Camp Fretterd Readiness Center (Building 114)

13700 Hanover Pike,
Reisterstown, MD 21136

Energy Survey Analysis Report

Prepared for:
Maryland Department of General Services (DGS)

DGS
Department of
General Services

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Introduction

Project Team

The UMD Smart and Small Thermal Systems (S2TS) team is managed by the Maryland Department of General Services (DGS) Office of Energy and Sustainability and collaborates with multiple state agencies. The principal investigator and project director is Dr. Michael Ohadi, and the project deputy director is Dr. Amir Shooshtari. The other UMD S2TS members who assisted on this project included Ji Bae and Aditya Ramnarayan (lead members), Dr. Roxana Family, Yash Oza, and Alibek Bekenov.

Acknowledgment

We would like to acknowledge James Bonner, the facility manager at Camp Fretterd Military Reservation, which is located in Reisterstown, Maryland, as well as the other staff members for their help and cooperation during the walkthroughs and for answering our questions. We would also like to thank Mr. Lorenzo Taylor for his leadership, insights, and overall guidance of the project and Mr. Tony Myers for his diverse help, including coordinating the walkthrough and assisting with gathering the relevant technical information for the buildings studied.

Overview

This energy audit supports Governor Hogan's Executive Order 01.01.2019.08 - Energy Savings Goals for State Government, which was issued in July 2019 to signal the administration's desire to improve the energy efficiency of state-owned buildings, to reduce their environmental impact, and to save taxpayers' money. The executive order set the energy savings goal at 10% savings over a 2018 baseline by 2029. The executive order requires DGS to audit 2 million square feet of State facilities annually and to present the audit reports to each building's owner. The executive order goes on to state that:

> Each unit of state government that occupies the space audited shall, to the fullest extent practicable, implement the measures identified in the audit.

The UMD's S2TS group, led by Professor Michael Ohadi, in general divides an energy audit project into three phases: Building Comprehension which includes comprehensive walkthroughs and energy survey notes, Energy Model Development (if applicable and necessary), and Energy Efficiency Measures/Opportunities Analysis. The team carried out a facility walkthrough, analyzed the utility data and building plans to evaluate the energy usage of the building, as well as summarized their findings in this report. This report identifies actionable energy-saving opportunities to increase the building's energy efficiency. The DGS Office of Energy and Sustainability will coordinate with each building owner on financing and implementing the measures identified in this audit report.

Building Description

The 114 Armory building is located at 13700 Hanover Pike, Reisterstown, Maryland 21136. This building is one of the thirteen buildings in the Maryland Military Department (DMIL). The building was constructed in 1997 and is a two-story building with an overall floor area of 89,568 square feet according to the existing building plans. Fig. 1 shows an overview of the building. Table 1 shows the average annual utility consumption and costs for the calendar years of 2018 to 2020. Water data was not available/consistent to include a respective table for the water data.

Fig. 1: Camp Fretterd Armory Building.

Table 1: Average annual utility use and cost from January 2018- December 2020.

Utility	Annular Usage	Annular Cost
Electricity	1,431,704 kWh	$121,019
Natural Gas	34,725 therms	$30,490

The armory building is otherwise a typical office building that houses primarily office spaces, conference rooms, assembly rooms, and a kitchen space. The building also consists of several other miscellaneous spaces, such as mechanical rooms and electrical rooms.

There are six main air handling units (AHUs) on the roof of the building, and the mechanical room located on the first floor of the building houses two boilers. All of these units work to serve and provide the HVAC needs of the entire building.

The envelopes of the building, most of the exterior walls consist of 4-inch face brick, 8-inch rigid insulation, and a 6-inch lightweight concrete masonry unit. The roofs throughout the building are sloped roofs, which consist of a metal roof deck with a 2-inch lightweight concrete ballast, and R-13 6-inch rigid insulation. Finally, most of the existing windows for the building are double-glazed windows.

The facility exemplifies a typical office building in function. The entire building is operating on a 7:00 am to 5:00 pm building occupancy schedule on weekdays (Monday to Friday) throughout the year. Likewise, the building HVAC systems operate during all these hours, and they are off during unoccupied hours. The building is occupied throughout most of the year with approximately a total of 300 people occupying the building each day. Also, the existing mechanical drawings suggest that the HVAC system is operating at full load throughout the year.

The building consumes energy from two primary energy sources: electricity and natural gas. Electricity is metered and supplied by Constellation New Energy and Baltimore Gas and Electric. Natural gas consumption is metered and supplied by WGL Energy. The building's annual average electricity consumption is 1,431.704 MWh, and the annual average natural gas consumption is 34,725 therms. The annual average water consumption and cost could not be accurately determined due to the archived utility data's limited/incomplete water consumption. Therefore, water information had to be excluded from the report. The annual average utility cost of the building, excluding water, is $151,509. This annual average utility cost was determined by using the archived 2018-2020 monthly utility bills, which were obtained from EnergyCAP.

EUI Analysis

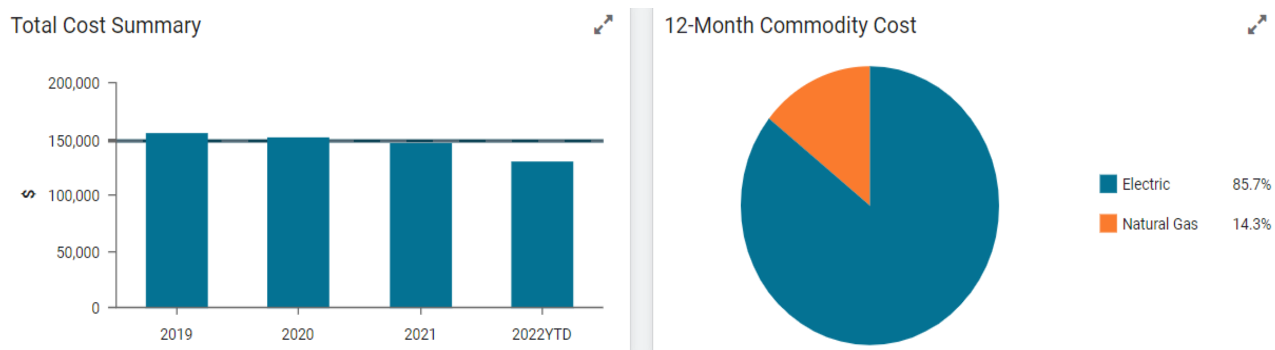
Table 2 shows the Energy Use Intensity (EUI) analysis of the Camp Fretterd Armory and its comparison with the widely known EnergyStar reference. The EUI for the building was calculated for FYs 2018 and 2019 based on the data available in EnergyCAP [2].

Table 2: Utility Analysis and EUI Summary Calculation.

Baseline Energy Usage	**Electricity**		**Natural Gas**		**Total Site Energy**	**FYs 18 and 19 EUI** (kBtu/SF/Yr)	
	MWh/yr	kBtu/yr	therms/yr	kBtu/yr	kBtu/yr	Site	Reference
	1431	4,886,296	34,725	3,471,671	8,357,967	125.92	52.9 [1]

The EUI values for 2020 and 2021 were not included, due to the COVID-19 pandemic and the fact that buildings were not operating with normal occupancy, among other factors. For example, the EUI for 2021 was 33.76 kWh/sq. ft. (115.22 kBtu/sq. ft.), which is ~10% below the average for 2018 and 2019. The calculations listed in Table 2 (above) considered electricity and natural gas consumption based on available data. The EUI for FYs 2018 and 2019 is nearly two and a half times the EnergyStar reference EUI for an office building. This implies that there is ample scope for energy efficiency improvements in the buildings.

Energy Spend Analysis:



Daily Cost

2.5%

$ 396
Previous Year
May 2020–Apr 2021

$ 406
Current Year
May 2021–Apr 2022

Time period	Cost
May 2020–Apr 2021	$ 396
May 2021–Apr 2022	$ 406

Fig 2: Energy usage and Cost for Camp Fretterd Armory.

Building Observations:

- The AHUs are oversized, and 4 out of the 6 AHUs are single-zone systems.
- There are currently traditional fluorescent lights serving the entire building.
- There are no occupancy sensors integrated into the existing lighting.
- Many of the non-HVAC appliances in the building are not Energy Star certified.
- The facility does not possess a BAS to automate its HVAC and Lighting Systems.

Energy Efficiency Measures

After the baseline energy model was validated, a series of actionable proposals aimed at increasing the building's energy efficiency were identified and simulated to estimate the energy and cost savings that will result from their implementation.

