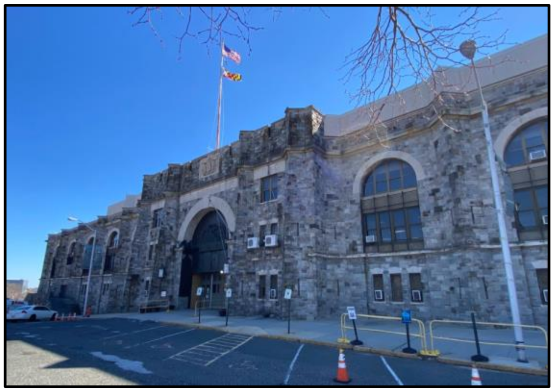
Fifth Regiment Armory
Army National Guard
Maryland Department of Military
219 29th Division St, Baltimore, MD 21201



Energy Survey Analysis Report

Prepared for:
Maryland Department of General Services (DGS)*

Department of
General Services

Prepared by:
UMD Smart and Small Thermal Systems (S2TS)
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Introduction

Project Team

The Smart and Small Thermal Systems (S2TS) group, led by Professor Dr. Michael Ohadi, within the Center for Environmental Energy Engineering at the University of Maryland, College Park (UMD), performed this project, which 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 Prof. Michael Ohadi. The project Deputy Director is Dr. Amir Shooshtari. The UMD S2TS team members who contributed to the present building audit project included Alibek Bekenov and Aditya Ramnarayan (Team leaders), Dr. Roxana Family, Chirag Prasad Naga, Jordan Higgins and Yash Jatin Oza.

Acknowledgment

We would like to acknowledge the building manager Mrs. Anita Stewart-Hammerer at the Fifth Regiment Armory, Army National Guard, as well as other staff members for their help and cooperation during the walkthroughs and for answering our questions. We would also like to thank the officers and the armory building management for their interaction and the overall support and guidance to accomplish this project. We are also grateful to Mr. Tony Myers, Mr. Lorenzo Taylor, and Mr. Olatunde Babalola for their diverse help, including coordinating the walkthroughs, assisting with gathering the relevant technical information for the buildings studied, and reviewing the reports and offering feedback to the energy audit team.

Overview

This energy audit supports Governor Hogan's Executive Order 01.01.2019.08 - Energy Savings Goals for the State of Maryland Government, which was issued in July 2019 to signal the administration's desire to improve the energy efficiency of state-owned buildings, reduce their environmental impact, and save taxpayers' money. The executive order sets 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. Due to the smaller size and the energy consumption trends, energy modeling was not deemed necessary for this building.

Based on our overall analysis, 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 Fifth Regiment Armory is located at 219, 29th Division Street in Baltimore, Maryland. This is a four-story building with a basement that was constructed in 1906 with an overall building floor area of 322,434 square feet according to the EnergyCap. Fig. 1 shows an aerial view of the building.

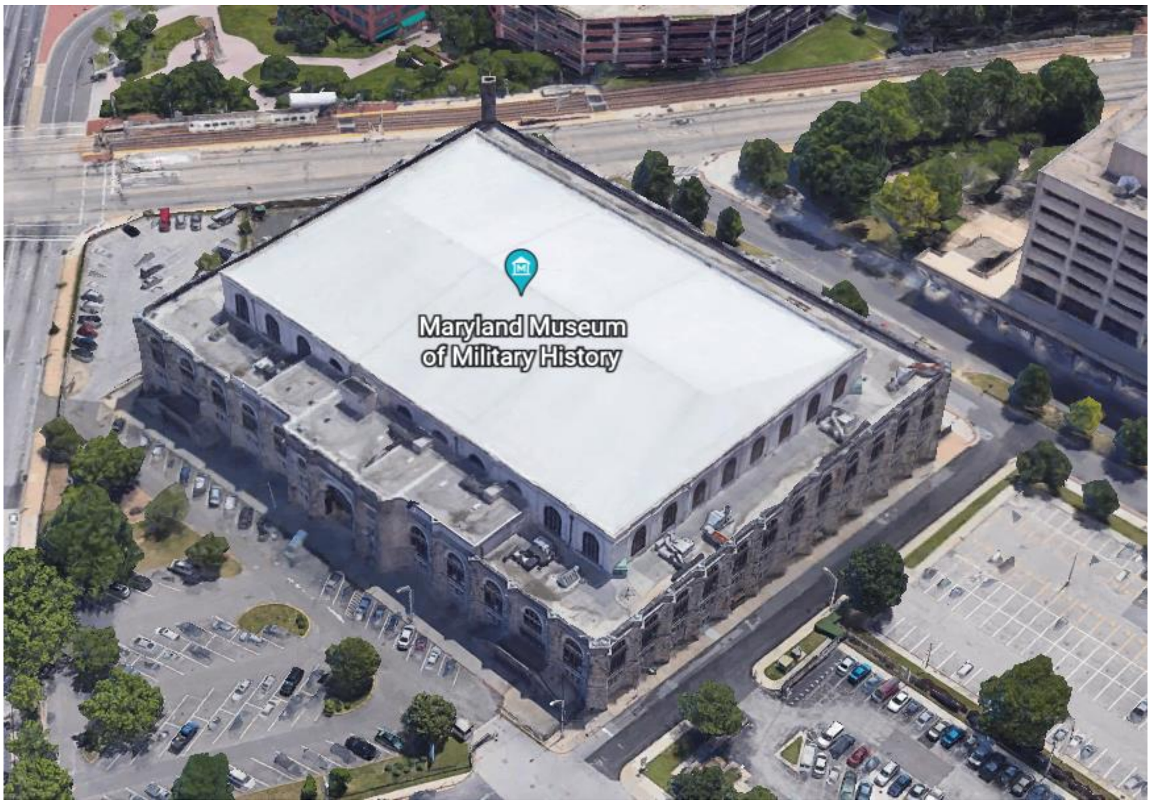


Fig. 1: Aerial views of the Fifth Regiment Armory [1].

