2020

Building energy efficiency retrofit prioritization: A case study of the Iowa Army National Guard

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Building energy efficiency retrofit prioritization: A case study of the Iowa Army National Guard

by

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A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Mechanical Engineering

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Iowa State University

Ames, Iowa

2020

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NOMENCLATURE

B_1	Benchmark 1
$B_{1,dx}$	Benchmark 1 of buildings with building designation of building *x*
B_2	Benchmark 2
$B_{2,dx}$	Average EUI of all buildings for the building designation of building *x*
B_3	Benchmark 3
$B_{3,dx}$	Benchmark 3 of buildings with building designation of building *x*
B_4	Benchmark 4
$B_{4,dx}$	Value of Benchmark 4, 42.48 MBtu/SF
$B_{i,x}$	Benchmark *I* value of building *x*
E_x	EUI of building *x*
EUI	Energy Use Intensity
IEWP	Installation Energy and Water Master Plan
IAARNG	Iowa Army National Guard
MVSB	Motor Vehicle Storage Building
P_x	Priority level of building *x*
X	Building Name

ACKNOWLEDGMENTS

I would like to thank my major professor, Dr. Song-Charng Kong, and my committee members, Dr. Mark Mba-Wright and Dr. Kristen Cetin for their guidance and support throughout the course of this research. I also thank Dr. Anne Kimber for her guidance and support during this project.

In addition, I would also like to thank my friends, colleagues, the department faculty and staff for making my time at Iowa State University a wonderful experience.

I am grateful to Mr. Ken Thornton of the Iowa Army National Guard for his assistance with this research. Financial supports by the Iowa Army National Guard and Iowa State University's Electrical Power Research Center are greatly appreciated.

Finally, I want to thank my family for being the foundation of support that has continually allowed me to grow and improve.

ABSTRACT

The Iowa Army National Guard (IAARNG) is required to complete an Installation Energy and Water Master Plan (IEWP). Part of the IEWP is an analysis of their energy systems, actionable plans to reach energy use goals, and a method to evaluate the successfulness of these plans. This research presents and develops a method to identify key buildings for energy retrofits and provides a format to evaluate IAARNG's efforts in energy consumption reduction.

Each building at IAARNG is categorized based on use. This categorization allows for the energy consumption of each building to be compared to similar buildings. In this research, four benchmarks are used to evaluate the energy use intensity (EUI) of each IAARNG building. These benchmarks compare each individual EUI to the Average IAARNG EUI of the same category, the median EUI of all buildings of the same category. The five priority levels are none, low, medium, high, and critical, and can be used to identify which buildings that energy retrofits will be the most effective on. This research uses the priority system to compare 2017 and 2019 energy consumption at IAARNG. From 2017 to 2019 the number of critical priority buildings increased from 50 to 63, the number of high priority buildings went down from 46 to 43 buildings, the number of medium priority buildings went down from 38 to 29, the number of low priority buildings went down from 36 to 42, and the number of none priority went down from 80 to 59 buildings. By performing the analysis each year, IAARNG is able to evaluate the effectiveness of their current efforts in reducing EUI. The analysis also identifies building that are performing poorly, which gives IAARNG direction and focus for future efforts.

CHAPTER 1. INTRODUCTION

1.1 Motivation

By the end of August 2020, the Iowa Army National Guard (IAARNG) is required to create an Installation Energy and Water Plan (IEWP). This plan is extremely important to each state's national guard as it is a collection of all information related to their energy and water systems. This information includes energy and water assets, purchase agreements, consumption data, goals, improvements plans, etc. The plan also serves as a way to evaluate the strengths and weaknesses of IAARNG's energy and water systems.

IAARNG is particularly interested in increasing the resiliency of their energy and water systems. Resiliency is the ability to recover quickly from difficulties or to resist these difficulties. In the context of energy and water, this could be a partial or total disruption of services. It is important for IAARNG to have a high resiliency because they act as first responders to large scale disasters, both intentional or unintentional, within the United States. If IAARNG is struggling to recover from a disaster, they will not be able to assist other essential entities in their recovery efforts. IAARNG must be ready for large scale disaster, but these do not occur often, hopefully, and so they are also concerned with efficiently running operations.

A major way to make operations run more efficiently is by increasing energy and water efficiency. Increasing energy and water efficiency will lower the consumption of energy and water for IAARNG, and consuming less of a resource is one way to increase the resiliency of a system that uses that resource. However, consuming less also leads to lower costs for running their energy and water systems. IAARNG can, and often does, reinvest this saved money into other efficiency upgrades or other projects. The scale of IAARNG operations and facilities leads to a large number of projects and goals, so one purpose of the IEWP is to organize, execute, and evaluate these goals and projects. By organizing this all into one space, it helps prevent redundant plans, loss of plans, or undertaking multiple plans that have to real impact or progress towards any goals. The evaluations will serve as a guide for future efforts at IAARNG or other National Guards. Finally, by collecting all of this information in one space, IAARNG will have a much easier time identifying particular weaknesses and strengths their systems have. This in turn will allow IAARNG to expand on their strengths and develop action plans to address their weaknesses.

1.2 Objective

The objective of this research is to improve on the current methods of IAARNG for identifying key buildings to undergo more specific energy efficiency retrofits. Currently IAARNG only identifies buildings with high energy consumption values, and does not consider the use of the building. An improvement can be made by taking into account the use of a building and the typical energy consumption rates of this type of building. This research expands on this idea, and evaluates each individual building's energy consumption intensity compared to similar buildings across the installation and the nation. This research then semi-automates this process, so IAARNG can evaluate the effectiveness of their projects and action plans on energy consumption intensity and continually identify buildings with poor energy consumption performance.

CHAPTER 2. BACKGROUND AND LITERATURE REVIEW

2.1 Energy and Water Plan at IAARNG

Currently the IAARNG has minimal methods for prioritizing buildings for retrofits and evaluating the implemented retrofits. IAARNG underwent a comprehensive energy and water evaluation (CEWE) by the Pacific Northwest National Laboratory (PNNL) that looked at energy and water usage in all IAARNG federal buildings. They used the CEWE to identify building retrofits for each building. There was no prioritization to which retrofits should be performed first. The CEWE does give a cost analysis, which can be used to assign priority, but by not assigning priority itself, another analysis is needed to reach this point. IAARNG also looks at their top five and bottom five performing buildings, but only these in their yearly report on energy use. They do not take into account the relative consumption of each building type in their considerations. Finally, IAARNG does not have a particular way to evaluate their executed action plans. They look at the overall effect of their action plans, but have no standard way to evaluate the individual ones.

2.2 Plans at Other National Guards and Military Installations

The New Jersey Army National Guard (NJARNG) does less than IAARNG in their Energy and Water Master Plan [1]. They only look at the most recent year's energy and water consumption. They breakdown energy consumption by month and by energy type, but do not go into specific building type nor building energy consumption.

It is a similar case with the Redstone Arsenal [2]. They breakdown energy consumption both yearly and monthly by energy type, but they do not breakdown individual building energy consumption. There is also no mention of evaluation methods in their Comprehensive Energy and Water Master Plan.

2.3 Literature Review

The literature of energy and water efficiency and retrofits is large, with many different focuses. The literature review of this research focuses on the selection of energy retrofits and different methods for prioritizing what efforts are done. Most of the literature review also contains case studies for the proposed methods of prioritization. This gives context for the effectiveness of the methods proposed by each author.

Tan et al.[3] Looks at creating an analytical approach to select building level, energy retrofits that take into account financial and environmental impacts. They use a mathematical model to select an optimized set of retrofits using budgetary and logistical constraints, and their research was done as a case study at Boğaziçi University Kilyos Campus, where they were set with "maximizing the environmental benefits within a given budget". Baris et al approaches this task in both a single-period scope, where they implement everything at once, and in a multi-period scope, where they implement retrofits periodically at different periods. This allows them to further optimize the implementation of retrofits.

Kolokotsa et al. [4] looks specifically at the decision methodologies for energy efficiency improvements within buildings. These methodologies include discrete decisions when a finite number of actions are considered, simulation based approaches, multi-criteria approaches, and various combined approaches. They discuss the relative strengths and weaknesses of each approach, and it ultimately boils down to the best approach is based on the number and complexity of buildings and approaches being considered.

Shao et al [5] create a model to optimize multi-criteria decision making for energy retrofits, and use an existing office building in Germany as a case study. One purpose behind their approach was to take into account many different viewpoints from different stakeholders with often very different criteria for success. Their process starts by identifying and subsequently quantifying stakeholders' needs as inputs into an automated modular analysis and optimization model. While their approach needs the designers to organize and gather inputs from each stakeholder in each separate project, this also allows for their approach to be applied in many different scenarios.

Jafari and Valentin [6] create a decision-making model for energy retrofitting that calculates their benefits based on reduction of the life-cycle cost, and not just on initial cost. This study separates itself from other similar studies by looking more comprehensively at the economics and total life-cycle cost behind the energy retrofit projects than other researchers, and its purpose is to assist homeowners in planning their energy retrofits. They categorize their retrofitting measures into, controlling measures, load reduction measures, enveloping measure, renewable energy technologies, and human behavior. The authors use a combination of dynamic and static building modeling to overcome the weaknesses each method has. Finally the results of this research is a decision-making framework that optimizes the budget and measures for retrofitting a home.

Jarari and Valentin expand on the previous decision making model in a later paper [7] that expands on this matrix and applies it to different decision-makers and investors within energy retrofitting projects. This research differs from the previous paper in that it heavily considers the benefits to the investors and decision-makers. There is also a greater emphasis on the particular benefits which range from economic to environmental and even social benefits.

Kaklauskas et al [8] develop a method of multiple criteria complex proportional assessment (COPRAS) for energy retrofits for a particular customer. In particular they are looking at the most cost effective windows to replace old windows. With this particular application, the authors spend time discussing the criteria and the subsequent weight of each criteria in their decision making process and how their process can have a high level of precision in the assessment of the needs of a customer or stakeholder.

In their study [9] Kumbaroğlu and Madlener introduce a method for finding an optimized set of energy retrofits. Their method includes four modules which include: data compilation module, a building energy performance evaluating tool, potential retrofit option, and an economic evaluation. They go onto address energy price uncertainty and other common difficulties such as irreversibility of retrofits and split incentives in their analysis of optimal retrofits. Their analysis combines both static and dynamic evaluation methods in an effort to reduce any difficulties and gaps in their analysis.

Karmellos et al. [10] in their paper develop a model for the prioritization of energy efficiency measures in new buildings, buildings under construction, and existing buildings. They prioritize energy efficiency measures based on energy consumption and investment cost using a generic methodology in an effort to develop a tool to be applied in other scenarios. Their paper expands on previous models by taking into account lighting, appliances, and renewable energy sources.

The majority of the literature surrounding the prioritization of building energy retrofits is concerned with building specific retrofits and prioritizing these measures. However, there is considerably less that is concerned with the prioritization of the buildings to undergo energy retrofits. The main focus of this research is to fill this void of research with a methodology for selecting buildings to undergo retrofits.

CHAPTER 3. METHODOLOGY

IAARNG has a system for analyzing data and prioritizing energy solutions in buildings, however this approach leaves room for improvement in data processing and display. This research expands on the methods used at IAARNG to assess retrofit prioritization in buildings, and it can also be used to evaluate the effectiveness of the retrofits performed using IAARNG's yearly building energy data.

3.1 Data Collection

The data used in this research comes from IAARNG's existing energy data. IAARNG has attached smart energy meters to most of their buildings that read electrical energy use and natural gas energy use. Some buildings are grouped together on the same meter, and all of these data are then entered into an application called B3 Benchmarking Iowa. The data is semi-manually entered into the application, and this manual entering can cause a few issues. First, some data such as building use or type can be incorrectly entered. However, this is very rare as IAARNG has gone through this database on several occasions to update this information. The other issue is that the data is not always updated to the most recent month. This causes a delay in the evaluations of recent retrofits efforts.

B3 Benchmarking Iowa is a powerful energy management tool that can track and store large amounts of data. However, only three categories of data were used in this research. The first two categories, Site name and Designation, were used to identify and categorize each building at IAARNG. The final category of data selected is labeled as "Actual (MBtu/SF)" which is referred to as Energy Use Intensity (EUI) in this report. EUI is the measure of Mega-British Thermal units energy consumed, both electric and natural gas, per square foot of building. This is the standard unit used at IAARNG for discussing energy consumption, and it allows a comparison between buildings of different sizes. The data were selected over two year-long time periods. The two years that were selected in this research had available energy consumption data for 95% of IAARNG buildings. The first year is from October 2016 through September 2017 and is referred to as “2017”. The second year analyzed is from July 2018 through August 2019 and is referred to as “2019”. The difference in the start and end month does not have a large impact on the results of this experiment because a full year of data is still included in each dataset, and the focus of this project is developing a new method of analysis and evaluation. If this research were expanded to a continuous analysis, a standardization of years would be implemented. Higher data resolution could also be used to compare energy usage between months in specific buildings and further refine their prioritization process. However, this is outside the scope of this research.

The analysis in this research is done using Microsoft Excel. This is done for a number of reasons. First, B3 Benchmarking Iowa allows users to download different categories of data into the Microsoft Excel files, so there is no need to transform or change any of the data. Secondly, IAARNG is particular with the programs and formats that they use and is often resistant to changing these programs. Microsoft Excel is widely used at IAARNG and keeping the data and analysis within Microsoft Excel eliminates any issues with using different programs and software. Finally, the simplicity of Microsoft Excel makes the analysis done in this research accessible to more people. This will allow IAARNG to have non-experts perform any future analysis. In this research, buildings with no energy consumption were not considered because they have no priority for energy efficiency efforts. There is one major outlier, Knoxville MVSB, which has an EUI that is significantly higher than any other building at IAARNG. It is included within this research and assigned a priority level. However, a case without the Knoxville MVSB is also considered to give a better visualization of the state of the other conditioned warehouses.

3.2 Data Analysis

The approach this research takes is to compare the EUI of each building to four EUI benchmarks and assigning a priority level to the buildings analyzed. A simple flowchart for the analysis is shown in Figure 1 below.

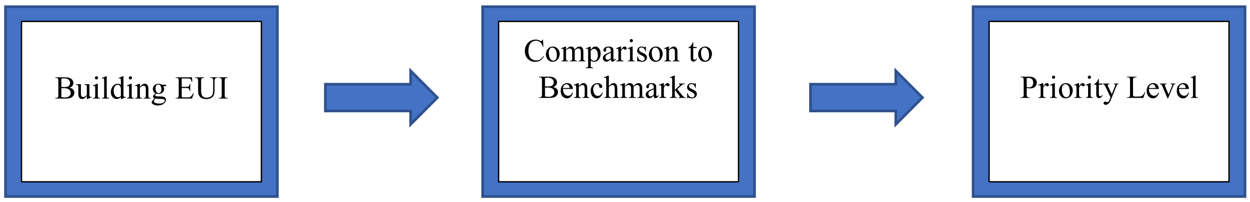

Figure 3.1. Flowchart of Assigning Priority Level

Each benchmark was selected because they can be used to evaluate the performance of a particular building from different perspectives. By combining all four benchmarks into one analysis, a more comprehensive analysis can be done. A point system categorizes each building into priority groups based on the number of points "awarded" to the building. The five levels of priority from lowest priority to highest are: None, low, medium, high, and critical. The point values and the corresponding level of priority can be seen in Table 1 below.

Table 3.1. Point Value of Each Priority Level

Priority Level	None	Low	Medium	High	Critical
Points	0	1	2	3	4

The points are "awarded" to a building each time its individual EUI is above one of the four benchmark EUIs. Benchmark one (B_1) is the average EUI for a specific building type within the IAARNG facilities. The purpose of B_1 is to identify buildings that are performing poorly in comparison to the other buildings within a building category. However, B_1 is heavily affected by outliers, such as the Knoxville MVSB. That is why benchmark 2 (B_2) is the median EUI value for a specific building type within the IAARNG facilities. B_2 also identifies buildings that are performing poorly in comparison to similar buildings, but it is less affected by outliers. However, B_2 only gives limited statistical information. By combing B_1 and B_2 we are able to compare the performance of a specific building to other similar buildings within IAARNG. Benchmark 3 (B_3) is the Site EUI, which is the national median EUI for that specific building type. This value comes from the government's Energy Star program [11]. B_3 serves as a comparison between IAARNG buildings and similar buildings across the United States. Not all IAARNG buildings have a value in this category, so their value is set at 0. This does potentially lower their priority level, but poorly performing buildings will still be in a high priority level because of the other benchmarks. Finally, benchmark 4 (B_4) is the IAARNG goal average EUI by 2025. This value serves as the final goal for all of the buildings to reach, and identifies buildings not yet below this consumption value. B_4 can be used independently to identify buildings that are bringing the average EUI of IAARNG above the desired level, and thus focusing energy efficiency efforts for IAARNG. However, this would defeat the purpose for the other three benchmarks. A summary of the benchmarks is below in Table 2.

Table 3.2. A Summary of the Benchmarks.