EEM 1 - HVAC Equipment Replacement

- **Replace existing AHUs and boilers in-kind.**

The first EEM that was investigated was replacing all of the existing AHUs and boilers in-kind with new efficient ones at the existing capacities. This was an EEM that was strongly considered because the existing AHUs and boilers were installed when the building was first constructed in 1997. This means that these systems are far past their useful operational life and are most likely operating with low energy efficiency due to their age. This would result in unnecessary losses in electricity and natural gas. Notably, HVAC equipment accounts for 40% of energy usage in commercial buildings [2]. In order to model this EEM and calculate the savings in electricity and natural gas consumption, a baseline energy model was first created. Then, in an alternative model, all AHU fan efficiencies were increased from 80% to 95%, all AHU natural gas heating coil efficiencies were raised from 80% to 95% [3], and all natural gas boiler efficiencies were increased from 80% to 95% [4]. The total annual electricity and natural gas consumption was calculated for both the baseline and EEM models, and the differences were calculated in order to determine the total savings from implementing the EEM.

EEM 2 - Lighting Upgrades

- **Replace all fluorescent lights in the building and parking lots with new LED bulbs.**

The building and parking lots mostly employ fluorescent lighting, and most of the building is served by T8's. Currently, there aren't any functional occupancy sensors for most of the spaces in the building. Upgrading the light fixtures to LED solutions has multiple end-user benefits. LED lighting can yield significant energy savings while also reducing the maintenance and labor costs associated with fluorescent lighting. LED light fixtures have a longer rated life which would mean fewer costs associated with replacing them. This work would need to be contracted out as the lights would need to be retrofitted to fit LEDs. Lighting control options further enhance the energy-saving potential of LED lighting. During the retrofit controls such as daylight saving, occupancy, dimming can be integrated into the lighting system to yield additional energy savings. Transitioning towards LED lighting along with controls could yield electricity savings of around 50% of total annual lighting consumption with short payback periods of 2-3 years [5].

EEM 3 - Solar Photovoltaic (PV) Panels

- **Install Solar PV/Energy Storage system on the roof of the building.**

Solar PV panels can be installed on the roof to provide supplemental electricity to the building. By using the NREL PVWatts Calculator, an assumption of the system parameters can be made [6].

This system can be sized appropriately based on the available space at the site, preferably the roof, and further space can be explored near the site such as parking spaces or other open spaces. The available size of the solar PV panels will need to be calculated and compared to the total electricity consumption for the building in order to determine whether installing solar PV panels is a reasonable method of energy conservation. For the purposes of modeling the EEM, the solar PV panels were assumed to be installed only on the roof. The available roof area was estimated to be 67,425 square feet by using the measuring tool in aerial view of the building on Google Maps. A cell efficiency of 16% was used as the average solar PV cell efficiency in the current market is 15% to 18% [7].

Installing solar photovoltaic panels on the roof of the building has numerous benefits. Not only does it help in offsetting the energy consumption, but it also drops the utility cost of the building and reduces the CO_2 emissions in the process. Solar PV bears an upfront cost of installation, but rebates and incentives like the federal solar tax credit can help you save even more and make installing solar panels even easier. Energy demand tends to be higher in the 11:00 am to 4:00 pm time frame and then early in the evening, which is also when the rate of electricity peaks. Installing solar panels on the roof could prove to be hugely advantageous as it would help meet the electricity demands of the building without relying too much on the power grid. Since solar energy coincides with energy needs for cooling, solar PV panels can provide an effective solution to energy demand peaks, especially in hot summer months where energy demand is high. The model investigates the use of solar panels for the building and how much of the energy load can be offset by solar panels.

The recommended solar PV system should have an appropriately sized electrical energy storage/battery capacity to provide power to the building in case of power interruptions. The battery storage system, when equipped with a dual inverter, will enable the facility to operate off of battery storage at night (at least for partial coverage of the loads based on the demand) and have renewable energy backup options during times of power outages during the day. A combination of thermal and electrical energy storage is also possible. In that case coverage for periods of 2 to 6 hours can be an example option to consider

EEM 4 - VRF System

- **Replace the existing HVAC system with variable refrigerant flow (VRF) system.**

Currently, the 114 Armory building satisfies its heating and cooling needs using traditional natural gas boilers and rooftop units. The existing HVAC system is over 20 years old, and there is a need for an immediate replacement due to the age. An all-in-one VRF system has been considered as an EEM in order to explore the potential benefits of using this technology for building electrification. For the EEM model, the entire existing HVAC system was replaced with a VRF loop, and the energy savings were calculated accordingly. For the implementation of the indoor units, the existing zoning configuration has been used in the EEM model.

VRF is an HVAC system configuration where there are one or more outdoor condensing units and multiple indoor units.

The term VRF refers to the ability of the system to control the amount of refrigerant flowing to each of the evaporators, enabling the use of many evaporators of differing capacities and configurations, individualized comfort control, simultaneous heating and cooling in different zones, and heat recovery from one zone to another. VRF systems operate on the direct expansion (DX) principle meaning that heat is transferred to or from the space directly by circulating refrigerant to evaporators located near or within the conditioned space. Refrigerant flow control is the key to many advantages as well as the major technical challenge of VRF systems. Fig. 3 shows a schematic VRF arrangement.

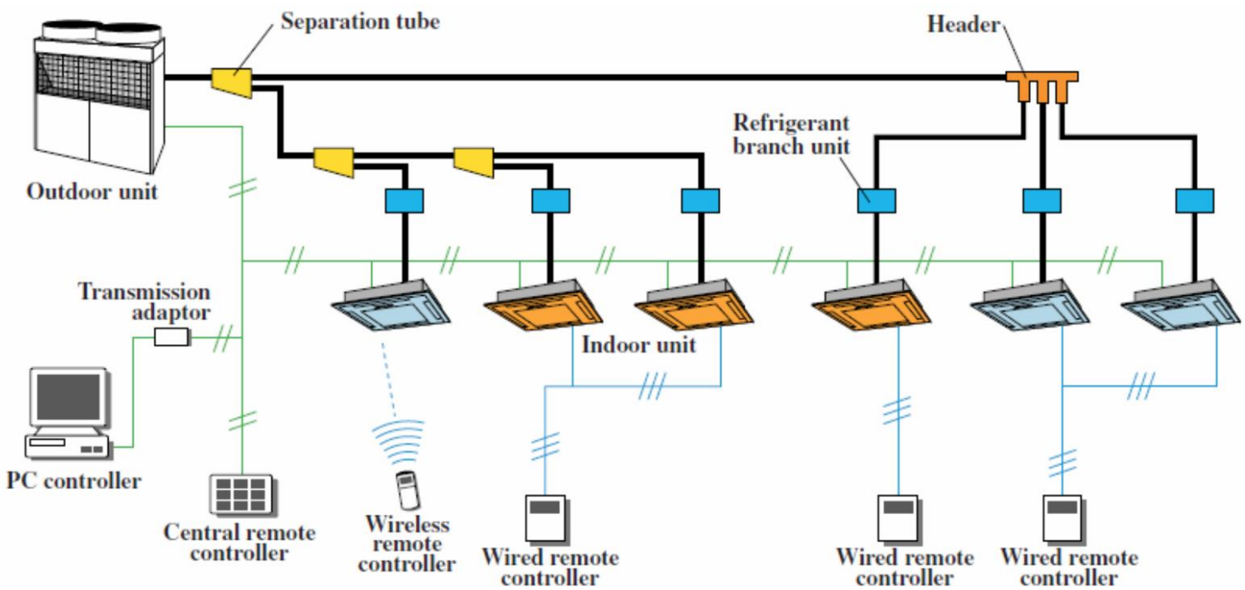


Fig. 3: A schematic VRF arrangement [8].

There are 2 types of VRF systems; heat pump and heat recovery. VRF heat pump systems permit heating or cooling in all of the indoor units but not simultaneous heating and cooling. VRF systems with heat recovery capability can operate simultaneously in heating and/or cooling mode, enabling heat to be used rather than rejected as it would be in traditional heat pump systems. VRF systems are unorthodox HVAC systems, as opposed to conventional ducted systems circulating the air or chilled water throughout the building. VRF systems possess the ability to vary and control the refrigerant flow to provide individual temperature control in various comfort zones. VRF systems have great part-load performances mainly due to variable-speed compressors regulating the capacity from 10% to 100%. Typical VRF systems have a very high energy efficiency ratio (EER) of 15 to 20 [9]. Implementing a VRF loop for the building will not only help in reducing the utility costs but also will bring about efficient temperature control and thermal comfort to the occupants. A VRF system could replace the current boilers and AHUs of the building, which would enable the transition towards the State of Maryland’s future greenhouse gas and environmental goals related to the electrification of state buildings and elimination of fossil fuel systems.

Additional Building Observations and Recommendations

1. Energy Star Certified Appliances

There are currently several different appliances being used throughout the building, including but not limited to microwaves, refrigerators, and dishwashers for small kitchens. Fig. 4 shows examples of these types of appliances. These appliances can be high energy consuming devices, depending on their energy ratings and age. Replacing all appliances that are more than ~ five to seven years old and are also not Energy Star certified with new ones that are Energy Star certified will result in savings in electricity consumption, and savings may be shown in water consumption as well.