The building primarily houses one drill floor, five vaults, approximately one hundred eighty offices, three classrooms, three mechanical rooms, three museum rooms, thirty-five storage spaces, three locker rooms, one kitchen, one dining area, one bar, seventeen restrooms/toilets, one garage, one gymnasium and one boiler room, as specified in the building plans. The equipment in the kitchen includes a freezer, refrigerators, an electric microwave unit, a natural gas commercial oven, a natural gas stove. Other major plug-in device inventories in the building include air purifiers, computer systems, copier machines, routers, heaters, shredders, drinking fountains, window AC systems, screens, ceiling and pedestal fans, and water coolers.

Based on the questionnaire, the building occupancy schedule is from 6:30 AM to 5 PM on weekdays (Tuesday to Friday). Estimated number of staff during working hours is 300 people. However, this number increases by 100-150 people during the drills, which usually takes place on Saturday and Sunday of the first week of a month.

The building consumes energy from two primary energy sources – electricity and natural gas. The electricity consumption is metered and supplied by the Constellation New Energy and BGE/ Baltimore Gas and Electric Company, while the natural gas is metered and supplied by the WGL/ Washington Gas and BGE/ Baltimore Gas and Electric Company. In addition, water is metered and supplied by the Baltimore City Department of Public Works.

The building has a roof area of roughly 77,350 ft^2 which can be utilized to maximize the usage of on-site Solar Power generation.

EUI Analysis

Table 1 shows the Energy Use Intensity (EUI) analysis of the Fifth Regiment Armory based on different references. The Energy Use Intensity (EUI) analysis of the building is compared with the widely known EnergyStar rankings for buildings reference. Comparing such a figure to the EnergyStar reference for a similarly sized and equipped building is valid and it was found that the value of EUI is artificially low, because 2021 was a pandemic year and buildings not in actual use.

Table 1: EUI analysis of the Fifth Regiment Armory.

Building name	FYs 2018 and 2019 EUI (E-cap)	Ref. EUI (Energy Star) [2]
Fifth Regiment Armory	14.46 kWh/sq. ft.** (49.35 kBTU/sq. ft.)	15.5 kWh/sq. ft. (52.9 kBTU/sq. ft.)

<u> Important Note:</u>** There is missing crude oil and propane data for the Fifth Regiment facility that does not have an explanation. For this reason, oil and propane consumption has not been included in the EUI calculations. This means the EUI listed in Table 2 (above) can be artificially and possibly substantially lower than the actual amount, thus suggesting further room for energy efficiency measures.

Table 1 shows the Energy Use Intensity (EUI) analysis of the Fifth Regiment 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]. 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 10.50 kWh/sq. ft. (35.84 kBtu/sq. ft.), which is ~25% below the average for 2018 and 2019. The calculations listed in Table 1 (above) considered electricity and natural gas consumption based on available data.

However, as stated above, missing propane and oil consumption data, as well as highly irregular natural gas consumption in 2018 all cast uncertainty on the seemingly low EUI value listed in table 1. Based on our team walkthrough and further analysis, the building's envelope and the HVAC equipment are mostly outdated and far from receiving an EergyStar rating. This issue needs to be revisited to determine a realistic EUI for this building with more recent data as they become available.

Energy Modeling wasn't performed for the facility as no redundant/oversized systems were found to be present in the facility which required further detailed modeling studies. However, numerous energy efficiency measures were identified that can improve the energy efficiency of the facility and are discussed in detail in later sections of this report.

