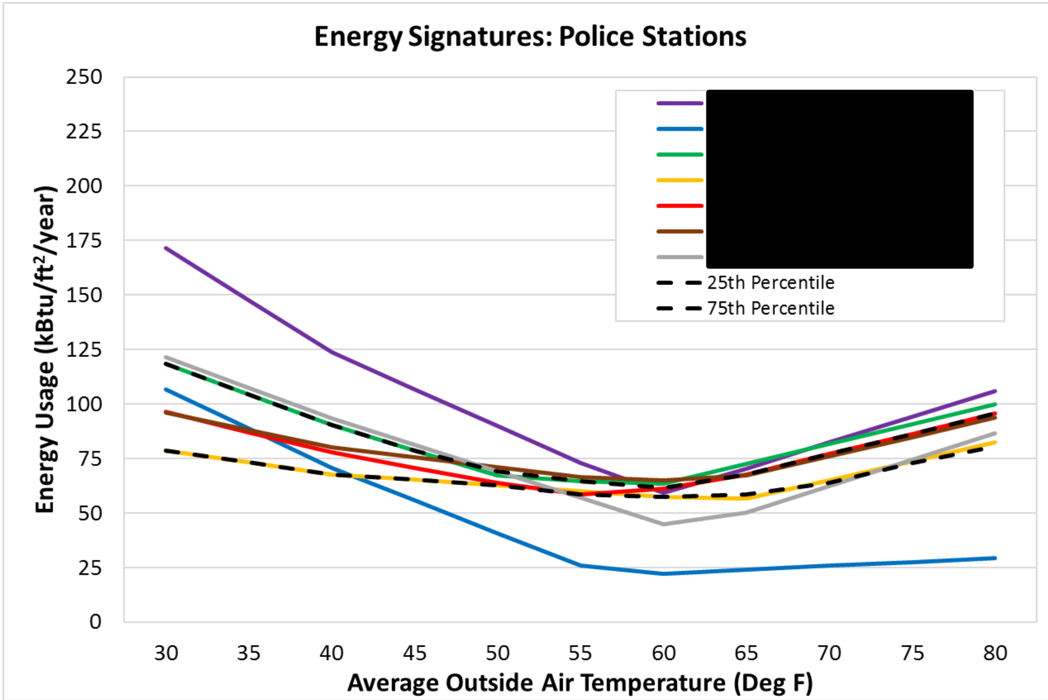

Figure 16: Energy Signatures of All Police Stations

Figure 16 shows each [REDACTED] police station at various outside air temperatures compared to NBI's database police station spectrum. This spectrum does not include as many buildings as other spectra given that police stations are less commonly analyzed. This smaller sample leads to a narrow range between 25th and 75th percentile signatures. As a result, this spectrum should be viewed more as an average police station rather than a representative range of performances.

Compared to one another, it is clear that there are variations on total energy usage (overall height of signatures), as well as building and system efficiencies (signature slopes). Both the **[REDACTED]** and **[REDACTED]** have steeper slopes in the cooler temperatures, suggesting poor shell and ventilation efficiency and/or poor heating system efficiency. In terms of total energy usage, the **[REDACTED]** uses half the energy of other buildings in the warmer months. However, the **[REDACTED]** is a top energy consumer in this portfolio due to its large size, and should therefore be investigated further for energy savings related to heating.

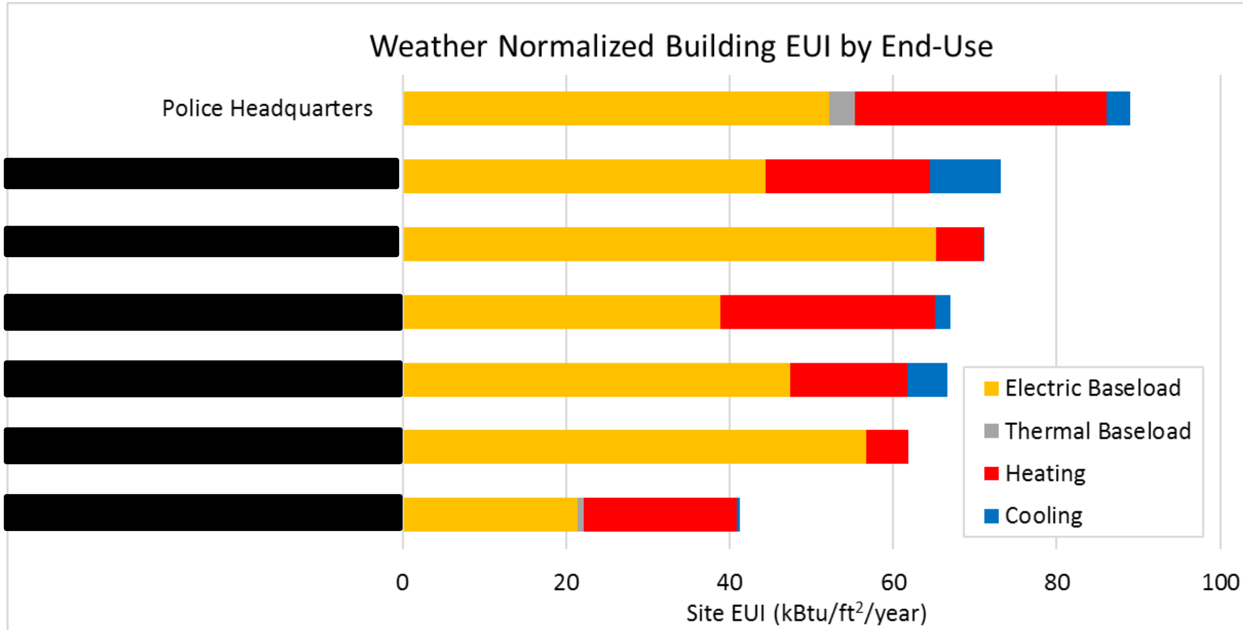

Figure 17: Breakdown of End-Use EUI for All Police Stations

The breakdown of end-use EUI (Figure 17) shows the wide variation between buildings. Buildings such as the **[REDACTED]** and **[REDACTED]** use much more heating energy than the other police stations. The strong example of low heating energy usage of **[REDACTED]** and **[REDACTED]** may serve as a good example of effective systems, envelope, and controls to peer buildings. Although the **[REDACTED]** has the lowest EUI, it actually uses more energy than the other police stations and other buildings in the portfolio at large. Targeting the relatively high heating energy usage as well as the electric energy baseload will lead to the largest potential energy savings.