Fig. 4: Examples of Miscellaneous Appliances.

2. Leakage from Domestic Water Heaters

It was observed that there were a few electric domestic water heaters that had a leakage issue in the mechanical room of the Armory Building. An example of this is shown in Fig. 5. Although the leakage from a few of these units may not seem like a significant energy loss to the building, it is always desirable to have these water heaters work at the highest efficiency levels to provide hot water to the various sections of the building. It is recommended to ensure that these units are properly maintained so that they are working as efficiently as possible and to prevent leakages because these could hamper the efficiency with which the system might operate and could lead to eventual failure when it is needed the most.

Fig. 5: Typical Unit Water Heater Leakage.

3. Green Wall

Green walls in the lobby area of the facility could be considered to further condition the air in the space.

A drip-free indoor living wall option (for water containment) can be considered in the lobby. Green/living walls contribute to indoor air quality. They naturally provide oxygen, humidity, and reduce particulates and volatile organic compounds. Additionally, studies have indicated plants enable more productivity among the building occupants while also ensuring comfort levels. Indoor living wall solutions provided by LiveWall could be considered for the lobby space [10].

4. Smart Power Strips

Smart power strips, such as ones provided by Tricklestar, can reduce energy waste, prolong the life of electronics, and offer premium fireproof surge protection. It will be advantageous from an energy audit standpoint to replace all power strips in the building with smart power strips to reduce annual electricity consumption.

5. Variable Frequency Drives

Many of the existing HVAC systems currently do not have variable frequency drives installed and integrated into them. Variable frequency drives modulate the frequency of fans and pumps to control the speed of these components so that they are not operating at a higher load than needed. This allows for improvements in the energy efficiency of the HVAC systems, and there will be reductions in annual electricity consumption.

6. WaterSense at Work, Sanitary Fixtures and Equipment

Sanitary fixtures and equipment in restrooms and laundries can account for nearly 50 percent of total water use within a facility and can provide significant opportunities for water and energy savings, particularly in older buildings with inefficient fixtures and equipment [11].

Major Energy Efficiency Measures Summary

The energy efficiency measures discussed above were simulated into the baseline energy model and the expected savings resulting from the implementation of these measures are summarized in Table 3.

Table 3: Energy and Cost Savings Summary.

Energy Efficiency Measures (EEM)	Modeled Annual Consumption		Projected Energy Savings		Projected Energy Savings Percentage		Utility Savings*		
	Electricity (MWh/yr)	Natural gas (therms/yr)	Electricity (MWh/yr)	Natural gas (therms/yr)	Electricity (%)	Natural gas (%)	Electricity ($/yr)	Natural gas ($/yr)	Total ($/yr)

EEM 1 - HVAC Equipment Replacement	1586	37,968	61	4580	3.7	10.8	6030	45,351	51,381
EEM 2 - Lighting Upgrades	1589	43,050	58	-502	3.5	-1.2	5,812	-4,971	841
EEM 3 - Solar PV Panels	1495	42,548	152	0	9.2	0.0	15,158	0	15,158
EEM 4 - VRF System	993	0	654	42,548	39.7	100.0	65,372	42,131	107,503
Total Savings			925	46,626	56.1	109.6	92,372	82,511	174,883

***** The electricity rate considered was $0.10/kWh and for natural gas, the rate considered was $1/therm. These rates were estimated based on the utility analysis from EnergyCap.

The annual electricity usage and natural gas usage derived from the baseline model is 1,647 MWh and 42,548 therms, respectively. The total annual utility cost of electricity (1,647 MWh) and natural gas (42,548 MBtu) is $177,832. The observed annual utility savings associated with implementing each of the EEMs are shown in Table 3.

Table 4: Carbon Footprint Analysis.

Energy Efficiency Measures (EEM)	**Projected Energy Savings**		**Carbon Dioxide Reduction**	
	Electricity (MWh/yr)	**Natural gas (therms/yr)**	**Electricity (lbs/year)**	**Natural gas (lbs/year)**
EEM 1 - HVAC Replacement	61	4580	44,320	746,540
EEM 2 - Lighting Upgrades	58	-502	42,598	-81,826

EEM 3 - Solar PV Panels	152	0	111,104	0
EEM 4 - VRF System	654	42548	479,175	6,935,324
Total Savings	925	46,626	677,197	7,600,038

The above carbon footprint analysis shown in Table 4 is estimated for a specific efficiency wherein the equipment degradation would result in an increase of carbon dioxide emissions both for the upgrade and baseline equipment. The above values are based on the State of Maryland estimates of 733 lb of CO_2 emissions per every MWh of Electricity based on 2019 data [12] and 11.68 lb of CO_2 emissions per every therm of natural gas [13]. Based on the current average annual utility data, carbon dioxide emissions are 1,048,977 lbs per year from electricity and 405,588 lbs per year from natural gas. Reductions in carbon dioxide emissions per year for the respective EEMs are shown in Table 4. However, it must be noted that the CO_2 emission per MWh for the grid electricity source is projected to continue to drop over time (with a rate of 23 lbs/MWh per year until 2030 and 8 lbs/MWh per year afterward) due to the use of cleaner fuels and renewable energy sources. See Fig. 6 for more detail.

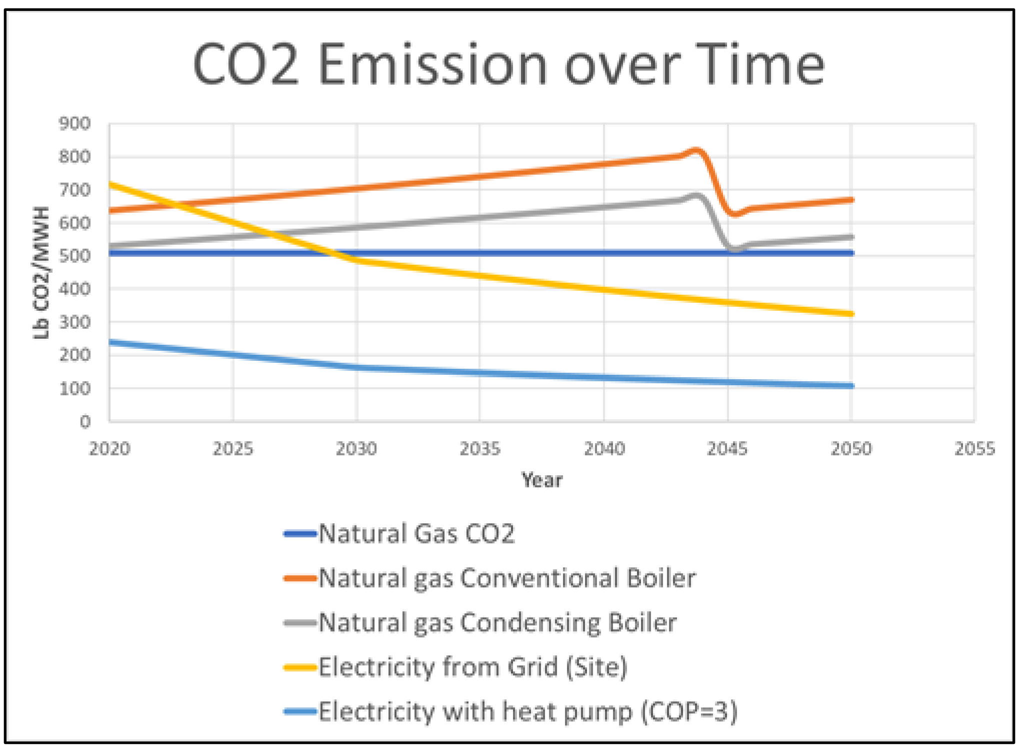


Fig. 6: CO_2 emission over time (source: DGS).

Building HVAC Description

The hot water is supplied by two gas-fired boilers (Smith J50A-15HBS-5), each with a capacity of 1491 MBH according to the existing base building mechanical drawings. These two boilers work in manual lead-lag operation, and the alternation is performed by the facility manager to ensure that the boiler work is distributed evenly between the two units throughout the year. There are four identical hot water pumps with two on standby and the remaining two working together simultaneously to supply hot water to the AHU heating coils and variable-air-volume (VAV) reheat coils. Fig. 7 shows the boiler units installed in the mechanical room. The boilers were installed in 1997 when the building was originally constructed.

Fig. 7: The Boiler Unit.

There are six AHUs in the building serving most of the building's needs. Five serve the ground floor and one AHU serves the mezzanine level are located at the mezzanine level and have dedicated return air fans. There are also several VAV boxes throughout the building serving different zones to provide temperature control for each of those respective zones.