Energy Spend Analysis

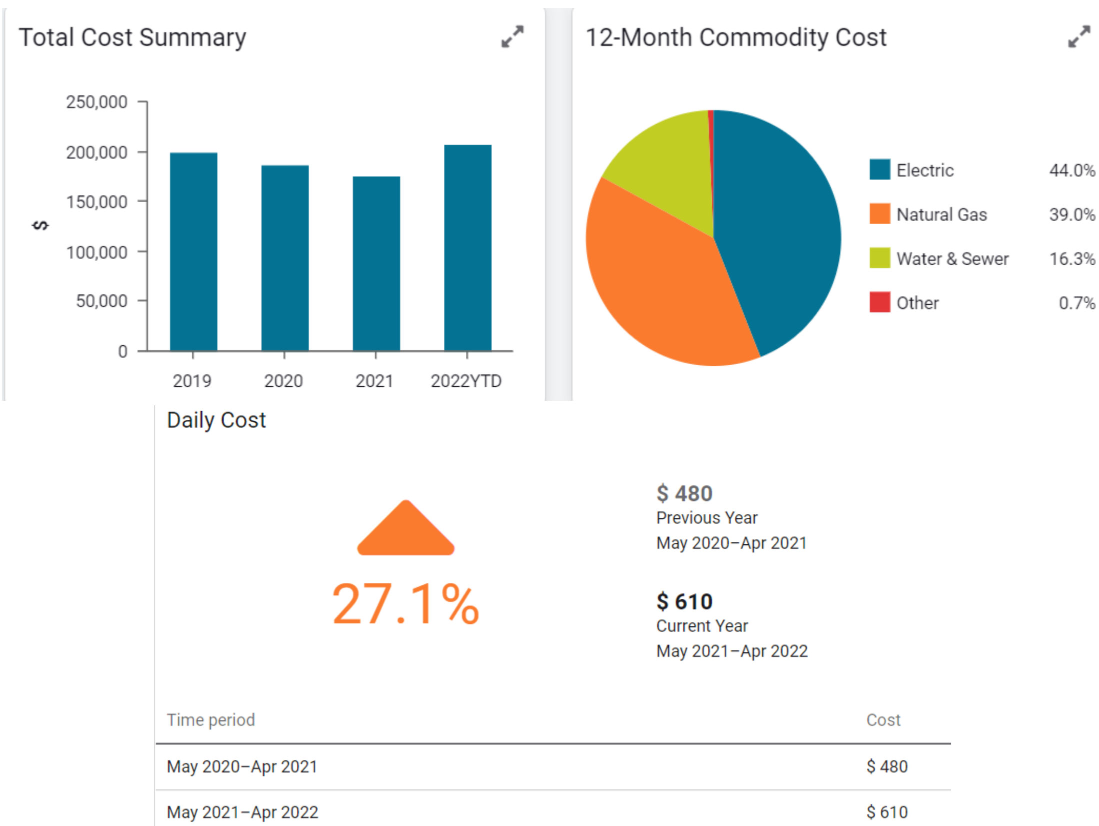


Fig 2: Energy use and cost for Fifth Regiment Armory [2]

Building Observations

- The first and the second floors have window Air conditioning (AC) and Split systems to meet cooling needs.
- The third and the four floors employ ducts and ten Roof top units (RTU)s for cooling needs.
- RTUs have been manufactured in 1994-1995 (except for RTU-2 that was replaced in 2021). They are well past their useful life.
- Heating for the entire building is distributed through finned tube radiators. Gas-fired boilers were replaced in 2021.
- The building does not have any Building Automation System (BAS) for the efficient use of the resources.
- No thermostats were installed in the building.
- The occupants frequently complain about Hot Zones in the building. They use plug-in ceiling and pedestal fans to cool their zones/rooms.
- According to the information provided by the building manager, approximately 50% of the interior lighting were replaced from the Compact Fluorescent Lamps (CFL), the Sodium Vapor Lamps, and the linear fluorescent tubes to Light-Emitting Diode (LEDs).
- The lighting control occupancy sensors are present in common areas, hallways, drill floor, and garage.
- Windows have gaps that allow outside air infiltration. Double-glazed windows installed throughout the building, except for the large ones in the drill room, are outdated and have lost their thermal insulation properties. The large ones in the drill room, are single-glazed and original to the building.
- Most of the plug inventories in the building are not EnergyStar certified.
- Toilets were renovated in 2000.
- Domestic water heaters were replaced in 2017.
- The entire roof was replaced in 2020.

Combined/Comprehensive EEMs

EEM 1- HVAC Equipment Replacement

Current Heating Units

The mechanical room in the basement contains two gas furnaces (Weil-McLain 88 series, model number 1788) with a heating capacity of 4,570 MBH (1339 kW) each (Fig. 3).

They provide hot water for the finned tube radiators (Fig. 4) and twenty-eight-unit heaters UHs throughout the building (Fig. 5). The boilers are new to the building and were installed in 2021.

Fig. 3: Boilers in the mechanical room.

Fig. 4: Finned tube radiators in the office (left) and the toilet (right).

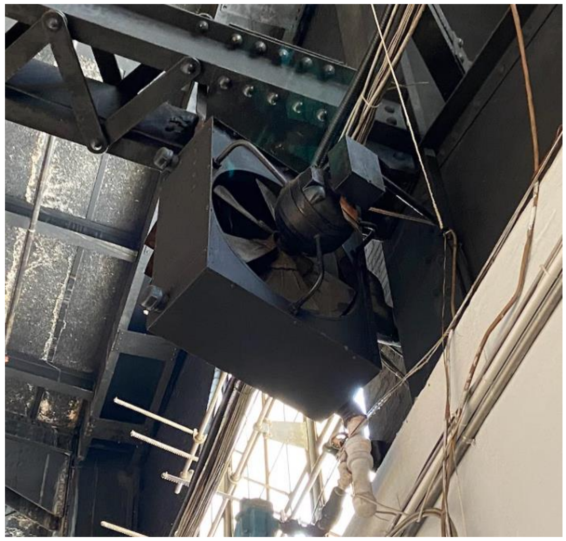


Fig. 5: Unit Heater in the drill room.