Benchmark	**Description**	**Use**
B_1	IAARNG Average EUI for building type	Identifies buildings performing poorly compared to other IAARNG buildings.
B_2	IAARNG Median EUI for building type	Identifies buildings performing poorly compared to other IAARNG buildings.
B_3	National median EUI for building type	Identifies building performing poorly compared to similar buildings nationally.
B_4	IAARNG average EUI goal	Identifies buildings not yet at IAARNG average EUI goal.

3.2.1 Calculating Priority

The following equations are how the benchmark are compared to the individual buildings as well as how the priority is assigned.

$$P_x = \sum_{i=1}^{4} b_{i,x} \tag{3.1}$$

$$b_{1,x} = \begin{cases} 0 & B_{1,dx} > E_x \\ 1 & B_{1,dx} < E_x \end{cases} \tag{3.2}$$

$$b_{2,x} = \begin{cases} 0 & B_{2,dx} > E_x \\ 1 & B_{2,dx} < E_x \end{cases} \tag{3.3}$$

$$b_{3,x} = \begin{cases} 0 & B_{3,dx} > E_x \\ 1 & B_{3,dx} < E_x \end{cases} \tag{3.4}$$

$$b_{4,x} = \begin{cases} 0 & B_4 > E_x \\ 1 & B_4 < E_x \end{cases} \tag{3.5}$$

P_x = Priority level of building *x*

$B_{i,x}$ = Benchmark *i* value of building *x*

$B_{1,dx}$ = Benchmark 1 of buildings with building designation of building x

$B_{2,dx}$ = average EUI of all buildings for the building designation of building x

$B_{3,dx}$ = Benchmark 3 of buildings with building designation of building x

$B_{4,dx}$ = Actual value of Benchmark 4 = 42.48 MBtu/SF

X = Building Name

E_x = EUI of building *x*

The methodology introduced in this research improves on current efforts in a number of ways. First, it identifies individual buildings within a group of buildings for retrofits. This gives decision makers direction for their focus. By improving this focus, the most efficient changes can be made to lower the overall EUI of IAARNG.

Second, the simplicity of the analysis allows for future analysis to be performed without too much inconvenience or issue. By continually performing this analysis, it is possible to evaluate the effectiveness of the retrofits implemented. While this approach does not lend to evaluating individual efforts, it is very adept at evaluating groups of efforts over a given timespan.

Finally, this research fills a gap within the academia. It focuses on identifying which buildings are the best and worst performing in terms of EUI, and using this as an identifier for the buildings that will have the largest impact on overall EUI when energy efficiency efforts are implemented. Using this method in combination with the other methods listed in the literature review will allow for highly efficient and effective energy retrofit decision making and implementation.

CHAPTER 4. RESULTS

4.1 Building Priority Levels

In 2017 IAARNG had 50 building at critical priority, 46 buildings at high priority, 38 buildings at medium priority, 36 at low priority, and 80 buildings at none priority.

In 2019 IAARNG had 63 buildings at critical priority, 43 buildings at high priority, 29 buildings at medium priority, 42 buildings at low priority, and 59 buildings at none priority. The number of buildings in each priority level from 2017 to 2019 are shown in Fig. 2, and Table 3 shows the color designation to be used for each priority level. Finally, Fig. 3 to 40 use this color designation to show the priority level of each building in a specific building designation in both 2017 and 2019.

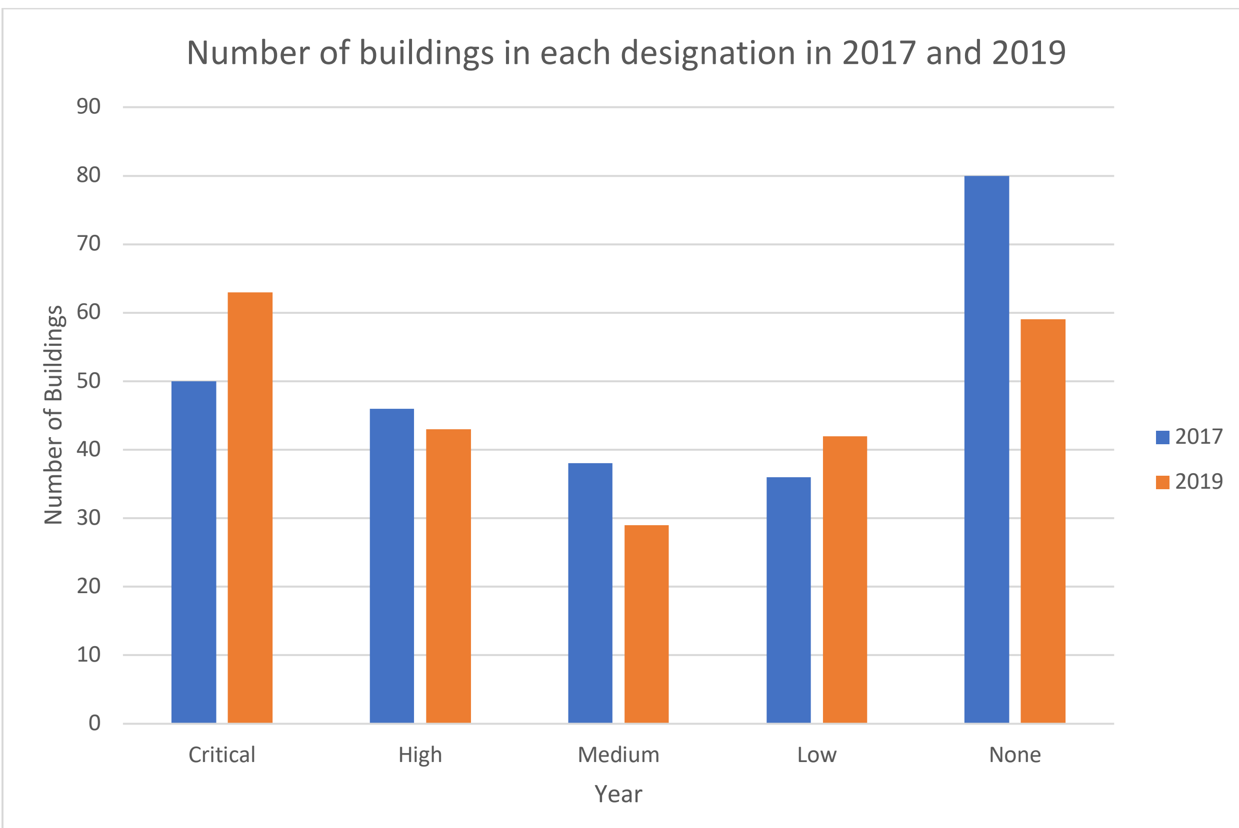

Figure 4.1. Number of buildings in each designation in 2017 and 2019

Table 4.1. Color Designation of Priority Levels

Color	Priority Level
Blue	None
Green	Low
Yellow	Medium
Orange	High
Red	Critical

IAARNG has downsized the number of buildings on the installation. They removed the Davenport AFRC before 2017, but it was finally removed from B3 by 2019. This deflated the priority level of the Des Moines Armory from high to medium from 2017 to 2019.

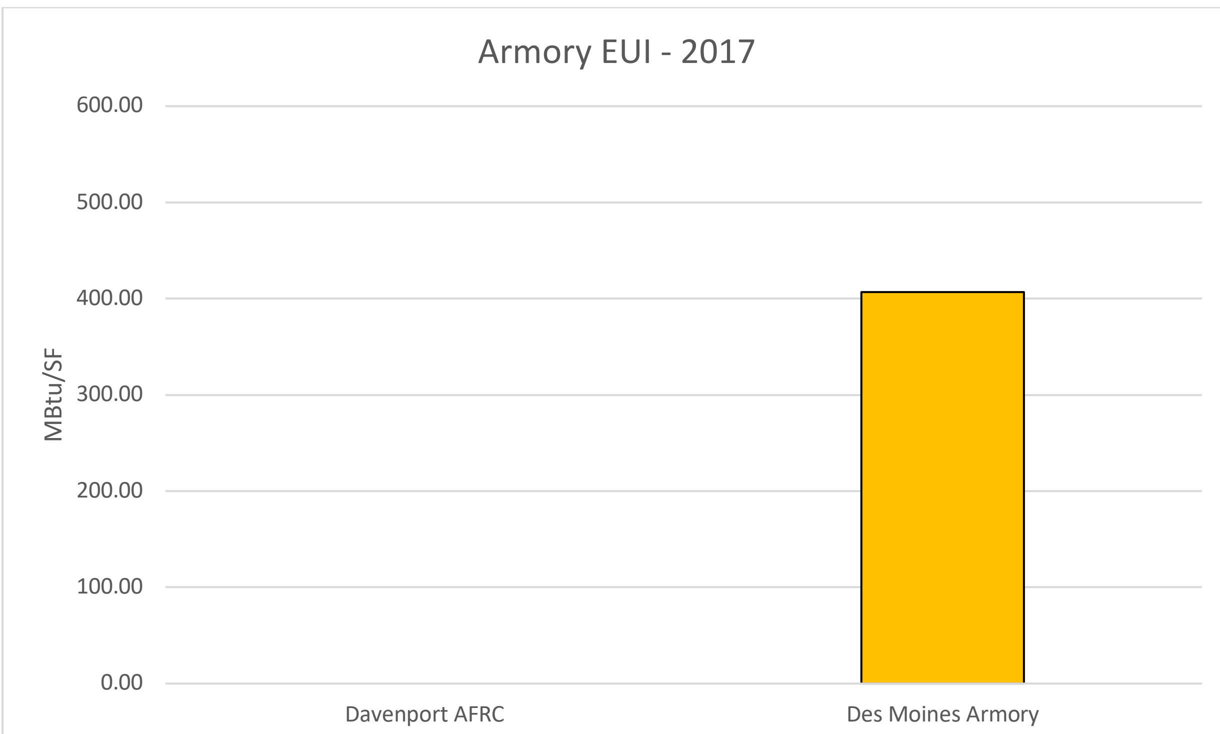

Figure 4.2. Armory EUI Priority Level Breakdown 2017

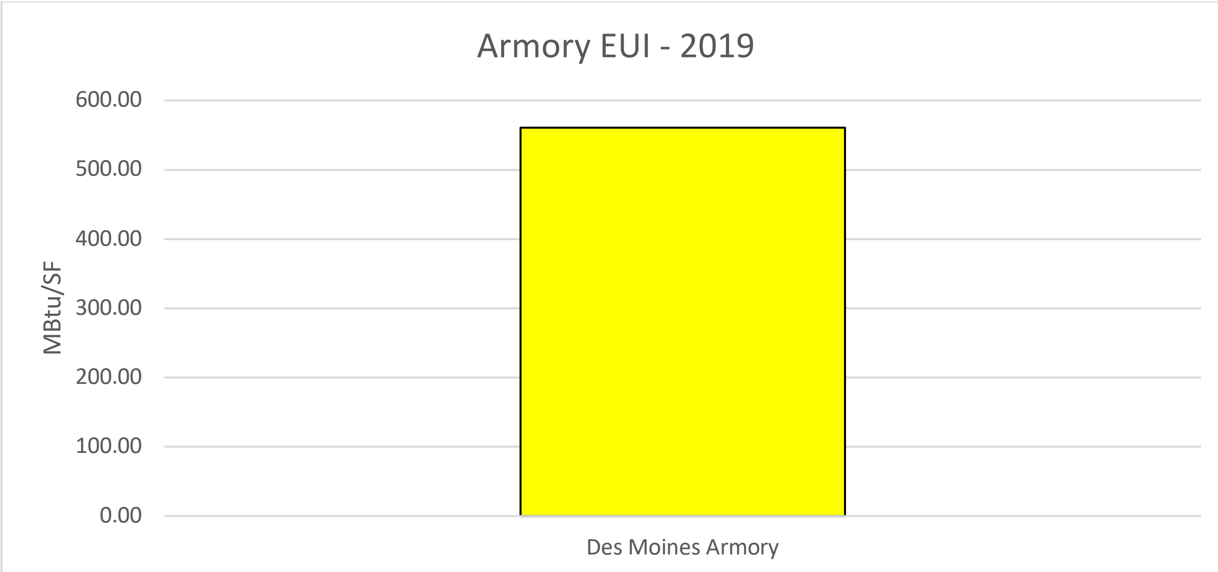

Figure 4.3. Armory EUI Priority Level Breakdown 2019

From 2017 to 2019 the IAARNG auditoriums switched which priority they were at. However, the combined EUI went up 23.98 MBtu/SF.

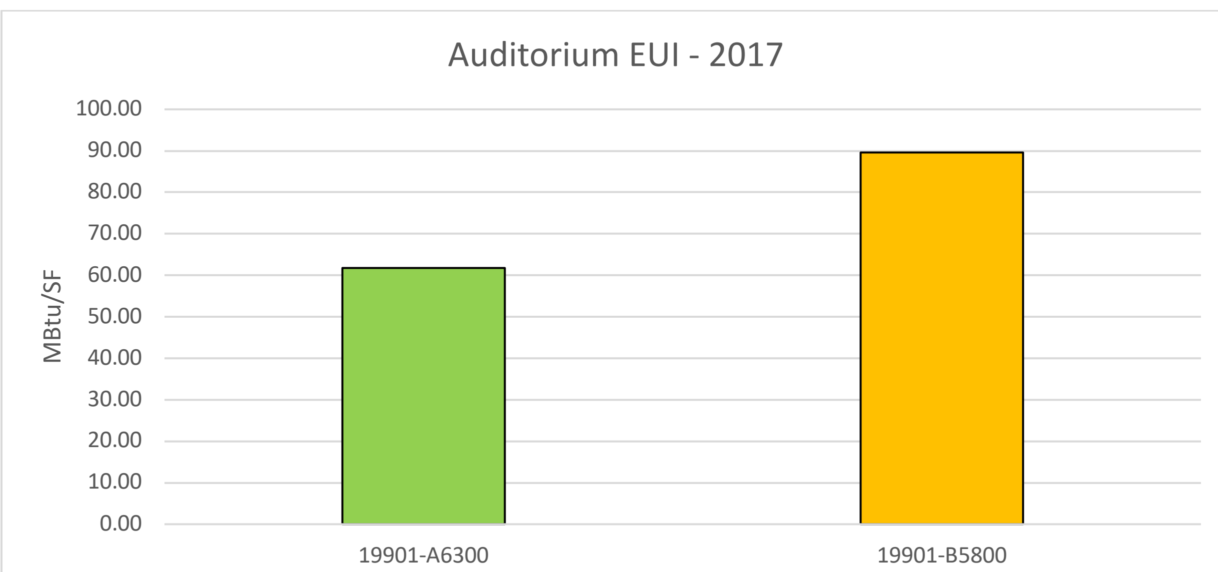

Figure 4.4. Auditorium EUI Priority Level Breakdown 2017

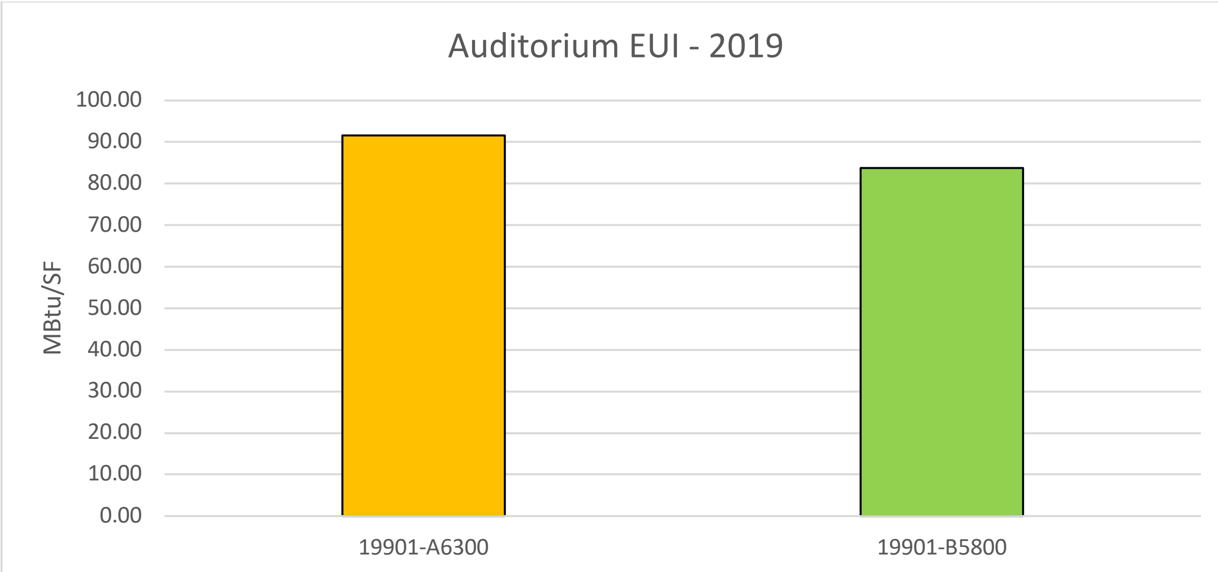

Figure 4.5. Auditorium EUI Priority Level Breakdown 2019

From 2017 to 2019 there was one less college classroom in the B3 application. There is also a shift in the number of buildings in each priority level. There are two less critical priority buildings, four more high priority buildings, one less medium priority building, one less low priority buildings, and the same number of none priority buildings.