In addition, several other HVAC systems are serving the building to provide supplemental heating and cooling. These include unit heaters, finned tube radiators, and split systems serving IT rooms. The building's HVAC system schedule is consistent with the building schedule, and the occupied room setpoint temperatures are around 70°F and 75°F during the winter and summer seasons, respectively. There are also six water heaters original to the base building supplying domestic hot water. WH-1 is a 30-kW electric water heater with a 300-gal tank, WH-2 is a 3-kW electric water heater with a 30-gal tank, WH-3 is a 9-kW electric water heater with a 30-gal tank, WH-4 is a 3-kW electric water heater with a 20-gal tank, WH-5 is a 700 Btuh electric water heater with a 69-gal tank, and WH-6 is a 370 Btuh with a 75-gal tank. Three identical pumps are serving the domestic hot water system. Each pump has a flow of 4 GPM and a pump motor of 5 HP. A summary of the design specifications of the existing building HVAC system retrieved from the building's mechanical drawings is shown in Table 5.

Table 5a: Air handling units specifications summary.

Air Handling Units				
Designation	**Serves**	**Cooling Capacity (MBH)**	**Heating Capacity (MBH)**	**Model**
AHU-1	East	1086	-	McQuay
AHU-2	1st Floor	461	-	McQuay
AHU-3	Central	-	1432.4	McQuay
AHU-4	Central	-	438	McQuay
AHU-5	West	-	496	McQuay
AHU-6	West	-	500	McQuay

Table 5b: Hot Water Unit Heaters specifications summary.

Hot Water Unit Heaters			
Designation	**Location**	**CFM**	**Heating Capacity (MBH)**
UH-1	Room 113	543	14
UH-2	Room 112	543	14
UH-3	Room 116	543	14

UH-4	Room 117	543	14
UH-5	Room 137	280	4
UH-6	Room 118	1535	48.1
UH-7	Room 127	315	8.3
UH-8	Room 123, 124	280	4
UH-9	Room 125, 126	280	4
UH-10	Room 114	280	4
UH-11	Room 103	590	15
UH-12	Room 103	590	15
UH-13	Room 153	543	14
UH-14	Room 150	543	14
UH-15	Room 147	543	14
UH-16	Room 144	543	14
UH-17	Room 138	280	4

Table 5c: Boilers specifications summary.

Boilers				
Designation	**Location**	**Fuel**	**Output MBH**	**Model**
Boiler-1	Basement	Natural Gas	1491	Smith
Boiler-2	Basement	Natural Gas	1491	Smith

Table 5d: Pumps specifications summary.

Pumps				
Designation	**Location**	**Service**	**HP**	**Flow Rate (GPM)**
Pump-1	Basement	Primary Heating Water	5	115
Pump-2	Basement	Primary Heating Water	5	115

Pump-3	Basement	Second Heating Water	7.5	100
Pump-4	Basement	Second Heating Water	7.5	100
Pump-5	Mezzanine	Preheat Water: AHU-1	1/35	3
Pump-6	Mezzanine	Preheat Water: AHU-2	1/25	5
Pump-7	Mezzanine	Preheat Water: AHU-3	1/25	5
Pump-8	Mezzanine	Preheat Water: AHU-4	1/25	5
Pump-9	Mezzanine	Preheat Water: AHU-5	1/25	5
Pump-10	Mezzanine	Preheat Water: AHU-6	1/35	3

Energy Audit Methodology

The project can be generally divided into three phases: Building Comprehension, Energy Model Development, and Energy Efficiency Measure analysis.

Building Comprehension

Building comprehension is the process of data collection and analysis is performed in 4 steps: Utility Analysis, Building Walkthrough, Archival Review, and Monitoring the Building Automation System.

The first objective during the building comprehension phase is to understand the building's energy consumption patterns. Once notable patterns and characteristics of a building's energy consumption are known, they can be compared to available "benchmark" data to assess a building's relative performance.

A building walkthrough was conducted with the facility personnel. The aim was to provide a first-hand examination of all building spaces and equipment as well as establish relationships with people involved in the building's operations. The walkthrough was thorough and included visiting every available space, including mechanical rooms, electrical rooms, offices, restrooms, and locker rooms. A walkthrough is often crucial in revealing operational issues and helping to elucidate building use patterns that cannot be found anywhere else. The building walkthrough revealed data including the integrity of building envelope and mechanical systems, thermal zone temperature controls and setpoints, office and courtroom equipment, construction materials, schedules, as well as occupant behavior.

An archival review of the building's documentation was conducted alongside the utility analysis before developing the energy model. The referenced documents included the floor plans as well as architectural, mechanical, electrical, and plumbing diagrams. However, certain assumptions had to be made for the unavailable data.

In the final step of building comprehension, access to any Building Automation System (BAS) is sought out and analyzed. In the case of the Armory building at Camp Fretterd, the facility didn't have a working BAS system to be analyzed.

Energy Model Development

The energy model was developed as follows: The simulation software was selected, a baseline model was developed, the model was calibrated, and the results were validated. For this project, the commercially available building simulation software Trane Trace 3D Plus was used.

The early stages of energy model development began after the building walkthrough and utility analysis was completed as well as once the archival review had begun. Fig. 8 describes the general flow of data in energy models. Building geometry, weather data, HVAC system data, internal loads, operating schedules, and simulation-specific parameters are inputted in the simulation engine, which then simulates the energy consumption in the building.

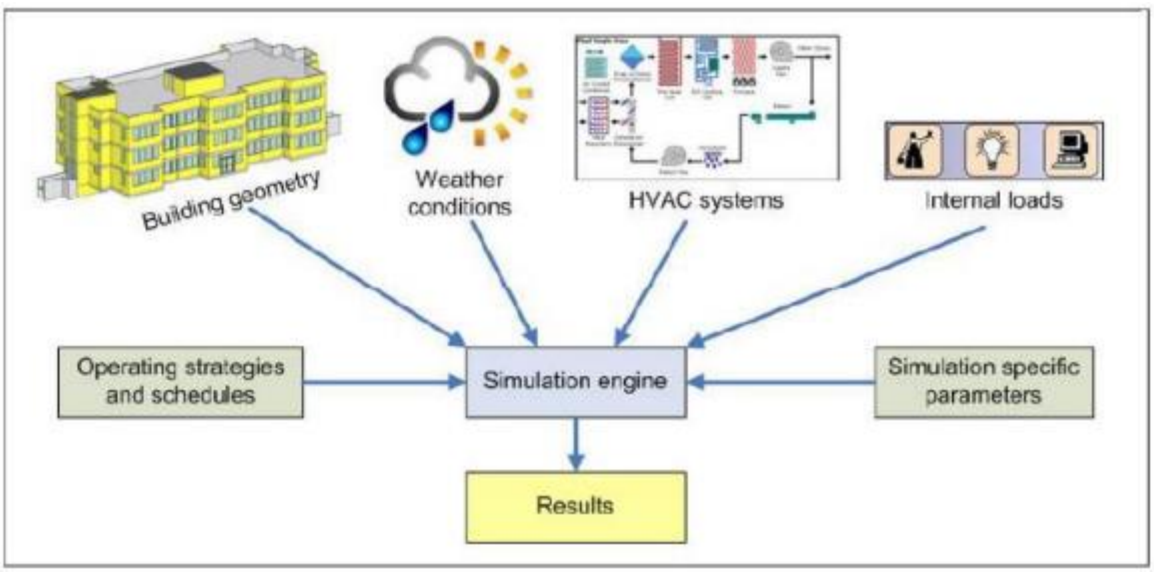


Fig. 8: General data flow of building energy simulation software. [14]

Energy Efficiency Measure Analysis

The energy efficiency measures were selected primarily through data obtained during the building comprehension phase and after reviewing the relevant literature. For example, the ASHRAE Standard 90.1 - 2019: Energy Standard for Buildings Except Low-Rise Residential Buildings provides full-scope strategies and technical guidance for achieving at least 30% energy savings [15]. ASHRAE also provides registrants with function-specific Advanced Energy Design Guides for achieving additional energy savings up to 50% [16]. When possible, these energy conservation measures were analyzed by the energy model of the building.

Load Calculations

The building load calculations were carried out and analyzed to determine and evaluate whether the existing building HVAC system is properly sized based on the calculated total design cooling load. The total cooling capacity of the building's existing HVAC system was estimated to be about 129 tons by determining the sum of the cooling capacities (sensible + latent) of the AHU's and split systems. The Trane Trace 3D Plus energy model calculated the site peak cooling load to be 53 tons, which is way lower than the building's existing HVAC system's total cooling capacity. Therefore, the existing HVAC systems were determined to be oversized by about 140% when compared to the baseline energy model. The uncertainty can be due to several factors such as changes in the building conditions, changes in the building use, as well as human modeling error. However, the team has determined that the building was modeled as accurately as possible and that the difference is likely due to the account for redundancy when the chillers were first sized. Therefore, the model was able to be used to complete the energy audit for this building.