There are four domestic hot water (DHW) heaters. Two large gas fired heaters (State Industries, model number PVG025000VTA125, capacity 160 gallons each, year of build 2017) and one small gas fired water heater (LAARS MIGHTY THERM 2, series 400, serial number C21307859, capacity 400 MBH (117 kW), year of build 2021) are located in the same mechanical room (Fig. 6 and 7). Another small electric heater (State Industries, model number EN630DOLS100, capacity 28 gallons, year of build 2018) is located in the corridor of the second floor (Fig. 8).

Fig. 6: The large Domestic water heaters (DWH) in the mechanical room.

Fig. 7: The small Domestic water heater (DWH) in the mechanical room.

Fig. 8: The small electrical Domestic water heater (DWH) in the corridor.

In addition, the building employs five electric Unit Heaters (UH) type-1 and one electric UH type-2 with capacities indicated in Table 2. They serve the kitchen and toilets on the third floor.

Table 2: Schedule of the electric Unit Heaters in the Fifth Regiment Armory.

ELECTRIC CONVECTOR BASEBOARD HEATER SCHEDULE							
UNIT NO.	LOCATION	CAPACITY		ELECT. DATA			REMARKS
		WATTS	BTUH	V	PH	CYC	
1	TOILETS	1000	3413	208	1	60	BERKO SERIES NO. MCB4-1020-W WITH INTEGRAL THERMOSTAT OR APPROVED EQUAL
2	JAN. CLO.	750	2560	208	1	60	BERKO SERIES NO. MCB3-720-W WITH INTEGRAL THERMOSTAT OR APPROVED EQUAL

Current Cooling Units

The building employs the next Roof Top Units (RTU) that are located on the lower roof:

- RTU#1, Trane, model TCH120B300DB, Cooling (R22), capacity 120MBH (35kW);
- RTU#2, Trane, model TSC120H3R0A26, Cooling (R410a), capacity 120MBH (35kW);
- RTU#3, Trane, model TCH150B300DB, Cooling (R22), capacity 150MBH (44kW);
- RTU#4, Trane, model TCH150B300DB, Cooling (R22), capacity 150MBH (44kW);
- RTU#5, Trane, model TCH150B300DB, Cooling (R22), capacity 150MBH (44kW);
- RTU#6, Trane, model TCD060C300BB, Cooling (R22), capacity 60MBH (17.5kW);
- RTU#7, Trane, model TCH180B300DA, Cooling (R22), capacity 180MBH (52.7kW);
- RTU#8, Trane, model TCH150B300DB, Cooling (R22), capacity 150MBH (44kW);
- RTU#9, Trane, model TCH150B300DB, Cooling (R22), capacity 150MBH (44kW);
- RTU#10, Trane, model TCH150B300DB, Cooling (R22), capacity 150MBH (44kW).

All RTUs (Fig. 9) were installed in 1994-1995, except for the RTU2 (Fig. 10) that was manufactured in 2021. They supply a cooling air to the Third and Fourth floors through the duct system.

Fig. 9: RTU-5 on the lower roof.

Fig. 10: RTU-2 on the lower roof.

The summary of the design specifications of the RTUs and Exhaust fans retrieved from the building's mechanical drawings is shown in Tables 3 and 4.

Table 3: Schedule of RTUs in the Fifth Regiment Armory.

AIR CONDITIONING U																										
		SUPPLY FAN DATA									RETURN FAN DATA								COOLING COIL DATA ①							
					ELECTRICAL DATA								ELECTRICAL DATA													
UNIT No	AREA SERVED	MIN. OA	TOTAL CFM	ESP (IN H_2O)	BHP	HP	RPM	VOLTS	PH	CYC	TOTAL CFM	ESP (IN H_2O)	BHP	HP	RPM	VOLTS	PH	CYC	EAT DB °F	EAT WB °F	LAT DB °F	LAT WB °F	MBH (TOTAL)	MBH (SEN)	MAX FACE VEL (FPM)	MAX APD (IN H_2O)
ACU-1	BALCONY ROOF	340	3610	0.50	1.25	1.5	850	208	3	60	3610	0.50	—	1.0	1289	208	3	60	77.0	64.2	58.5	57.0	117.6	97.6	500	0.05
ACU-2	BALCONY ROOF	340	3605	0.50	1.25	1.5	850	208	3	60	3605	0.50	—	1.0	1289	208	3	60	77.0	64.2	58.5	57.0	117.4	97.2	500	0.05
ACU-3	BALCONY ROOF	440	4555	0.50	2.05	3.0	982	208	3	60	4555	0.50	—	1.5	1565	208	3	60	77.0	64.2	58.1	57.4	151.0	123.2	500	0.13
ACU-4	BALCONY ROOF	400	4300	0.50	1.77	2.0	933	208	3	60	4300	0.50	—	1.5	1488	208	3	60	77.0	64.2	59.1	57.4	140.6	114.5	500	0.07
ACU-5	BALCONY ROOF	450	4550	0.50	2.05	3.0	982	208	3	60	4550	0.50	—	1.5	1565	208	3	60	77.0	64.2	57.9	57.2	147.8	121.0	500	0.13
ACU-6	BALCONY ROOF	160	2000	0.30	0.87	1.0	1030	208	3	60	2000	—	—	—	—	—	—	—	76.6	63.9	57.5	59.0	61.1	41.2	500	0.08
ACU-7	BALCONY ROOF	460	5000	0.50	2.58	3.0	1050	208	3	60	5000	0.50	—	2.0	1695	208	3	60	76.9	64.2	58.8	58.0	161.1	131.8	500	0.13
ACU-8	BALCONY ROOF	320	4965	0.50	2.58	3.0	1050	208	3	60	4965	0.50	—	2.0	1695	208	3	60	76.5	63.9	58.2	57.4	150.7	128.1	500	0.13
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