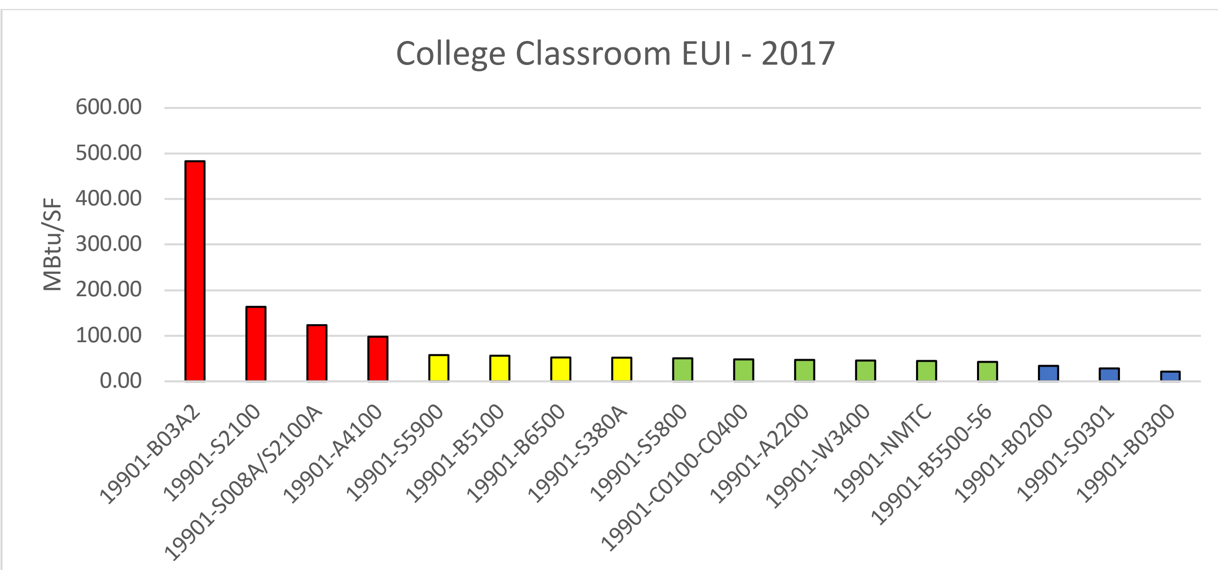

Figure 4.6. College Classroom EUI Priority Level Breakdown 2017

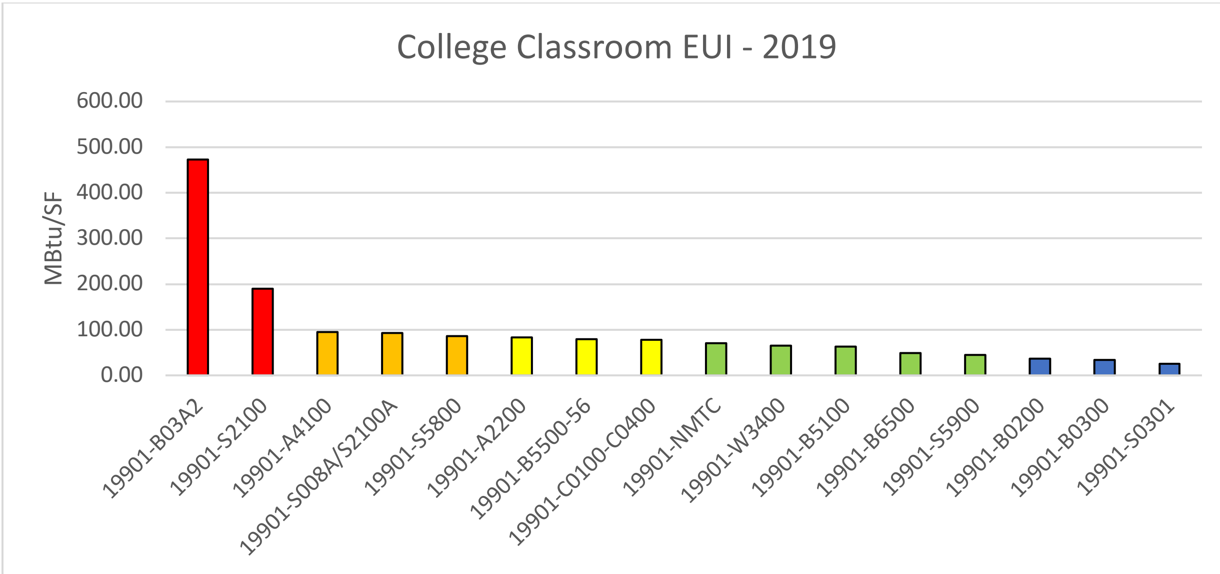

Figure 4.7. College Classroom EUI Priority Level Breakdown 2019

The EUI of the only community/recreation center at IAARNG increased by 26.3 MBtu/SF

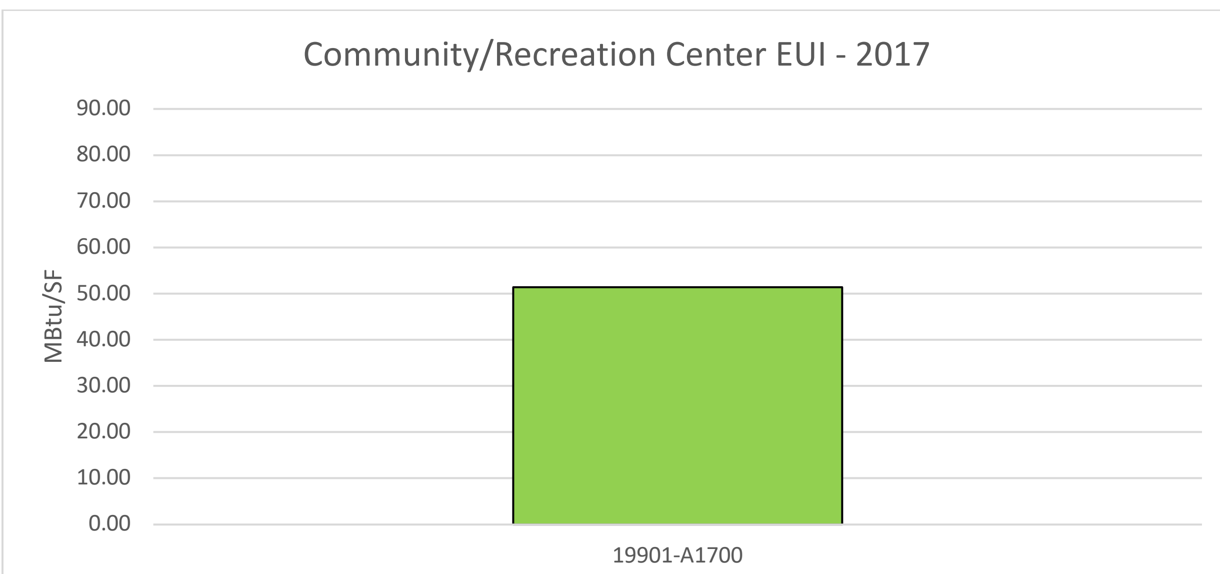

Figure 4.8. Community/Recreation Center EUI Priority Level Breakdown 2017

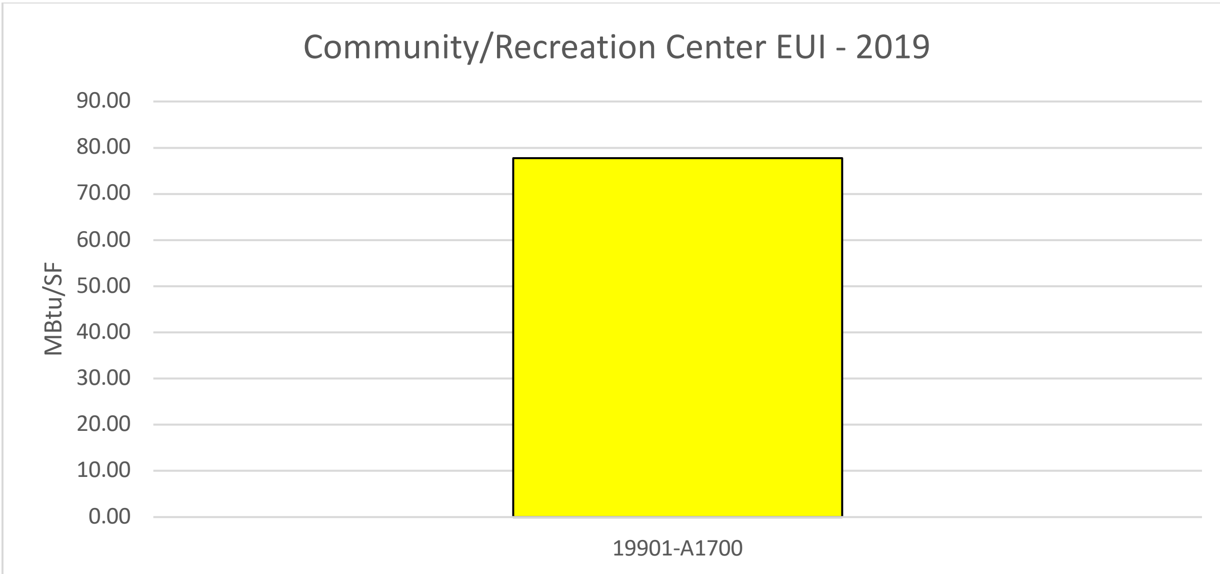

Figure 4.9. Community/Recreation Center EUI Priority Level Breakdown 2019

The data centers have stayed fairly consistent from 2017 to 2019. Building 19901-A0600 did see a large increase from 2017 to 2019.

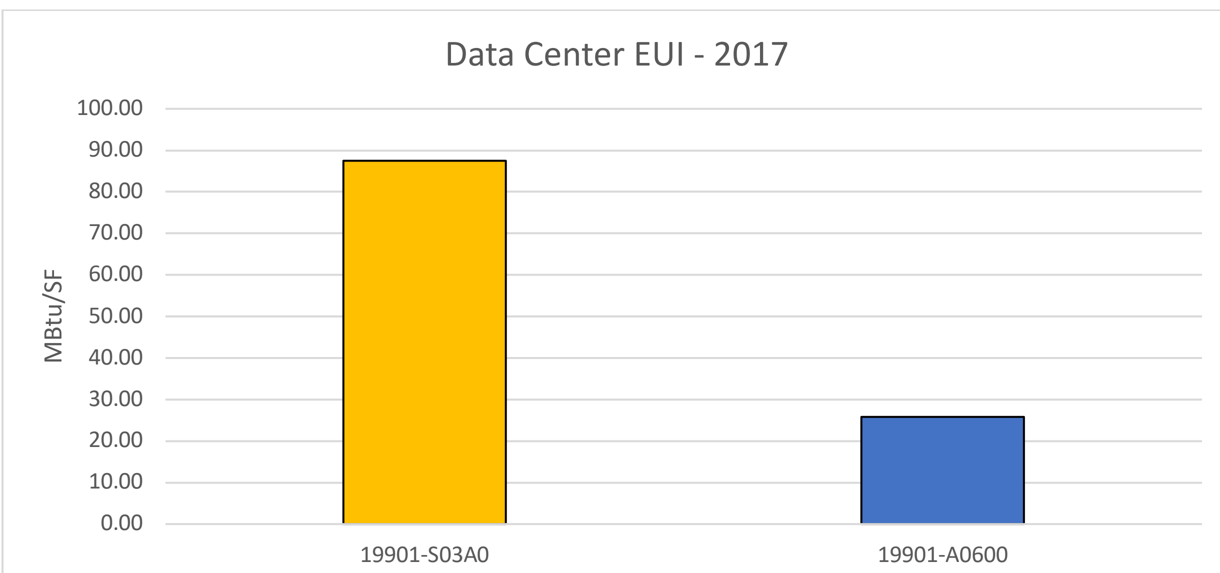

Figure 4.10. Data Center EUI Priority Level Breakdown 2017

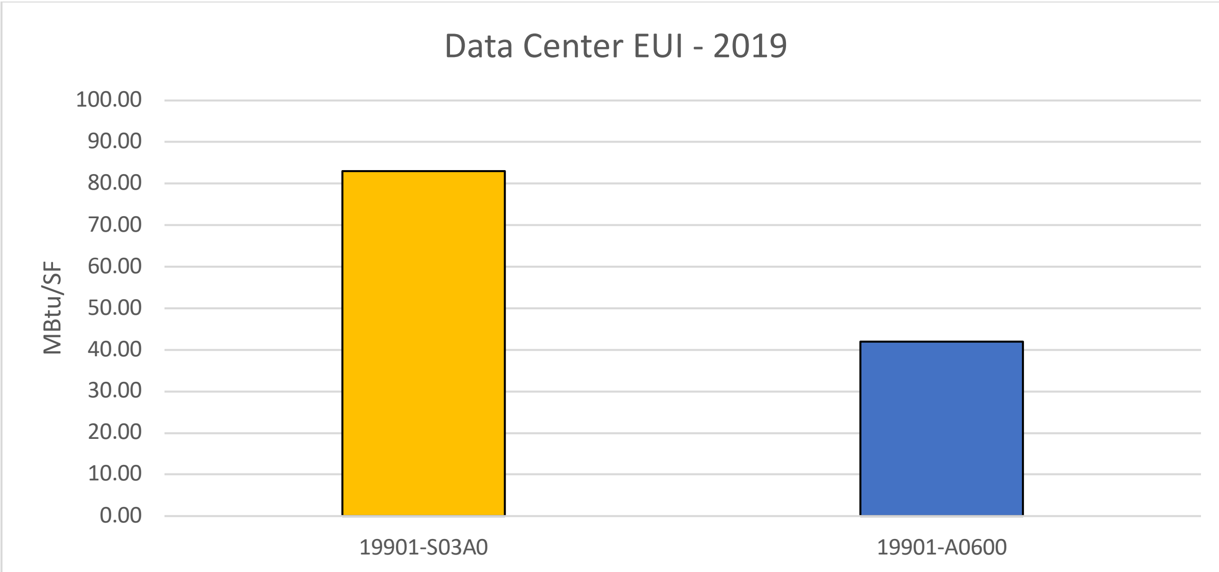

Figure 4.11. Data Center EUI Priority Level Breakdown 2019

From 2017 to 2019 there was an increase in the EUI of building 29901-B6000 that pushed it into critical priority. 19901-S5000 went from medium priority to none priority, 19901-B5000 went from low to high priority, and finally 19901-S5100 stayed on none priority.

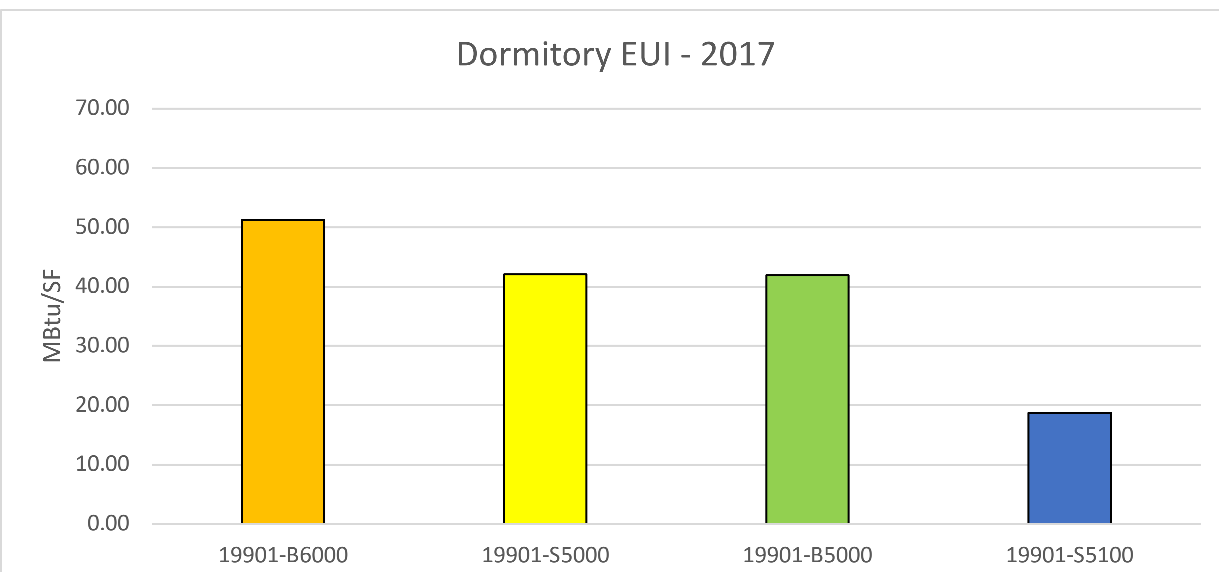

Figure 4.12. Dormitory EUI Priority Level Breakdown 2017

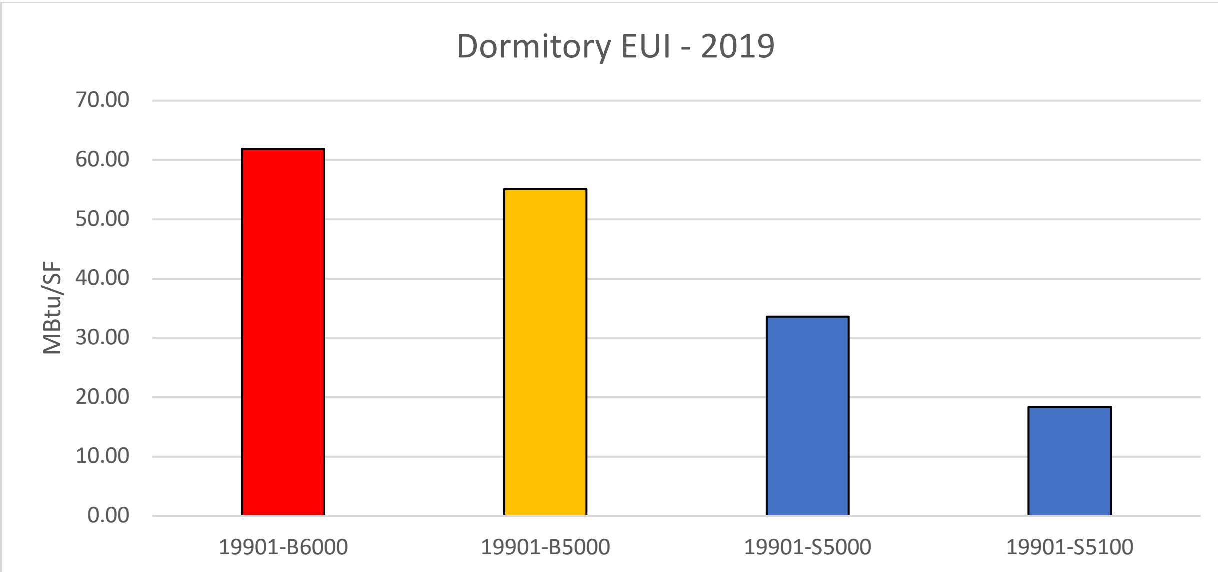

Figure 4.13. Dormitory EUI Priority Level Breakdown 2019

Building 19901-PT010 is the only actual gymnasium in this designation. From 2017 to 2019 it stayed in the same priority level. 19901-S2900 went from low to critical priority over the two years, 19901-S6000 stayed in none priority, and 19901-S7000 went from high to medium priority.