As for the boilers, the calculated site peak heating load from the energy model was 210 MBH and the capacity of the two current boilers is 1,491 MBH each. With the combined capacity of both boilers, the boilers seem to be oversized by about 610% when compared to the heating needs of the building as calculated in the model. The boilers are controlled in lead-lag operation. In addition, the boilers may be oversized to accommodate for higher demand due to unexpected extreme weather conditions as well as many other factors. Usually having some degree of redundancy is recommended, which is typically N+1 for boilers, depending on the nature of the building and its mission. For a typical school building, N+1 is an acceptable degree of redundancy for boiler sizing. Therefore, it can be determined that the existing boilers for this particular building have been sized properly. However, boilers having 7 times the capacity as compared to the heating load seems like overkill and should be downsized in accordance with the actual heating loads of the building. It is strongly recommended to seek engineering consulting and revisit the HVAC loads of the building in order to select the most efficient and appropriate replacement equipment as possible.

Utility Analysis and Benchmarking

Utility data from 2018-2020 were retrieved through the State of Maryland's EnergyCAP tool, which collects and stores energy consumption data from most facilities in the State of Maryland. Monthly energy consumption data for the electricity and natural gas were collected in the units of kWh and therms respectively. Then, these values were converted to units of kBtu using conversion factors provided by the US DOE and shown in Table 2 [17].

Fig. 9 & 10 show the average monthly electricity and natural gas consumption respectively for the years of 2018-2020 as well as provide several key insights.

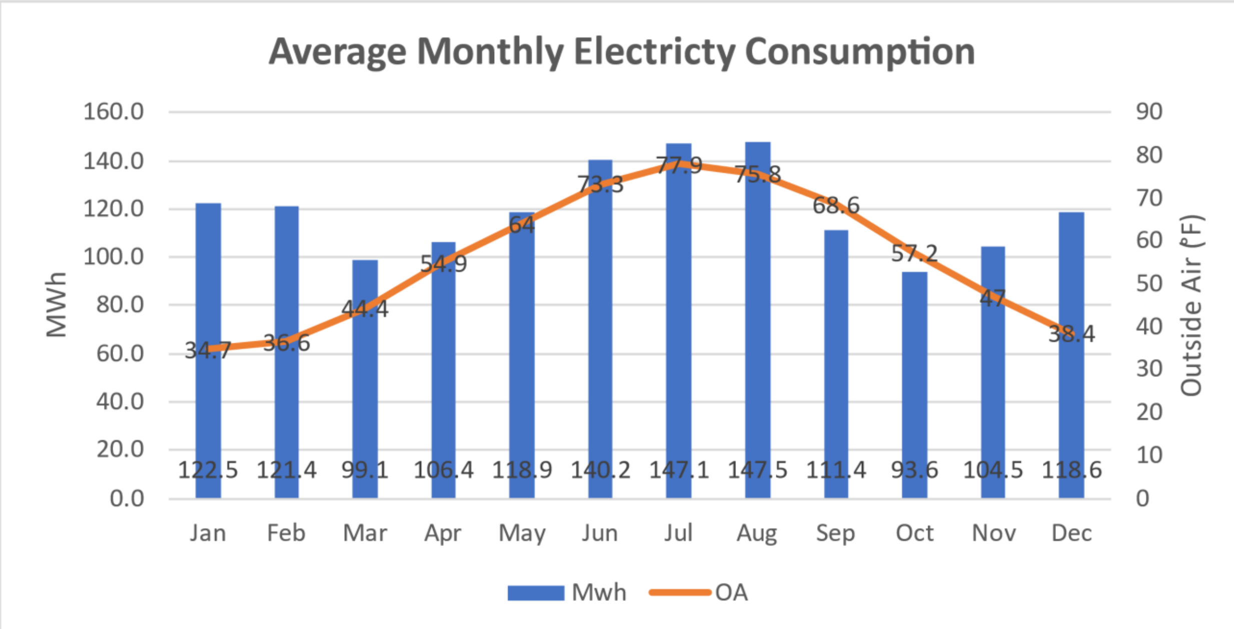


Fig. 9: Average Monthly Electricity Consumption

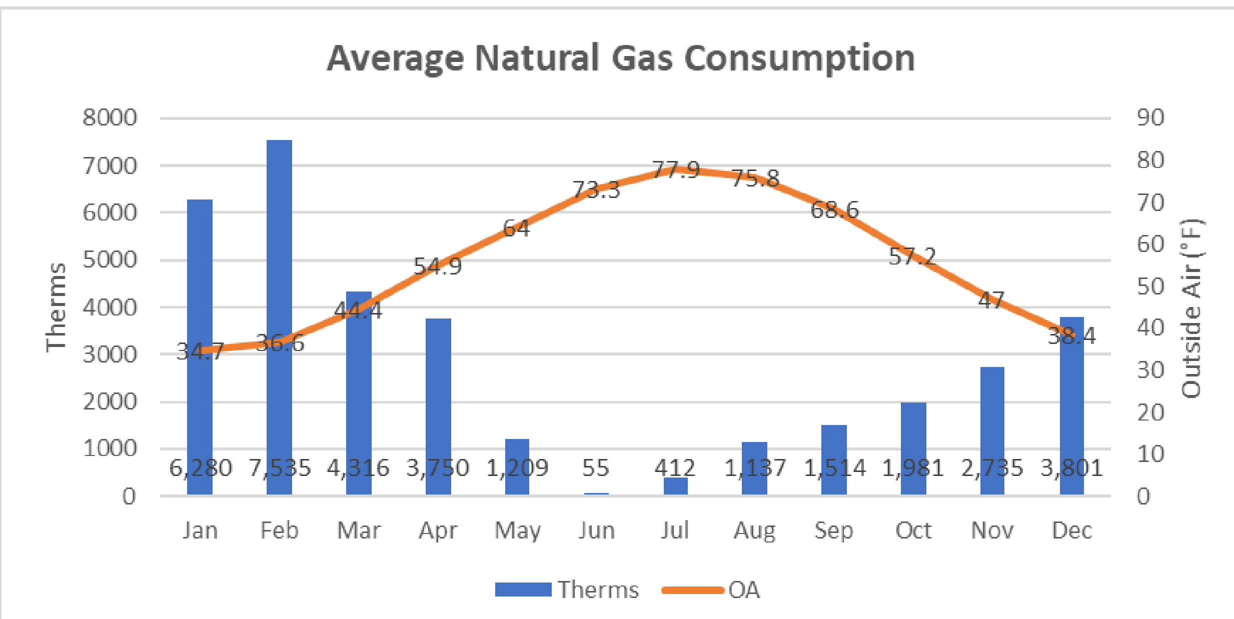


Fig. 10: Average Monthly Natural Gas Consumption

According to the utility data, an average of 1,431,074 kWh of electricity is consumed every year. Electricity consumption increases during the summer months due to the increased space cooling requirements. Likewise, natural gas consumption increases during the winter months due to increased space heating requirements. According to the utility data, an average of 34,725 therms of natural gas is consumed every year. The natural gas consumption in the summer is due to the reheat operation required to provide adequate dehumidification and occupant comfort in certain spaces.

Energy benchmarking assessment helps to identify the potential opportunities to improve energy efficiency and reduce the associated costs for utilities. To further verify the utility benchmarking calculations, benchmarking was performed using EnergyStar Portfolio Manager [18]. The Commercial Buildings Energy Consumption Survey (CBECS) database data was also used to evaluate the energy profile of the facility [19]. This comparison provides an opportunity to determine the scope of improving overall energy efficiency.

In the case of the EnergyStar Portfolio Manager, the facility utility data was fed to the Portfolio Manager. These included electricity and natural gas bills. They were further supplemented with the facility data such as floor area, building use, and occupancy. Table 6 provides a summary of the result of benchmarking analysis using both the EnergyStar Portfolio Manager and the CBECS database. This table also compares the obtained value with the standard EnergyStar and CBECS score for an educational facility [18].

Table 6: Benchmarking Results Summary.

Parameter	Armory Building Value	Standard Value	Reference
Energy Star Score (1-100)	46	75	EnergyStar Portfolio Manager
Site EUI (kBtu/sf)	125.92	52.9	Commercial Buildings Energy Consumption Survey (CBECS)
Utility Cost Per Area ($/sf)	2.35	1.93	Commercial Buildings Energy Consumption Survey (CBECS)

The overall Energy Star score of 46 indicates that the building is performing significantly below the median energy performance. The EUI value of 125.92 was obtained using EnergyStar Portfolio Manager, and this is consistent with the EUI report in Table 2. Based on the CBECS average data for offices, the 114 Armory building currently has an Energy Usage Intensity higher than the average (125.92 vs. 52.9). Also, the utility cost per area is higher than the average value (2.35 vs. 1.93). This means when compared to other reference office buildings, the 114 Armory building is performing worse than typical office buildings in the United State and that there may be additional opportunities to increase the overall energy efficiency of the facility. Once again, the 114 Armory utility cost per area does not include water consumption as the annual average water consumption and cost could not be accurately determined due to the limited amount of archived utility data. However, this may suggest that the utility cost per area is actually even greater than what is shown in Table 6. It is recommended that the latest water utility bills are obtained in their entirety to be able to accurately determine the comprehensive utility cost information for the building.