NOTES: ① SELECTION BASED ON 95°F DB AMBIENT TEMPERATURE ② HEATING FOR VENTILATION AIR ONLY

N I T S C H E D U L E															
HEATING COIL DATA ②									FILTER DATA			MCQUAY MODEL	WEIGHT (LBS)	DIMENSIONS L x W x H (IN.)	REMARKS
EAT DB °F	LAT DB °F	MBH (TOTAL)	MAX FACE VEL (FPM)	MAX APD (IN H_2O)	KW	ELECTRICAL DATA VOLTS	PH	CYC	TYPE	EFF (%)	MAX APD (FT H_2O)				
70	90	22.0	500	0.05	7.5	208	3	60	FLAT	35	0.50	CUR 110	1500		
70	90	22.0	500	0.05	7.5	208	3	60	FLAT	35	0.50	CUR 110	1500		
70	90	28.5	500	0.08	10.0	208	3	60	FLAT	35	0.50	CUR 126	1500		
70	90	25.9	500	0.08	10.0	208	3	60	FLAT	35	0.50	CUR 125	1500		
70	90	32.4	500	0.08	12.0	208	3	60	FLAT	35	0.50	CUR 126	1500		
70	90	10.4	500	0.05	5.0	208	3	60	FLAT	35	0.50	ERH 060	1500		
70	90	29.8	500	0.08	10.0	208	3	60	FLAT	35	0.50	CUR 126	1500		
70	90	20.7	500	0.08	7.5	208	3	60	FLAT	35	0.50	CUR 126	1500		
—	—	—	—	—	—	—	—	—	—	—	—	—			
—	—	—	—	—	—	—	—	—	—	—	—	—			

A I R C O N D I T I O N I N G U																
UNIT NO.	AREA SERVED	SUPPLY FAN DATA								COOLING COIL DATA						
		CFM (MAX.)	OA (CFM)	ESP (IN. OF H_2O)	ELECTRICAL DATA HP	RPM	V	PH	CYC	EAT DB (°F)	EAT WB (°F)	LAT DB (°F)	LAT WB (°F)	MBH (TOTAL)	MBH (SENS.)	MAX. FACE VEL. (FPM)
ACU-9	EX. DINING ROOM	2960	① 1390	0.5	1.0	925	208	3	60	O 85.6 / 79.0 UO	O 71.1 / 65.9 UO	57.1	56.9	153.1	93.3	500
ACU-10	NEW DINING ROOM	2740	① 1290	0.5	1.0	896	208	3	60	O 85.6 / 79.0 UO	O 71.1 / 65.9 UO	57.2	56.5	142.5	84.8	500

NOTES : ① OUTSIDE AIR SHOWN IS FOR OCCUPIED HOURS, MINIMUM CFM. DURING UNOCCUPIED HOURS OUTSIDE AIR DAMPER SHALL REMAIN CLOSED. ROOM TEMPERATURE: WINTER-70°F; SUMMER-75°F."

O OCCUPIED / UNOCCUPIED UO

I T S C H E D U L E												
HEATING COIL DATA									FILTER DATA			REMARKS
EAT DB (°F)	LAT DB (°F)	MBH (TOTAL)	MAX. FACE VEL. FPM	MAX. APD (IN. OF H_2O)	KW	ELECTRICAL DATA V	PH	CYC	TYPE	EFF (%)	MAX. APD (FT. OF H_2O)	
70	90	20.7	500	0.10	25	208	3	60	FLAT	35	0.5	MCQUAY MODEL NO. CUR 125
70	90	14.8	500	0.10	25	208	3	60	FLAT	35	0.5	MCQUAY MODEL NO. CUR 125

Table 4: Exhaust Fans' schedule in the Fifth Regiment Armory

FAN SCHEDULE												
UNIT No	LOCATION	DRIVE TYPE	CFM	ESP (INCHES H_2O)	MOTOR HP	BHP	RPM	ELECTRICAL DATA VOLTS	PH	CYCLES	MODEL SERIES	REMARKS
EF-1	BALCONY ROOF	BELT	2200	1.50	1.5	1.18	1820	208	3	60	FUMEX FMX 13B	② ATC & ON-OFF SWITCH
EF-2	BALCONY ROOF	BELT	3500	1.50	2.0	1.50	1267	208	3	60	FUMEX FMX 16BFT	② ATC & ON-OFF SWITCH
EF-3	THIRD FLOOR TOILET ROOF	BELT	870	0.50	1/4	—	1100	120	1	60	DOMEX DX 10B	② ATC
EF-4A	BALCONY ROOF	BELT	15400	0.65	7 1/2	—	1065	208	3	60	PROP. FAN WFB 48	① TYP.-4B, 4C & 4D. MANUAL CTRL.- ③ BASE BID. ATC - ALTERNATE
EF-5	THIRD FLOOR KITCHEN ROOF	BELT	1000	0.50	1/3	0.20	834	120	1	60	FUMEX FMX14B	② ATC
EF-6	THIRD FLOOR KITCHEN ROOF	BELT	2800	1.00	1 1/2	1.00	1437	208	3	60	FUMEX FMX 14BFT	② ATC
EF-7	BALCONY ROOF	BELT	300	0.50	1/4	0.13	1032	120	1	60	FUMEX FX8B	② ATC

① AMMERMAN CO., INC. ② PENN VENTILATOR ③ COMBINATION SUPPLY & EXHAUST APPLICATION.