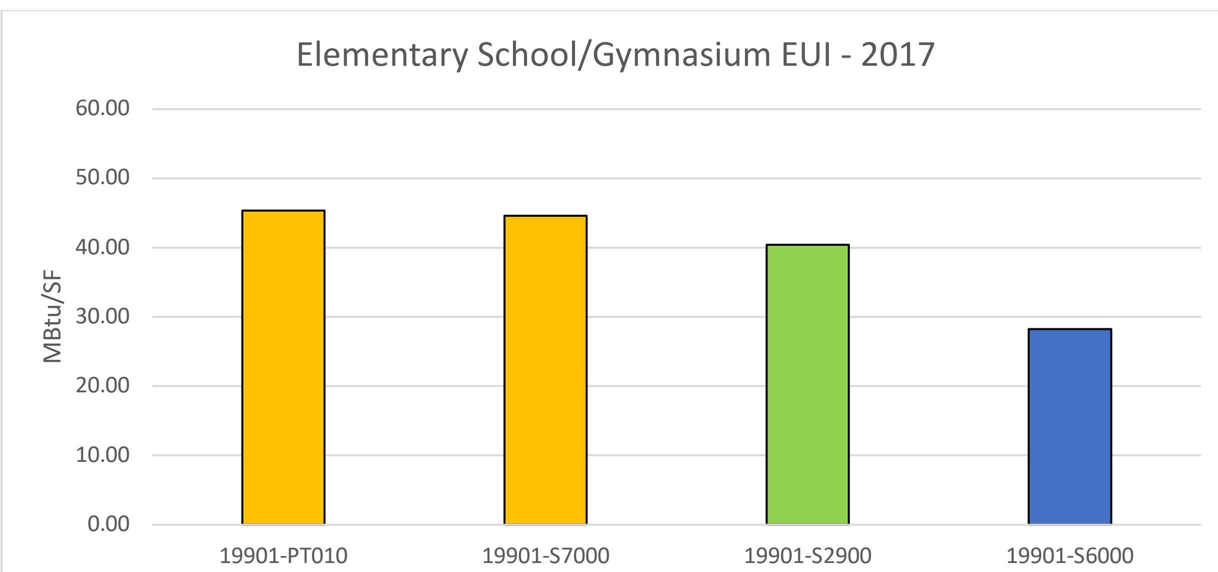

Figure 4.14. Elementary School/Gymnasium EUI Priority Level Breakdown 2017

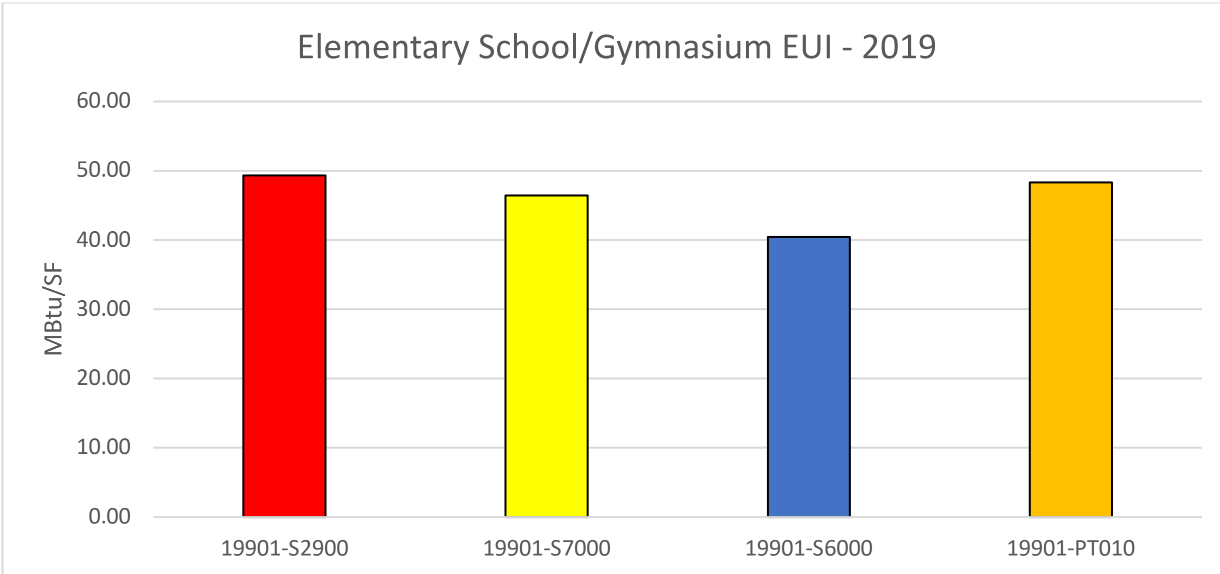

Figure 4.15. Elementary School/Gymnasium EUI Priority Level Breakdown 2019

The kitchen/food prep building actually consists of multiple buildings that are serviced by the same energy meter. There was an increase in EUI of 23.09 MBtu/SF from 2017 to 2019 which lead to an increase in priority level from low to high priority.

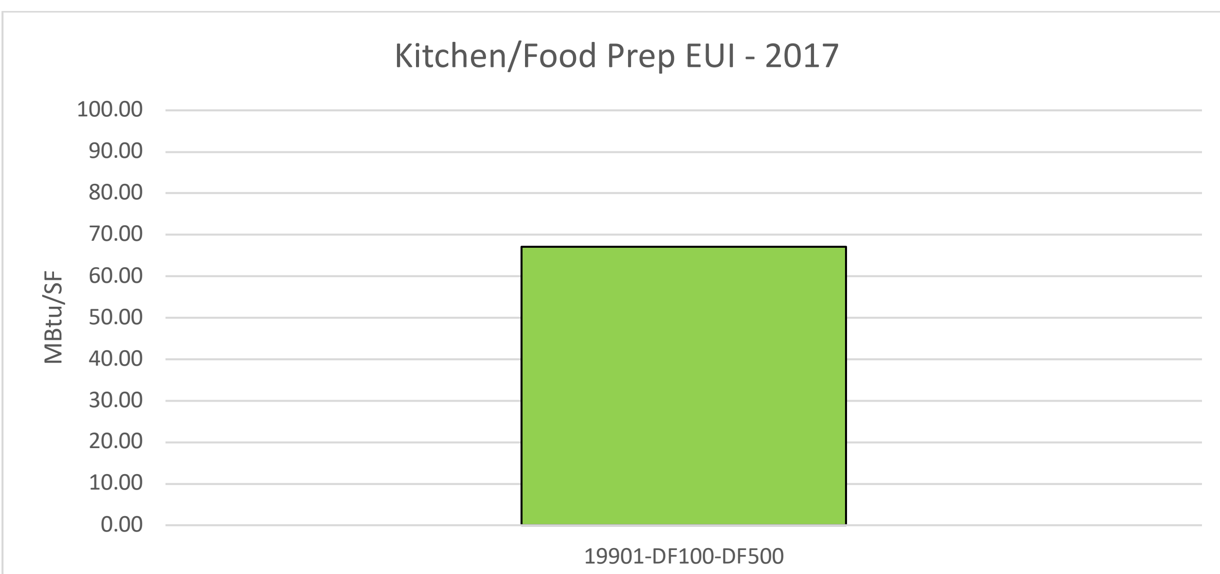

Figure 4.16. Kitchen/Food Prep EUI Priority Level Breakdown 2017

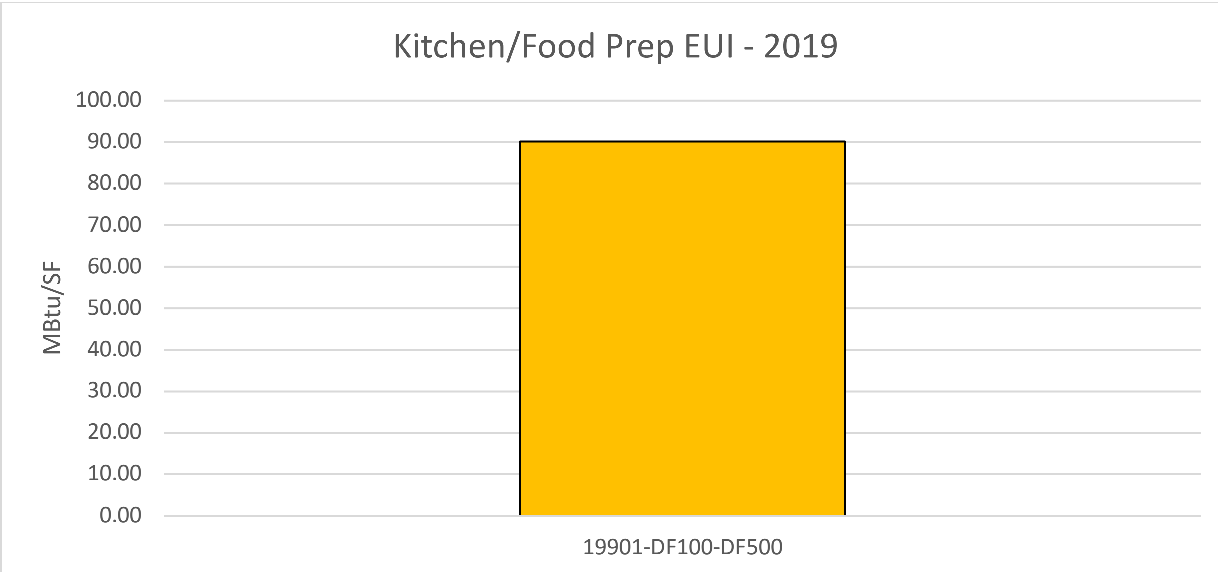

Figure 4.17. Kitchen/Food Prep EUI Priority Level Breakdown 2019

Each critical priority maintenance repair shop saw a decrease in EUI, however every other building saw an increase in EUI.

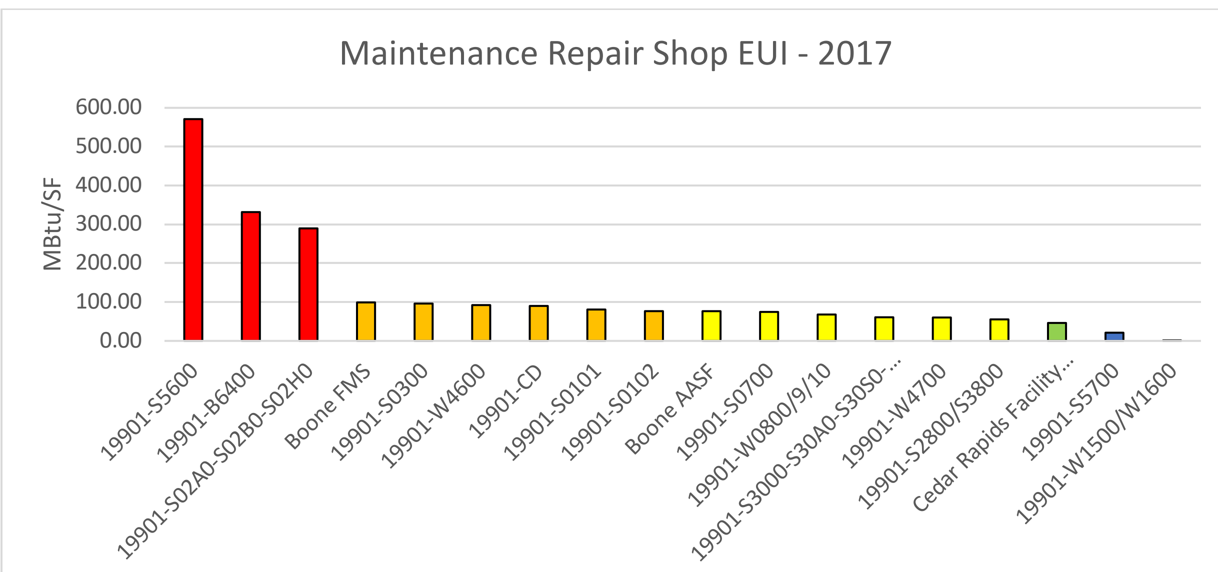

Figure 4.18. Maintenance Repair Shop EUI Priority Level Breakdown 2017

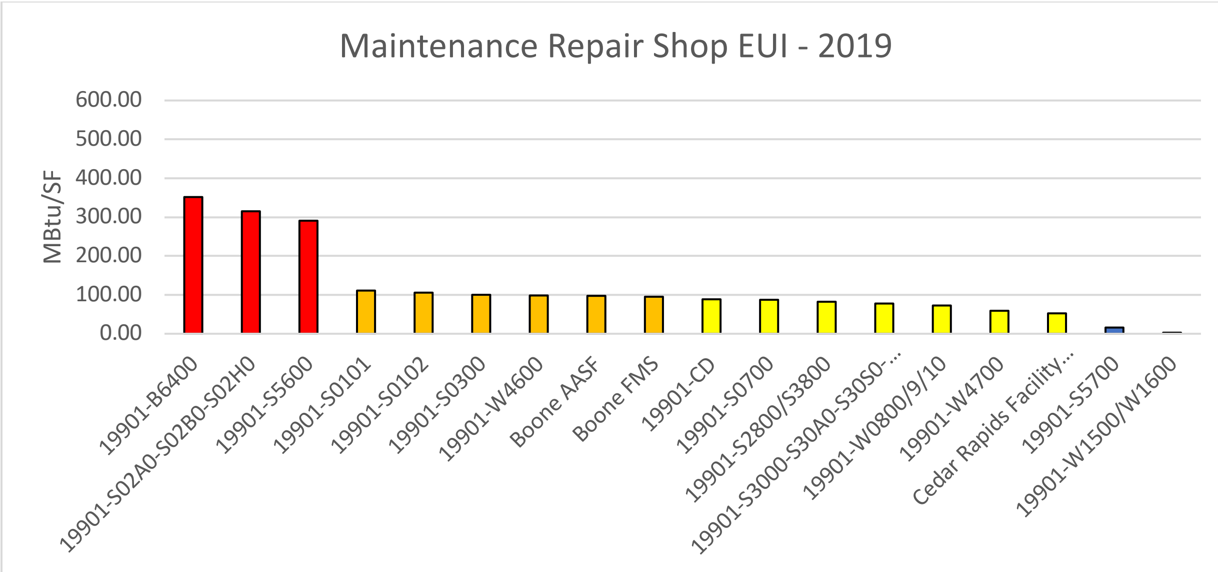

Figure 4.19. Maintenance Repair Shop EUI Priority Level Breakdown 2019

The manufacturing facilities remained relatively constant from 2017 to 2019, resulting in no change in priority levels.