Energy Modeling

The physical structure of the 114 Armory building was developed in Trane Trace 3D Plus. Initially, PDF images of the architectural plans were imported into Trane Trace 3D Plus to generate the initial building geometry. Floor dimensions were calculated by applying proper dimensional scaling based on the documented reference scale. Then, the required zones were modeled into the floor layout, and the subsequent HVAC systems were designed to be selected for the respective zones. The required model information such as building envelope construction was derived from the building plans as well as the data gathered during the building walkthrough. Certain informed assumptions were made for the unavailable data through physical observations, building plan analyses, and discussions with the facility personnel.

All of the spaces in each of the levels of the building were modeled and zoned in order to make the model as accurate as possible. The specific fenestration details such as doors and windows were also implemented. Fig. 11 shows the 3-D representation of the building model as rendered in Trane Trace 3D Plus.

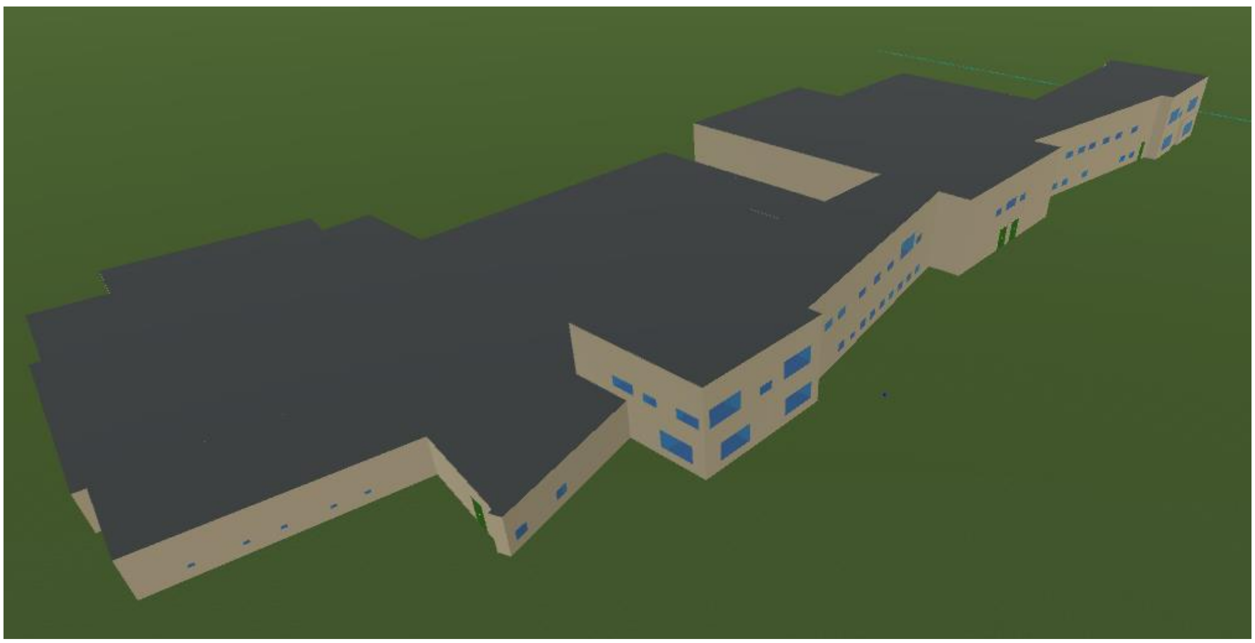


Fig. 11: Building energy model rendered in Trane Trace 3D Plus.

The energy model had a total of 120 thermal zones. Each thermal zone represents the space served by a VAV or AHU. Fig. 12 illustrates the method by which the thermal zone layout was created. Each zone was provided with unique air terminal unit specifications, exhaust capacities, and thermostats derived from the original mechanical drawings. An unconditioned thermal zone was also considered for spaces, such as stairways, that were assumed as insignificant compared to the model as a whole in order to increase efficiency and create ease of modeling.

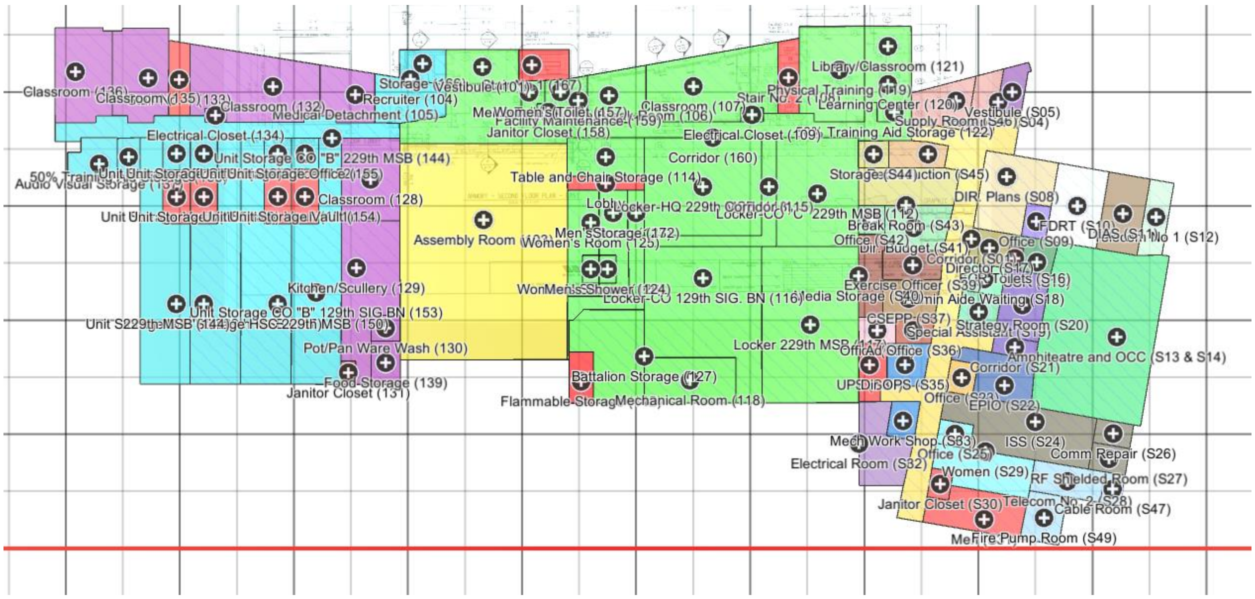


Fig. 12: Model thermal zone design.

The main space types defined to specify the lighting, plug loads, occupancy, and their associated schedules were offices, conference rooms, lobbies, storage rooms, IT rooms, kitchen, and corridors. These definitions were developed through the process of building comprehension. Trane Trace 3D Plus has several modes of data entry. Building envelope, boundary conditions, fenestration, construction materials, as well as simplified space type definitions, thermal zones, schedules, plant loops, and basic HVAC definitions were all entered into the software. The occupancy, equipment, lighting, and temperature set-point schedules were implemented as well.

Model Validation

Calibrating the baseline energy model to closely match the actual building energy consumption data is crucial. As discussed in an earlier section, *Utility Analysis and Benchmarking*, the main energy commodities are electricity and natural gas. Utility consumption data were averaged and compared to the Trane Trace 3D Plus simulation results. Fig. 13 and 14 show the results of the baseline energy model's monthly energy consumption as compared to the building's actual monthly energy consumption data for both electricity and natural gas. There are a few deviations in energy consumption for the model and actual utility data mainly due to the scheduling uncertainty. It is also important to observe that this period fell during the COVID-19 pandemic which may lead to a few discrepancies between modeled and observed data.