3.2.5 Other Building Types

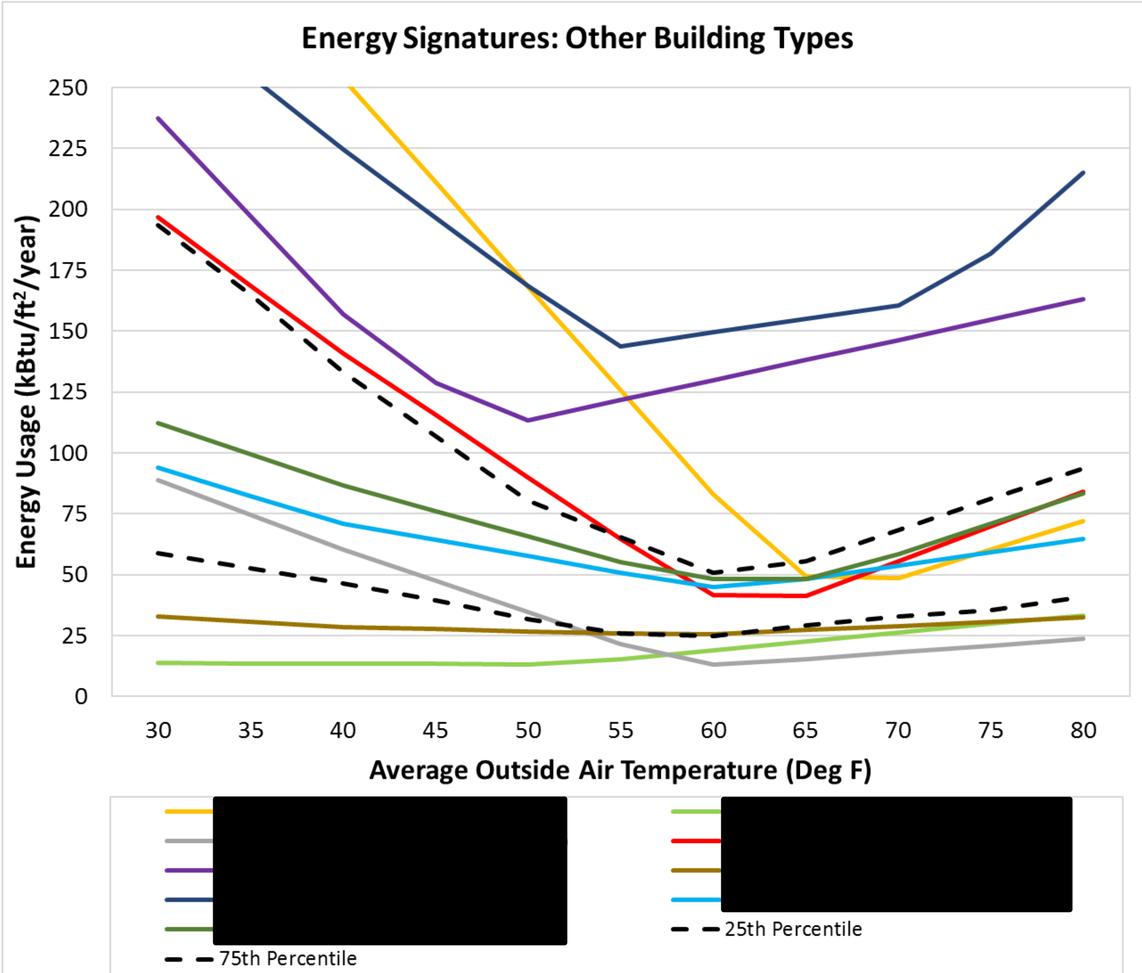

Figure 18: Energy Signatures for Other Building Types

Figure 18 shows the energy signatures of the remaining buildings in the portfolio. The comparison spectrum is made up of all studied buildings in this portfolio. Given the variety of building types in both the spectrum and signatures plotted, the spectrum should serve as a loose guideline for general building performances. From the figure, the steep heating slopes of **[REDACTED]**, **[REDACTED]**, and **[REDACTED]** stand out as strong candidates for potential heating, shell and ventilation efficiency improvements. On the warmer end, the **[REDACTED]** and the **[REDACTED]** have elevated slopes, which may indicate poor cooling system efficiency, and well as poor shell and ventilation efficiency. The **[REDACTED]** is a strong performer year-round, and may be a good candidate for a potential net zero energy retrofit, depending on occupancy intensity during the analyzed months.

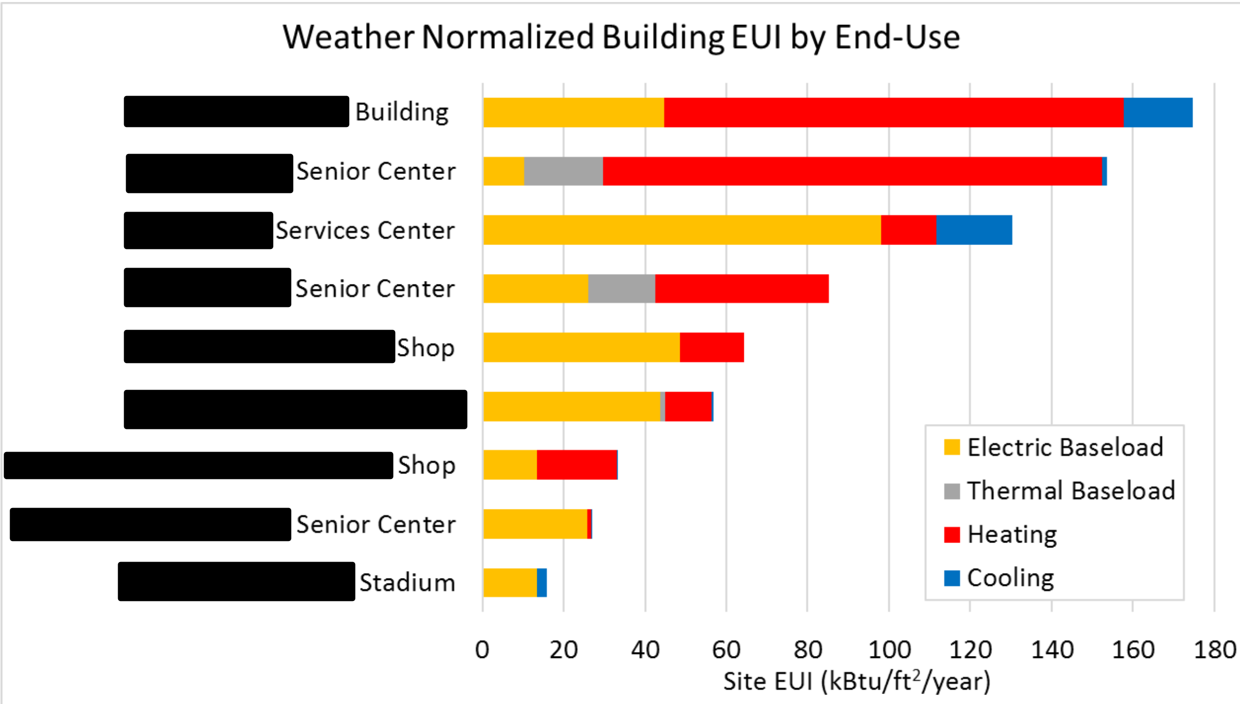

Figure 19: Breakdown of End-Use EUI for All Other Buildings

Figure 19 shows the breakdown of end-use energy for the remaining building types, including senior centers, stadiums, and others. The **[REDACTED]** has the highest EUI, but due to its small size, uses little energy. Conversely, **[REDACTED]** is the largest building of this group, and uses the most energy, despite its relatively average EUI. Further study looking into the electric baseload for this building may reveal potential for large energy savings. The **[REDACTED]** can offer some modest savings, though it uses a small amount of energy relative to the portfolio at large. It uses a relatively high amount of gas, which is attributed to heating in this case. However, some of this gas usage may be due to process loads for the senior center, notably domestic and service hot water heating and laundry service. The usage was attributed to heating because the gas usage shows a steep slope during winter months (that is, the gas usage is temperature-dependent).

3.3 FACILITY BENCHMARKING

Taking a broader look at the portfolio as a whole, the individual buildings are compared to the full set for several parameters identified in FirstView. These include EUI by end use, domestic hot water use, normalized UA (shell efficiency), internal gains (from lights and plug loads), and finally, diagnostics which can be used to quickly inform decision makers of retrofit opportunity areas by building.

3.3.1 EUI and Total Energy Consumption by End Use

The stacked bar chart in Figure 20, below, shows the end uses in the four categories for each building. The buildings are grouped in the chart by building types for quick peer building comparisons. This holistic view of all analyzed buildings in this portfolio quickly provides some useful insights. The overall breakdown of end-use energy attribution shows that heating and electric baseloads are the high priority areas for energy savings, while cooling and thermal baseloads typically offer less opportunity for savings.

Many of the features of this figure were covered in the previous section which examined the end-use EUI by building types. Figure 20 serves to show a high level summary of each building's performance compated to one another. The median EUI of the portfolio is **55** kBTU/ft^2/year. Looking forward to the potential of these buildings, the average EUI of Zero Net Energy (ZNE) buildings in the NBI database is **22** kBTU/ft^2/year.