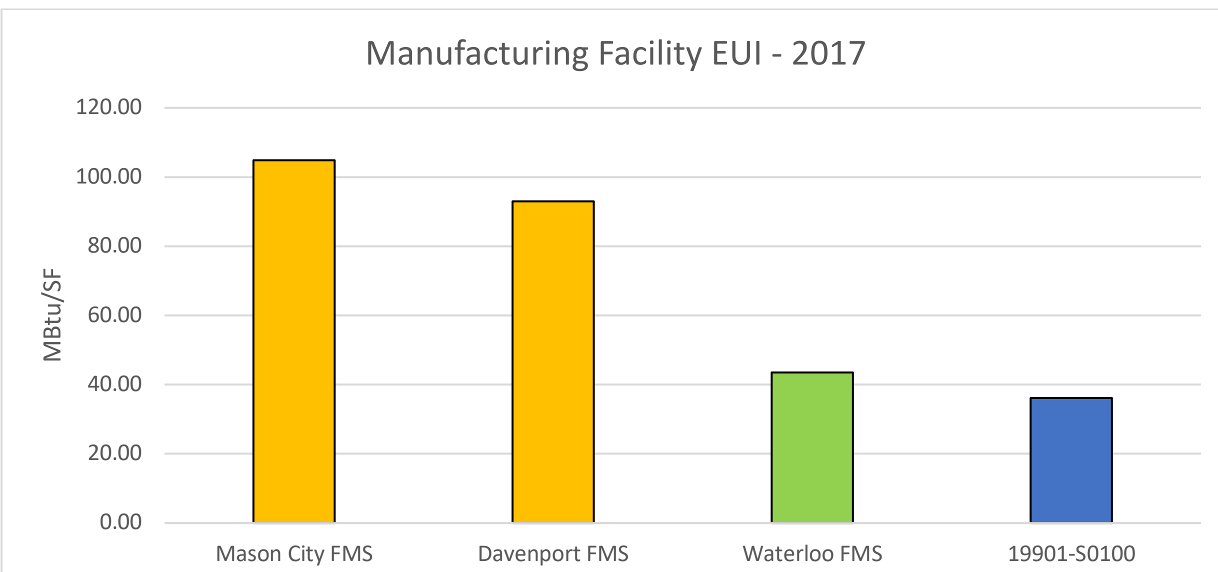

Figure 4.20. Manufacturing Facility EUI Priority Level Breakdown 2017

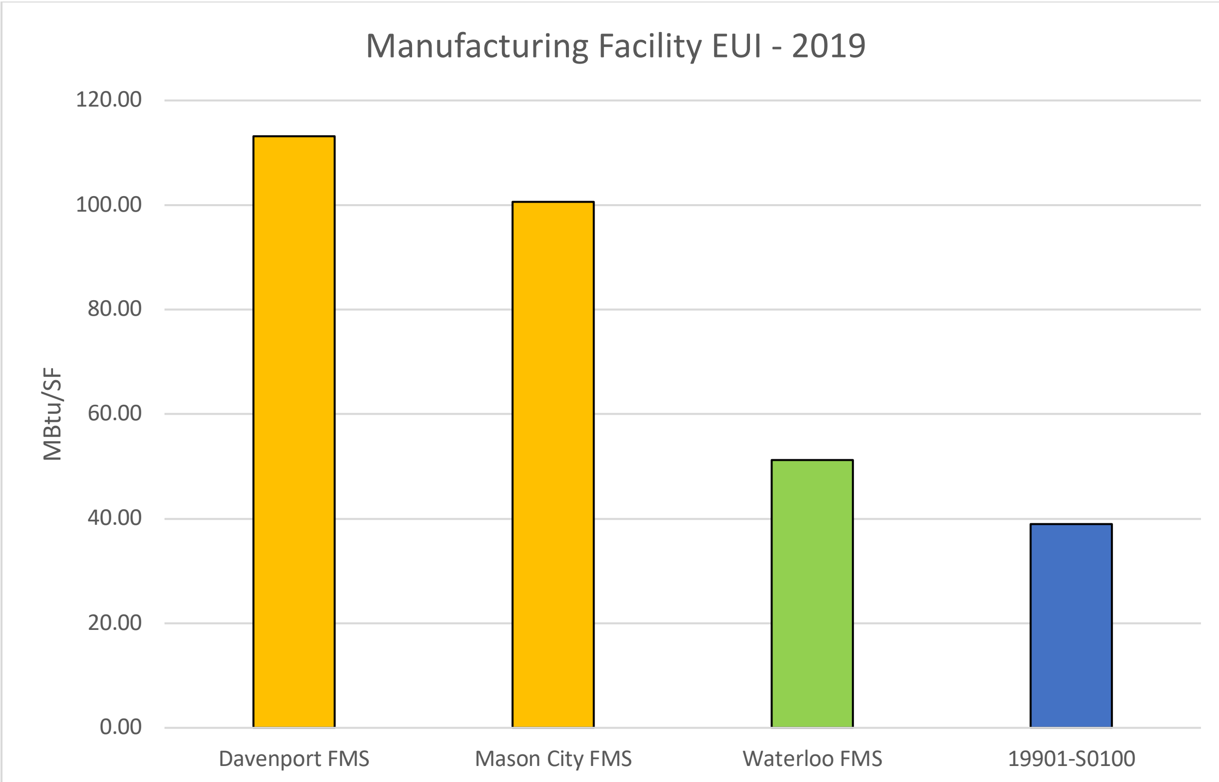

Figure 4.21. Manufacturing Facility EUI Priority Level Breakdown 2019

The multi-family housing grouping saw a few changes in the priority level breakdown. From 2017 to 2019 the number of critical buildings went from twenty-four to twenty-three, the number of high priority buildings went from one to twelve, the number of medium priority buildings went from ten to six, the number of low priority buildings went from ten to eighteen, and finally the number of none priority buildings dropped from twenty-six to twelve.

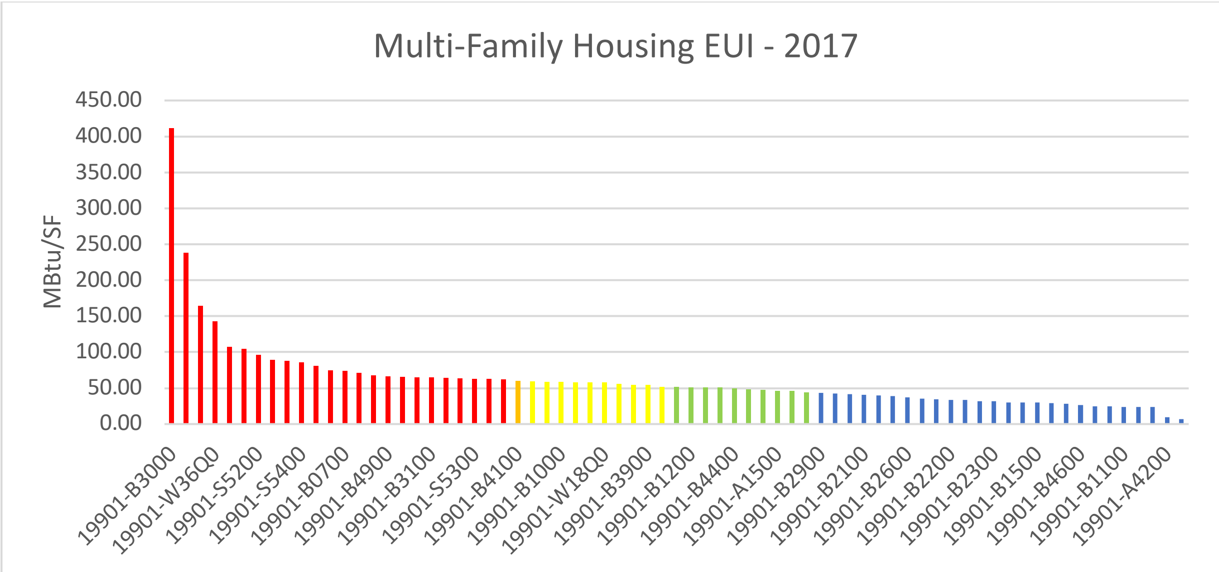

Figure 4.22. Multi-Family Housing EUI Priority Level Breakdown 2017

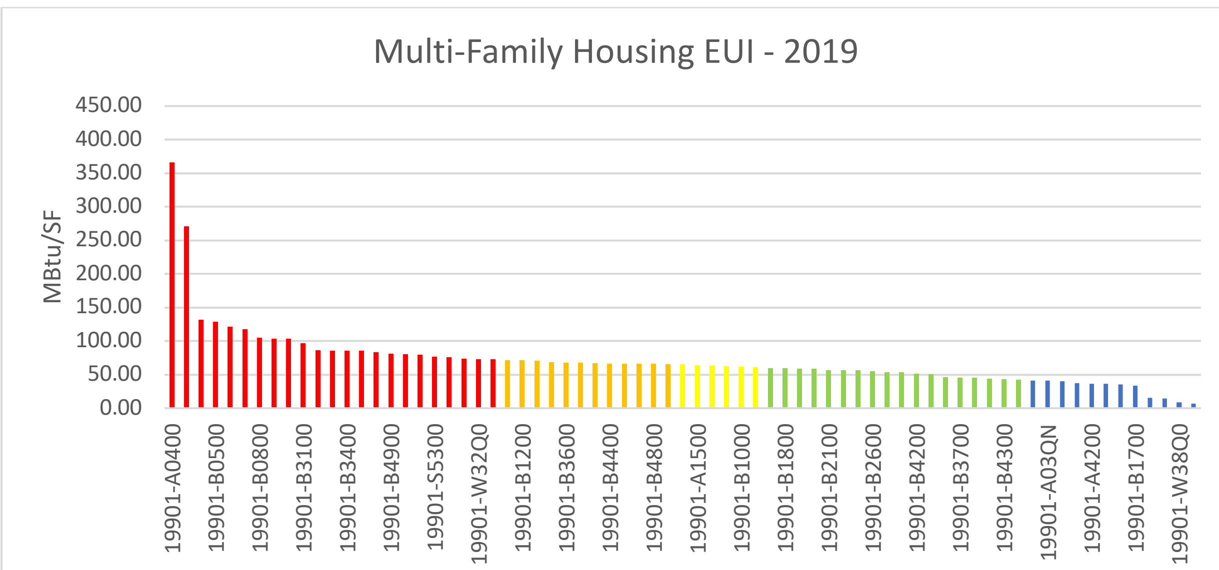

Figure 4.23. Multi-Family Housing EUI Priority Level Breakdown 2019

The one museum at IAARNG saw a slight increase in EUI which pushed it into low priority from none priority.

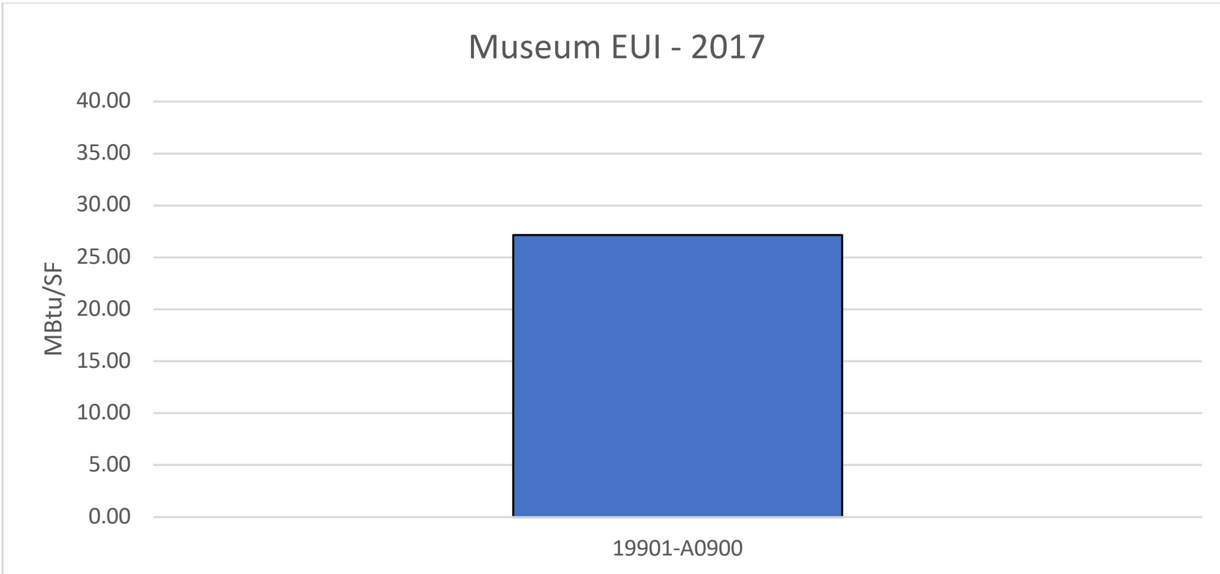

Figure 4.24. Museum EUI Priority Level Breakdown 2017

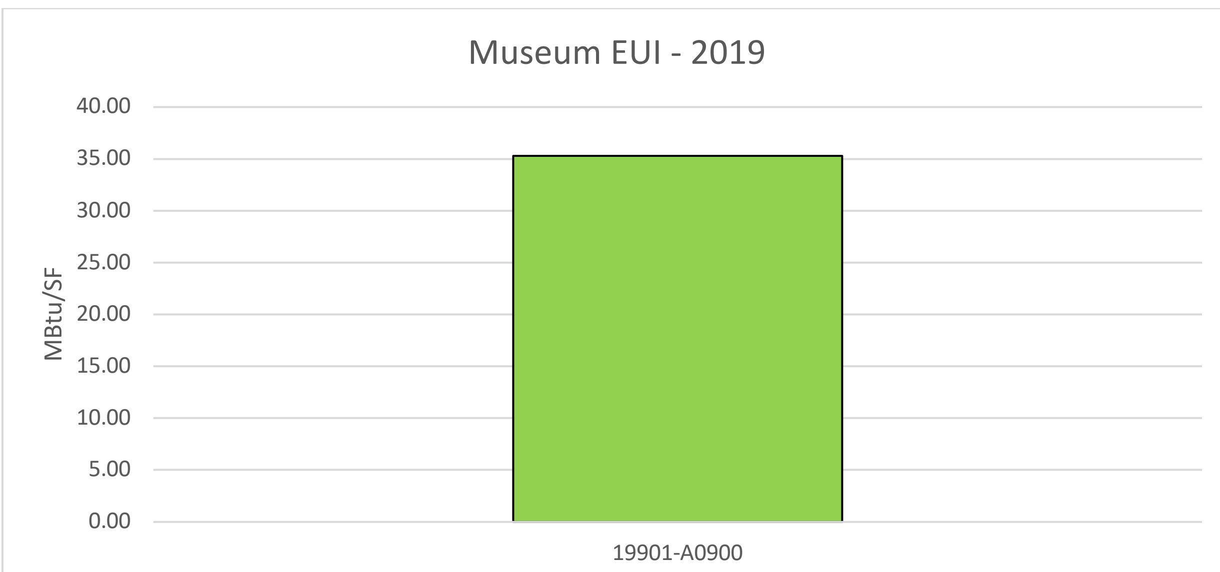

Figure 4.25. Museum EUI Priority Level Breakdown 2019

There was a decrease in the number of office buildings in the B3 database from fifty-six to fifty-three.

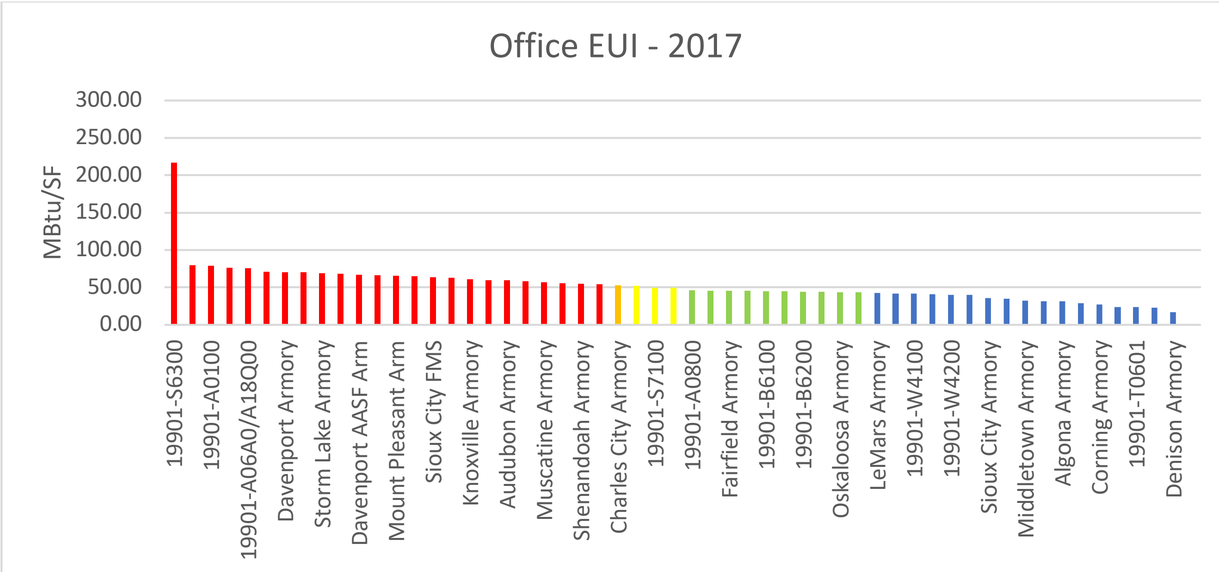

Figure 4.26. Office EUI Priority Level Breakdown 2017

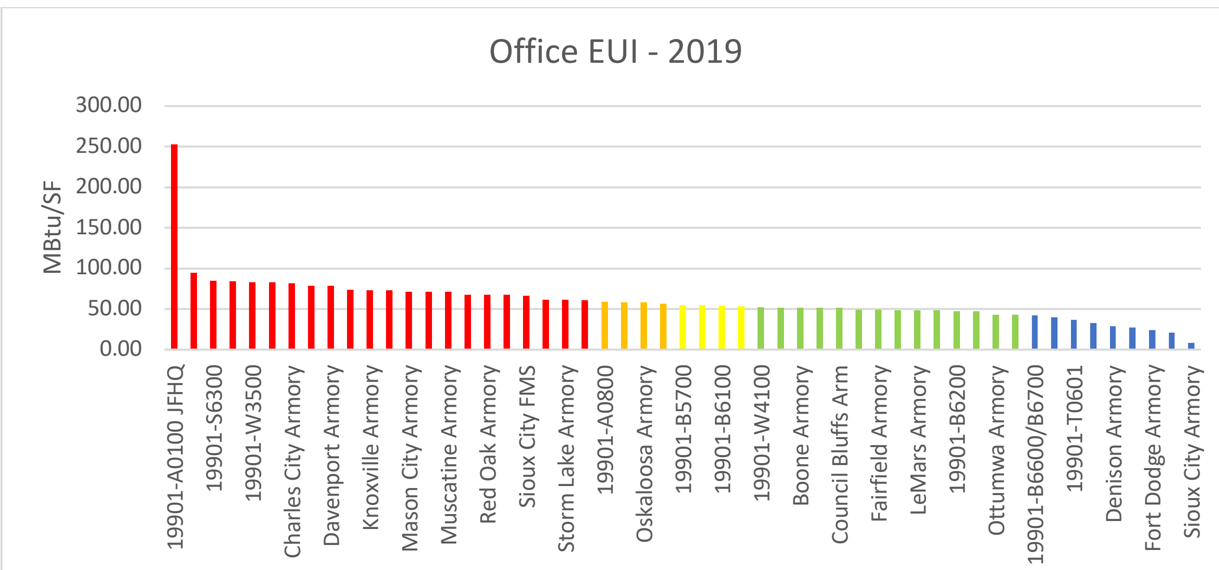

Figure 4.27. Office EUI Priority Level Breakdown 2019

19901-HARMON was decommissioned and removed from the B3 database, and there was a slight increase in EUI for buildings 19901-L0200-L1100 which is a series of buildings being measured by one meter.