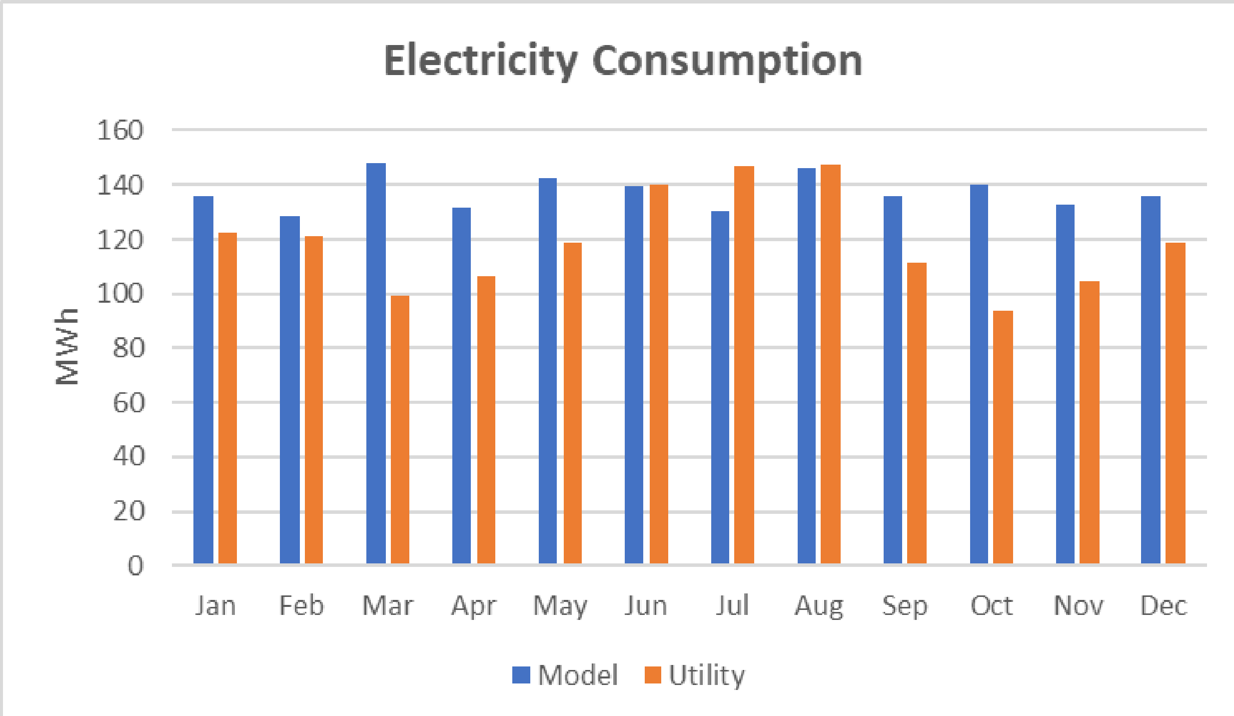


Fig. 13: Average monthly electricity consumption comparison (January 2018- December 2020).

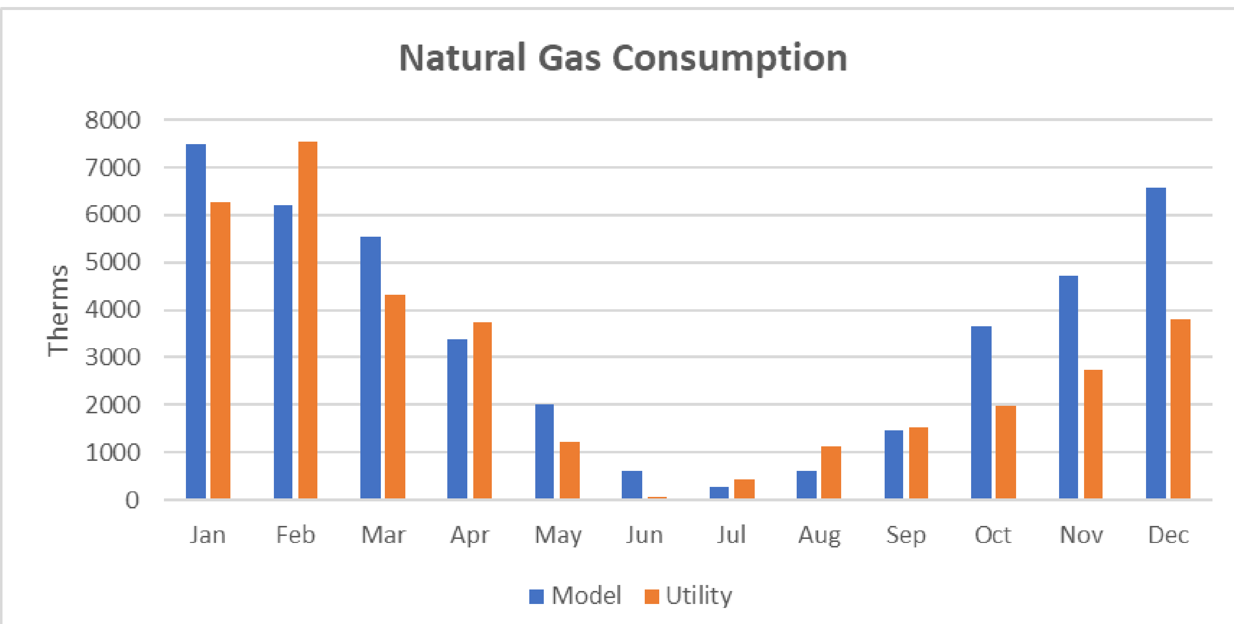


Fig. 14: Average monthly natural gas consumption comparison (January 2018- December 2020).

The predicted monthly energy consumption of the baseline energy model reasonably matched the trend of the average monthly energy consumption reported by utility bills between 2018 and 2020 except for the electricity consumption in the shoulder months. The utility data showed that electricity consumption was relatively high in the shoulder months compared to the predicted data, which indicates that an unnecessary amount of electricity may have been being consumed during these months, thus presenting opportunities for reductions through appropriate energy conservation measures, such as temperature setback for unoccupied periods and/or when the outside temperature is comfortable enough. This can be noticed from the absence of a curve for electricity consumptions in the utility bills from EnergyCAP. Such an uneven distribution in the utility bills can be attributed to the fact that there are multiple configurations of AHUs serving the different sections of the building; both single-zone AHUs as well Split System (DX) AHUs providing heating and cooling as per the occupancy. This makes it necessary to have temperature control settings to set the temperatures at the right values when occupied and unoccupied.

In the case of the modeled electricity consumption in comparison to the actual utility data, the values deviate by ~15% while the natural gas consumption values deviate by ~22%. The reason for the deviations in the electricity and natural gas consumption may be due to various reasons, such as the discrepancy in the occupancy and scheduling of the building. These deviations are close to the ASHRAE calibration requirements as given by Guideline 14-2002 which allows a deviation of up to 15% [20]. Therefore, the team has determined that the model is suitable to use for energy analysis and auditing of the Armory building at Camp Fretterd. Furthermore, the energy model used several template parameters for a typical low-rise office building provided by C.D.S., the provider of the Trane Trace 3D Plus energy modeling software. These template parameters include but are not limited to space-specific occupancy and load schedules, occupancy and load densities, as well as ventilation and infiltration rate. Using these template values allowed the team to gain more confidence that the model is consistent with the actual building.

Future Renewable Energy/Sustainability Scope

In 2018, the direct greenhouse gas emissions from the residential and commercial building sector accounted for 12.3% of total U.S. greenhouse gas emissions [21]. The greenhouse gas emissions from this sector vary from year to year often correlated with seasonal fluctuations in energy use caused primarily by weather conditions.

Building Decarbonization / Electrification Analysis

Residential and commercial buildings use large quantities of energy for heating, cooling, lighting, and other needs. In 2012-2013, the median ages of a U.S. home and commercial building were 37 years and 32 years, respectively. Slow turnover means that by the year 2050 much of the existing U.S. building stock will be 70 years old. Population and economic growth will also drive substantial increases in the total building stock. Decarbonizing the building sector requires steps in the near term to reduce the energy demand and carbon intensity of both existing buildings and new constructions. Replacing gas with efficient electric appliances in existing buildings and constructing new buildings as all-electric is the primary approach to building decarbonization [21].

Electrification

Electrification of end uses will be a key pathway to reducing emissions. Assuming a decarbonized power sector, using electricity for heating, cooling, and hot water needs, instead of burning natural gas or natural gas, can greatly reduce a building’s emissions. Based on DGS data on carbon emissions (Fig. 5, from above), by the year 2029, the carbon emissions in lb/MWh from the electricity grid will be at the same level as the amount from natural gas sources. This downward trend would continue after 2029 with the CO_2 emissions from the electricity grid being less than that of natural gas sources. Heat pumps are currently one of the most, if not the most efficient available technology for space heating in the commercial and residential sectors. Although heat pumps have high initial capital costs, high efficiency and minimal maintenance make air source heat pumps a rewarding investment over the long term. Additionally, the CO_2 emissions for an electric heat pump is less than that of a natural gas boiler. Other existing renewable thermal technologies such as geothermal heat pumps or solar water heaters can be installed as fossil fuel-powered replacements. Additional advancements in the heat pump to accommodate even colder conditions can be adopted in the next few years.

Energy Efficiency

Buildings undergo several phases over their lifetimes, including design, construction, operation, and retrofits. In each stage, there are opportunities to improve energy efficiency and reduce emissions: designing a building to use more natural lighting or installing district heating (similar to the central Satellite Central Utility Building {SCUB} units in the UMD campus), sourcing construction materials that have less embodied carbon, changing consumer behavior and electricity usage patterns to reduce energy demand or planning major retrofits over the life of the building. In particular, district heating systems are often connected to combined heat and power (CHP) plants. These are also known as cogeneration plants, and they generate electric power in addition to heating and cooling. This allows the system to achieve energy efficiencies above 80% [22].