In addition, below systems are located on the rooftop (Fig. 11):

- DX type condensing unit, Armstrong, model SCU10A42B (R22), capacity 42MBH (12kW), installation year - 1995;
- Inverter type condensing unit, Mitsubishi Electric, model PUY-A36NKA7 (R410a), capacity 36MBH (10.5kW), installation year – 2018, serves IT room.

Fig. 11: DX and Inverter type condensing units on the lower roof.

The building currently employs a number of Split (Fig. 12) and window AC systems (Fig. 13) to meet cooling needs on the first and second floors.

Among them:

Security room:

- Window AC, Frigidaire, model FAK103J1V4, capacity 10MBH (2.9kW), production year – 2003 (Fig. 12);

D-12 Office:

- Two window ACs, Frigidaire, model FFRS1022R1, capacity 10MBH (2.9kW) each, production year - 2015;

JAG Office:

- Split system (R22), Mitsubishi Electric, model MS09TW, capacity 9MBH (2.6kW), production year – 2012 (Fig. 12);
- Window AC (R410a), Frigidaire, model FFRE0533U10, capacity 5.2MBH (1.5kW), production year - 2019;

- Split system, Mitsubishi Electric, model MU09TW, capacity 9MBH (2.6kW), production year – 2011;
- Window AC (R32), GE Appliances, model AHV05LYW1, capacity 5.05MBH (1.5kW), production year 2019.

M27 Room:

- Window AC (R32), LG, model LW1017ERSM, capacity 12MBH (3.5kW), production year - 2021.

M5A Room:

- Window AC (R410a), Airwell-Fedders, model AZ7R24E7A, capacity 24MBH (7kW), production year – 1991 (Fig. 13).

Gymnasium:

- Window AC (R410a), Frigidaire, model FFRS0822S11, capacity 8MBH (2.3kW), production year – 2019;
- Window AC (R22), Frigidaire, model FAK103J1V4, capacity 10MBH (2.9kW), production year – 2003.

Fig. 12: Split system in JAG office.

Fig. 13: Window ACs in Security room (left) and M5A office (right).

There is currently no BAS to regulate heating and cooling during operational hours in the building. The HVAC elements are regulated by control thermostats, as well as manually by a building manager. It is important to note that there are no thermostats in the occupancy areas.

As mentioned above, nine RTUs (except the RTU-2) were last replaced during a renovation in 1994-1995, thus they have been operating for almost 30 years, are well past their useful life, and need to be replaced. In addition, half of split and window AC systems were installed more than 10 years ago. For example, the split system in the JAG office has leaked and destroyed the walls and floor. As noted during the site survey, some of the refrigerant piping is missing the required insulation (Fig. 14).

Fig. 14: Damaged Insulation on Refrigerant-carrying lines.

The occupants frequently complain about hot zones in the building. They use plug-in ceiling and pedestal fans to cool their zones/rooms as shown in Fig. 15.

Fig. 15: Fans in the office areas on the first and second floors.

Variable Refrigerant Flow (VRF) system

We recommend replacing current HVAC equipment with a Dedicated Outdoor Air System (DOAS) coupled with a Variable Refrigerant Flow (VRF) system. VRF is an HVAC system configuration with multiple outdoor (condenser) units connected in a modular fashion and multiple indoor (evaporator) units that will take care of the sensible loads within a zone whereas a DOAS will be dedicated towards the latent loads in a zone. The DOAS combined with VRF provides the ability of this system to decouple the sensible and latent loads in a zone, enabling the use of multiple evaporators of differing capacities and configurations, improved Indoor Air Quality (IAQ), individualized comfort control, simultaneous heating and cooling in different zones, appropriate ventilation and satisfaction of all building occupants. Implementing a DOAS with VRF offers greater design flexibility as the equipment is more compact than traditional systems and has the added benefit of being easily integrated with Building Automation Systems (BAS). Fig. 15 shows a schematic DOAS and VRF arrangement.

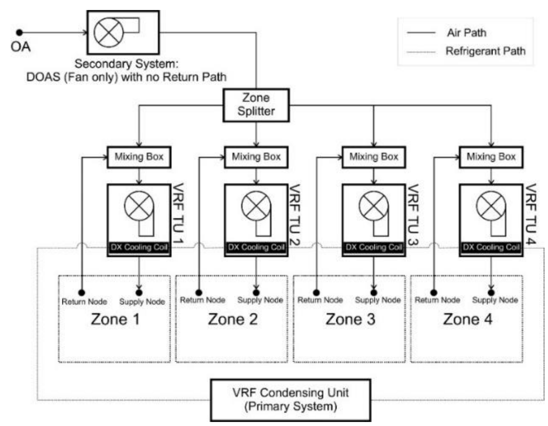


Fig. 16: Schematic VRF arrangement [3].