The total energy consumption for each building is shown in Figure 21. As in Figure 20, the buildings in the figure are grouped by building type in order to allow for side-by-side comparison. The key takeaway from this figure is the high total energy consumption of several buildings, most notably the **[REDACTED]**, **[REDACTED]**, **[REDACTED]**, **[REDACTED]**, **[REDACTED]**, **[REDACTED]**, and **[REDACTED]**. These buildings may be good candidates for further investigation such as ASHRAE Level 2 energy audits and actions such as retro-commissioning, or retrofits. While they may not necessarily have the highest EUIs of the portfolio, they do have the highest potential for bottom line BTU energy savings and CO_2 emissions reductions, and should therefore be explored for potential savings opportunities that may have a larger impact on energy consumption. Conversely, certain buildings have higher EUIs (see Figure 20) but use relatively small energy overall. This is an important consideration to keep in mind when selecting buildings to further investigate for retrofit potential. Using these results, we recommend that the City of [REDACTED] develop a retrofit prioritization for the portfolio based on total savings potential, cost-effectiveness, and return on investment.

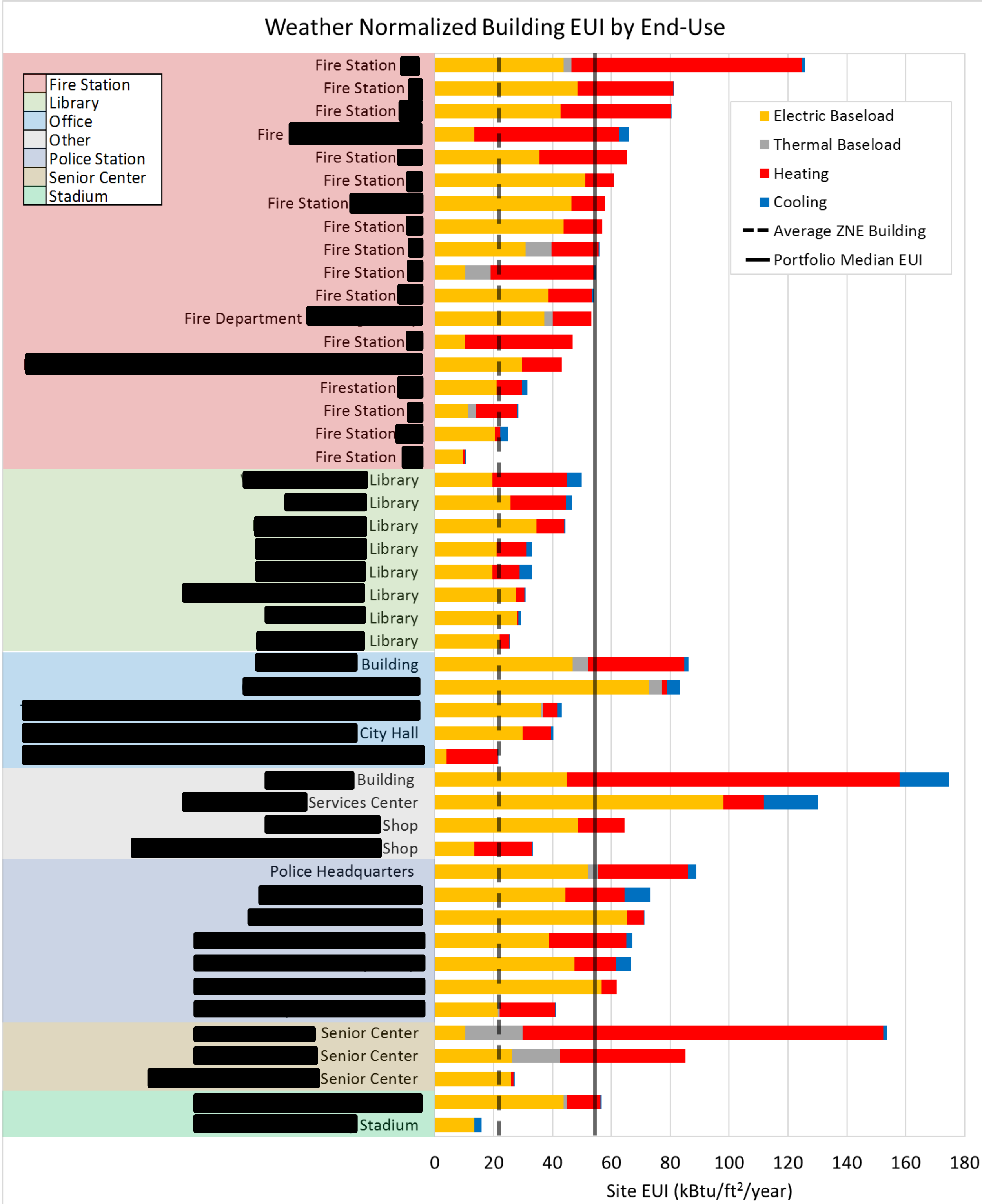

Figure 20: Disaggregated End Use Energy Intensity - All Buildings (grouped by building type)

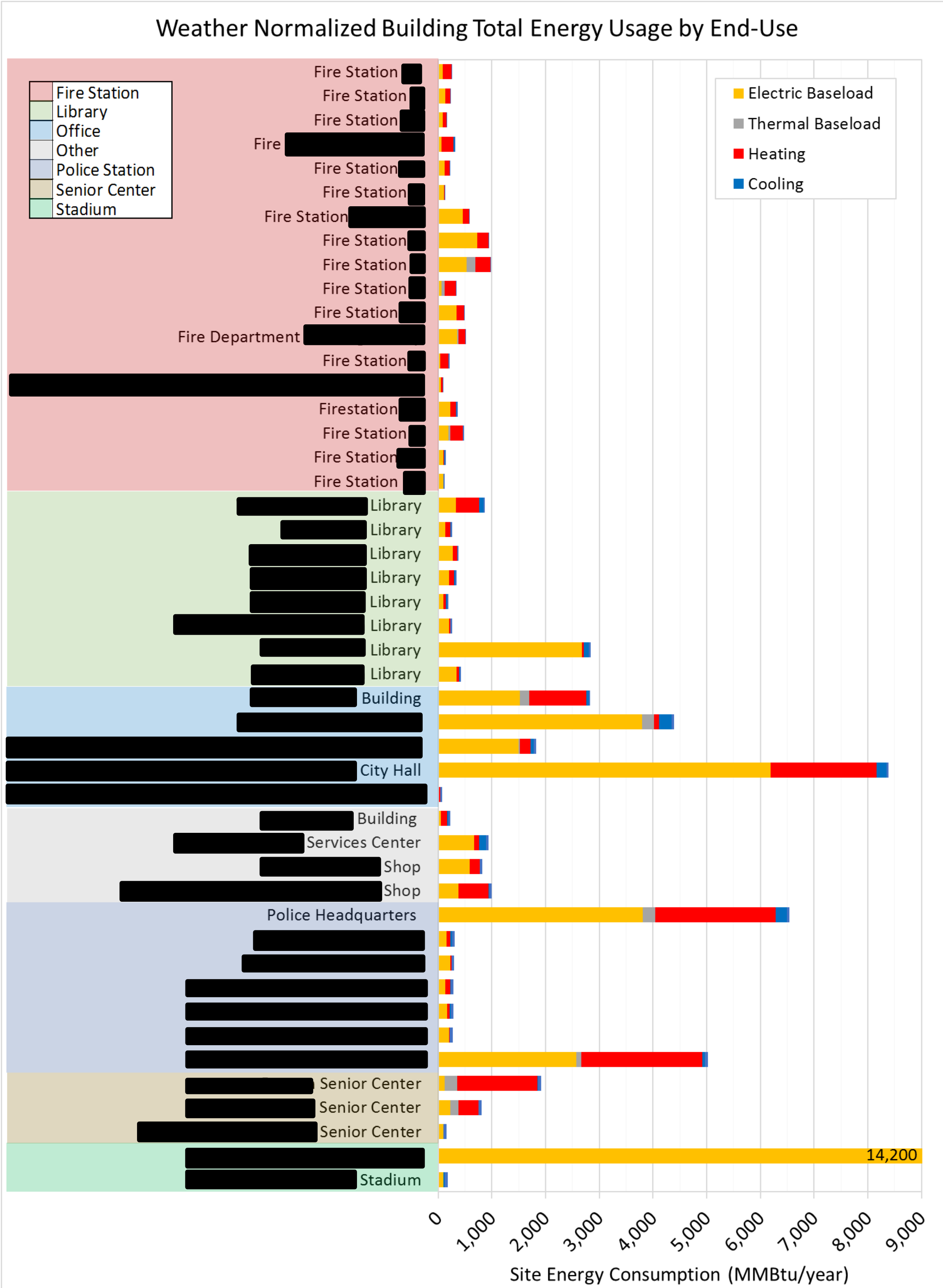

Figure 21: Total Annual Energy Consumption by End Use – All Buildings (grouped by building type)

3.3.2 Internal Gain

A closer look at the electric baseload is given by examining the calculated internal gain for each facility. Figure 22 gives the sum of estimated plugs and lights, expressed in W/ft^2. The observed values range from nearly 0 **([REDACTED])** to all the way up to 3.0 **([REDACTED])**. The average value is about 1 W/ft^2.