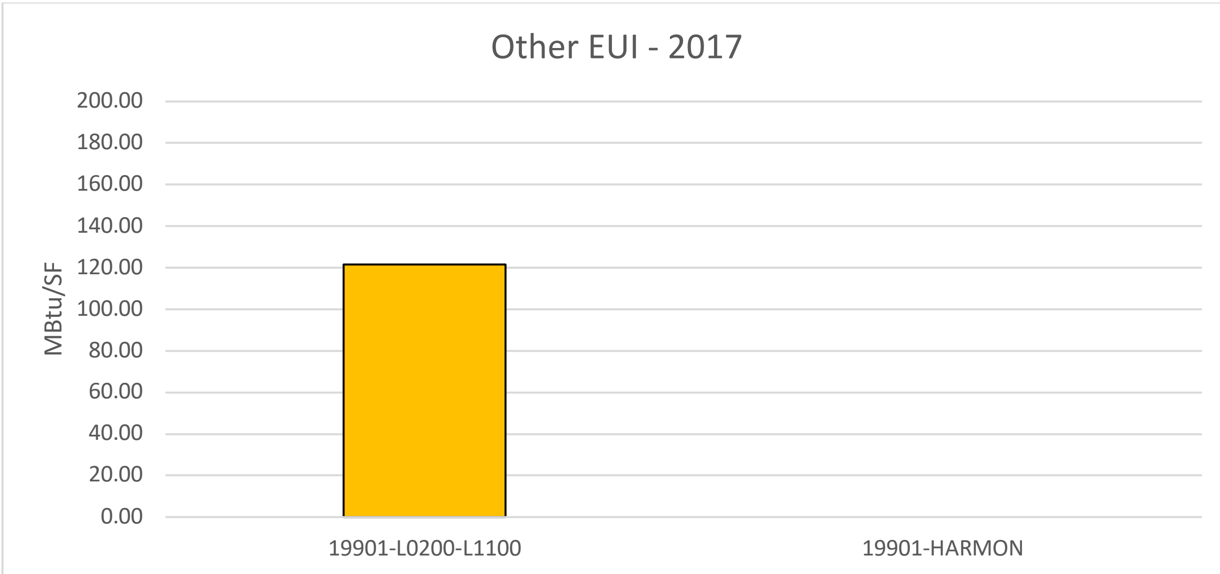

Figure 4.28. Other Building EUI Priority Level Breakdown 2017

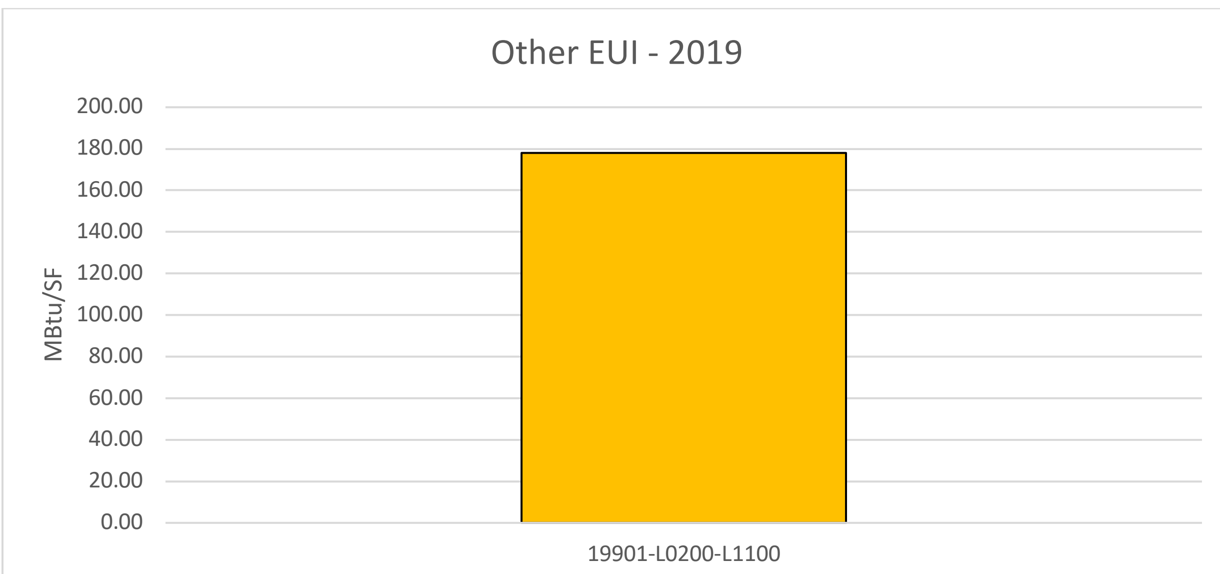

Figure 4.29. Other EUI Priority Level Breakdown 2019

From 2017 to 2019 there was a decrease in EUI for the Retail Store, however the priority level did increase.

Figure 4.30. Retail Store EUI Priority Level Breakdown 2017

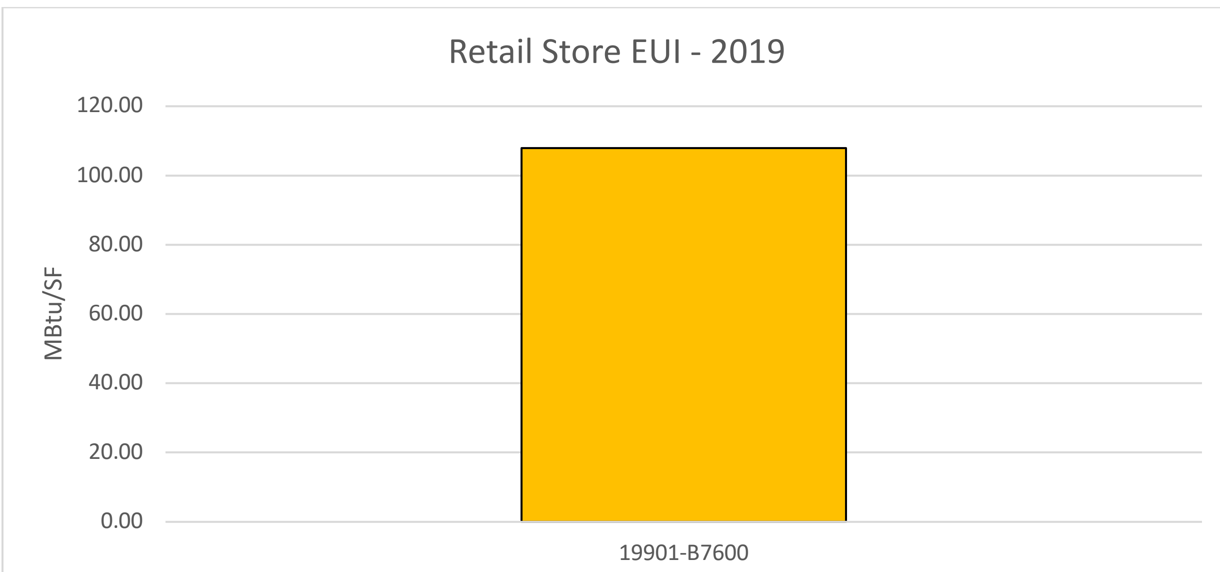

Figure 4.31. Retail Store EUI Priority Level Breakdown 2019

The Warehouse (Conditioned) building grouping is difficult to analyze with the Knoxville MVSB taken into account. This building has an EUI of 57684.54 MBtu/SF in 2019, which is significantly higher than any other building at IAARNG. This high value heavily skews the results when taken into account, and so an analysis is done with and without this building. The priority level split is similar to other buildings categories.

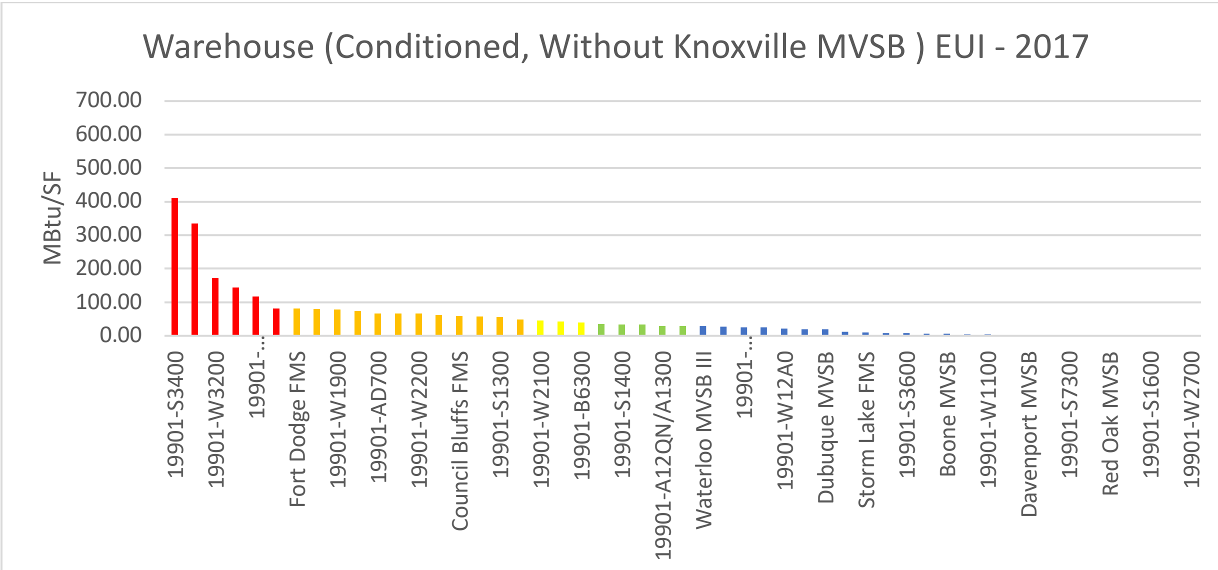

Figure 4.32. Warehouse (Conditioned, Without Knoxville MVSB) EUI Priority Level Breakdown 2017

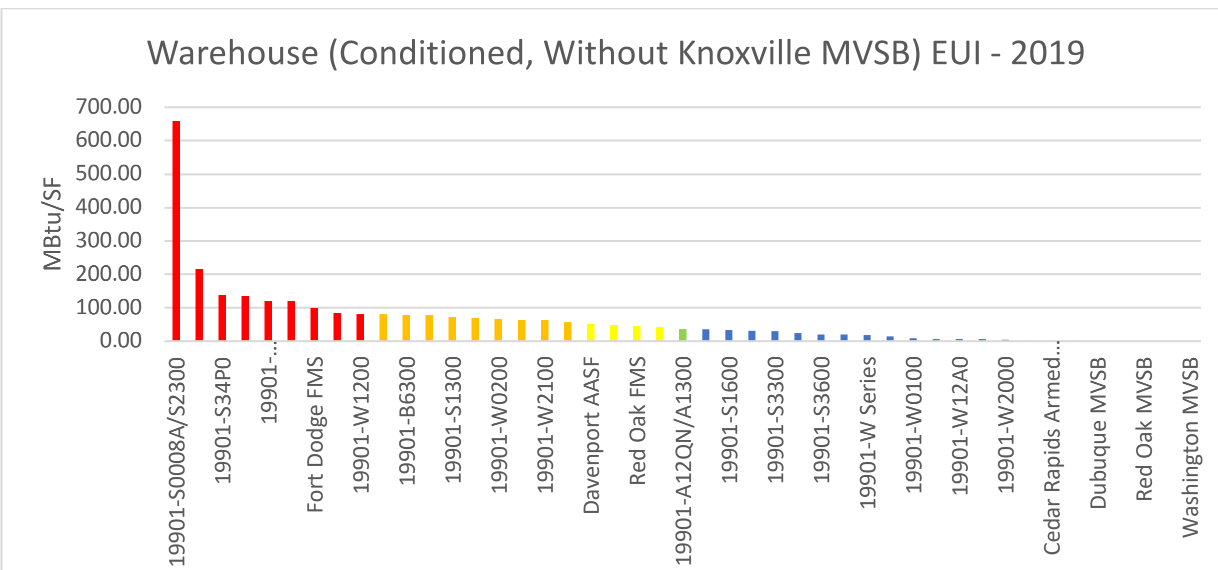

Figure 4.33. Warehouse (Conditioned, Without Knoxville MVSB) EUI Priority Level Breakdown 2019

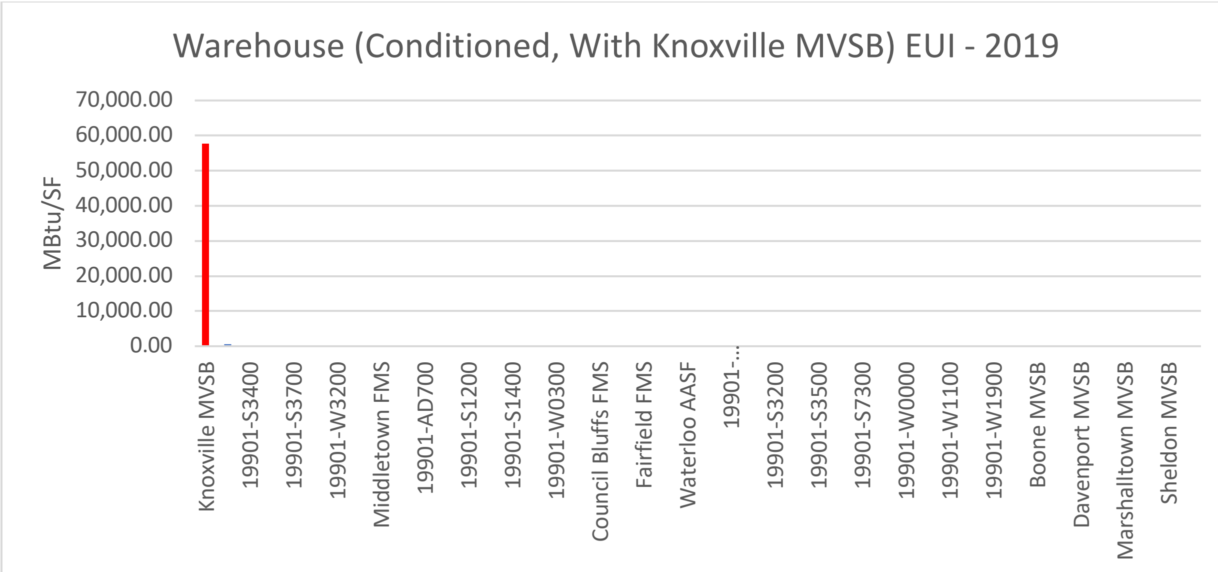

Figure 4.34. Warehouse (Conditioned, With Knoxville MVSB) EUI Priority Level Breakdown 2019

The EUI of buildings within the warehouse (unconditioned) is relatively low, with the exception of 19901-S1100 which is the only building at critical priority.