Further areas where technological advances can increase energy efficiency include improving building envelopes and window insulation to control air and moisture and optimizing the cost and performance of LED lighting. Additional challenges include building occupants' lack of awareness and information about energy use, which could pave the way for the further deployment of smart metering.

Water Management

Since consistent and reliable water consumption data was not available to include a respective table for consumption, direct savings for water efficiency measure calculations were not possible here. The Federal Energy Management Program's - Water Project Screening Tool [23], however, would be a good option to quickly screen for water efficiency opportunities. The tool has easy-to-use inputs that look at the location, water supply, rates, site-level data, and water end-use data to make recommendations to lower water usage in restrooms, landscape irrigation, cooling towers, steam systems, vehicle washes, and single-pass cooling.

Future Renewable Energy Scope

Transitioning towards an all-electric system would not only help with the reduction of greenhouse gas emissions but also enable the opportunity to deploy renewable energy options at the site to supplement the energy demands.

In the current building, the domestic hot water is supplied by a gas-fired water heater. ENERGY STAR certified electric storage water heaters use a highly efficient heat pump – essentially a refrigerator run in reverse – to transfer heat from the surrounding air to the water, using less than half the energy of an electric resistance unit. It is suggested that hot water heaters could be replaced with Heat pump water heaters (HPWHs).

Further opportunities include purchasing electricity from Renewable utilities wherein the source of renewable energy could go hand in hand with the site's renewable energy implementation. Rebate incentives can be claimed in the form of Solar Renewable Energy Credit (SRECs) [24]. SRECs are created for each 1000 kWh of electricity produced by a qualified alternative energy source. There is no specific size limit, but the systems generally must be connected to the distribution system serving the state in order to qualify.

Conclusions

The Armory Building at Camp Fretterd is an interesting facility. Since it is an old construction that is more than 20 years old, its energy consumption performance is rather considerably higher than the average levels of a typical office facility building.

The facility would benefit by replacing the existing HVAC systems with new higher efficiency models so that they are energy efficient and perform according to the benchmark standards. The facility would also benefit from lighting upgrades on account that it is currently mostly operating with fluorescent light bulbs while the trend for modern buildings is LEDs for increasing energy efficiency. Energy Efficient Measures were identified to transition the building system to these newer technologies (such as LED lighting) and make the building energy-efficient as a whole. The expected energy savings resulting from the implementation of lighting upgrades introduced in this report will decrease the annual electricity consumption in kWh by 3.5%, and natural gas consumption will increase by 1.2%. This amounts to a total energy reduction of 198,285 kBtu or 58,114 kWh. These are relatively high numbers in energy savings potential in comparison to other Maryland state buildings, so it will be very beneficial to implement these EEMs as soon as possible.

According to the baseline model, HVAC accounts for 80.6% of the total building energy consumption, while lighting only accounts for 8.4%. As shown in Table 5, the EUI for the building is significantly higher than the average standard from CBECS data for educational facilities, so there may be potential for more energy savings by performing more large-scale improvements or replacements of the building’s existing HVAC systems as shown in the results for the other EEMs discussed in the report.

Detailed and accurate building energy auditing and modeling are highly involved processes requiring substantial time, resources, and coordination. Buildings are complex systems whose behavior and energy consumption are often not understood without a thorough investigation of mechanical systems, electrical equipment loads, environmental conditions, and occupant behavior.

In spite of the challenges associated with energy modeling, the applied baseline energy model detailed in this report can provide a number of powerful tools to a diverse range of public courthouses. This model can be further fine-tuned based on future developments to account for changes in the energy profile of the facility.

Summary SOW for the identified EEMs

HVAC Upgrades

Option 1 (HVAC Replacement) - All existing HVAC systems shall be replaced in-kind with new and high-efficiency equipment after new load calculations are performed for the building by a certified consulting engineer in order to properly size the new equipment for maximum efficiency. These types of equipment include but are not limited to boilers, air handling units, and air terminal units. Ensure that the controls and scheduling of the new HVAC systems are set so that proper temperature setpoints are maintained to ensure the thermal comfort of occupants. The contractor shall be responsible for the provision and installation of all equipment and associated piping, ductwork, and accessories.

Option 2 (VRF System) - All existing HVAC systems shall be replaced by an all-in-one VRF system after new load calculations are performed for the building by a certified consulting engineer in order to properly size the new equipment for maximum efficiency. Ensure that the controls and scheduling of the new HVAC systems are set so that proper temperature setpoints are maintained to ensure the thermal comfort of occupants. The contractor shall be responsible for the provision and installation of all equipment and associated piping, ductwork, and accessories. VRF Systems have typical average payback periods of 6-8 years [25].

Lighting Upgrades – All fluorescent lights in the building and parking lots shall be replaced with new energy-efficient LED light bulbs to match the existing fixture styles. Occupancy sensors and controls shall also be provided and shall integrate the new LED lighting [26]. LED lights with the implementation of controls could give 50% electricity savings annually while having a typical payback period as short as 2-3 years [5].

Solar PV Panels - Solar PV panels shall be provided and installed by the contractor. The total area available on the roof, parking lots, and other site locations for the solar PV panel installation shall be coordinated with the building owner. All required controls, wiring, and accessories shall also be provided. The average payback period for roof-mounted Solar PV systems in the state of Maryland is ~11 years [27].

Replace applicable Appliances with Energy Star Certified Appliances – All existing appliances in the building should be examined for their age and SEER rating. The applicable appliances that are inefficient should be replaced with the Energy Star certified units. The appliance types include but are not limited to microwaves, refrigerators, freezers, ice makers, and dishwashers. The contractor shall locate all applicable appliances within the building and after careful and professional assessment provide replacement options with pricing to include installation costs and estimated payback periods.

Green Wall – A green wall can be provided for one or more lobby areas in the building. The choice of lobby area(s) shall be coordinated with the owner. The basis of the design for the green wall shall be indoor living wall solutions provided by LiveWall.

Smart Power Strips – All power strips in the building shall be replaced with smart power strips, equal to ones provided by Tricklestar. The contractor shall provide pricing for the provision of smart power strips as well as for their installation in accordance with existing power connection setups for each room in the building. The payback periods for Smart Power Strips is as short as 1.1 years [28].

Variable Frequency Drives – The contractor shall identify all HVAC-related fans and pumps that currently do not have variable frequency drives installed on and to integrate them. The contractor shall also provide pricing for the provision of variable frequency drives as well as for installation and integration for these fans and pumps. Pricing shall also include any controls modifications as necessary.

Sanitary Fixtures and Laundry – WaterSense at Work, Sanitary Fixtures and Equipment, provides information on equipment that nearly every type of commercial and institutional facility has including: toilets, urinals, faucets, showerheads and laundry equipment [11]. WaterSense labeled products are 20% more water-efficient than average products with payback periods as short as 2-3 years [29].

General Low cost-No cost Energy Efficiency Opportunities (General EnergyStar recommendations)

Following is a general list of low cost/no-cost energy saving opportunities that apply to most buildings in the areas of lighting, heating, cooling, and water heating consumption. It is offered as a supplementary piece of information for the report.

✓ Regularly change or clean HVAC filters, particularly during peak cooling or heating season, as dirty filters cost more to use, overwork the equipment, and result in lower indoor air quality.

✓ Calibrate thermostats to ensure that their ambient temperature readings are correct, and adjust temperature set points for seasonal changes.

✓ Maximize daylight harvesting by opening or closing blinds to make the best use of the natural daylight. Take advantage of skylights or other natural daylight sources to reduce lighting consumption during daytime hours.

✓ Program the lights so that they are off when not in use or when natural daylight is sufficient. This can reduce lighting energy consumption expenses by 10-40% [30].

Appendix

List of the Nomenclature used in the report

AHU – Air Handling Unit
BAS – Building Automation System
BGE – Baltimore Gas and Electric company
CFL – Compact Fluorescent Lamp
DGS – Department of General Services
DOAS – Dedicated Outdoor Air System
GMP – Gallons Per Minute
IAQ – Indoor Air Quality
DHW – Domestic Hot Water
DLC – Design Lights Consortium
EEM – Energy Efficiency Measure
EUI - Energy Use Intensity
ERV – Energy Recovery Ventilator
HID – High-Intensity Discharge
LED – Light-Emitting Diode
NFRC – National Fenestration Rating Council
RTU – Roof Top Unit
S2TS – Smart and Small Thermal Systems
SCIF – Sensitive Compartmented Information Facility
SHGC – Solar Heat Gain Coefficient
SREC – Solar Renewable Energy Credit
VFD – Variable Frequency Drive
WGL – Washington Gas Limited

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