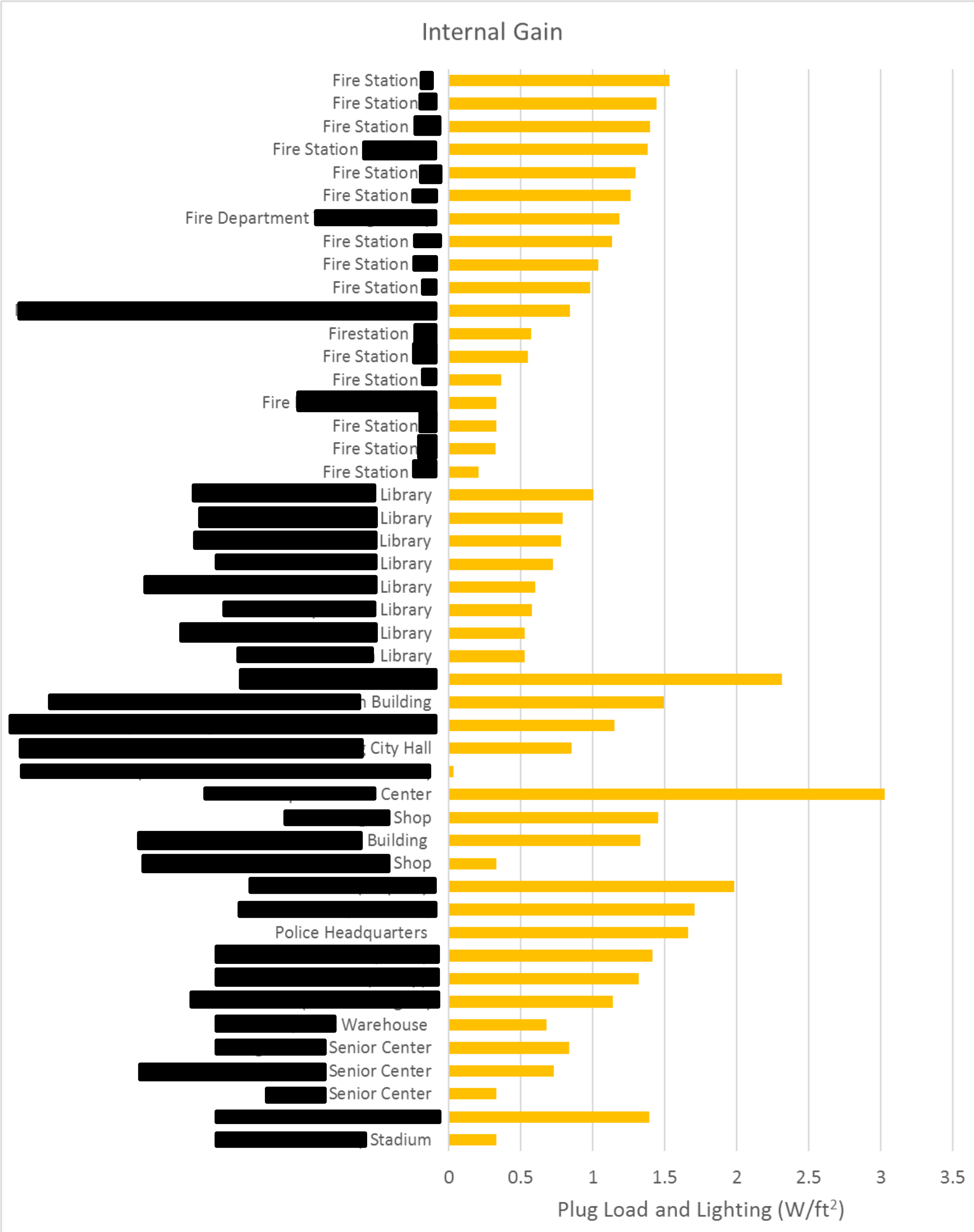

Figure 22: FirstView Calculated Internal Gain - All Buildings

3.3.3 Thermal Baseload

Since thermal fuels such as natural gas are typically used only for water heating in the summer, analysis of the calculated[8] DHW use can quickly reveal unusual fuel consumption trends. The normalized gallons/day of water heating for each facility is presented in Figure 23. When FirstView encounters a building with no summer thermal fuel use, the assumption is that DHW is served by an electric system operating at 0.0015 Gal/(day*ft^2). This level of consumption is typical for offices and similar building types. As seen in the figure, there are several buildings below the 0.0015 Gal/(day*ft^2) assumption, and nearly equally as many above that assumption. The very high users are the **[REDACTED]**, and the **[REDACTED]**. These buildings likely have process loads that require hot water use, such as showers and laundry, which would account for the unusually high usage. If this is not the case, these buildings should be investigated for potential summer gas usage reductions (uninsulated domestic hot water recirculation systems can be a major contributor to these loads), using examples from other buildings with low baseloads such as **[REDACTED]**.

[8] The DHW values are modeled in FirstView independently of the actual metered water consumption of the building.