DOAS equipped with Energy Recovery Ventilators (ERV) recapture cooling and heating energy while ventilating and equalizing humidity levels [4]. An ERV typically handles half of the load required to bring outside air to the required temperature. In other words, facilities with a ventilation system that lacks an ERV will require nearly double the tonnage of mechanical cooling and heating. Even if a facility makes use of a VRF system, the building will still need an ERV to achieve its maximum potential. In typical designs, where DOAS handles ventilation and the VRF system handles cooling and heating, ventilation air is delivered directly to conditioned spaces at room temperature, making it easier to implement proper ventilation rates compliant with ASHRAE 62.1 [5]. A DOAS in conjunction with a VRF system offers better control and IAQ that translates into a healthy and productive work environment for the occupants [4].

DOAS integrated with VRF systems such as the ones offered by Mitsubishi Electric can be considered for the Fifth Regiment Armory [6]. The City Multi products (R2 series, Y-series, WR2-series, WY-series) from Mitsubishi for VRF and PremiSys® DOAS series (MPF1 and MPF2) are designed for commercial applications [7].

They provide zone control, design flexibility, quiet operation, hyper heating inverter (H2i), personalized comfort control, quality air filtration (MERV 8 or MERV 13), and simultaneous cooling and heating operations (R2 and WR2-series). The City Multi Controls Network (CMCN) enables control of multiple centralized controllers, and it can be utilized from any networked PC, tablet, or smartphone. DOAS in conjunction with VRF systems have high energy savings potential which leads to a relatively shorter payback period of five years or less [8].

DOAS plus VRF systems are typically 25% more efficient than conventional HVAC systems [9] due to partial load operation, speed modulation, zoning capabilities, and energy-recovery technology. It could replace current RTUs, window AC and split systems, and boilers of the building, and would also enable progress towards the State of Maryland’s future greenhouse gas and environmental goals, starting with electrification of State Buildings and elimination of Fossil Fuel Systems.

In addition, the system discussed is completely powered by electricity, which eliminates the cost of transporting and storing oil for the boiler.

EEM 2 – Lighting Upgrades

- Replacement of all fluorescent lights in the building with energy-efficient Light-Emitting Diode (LED) bulbs.
- Provide lighting controls for daylight harvesting and dimming.
- Provide occupancy sensors to control/reduce lighting energy consumption.

As mentioned above, interior lighting in common areas, hallways, drill floor, garage, and partially in the gymnasium has already been replaced from the compact fluorescent lamps (CFLs), the sodium lamps and the linear fluorescent lamps to LEDs. The lighting control occupancy sensors were also installed in these areas.

However, the CFLs and T8 fluorescent lamps are still being used to illuminate offices, vaults, storages and other rooms (Fig. 17). Completion of the replacement of lighting with LEDs along with the implementation of the occupancy sensors and lighting controls has multiple end-user benefits. Compared to fluorescent lighting, LED lighting can yield significant energy savings while also reducing the maintenance and labor costs associated with fluorescent lighting. LED light fixtures also have longer rated lifespans which would mean fewer costs associated with replacing them. Lighting controls, such as daylight harvesting and dimming, further enhance the energy-saving potential of LED lighting. Therefore, all fluorescent light bulbs in the building shall be replaced with energy-efficient LED light bulbs to match the existing bulb size/type and fixture styles. Occupancy controls and sensors shall then be integrated with LED lights in all spaces, which are applicable. Additionally, lighting controls with daylight harvesting and dimming shall be provided. Transitioning towards LED lighting along with the implementation of controls could yield electricity savings of around 50% of total annual lighting consumption with short payback periods of 2-3 years [10].

The lighting disposal and replacements as well as the lighting controls shall be Design Lights Consortium (DLC) or Energy Star certified and comply with the Maryland Green Purchasing Committee Approved Specifications [11].

Fig. 17: CFL (left) in the drill area and T8 bulbs (right) on the fourth floor.

In addition, old fluorescent/compact fluorescent lighting (CFL) EXIT signs (Fig. 18) also have to be replaced with LED ones. Illuminated EXIT signs are important and must operate 24 hours per day. They can consume large amounts of energy to operate. According to EnergyStar [12], EXIT signs using LEDs consume 3 times less energy than those with fluorescent bulbs.

Fig. 18: EXIT signs on stairway on the first floor.

EEM 3 – Windows and doors Upgrade

- Replace old single glazed and double-glazed windows and doors with new double-glazed, energy efficient windows and doors.

During the inspection of the site, it was noticed that the existing double-glazed windows installed throughout the building had long served their time. The following issues were found:

1) through holes in the air conditioner installation points (Fig. 19, left);
2) lack of glass (Fig. 19, right);
3) cold emanating from the windows indicates a possible leakage of inert gas.