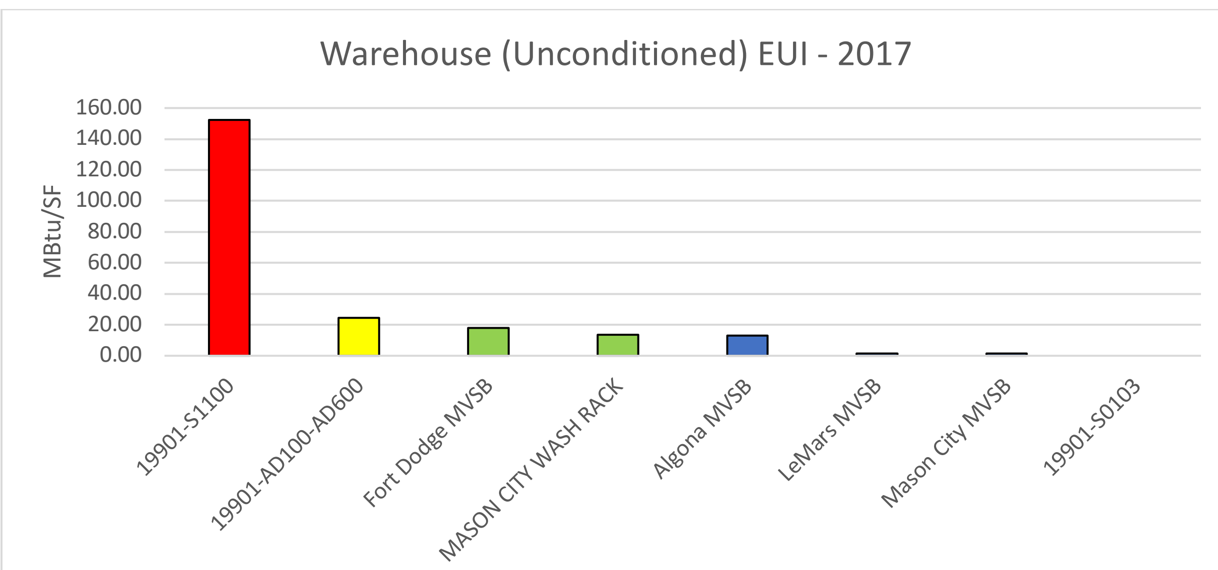

Figure 4.35. Warehouse (Unconditioned) EUI Priority Level Breakdown 2017

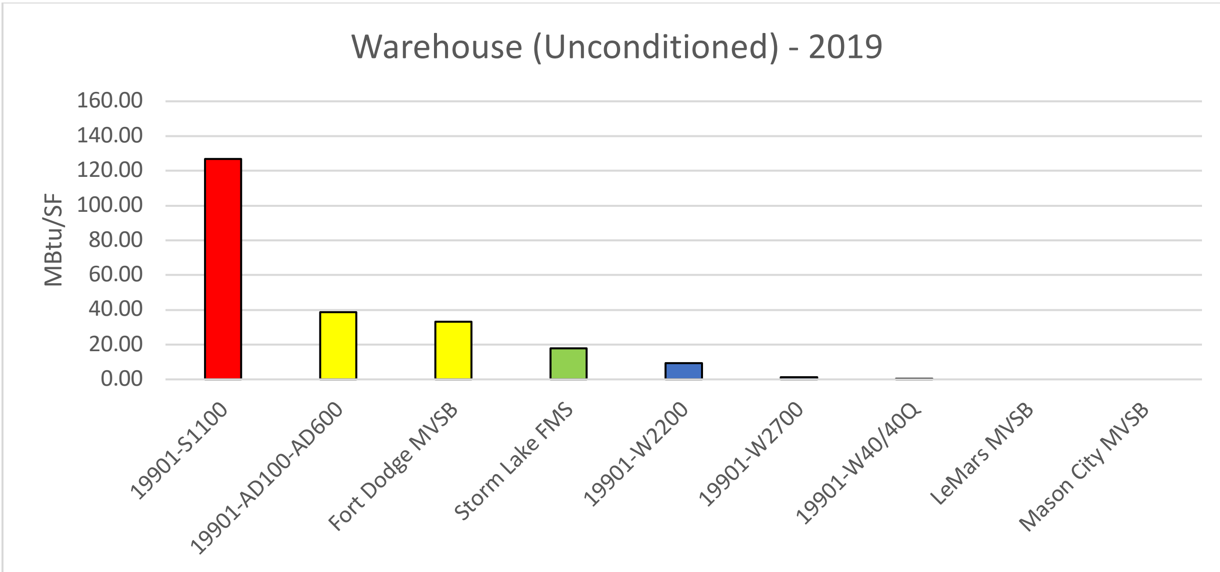

Figure 4.36. Warehouse (Unconditioned) EUI Priority Level Breakdown 2019

The high EUI of the water treatment plants is to be expected because IAARNG pumps and treats their own water. This is one of their largest single energy consumers, and there is an increase in EUI for both buildings from 2017 to 2019.

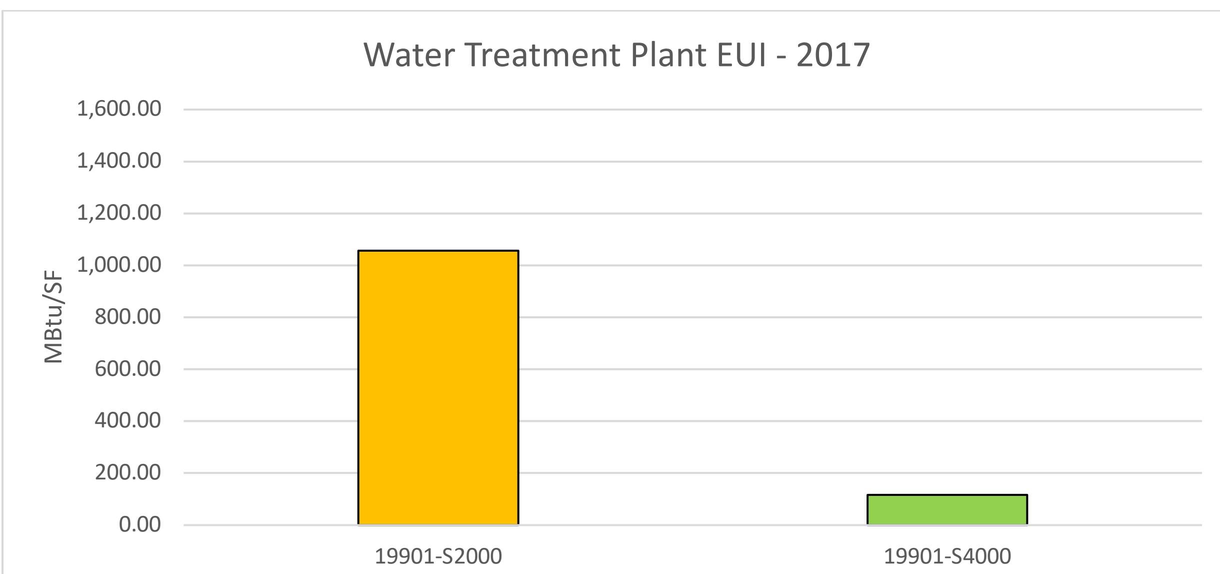

Figure 4.37. Water Treatment Plant EUI Priority Level Breakdown 2017

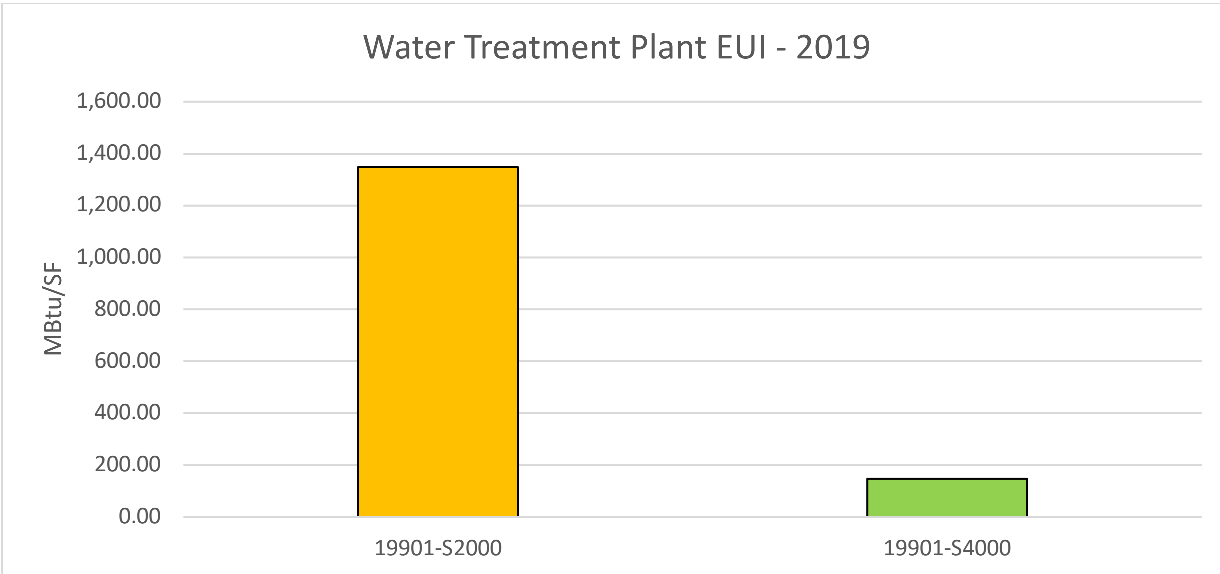

Figure 4.38. Water Treatment Plant EUI Priority Level Breakdown 2019

The workshop building designation was no longer used in 2019, so there is no comparisons that can be made.

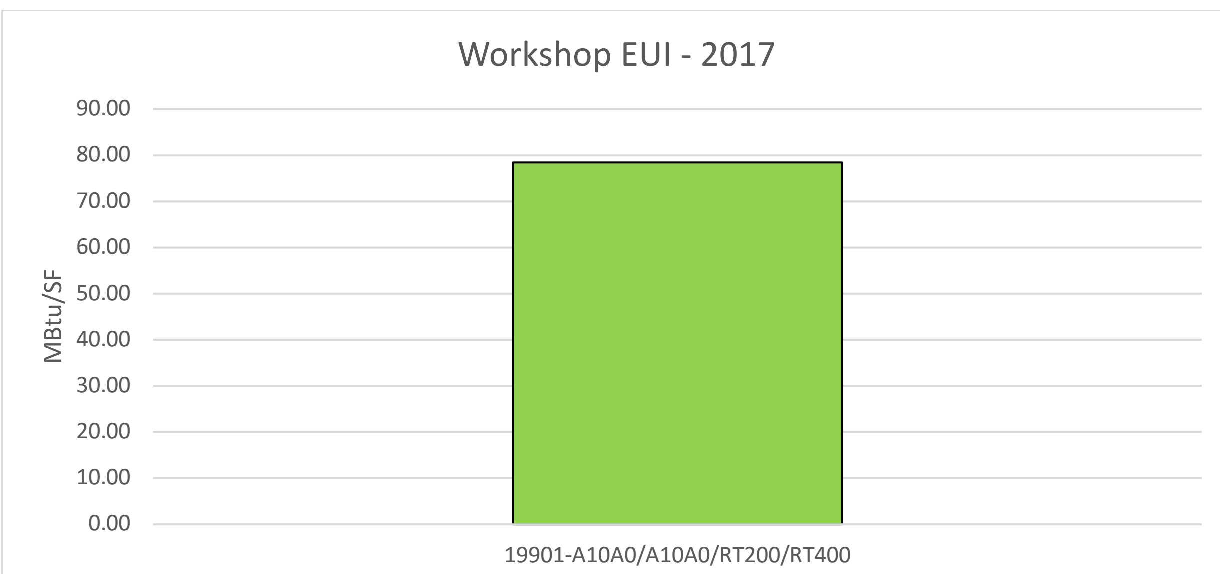

Figure 4.39. Workshop EUI Priority Level Breakdown 2017

B_3 can be used as a cut-off point for assigning priority. Any buildings below B_3 could be moved to Priority none. This however, limits the scope of this process, and limits the overall potential for energy savings. It could also cause problems reaching the overall consumption reduction goal. This is because some buildings cannot, by nature, go below a certain EUI, and thus it is important to have all buildings performing at their most efficient levels

4.2 Overview of IEWP

The IEWP is broken into six sections to accomplish the above purposes. It was requested through discussions with stakeholders at IAARNG that the plan be written as a “story” that answers three questions related to their energy and water systems. Where are we? Where do we want to be? How do we get there? The plan begins with an executive report, where the goal is to communicate the most important information, without focusing on the methodology or any finer details. The next section is the Introduction, which gives an overview of the purpose and scope of the IEWP, a description of the plan’s sections, and context of the physical setting of IAARNG. Following the Introduction is the Mission and Vision section. In this section are Army National Guard policies and guiding principles for sustainability and energy and water usage. These principles are what guides IAARNG to make improvements to their systems as well as produce this report.

The next section, Energy and Water Profiles, makes up the bulk of the report. This section answers the question, where are we? The Energy and Water Profiles section is one that should be regularly updated as more data is made available because it contains information on supply, distribution, and consumption. Consumption data is shown at various levels. Monthly consumption and consumption intensity are shown for the installation as a while, as well as for each metered building. This section also includes recent energy and water audits, as well as an overall assessment of each sector of energy and water usage. It is important to note that

IAARNG pumps and treats its own water, and historically were not concerned with water consumption. However, because of the interconnectedness of water pumping/treatment with energy usage, they have begun to install water meters. As these meters come online, a similar methodology as is described in this research can be used to identify and improve key buildings within the installation.

Following the Energy and Water Profiles is the Goals section of the plan. This section addresses the question of, where do we want to be? The Goals section starts off with the strengths, weaknesses, opportunities, and threats (SWOT) analysis. By doing this type of analysis, IAARNG can identify specific weaknesses in their systems and set goal and create action plans to address them. It also provides an opportunity to catalog their specific strengths for future expansion and collaboration with other State Army National Guards. Next, a risk assessment for potential hazards to IAARNG's energy and water system is performed. This assessment starts by identifying natural, human-caused, and technological hazards that threaten IAARNG. It then breaks down each hazard into the likelihood of occurring, effect on the mission, and recommended courses of action. This section is imperative to complete because it further identifies potential weaknesses in IAARNG's energy and water systems, and what could happen if one were to occur. Finally, by recommending a course of action, IAARNG is able to evaluate their current systems and strategies set to address each risk, as well as update and develop new strategies that may be more comprehensive than their current strategies.

The final part of the goals section are the specific goals categorized by the strategy they utilize. There are four strategies that cover their goals, conservation, security, communication, and education. These goals all lead to an increase in installation resiliency and energy and water efficiency. Goals that fall under the conservation strategy are ones that pertain to the reduction of energy and water use. These goals push IAARNG to use less water and energy, as well as use energy and water more efficiently. By addressing and reaching these goals, IAARNG will lower their operating costs while still maintaining the same level of service.

The next strategy is security. Security pertains to the protection of IAARNG's energy and water assets. These assets include resources, system, and function. By reaching these goals, IAARNG will assure continued operations with a lowered risk to all missions.

Communication is the third strategy, and it pertains to the awareness and knowledge of sustainability among IAARNG members. These goals are put in place to increase and improve the cooperation of energy and water stakeholders with IAARNG. These stakeholders include individuals within IAARNG as well as outside energy companies. The communication strategy also addresses the development and adoption of policies and works towards greater compliance to these policies.

The final strategy could fit under communication, but is its own category to add extra emphasis on the importance of it. The education strategy concerns goals that are meant to improve the understanding of IAARNG energy and water policies, the effects of individual habits on the mission, as well as why certain conservation practices are important and superior to other practices. This strategy is important because even if the perfect policies are in place, if nobody is compliant to these policies, they are meaningless. By providing individuals with the reasoning behind certain decisions, popular or not, they begin to understand the impact these decisions will have. This in turn leads to greater compliance with these policies and decisions. Some of these goals are specific to IAARNG and their current system. However, other goals come from various executive order, laws, and mandates. An organized list of these goals, and the resources they came from, can be found in the appendix of the plan.

The final section of the IEWP is the action plan section. This section answers the question: how do we get there? In this section a format for action plans has been developed that includes the following sections: Mandate, Security Risk Reduction, or Element Addressed, Project Description, Business Case, Planned Execution Year, Action Plan/Task Breakdown, and Plan Evaluation. This format creates consistency between plans and is designed to organize all important aspects of each action plan. Identifying the mandate, security risk reduction, or element addressed allows IAARNG address each of these goals individually and prevent confusion to the purpose of a specific action. By cross-referencing action plans with specific goals, IAARNG can identify goals that have not yet been addressed and develop new action plans to do address them. The project description is an overview of what the project is and how it is to be accomplished. This prevents any confusion between parties about what is to be done. The business case may look different for each action plan, but in general it will describe the initial cost, savings, and payback of each plan. Planned execution year and action plan/task breakdown creates a timeline for completion and gives the necessary steps for an action plan to be accomplished. This helps moving an action plan forward and prevents plans from hitting certain roadblocks. Finally, one of the most important parts of the action plans are the plan evaluations. Currently IAARNG has no standardized method for evaluation, and reporting on the evaluations, of specific actions and projects accomplished. Adding this section to the action plan format will make these evaluations more common and organized. This will help to identify effective and ineffective projects and action plans and steer IAARNG away from ineffective plans. IAARNG is particularly interested in "blanket solutions," which are solutions where one specific action or project can be applied over a large area or scope and provide high levels of results. Examples of a blanket solution are: changing the lightbulbs in all buildings to more efficient models, occupancy sensor, automate HVAC controls, etc. However, only using these blanket solutions will not push IAARNG to their most efficient levels. In order to do this, solutions for individual or select groups of buildings must be created.