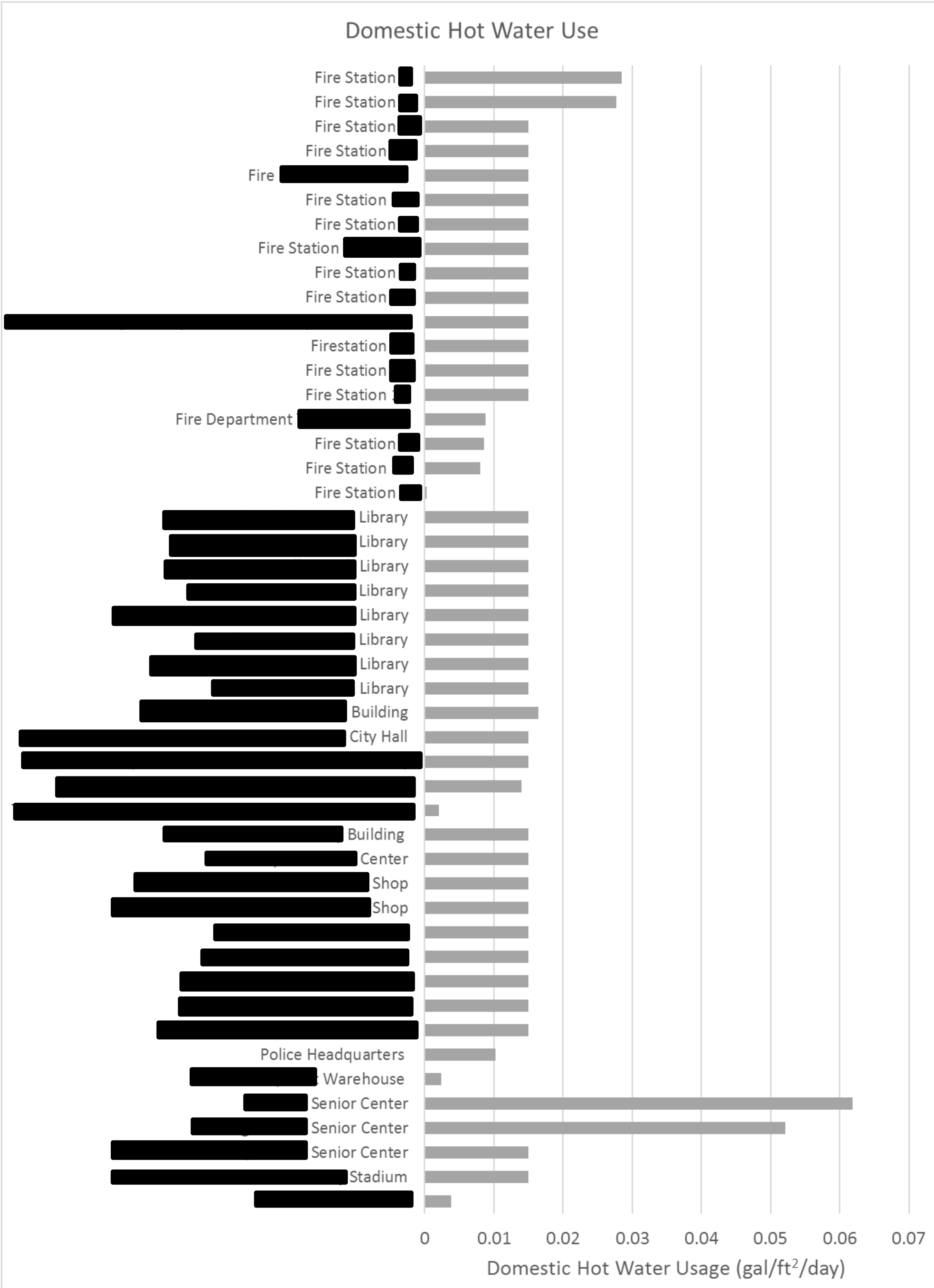

Figure 23: DHW Consumption - All Buildings

3.3.4 Shell and Ventilation Efficiency

As part of the inverse energy model, FirstView derives an aggregate UA value expressed in Btu/(°F*hr*ft^2). This UA value is an expression of the combined impact of envelope efficiency and ventilation efficiency, which, for this portfolio, is mostly a reflection of the heating efficiency. Buildings with a less efficient envelope, high outside air rates, or infiltration problems will have a higher UA value. Builidngs with a more efficient envelope and ventilation system should have a lower UA value.

The range of calculated UA values for this portfolio is presented in Figure 24. NBI's previous experience using FirstView to analyze hundreds of office and other buildings has shown that most buildings fall between 0.2 and 0.3. In this portfolio, almost all buildings exceed 0.3 UA. While many [REDACTED] buildings have evidence of poor shell and ventilation efficiency, the relatively mild [REDACTED] climate results in a lower heating load, which explains why heating accounts for only 37% of the overall energy use in the portfolio. The diagnostic flag for poor performers in this portfolio has been moved to a UA value of **0.5**. Beyond the 0.5 cutoff, there is a subset of facilities with especially poor performance, with a UA value above 1. These buildings should be investigated first, with an eye for over-ventilation and infiltration problems. These buildings are: **[REDACTED], [REDACTED], [REDACTED], [REDACTED], [REDACTED], [REDACTED], [REDACTED], and [REDACTED].**

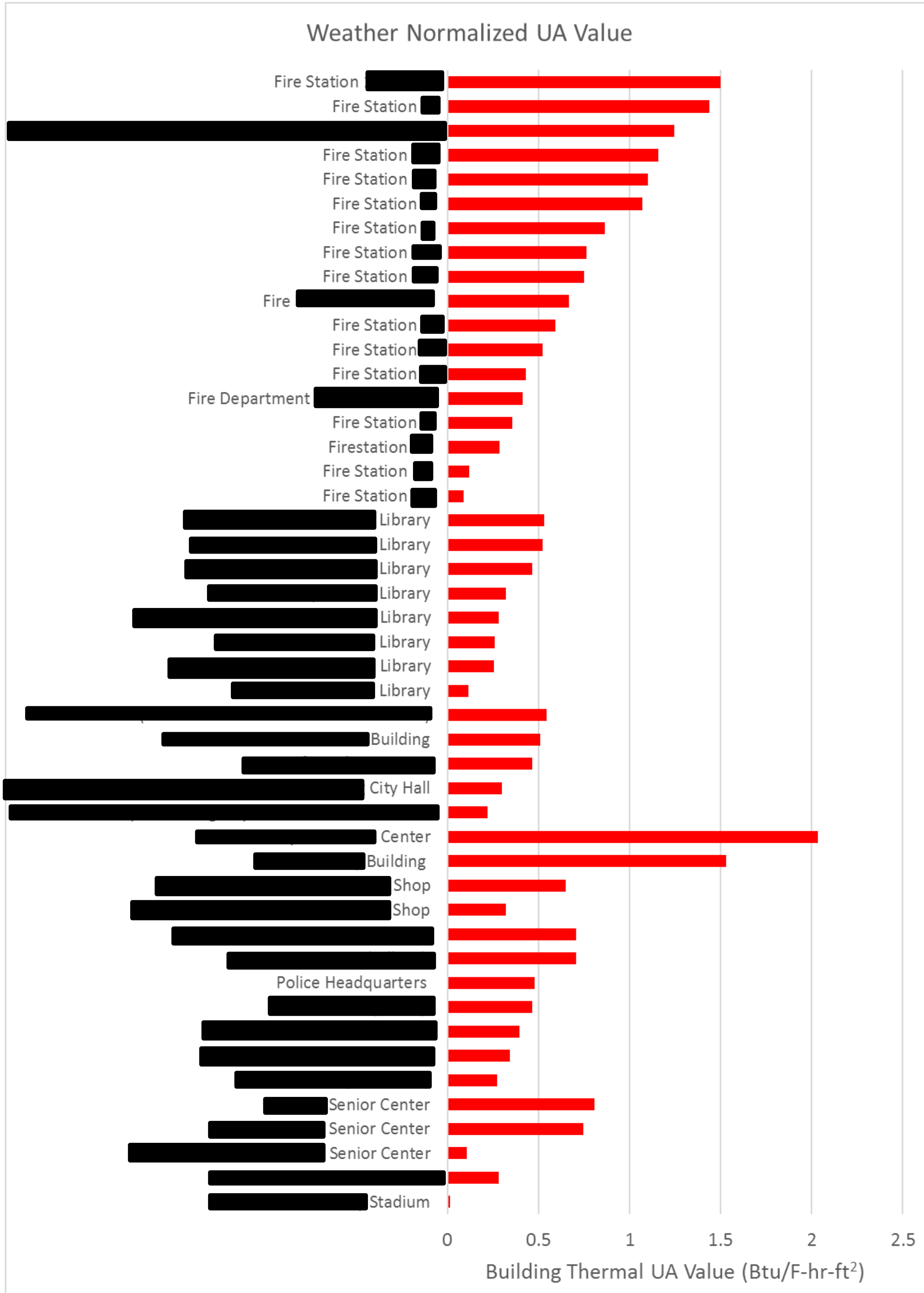

Figure 24: Aggregate Weather-Normalized UA Value - All Buildings

3.3.5 Diagnostics

A high level perspective of the detailed discussion above is given by a summary of FirstView diagnostics, presented in Table 4. However, it is important to note that the diagnostics for Occupant Load (Electric Baseload) and Shell & Ventilation Efficiency are derived from this dataset and will inherently be centered on "typical" values specifically for City of [REDACTED] buildings. In the case of Shell & Ventilation Efficiency, the observed values for nearly every building exceed the typical range for comparison buildings calculated during previous NBI studies; the thresholds were adjusted as noted in section 2.3.5. Automated diagnostics have been developed for office (and broadly similar) buildings; this should be taken into account when applying these diagnostics to buildings that are substantially different from office buildings.

As a reminder, the various diagnostics are defined as follows:

- **Occupant Load**: Estimated internal heat gain in the building due to people, lights, and plugs.
- **Shell and Ventilation Efficiency**: Winter weather dependent energy performance of the building, taking into account insulation, infiltration, ventilation rates, and HVAC heating efficiency.
- **Cooling Efficiency**: Summer weather dependent energy performance of the building, taking into account insulation, infiltration, ventilation rates, and HVAC heating efficiency.
- **Control Inefficiencies**: This estimates the concurrence of higher than expected heating and cooling loads, typically when the outside air temperature is between 50°F and 65°F.
- **Thermal Baseload**: Estimated energy usage attributed to domestic/service hot water and other temperature independent thermal loads.
- **Data Consistency:** Orderly building analyses have a model fit R^2 value of 0.9 or greater. Those analyses with an R^2 of less than 0.9 are flagged as irregular. This should be considered when interpreting the results and conclusions.

Table 4: Summary of FirstView Diagnostics

Building Name	Occupant Load	Shell and Ventilation Efficiency (Heating)	Cooling Efficiency	Control Inefficiencies[9]	Thermal Baseload	Data Consistency
Admin Building	High	Poor	Good	No apparent problems	High	Orderly
[REDACTED] Building	Low	Good	Good	No apparent problems	Typical	Irregular
[REDACTED] Senior Center	Low	Poor	Typical	No apparent problems	High	Irregular
[REDACTED]	High	Poor	Typical	No apparent problems	Typical	Orderly
Central [REDACTED]	High	Good	Typical	No apparent problems	Typical	Orderly
[REDACTED] Wastewater Treatment Plant	High	Good	Good	No apparent problems	Typical	Irregular

[9] Given that most control inefficiencies identified by FirstView stem from simultaneous heating and cooling, the lack of control inefficiency flags in this portfolio is likely due to low cooling loads (mild [REDACTED] climate) resulting in minimal evidence of cooling in these buildings.

[REDACTED] Stadium	Low	Good	Poor	No apparent problems	Typical	Irregular
[REDACTED] Library	Typical	Poor	Good	No apparent problems	Typical	Orderly
[REDACTED] Fire Department	Typical	Typical	Good	No apparent problems	Typical	Orderly
Fire Prevention Center	Low	Poor	Typical	No apparent problems	Typical	Orderly
Fire Station [REDACTED]	Typical	Poor	Good	No apparent problems	Typical	Orderly
Fire Station [REDACTED]	Typical	Poor	Typical	No apparent problems	Typical	Orderly
Fire Station [REDACTED]	Low	Good	Typical	No apparent problems	Typical	Orderly
Fire Station [REDACTED]	Typical	Poor	Good	No apparent problems	Typical	Orderly
Fire Station [REDACTED]	Low	Good	Typical	No apparent problems	Typical	Orderly
Fire Station [REDACTED]	Typical	Poor	Good	No apparent problems	Typical	Orderly
Fire Station [REDACTED]	Typical	Poor	Good	No apparent problems	Typical	Irregular
Fire Station [REDACTED]	Typical	Poor	Good	No apparent problems	Typical	Orderly
Fire Station [REDACTED]	Low	Poor	Good	No apparent problems	Typical	Orderly
Fire Station [REDACTED]	Low	Poor	Typical	No apparent problems	Typical	Irregular
Fire Station [REDACTED]	Typical	Poor	Good	No apparent problems	Typical	Orderly
Fire Station [REDACTED]	Low	Poor	Good	No apparent problems	High	Orderly
Fire Station [REDACTED]	Low	Poor	Good	No apparent problems	Typical	Irregular
Fire Station [REDACTED]	High	Poor	Good	No apparent problems	Typical	Orderly
Fire Station [REDACTED]	Typical	Poor	Good	No apparent problems	High	Orderly
Fire Station [REDACTED]	Low	Typical	Typical	No apparent problems	Typical	Orderly
Maintenance [REDACTED]	Low	Poor	Good	No apparent problems	Typical	Orderly
[REDACTED] Library	Low	Typical	Good	No apparent problems	Typical	Orderly
[REDACTED] Senior Center	Low	Poor	Typical	No apparent problems	High	Irregular
[REDACTED] Library	Low	Good	Typical	No apparent problems	Typical	Orderly
Fire Station [REDACTED]	Low	Poor	Typical	No apparent problems	Typical	Orderly
[REDACTED] Library	Low	Typical	Good	No apparent problems	Typical	Orderly

[REDACTED] Library	Low	Typical	Good	No apparent problems	Typical	Orderly
Municipal Services Center	High	Poor	Good	No apparent problems	Typical	Orderly
Parking Services Office	Low	Good	Typical	No apparent problems	Typical	Irregular
[REDACTED] Senior Center	Low	Good	Good	No apparent problems	Typical	Orderly
Police Headquarters	High	Poor	Typical	No apparent problems	Typical	Irregular
[REDACTED] Warehouse	Low	Poor	Good	No apparent problems	Typical	Orderly
[REDACTED] Library	Low	Typical	Good	No apparent problems	Typical	Orderly
[REDACTED] Building	Typical	Poor	Typical	No apparent problems	Typical	Orderly
[REDACTED] Library	Low	Typical	Typical	No apparent problems	Typical	Irregular
[REDACTED]	Typical	Typical	Good	No apparent problems	Typical	Irregular
[REDACTED] City Hall	Low	Typical	Typical	No apparent problems	Typical	Orderly
[REDACTED] City Hall 2	Typical	Typical	Typical	No apparent problems	Typical	Orderly
[REDACTED] Police Station	Typical	Poor	Good	No apparent problems	Typical	Orderly
[REDACTED] Police Station	High	Typical	Typical	No apparent problems	Typical	Orderly
[REDACTED] Police Station	Typical	Typical	Typical	No apparent problems	Typical	Orderly
[REDACTED] Police Station	High	Typical	Good	No apparent problems	Typical	Irregular
[REDACTED] Police Station	Typical	Poor	Typical	No apparent problems	Typical	Irregular
Traffic Signal Shop	High	Poor	Good	No apparent problems	Typical	Orderly
[REDACTED] Library	Low	Poor	Typical	No apparent problems	Typical	Irregular

4.0 FINDINGS AND RECOMMENDATIONS

The sections below summarize the findings of this report. Further discussion of each area is provided above, and detailed reports for each building are also attached.

4.1.1 Portfolio-Wide

A review of the 47 buildings studied in this portfolio indicates that heating and electric baseload together account for approximately 94% of the total energy use. These areas provide an opportunity for solutions that can be repeated across multiple facilities. Heating load savings can be targeted by improving building insulation and weatherization efforts, reviewing ventilation rates, equipment maintenance procedures, equipment repair or replacement, and control sequences including morning warm-up and overnight setbacks. There may be an opportunity at some sites to implement demand controlled ventilation strategies or heat recovery ventilation. Electric baseload can be targeted with lighting and plug load reduction programs, including traditional lighting retrofits as well as a review of scheduling and occupancy/daylight-based control solutions.

4.1.2 Total Energy Use

First, the **[REDACTED]**, though not a traditional building and therefore beyond the scope of this report, can offer the greatest energy savings. Efficiency measures addressing process and other loads at the plant are worth consideration given the large potential for savings.

[REDACTED] is another heavy energy user. Given that this is a stadium, major energy retrofits or other efficiency measures may prove challenging given the variety of end uses and occupant driven loads. Nevertheless, the high energy usage of this building warrants further investigation as cost-effective savings measures may be available. However, the [REDACTED] has substantial deferred maintenance backlog and the City's ability to make energy performance improvements to this facility may be constrained by competing budget demands. Energy retrofits would likely have a high return on investment.

The **[REDACTED]** is a high consumer and has a relatively high EUI (93 kBtu/ft^2/yr). For comparison, the average EUI for the other police stations in the portfolio is 63 kBtu/ft^2/yr. The large heating use and elevated electric baseload for this building should be a priority when further investigating the building for retrofit potential. However, electric baseload usage associated with 24/7 police functions and telecommunications equipment may be difficult to reduce.

The **[REDACTED]** is the next highest consumer. Although the EUI for this building seems low at 42, a typical warehouse in the same climate zone built to ASHRAE 90.1-2013 code standards is modeled as using 23.6 kBtu/ft^2/year[10]. Depending on how typical the usage patterns are for this building in comparison to other warehouses, significant savings may be available in the heating and electric baseload end-uses. Lighting upgrades, plug load controls, additional insulation and well as HVAC upgrades are potential avenues to address the majority of the energy usage.