A draft of the IAARNG IEWP can be found in the appendix of this research. This version is an early draft of the report. Sensitive material is not included with this version of the IEWP.

CHAPTER 5. CONCLUSION

IAARNG has seen a slight increase in their average EUI from the 2017 to 2019 data. While some buildings are performing better, there was no way to see the specific buildings that have been affected by changes made. This research highlights buildings and building types where retrofits will have a large impact. For instance, both office buildings and multi-family houses have a large portion of their buildings in the critical priority level. Efforts should be made within these building types to lower their energy consumption. The tables below also highlight building designations and their average EUI. Any building designation with an EUI above 42.48 MBtu/SF (which is IAARNG's target average EUI for 2025) should also be prioritized in energy retrofit efforts. Tables 4 to 31 give a summary of the average EUI and number of buildings in each building designation in 2017 and 2019.

Table 5.1. Armory results summary

Armory	**2017**	**2019**
Average EUI	406.66	560.76
Critical priority	0	0
High priority	1	0
Medium priority	0	1
Low priority	0	0
None priority	1	0

From 2017 to 2019 IAARNG removed the Davenport AFRC from their B3 database. This has caused a slight change in the designation for the Des Moines Armory. It moved from high to medium designation despite the fact that its EUI increased over these two years. There is also no national value for an armory EUI, so B_1 is zero for any building within this designation. The implications of this is there will never be an armory with critical designation. The Des Moines Armory has an EUI over 10 times the goal EUI. This high EUI causes the Des Moines armory to be a building of interest (BOI), which are buildings that may have low designations, but should still be highly considered during retrofit planning.

Table 5.2. Auditorium results summary

Auditorium	**2017**	**2019**
Average EUI	75.68	87.67
Critical priority	0	0
High priority	1	1
Medium priority	0	0
Low priority	1	1
None priority	0	0

There is no national value for auditorium EUI, which means there is no possibility for a critical designation for IAARNG auditoriums. The two buildings classified as auditoriums changed which priority designation they were in from 2017 to 2019.

Table 5.3. College classroom results summary

College Classroom	**2017**	**2019**
Average EUI	85.24	97.87
Critical priority	4	2
High priority	0	3
Medium priority	4	3
Low priority	6	5
None priority	3	3

IAARNG has one less building in their college classroom designation. Building 19901-S380A is no longer a building at IAARNG

Table 5.4. Community/recreation center results summary

Community/recreation center	**2017**	**2019**
Average EUI	51.38	77.68
Critical priority	0	0
High priority	0	0
Medium priority	0	1
Low priority	1	0
None priority	0	0

Table 5.5. Data center results summary

Data center	**2017**	**2019**
Average EUI	56.68	62.49
Critical priority	0	0
High priority	1	1
Medium priority	0	0
Low priority	0	0
None priority	1	1

There is a national value for data center EUI, but it is not in terms of MBtu/SF instead it is known as PUE where PUE = Total Energy / IT Energy [11]. This value is not used in determining their priority level, and so there is no possibility for a critical priority level.

Table 5.6. Dormitory results summary

Dormitory	**2017**	**2019**
Average EUI	38.50	42.23
Critical priority	0	1
High priority	1	1
Medium priority	1	0
Low priority	1	0
None priority	1	2

Table 5.7. Elementary school/gymnasium results summary

Elementary School/Gymnasium	**2017**	**2019**
Average EUI	39.67	46.12
Critical priority	0	1
High priority	2	1
Medium priority	0	1
Low priority	1	0
None priority	1	1

Building 19901-PT010 is a gymnasium. In 2017 it was within the elementary school designation, but in 2019 a separate designation of gymnasium was created. In this research 19901-PT010 is still considered as an elementary school for continuity.

Table 5.8. Kitchen/food prep results summary

Kitchen/food prep	**2017**	**2019**
Average EUI	67.07	90.16
Critical priority	0	0
High priority	0	1
Medium priority	0	0
Low priority	1	0
None priority	0	0

Table 5.9. Maintenance repair shop results summary

Maintenance repair shop	**2017**	**2019**
Average EUI	121.72	116.93
Critical priority	3	3
High priority	6	6
Medium priority	6	7
Low priority	1	0
None priority	2	2

Table 5.10. Manufacturing facility results summary

Manufacturing facility	**2017**	**2019**
Average EUI	69.37	75.98
Critical priority	0	0
High priority	2	2
Medium priority	0	0
Low priority	1	1
None priority	1	1

Table 5.11. Multi-family housing results summary

Multi-family housing	**2017**	**2019**
Average EUI	61.77	71.18
Critical priority	24	23
High priority	1	12
Medium priority	10	6
Low priority	10	18
None priority	26	12

Table 5.12. Museum results summary

Museum	**2017**	**2019**
Average EUI	27.15	35.29
Critical priority	0	0
High priority	0	0
Medium priority	0	0
Low priority	0	1
None priority	1	0

Table 5.13. Office results summary

Office	**2017**	**2019**
Average EUI	56.68	62.49
Critical priority	24	22
High priority	1	4
Medium priority	3	4
Low priority	10	14
None priority	18	9

Building 19901-A06A0/A18Q00, the Algona Armory, and the Corning Armory no longer exist as buildings for IAARNG. This designation may be confusing as some of the buildings have "Armory" in their name, but are listed as office buildings in B3. This designation is related to the use of the building as defined by IAARNG.

Table 5.14. Other results summary

Other	**2017**	**2019**
Average EUI	121.54	178.10
Critical priority	0	0
High priority	1	1
Medium priority	0	0
Low priority	0	0
None priority	1	0

19901-HARMON no longer exists in B3.

Table 5.15. Retail store results summary

Retail Store	**2017**	**2019**
Average EUI	108.57	107.83
Critical priority	0	0
High priority	0	1
Medium priority	1	0
Low priority	0	0
None priority	0	0

Table 5.16. Warehouse (Conditioned) results summary

Warehouse (Conditioned)	**2017**	**2019**
Average EUI	717.39 (Knoxville MVSB) 51.69 (no Knoxville MVSB	1314.18 (Knoxville MVSB) 61.50 (no Knoxville MVSB)
Critical priority	7	10
High priority	12	9
Medium priority	3	4
Low priority	5	1
None priority	24	23

The Waterloo ACSTR no longer exists in B3. Building 19901-W2200, Storm Lake FMS, and 19901-W40/40Q were moved to warehouse (unconditioned) designations.

Table 5.17. Warehouse (Unconditioned) results summary

Warehouse (Unconditioned)	**2017**	**2019**
Average EUI	28.05	25.26
Critical priority	1	1
High priority	0	0
Medium priority	1	2
Low priority	2	1
None priority	4	5

The Mason City wash rack and the Algona MVSB no longer exist, and the buildings noted above in warehouse (conditioned) were also moved to this designation.

Table 5.18. Workshop results summary

Workshop	**2017**	**2019**
Average EUI	78.50	N/A
Critical priority	0	0
High priority	1	0
Medium priority	0	0
Low priority	1	0
None priority	0	0

Building 19901-A10A0/RT200/RT40 is no longer in B3 and so in 2019 there were no buildings with the Workshop designation.

5.2 Next Steps

This research is a springboard for future energy retrofits. Now that IAARNG has a better idea of the areas their efforts should be focused, they should begin energy retrofits on critical priority buildings. After the implementation of these efforts, IAARNG should continue with collecting and entering energy use data into B3. This data should then be used to perform another analysis using the methodology described in this research. This cycle should be done each year to evaluate efforts and provide a focus for the next year.

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APPENDIX. EXCERPT IAARNG IEWP

This document is only an excerpt from the 70-page report developed for IAARNG. For the sake of length and in order to protect sensitive material, only a few pages are included in this research to show what the report looks like.

1. Introduction:

The Installation Energy and Water Plan (IEWP) is to be used by the Iowa Army National Guard (IAARNG) as a roadmap assure increased security, resilience, readiness, and mission assurance through their water and energy systems. It is a living document that presents actionable plans to attain new and existing energy and water visions and goals.

1.1 Purpose

This document is to assist IAARNG in satisfying the following, but not limited to, Executive orders, Army Directives, and Army Regulations:

- Army Directive 20017-07 (Installation Energy and Water Security policy 23 Feb 2017)
- Energy and Water Goal Attainment Responsibility Policy (13 Jan 2017)
- Sustainable Design and Development Policy (17 Aug 2013)
- The Army Energy Security Implementation Strategy (ADSIS) (13 Jan 2009)
- Federal Leadership in Environmental, Energy, and Economic Performance Energy Policy Act of 2005
- Energy Independence and Security Act (EISA) of 2007
- Army ES2 Strategy
- Executive order 13653
- Executive order 13693

It also serves to assist in developing a system flexible enough to use renewable energy generated on site to meet energy reduction and the following, but not limited to, renewable energy directives:

- EPAct of 2005
- Army Operational Energy Policy (30 Apr 2013)
- Renewable Energy Credits Policy (24 May 2012
- 2007 National Defense Authorization Act (ADAA) Public Law 109-364
- Title 10, United States Code (S.S.C.) Chapter 169, sections 286

1.2 Scope

This document evaluates current energy and water trends and data. The objective of the IEWP is to assist IAARNG in increasing the resilience and sustainability of current, and future, water and energy systems.

The resiliency of IAARNG water system hinges on the function of the Energy system. Camp

Dodge self-pumps water. This means that as long as there is sufficient power to run the water pumps, there will be water. For this reason, the IEWP focuses heavily on energy resiliency. This includes, but is not limited to, a reduction in energy consumption intensity, energy storage, and on-site energy generation.

2. Mission and Vision

2.1 ARMY NATIONAL GUARD MISSION IN SUSTAINABILITY

The Army National Guard will be empowered to maintain sustainable forces and capabilities to protect the nation through global and domestic operations. ARNG's broad goals in sustainability are to:

INSTITUTIONALIZE sustainability as an organizing and management principle;

INCREASE awareness, cooperation and support for sustainable practices;

INSTILL a sustainability attitude in soldiers and civilians; and

IMPLEMENT sustainable decision-making across ARNG.

2.2 ARMY NATIONAL GUARD VISION FOR SUSTAINABILITY

The Army National Guard (ARNG) will efficiently balance requirements and resources, effectively supporting all current and future missions. It will be a national leader in sustainable innovation driven by informed and empowered soldiers and civilians.

2.2.1 ARMY NATIONAL GUARD ENERGY AND WATER PROGRAM

The Army National Guard faces unprecedented demands on our soldiers, communities, natural resources, and the various other assets, systems, and infrastructures. The primary objective of the ARNG Energy and Water Management Program is to ensure the availability, quality, and security of energy and water for the ARNG without degrading the environment, mission readiness, or the well-being of soldiers. The program shall incorporate energy security considerations into all installation activities to reduce demand, increase efficiency, seek alternative sources, and create a culture of energy accountability while sustaining or enhancing operational capabilities. Energy Security is an integral component of mission readiness and unit preparedness – it is an operational imperative. Because of its importance to mission readiness, an Energy Security Plan is also being developed.

Increasing energy security is the responsibility of every ARNG soldier and civilian. Successfully meeting these challenges is dependent upon each individual's support and execution of cost-effective solutions to their organization's energy management and security needs.

3. Energy and Water Profiles

3.1 Energy Systems:

3.1.1 General

Energy sources at IAARNG include

- Electrical Power purchased from local providers
- Natural Gas purchased from local providers
- Diesel and JP-8

The IAARNG has 3,988,790 square feet of space and in FY15 used 219,223,337 kBtu of energy. The overall energy consumption intensity of IAARNG was 56.64 kBtu/SF. The Energy and Water Goal Attainment Responsibility Policy sets the goal of a 2.5% annual reduction in energy consumption intensity, with a 25% total reduction by FY2025, using FY15 as a baseline. Figure 3-1 shows current levels, as well as future benchmarks.

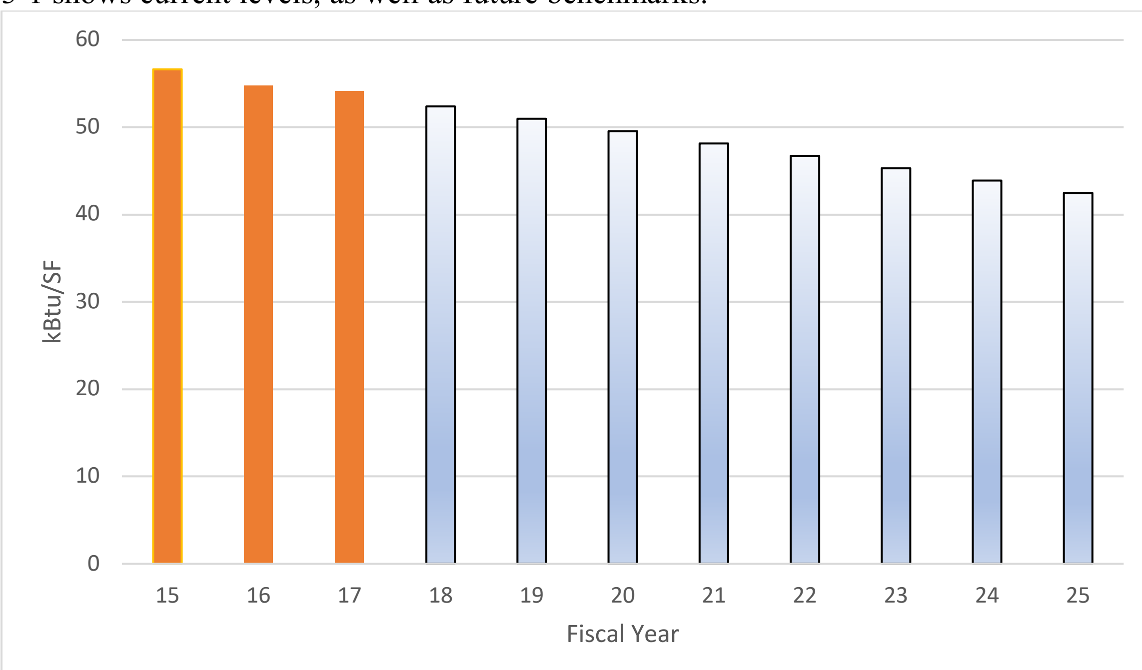

Figure 3-1 Energy Intensity Reduction Goals

3.2 Goals by Resources

Below is a list of goals from the following resources

- Army Directive 20017-07 (Installation Energy and Water Security policy 23 Feb 2017)
- Energy and Water Goal Attainment Responsibility Policy (13 Jan 2017)
- Ececutive Order 13653
- Executive Order 13693 of March 19, 2015
- National Defense Authorization Act, 2010

See these documents for a full list of goals, mandates, and orders.

4. Action Plans and Future Focus

Awareness Programs

Mandate, Security Risk Reduction, or Element Addressed:
EO 13693
Project Description:
Awareness programs can be an effective way to reduce occupancy energy use. Occupants can be reminded of best practices for energy conservation and small habits that can make a large difference. Lighting energy accounts for 10% of the total electrical load for IAARNG by rough estimates (Overall Report Summary with Appendices.pdf). These value has a potential do be decreased by over 40% in the most optimistic case.
Total Estimated Cost:
The only costs incurred with this project are those associated with printing and hanging signs. The printing prices below are the ISU printing costs for students. The actual values for IAARNG printing services are likely to be much lower. The cost for hanging is assuming 4, 1" pieces of clear tape are used per sign and that the tape was purchased at $2.00 per roll. An upper estimate is used to show that even when done inefficiently, the cost per page is low.

Cost	Cost per Sign ($)	Total Cost ($, assuming 10 signs per building)
Printing (B&W)	0.05	185.50
Printing (Color)	0.25	927.50
Hanging	0.006	22.26
Total	**0.06 – 0.26**	**207.76 – 949.76**

Annual Savings:
Energy, and therefore financial, savings are directly related to the primary use and occupancy patterns of each individual room. Bathrooms and meeting rooms will have the largest drop in energy consumption because of the variability of occupancy. One can reasonably expect a savings of $0.046/day [A]. Desk spaces and other areas with consistent occupancy will have a much smaller drop in energy usage and should not be a priority for signage.

Room type	Energy Saving per sign (kWh/day)	Cost Saving per sign	Simply Payback (d)
Bathroom/meeting room	10.6	$0.046/day	1.3 – 5.65

Planned Execution Year:
This plan's execution date should be no later than December 2021.
Action Plan/Task Breakdown

1) Identify rooms needing sings
   - Rooms with variable occupancy
   - Rooms with no automated lighting
2) Select sign design
3) Print appropriate signs
4) Hang signs