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[10] Per Pacific Northwest National Lab (PNNL) modeling. Source: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-24043.pdf

Finally, the **[REDACTED]**[11] is another potential target for large total energy savings. This building has a relatively high EUI of 85 and is relatively large as well at 52,200 ft^2. For comparison, the EUI benchmarks from CBECS for office buildings are 67 for the year 2003, and 61 for the year 2012. A medium sized office building built to ASHRAE 90.1-2013 standards in this climate zone is modeled as using 44.6 $kBtu/ft^2/year$[10]. The elevated electric baseload for this building should be the first priority when further evaluating this building. Process loads, inefficient lighting, and other year-round end-uses may be targeted for savings.

4.1.1 Shell & Ventilation Efficiency

A significant number of buildings in the portfolio appear to show signs of inefficiency in their shell and ventilation system. The worst performers are: **[REDACTED], [REDACTED], [REDACTED], [REDACTED], [REDACTED], [REDACTED], [REDACTED], and [REDACTED].** These buildings should be investigated, with a focus on ventilation related inefficiencies. Excess outside air rates, poor control settings, high infiltration rates, and 24-hour fan schedules may be present. Demand controlled ventilation and heat recovery ventilation systems may provide significant savings. Lessons may be learned from the buildings with better shell and ventilation efficiencies, including: **[REDACTED], [REDACTED], [REDACTED]**, and **[REDACTED]**, as seen in Figure 24.

4.1.2 Electric Baseload

[REDACTED], [REDACTED], [REDACTED], [REDACTED], and **[REDACTED]** have higher electric baseloads than other buildings in the portfolio. These facilities should all be considered for measures that address: lighting power density, lighting controls, plug loads, and 24-hour fan operation. On the other end of the spectrum, **[REDACTED]** and **[REDACTED]** have the lowest baseloads, and perhaps can serve as examples of how baseloads can be reduced. This category is the most important to focus on for energy performance upgrades in this portfolio.

4.1.3 Gas baseload

The **[REDACTED]** and **[REDACTED]** have the highest thermal baseloads, several times that of the median building, and more than other senior centers in the portfolio. These buildings may be investigated to ensure that the DHW system is functioning properly including recirculation and DHW set point, to confirm that there are no gas-driven process loads, and to determine whether gas is used for HVAC reheat. Laundry equipment repairs or upgrades should also be investigated as a potential means of reducing gas consumption in these buildings.

4.1.4 Electric Heating

Several of the buildings had larger than typical increases in winter time electric use. The facilities are: **[REDACTED]** and **[REDACTED]**. These buildings should be reviewed to confirm that this pattern matches the expected behavior of their heating systems. If significant electric resistance heating is present, a switch to a heat pump or variable refrigerant flow solution may produce significant savings.

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[11] NBI has worked with the City of [REDACTED] to ensure we have accurate data for this building. Although this building is [REDACTED] and was carefully designed to minimize energy usage, the results from our analysis concur with the energy usage patterns seen in Portfolio Manager. The EnergyStar score for this building is 44, which further supports the energy performance conclusions for this building. Process loads, high ventilation, or other lab-driven energy usage may be responsible for the high energy consumption.

4.1.5 Top Candidates for Further Investigation (ASHRAE Level 2 Audits, Retro-commissioning and Retrofit)

The candidates for deep energy retrofits are those buildings with high overall energy use, relatively high energy use intensities, and multiple opportunities for energy savings across various end-uses. These buildings may offer the greatest amount of absolute energy savings to lower the portfolio wide energy use. These candidates have relatively high electric baseload energy use, which allows for a more targeted retrofit, further increasing the cost-effectiveness of the improvements. The next step for these buildings is to conduct a focused ASHRAE Level 2 energy audit. The top candidates are listed in Table 5.

Table 5: Top Candidates for Further Investigation (Retro-commissioning and Retrofit)

Building	Building Type	Size, ft^2	EUI, $kBtu/ft^2/yr$
[REDACTED]	Office	32,500	86
[REDACTED]	Senior Care Community	12,122	154
[REDACTED]	Office	52,200	83
[REDACTED]	Police Station	73,000	89

The **[REDACTED]** analysis came up with several diagnostic flags, including high thermal baseload, high occupant load (electric baseload), and poor heating and ventilation efficiency. These areas may offer the greatest savings to bring down the total energy use for this building.

The **[REDACTED]** is a very energy intensive building, especially when compared to other senior centers in this portfolio. The thermal baseload for this building is particularly high, which suggests that savings in hot water usage through improvements in efficiency may provide savings. The majority of the energy use for this building goes towards heating, which is another area to target for savings.

The **[REDACTED]** has a very high electric baseload, making up 87% of the building's energy use. Targeting this electric baseload will provide the most savings. Potential measures for savings include upgrades in lighting, plug load management, and reduced summer ventilation rates.

The **[REDACTED]** is one of the highest energy consumers in the portfolio of studied buildings. This building has both a high electric baseload and poor heating efficiency. Upgrades to the heating system, including ventilation rates and controls, should be further investigated. Lighting and plug load management may help bring down the elevated electric baseload.

4.1.6 Zero Energy Retrofit Candidates

On the opposite end of the energy usage spectrum, some candidates may have the potential for a Zero Net Energy (ZNE) retrofit. These buildings have low overall site EUIs, typically 50 or less, and with deep energy retrofits the buildings' EUIs might be reduced below 40 kBtu/ft^2/yr., in range with the great majority of ZNE buildings that NBI has observed. Figure 25 shows the energy performance of all the ZNE Verified, ZNE Emerging, and Ultra-Low Energy Verified buildings known by NBI as of October 2016.

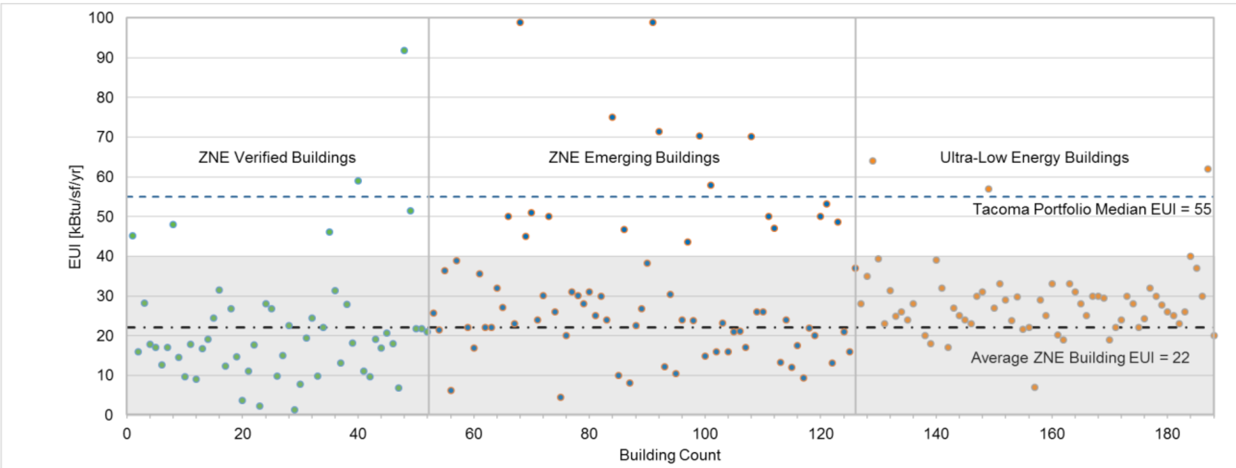

Figure 25: EUIs of Zero Net Energy and Ultra-Low Energy Buildings across North America[12]

By further improving the overall energy efficiency of these select buildings with coordinated deep energy retrofits, the buildings' energy usage could be reduced to a point at or below the available annual solar budget for the site (that is, the amount of energy that can be generated through on-site renewables over the course of one year). The potential to reach zero net energy depends on many factors, including the number of floors, potential savings via improvements in controls, HVAC equipment, as well as occupancy and building type. Figure 26 illustrates the steps on the way to a ZNE retrofit (source: The Miller-Hull Partnership, LLP).

[12] ZNE - Verified: Buildings which NBI has verified to have reached net zero energy performance over the course of a year

Ultra-Low Energy - Verified: Buildings which NBI has verified to have significantly reduced energy consumption over typical buildings

ZNE - Emerging: Buildings with a stated goal of reaching net zero energy performance, but have not yet reached a year of verified net zero performance which has been verified by NBI

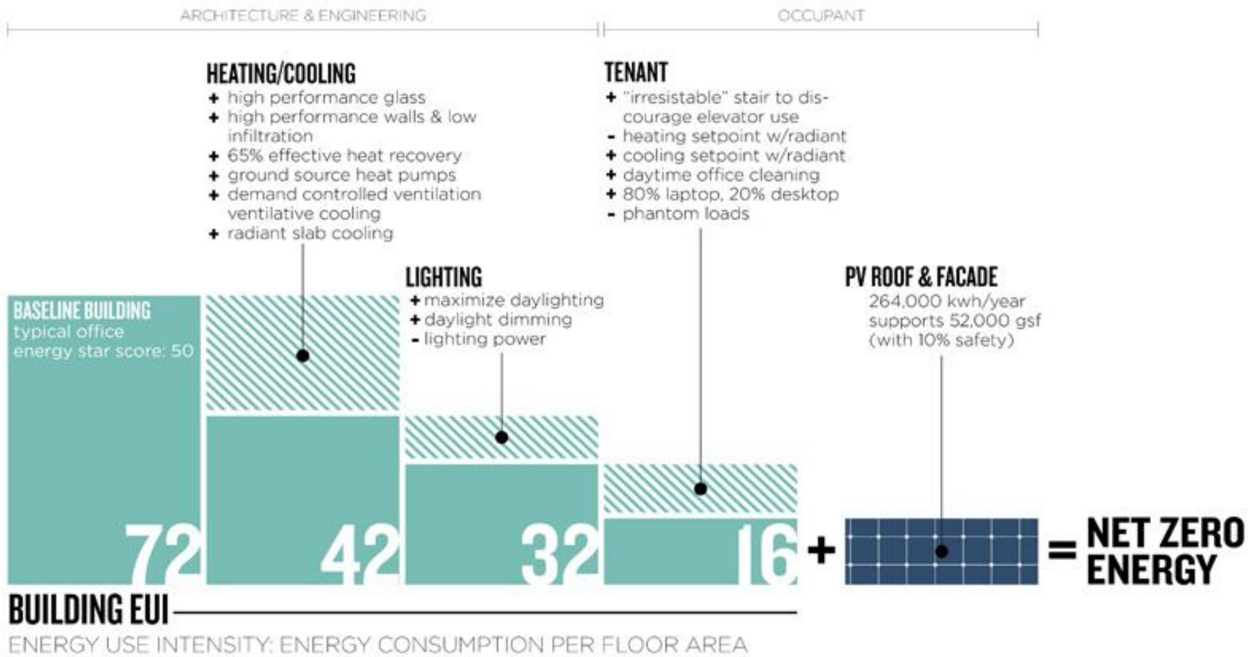

Figure 26: The Path to a Zero Net Energy Building

Reaching ZNE has benefits beyond energy savings, and many municipalities have established climate action plans and emission and energy usage targets. ZNE buildings have the potential to influence future projects and policy, while establishing an energy and financial case for forward thinking buildings. When considering ZNE retrofits it is critical to focus first on passive systems, energy load reductions, and energy efficiency, and only then layer in renewables (e.g. onsite solar PV panels) to offset the reduced energy needs of the building. Table 6 below highlights the top ZNE retrofit candidate buildings. In some cases, the available onsite roof or other area may not be enough to reach ZNE alone, and community solar or similar options should be considered. Finally, when installing onsite renewable energy systems, it is important to retain or retire the Renewable Energy Credits (RECs) to avoid double-counting of environmental benefits and maintain the ability to claim ZNE.

For the [REDACTED] buildings studied in this report, several candidates emerged as potential ZNE retrofit candidates. The buildings we are recommending are relatively small and have high onsite solar potential. ZNE retrofits on these buildings may provide learning experiences in a low-stakes format on simpler buildings. Once the city has some experience retrofitting smaller buildings to net zero, the city can achieve impacts by focusing on larger, more complex buildings with higher energy usage.

In this case, ZNE candidates are buildings with a low starting EUI (<40) and a solar PV budget that is near or that exceeds the annual consumption. Solar PV budgets are roughly estimated[13] based on available roof area, location, orientation, and roof angle. Generally, low-rise buildings with open roof plans and few shading obstructions have the best solar budgets. Table 6 below includes the top candidates for ZNE retrofit based on our initial analysis.

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[13] http://www.solarroofcalculator.appspot.com/

Table 6: Potential Zero Net Energy Retrofit Candidates

Building	Building Type	Size, ft^2	EUI, kBtu/ft^2/yr.
[REDACTED]	Library	15,487	26
[REDACTED]	Senior Care Community	3,806	27
[REDACTED]	Library	7,475	31
[REDACTED]	Library	9,586	33

The **[REDACTED]** has the one of the lowest energy usages of this portfolio and a flat roof which would be ideal for a PV system installation. With minor energy retrofits to drive down usage further, net zero energy may be well within reach for this building.

The **[REDACTED]** has a low EUI and a favorable building shape with a small floor area ratio. A further study of solar availability taking into account the trees on site will show how feasible reaching net zero is for this building. The parking lot area could also be used to install a canopy PV system as a way to expand the available space for renewable energy.

The **[REDACTED]** is a single story building with a flat roof with minimal existing equipment. With minor retrofits (daylighting, plug load controls, etc.) and a PV system installation, this building has the potential to reach net zero energy.

The **[REDACTED]** has an expansive flat roof and relatively low base energy usage. With minor energy retrofits to reduce energy consumption, there may be enough space on the roof for PV panels to reach net zero energy.

4.1.7 Next Steps: The Path to Better Facilities

The results of this analysis with the FirstView tool suggest a number of next steps that the City of [REDACTED] should consider in its strategic approach to energy improvement across its portfolio of municipal buildings.

Audits or Upgrades. The buildings highlighted in this report can be targeted for audits or upgrades as recommended in the body of this report. The actual actions taken as a result should be tracked as part of an overall evaluation of impacts. It would be instructive to re-analyze buildings that have taken steps to reduce their energy consumption a year or more after those steps have been implemented.

Ongoing Benchmarking. In addition, the [REDACTED] team recommends that the City of [REDACTED] continue and expand its efforts for ongoing tracking of building energy performance using the Maalka platform. Within the Maalka platform, [REDACTED] has been given the tools to set goals aligned with their initiatives and collaborate with building stakeholders in an ongoing basis. It also allows the City's sustainability program to continue to evolve and expand by allowing the addition of more data streams as they become available and to instantly assess the impact of specific improvements added to their buildings or portfolio.

Ongoing benchmarking is critical to having a strategic approach to energy management. This enables the City to evaluate its performance against its goals. [REDACTED]'s initial goal of reducing energy use in municipal facilities by [REDACTED] is probably conservative and worthy of reevaluating based on a comparison of these results to a 2014 baseline. This ongoing information is also critical to providing analytical continuity. The City can use this information to leverage the commitments made by departments and empower continuous improvement of building performance across the municipal buildings portfolio.

Goal Setting. Based on the comparison of [REDACTED]'s 2014 baseline results, a next step in the strategic energy management process is to conduct a goal setting session and create a plan for targeted field analysis and implementation. [REDACTED] could use either the Better Buildings Challenge (BBC) or Architecture 2030 framework, as they are ready for implementation. Under the Architecture 2030 framework, the City would be set a goal to be 20% better than the National Average, which has a Zero Energy Performance Index (zEPI)[14] score of 80. The BBC framework would set a goal of 20% improvement (or 10%, reflecting the City's current goal) relative to the City's baseline, rather than the national average.

[14] The Zero Energy Performance Index (zEPI) is a normalized rating scale centered on 0 (net zero energy performance). A score of 100 represents an average year 200 building performance. Negative scores indicate net energy generation.

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