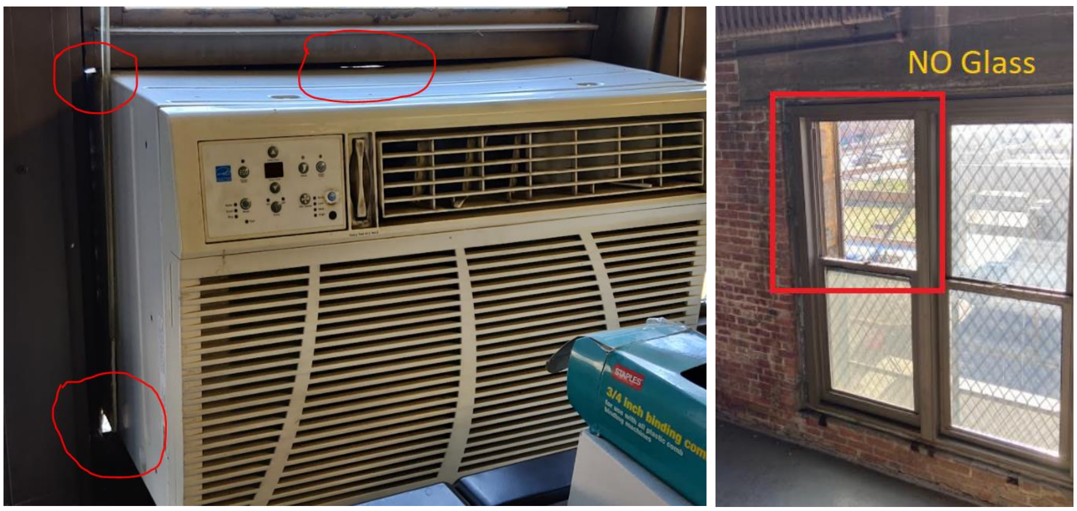
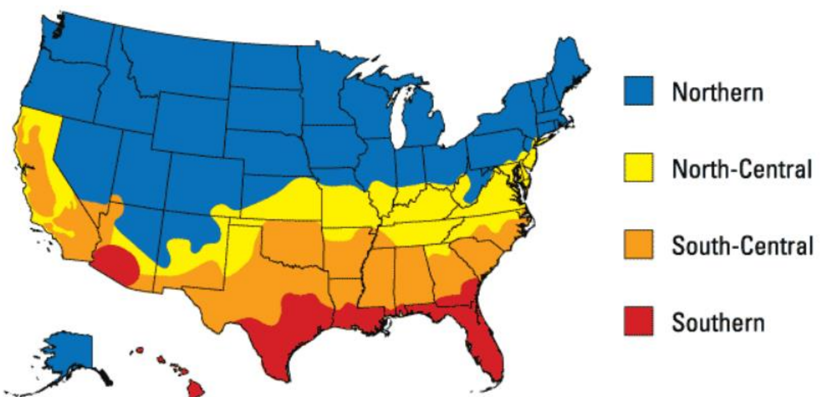


Fig. 19: Window AC in M5A room (left) and No glass window on stairway (right).

In addition, single glazed windows, that are original to the building, are installed in drill area as shown in Fig. 20.

Fig. 20: Single glazed windows in drill area.

Approximately 30% (or greater in certain cases) of the energy loss occurs through windows and doors [13]. Replacing windows with modern energy-efficient types will help reduce infiltration and thermal radiation losses from the building. Since the building is located in the North Central climate zone, it is recommended to install windows that meet performance criteria certified by the National Fenestration Rating Council (NFRC) [14]: U-factor <= 0.3 BTU/(h·ft²·°F) and Solar Heat Gain Coefficient (SHGC) <= 0.40 (Fig. 21). For the Energy Efficiency Model, we employed low emissivity (Low-E glass) double glazed tinted windows with U-factor = 0.33 BTU/(h·ft²·°F) and SHGC = 0.38, which are close to those recommended by the NFRC. Low-E glass reduces energy use by as much as 30-50%, especially during hot summer months [13]. Replacing the existing windows in the facility can help reduce energy consumption by reducing heat and energy losses through infiltration and thermal radiation losses. Windows are designed for a useful life of 15-20 years [15]. From a study conducted by EPA, it was found that energy-efficient windows for the North-Central Climate Zone criteria would save, on average, $80.75 per year, with a payback of 8.5 years [16].



WINDOWS

CLIMATE ZONE	U-FACTOR[1]	SHGC[2]	
Northern	≤0.27	Any	Prescriptive
	=0.28	≥0.32	Equivalent Energy Performance
	=0.29	≥0.37	
	=0.30	≥0.42	
North Central	≤ 0.30	≤ 0.40	
South Central	≤ 0.30	≤ 0.25	
Southern	≤ 0.40	≤ 0.25	

SKYLIGHTS

CLIMATE ZONE	U-FACTOR[1]	SHGC[2]
Northern	≤ 0.50	Any
North Central	≤ 0.53	≤ 0.35
South Central	≤ 0.53	≤ 0.28
Southern	≤ 0.60	≤ 0.28

Air Leakage ≤ 0.3 cfm/ft2

[1] Btuh ft2·°F
[2] Solar Heat Gain Coefficient

Fig. 21: Energy Star qualified windows by climate zones [14].

EEM 4 – SMART Thermostat Installation

As noted earlier, the building does not have any installed thermostat and we strongly recommend installing smart thermostats in the building.

Smart thermostats create automatic and programmable temperature settings based on daily schedules, weather conditions, heating and cooling needs. The advantage of a smart thermostat is its ability to learn a building's patterns and adjust heating and cooling according to when a property is occupied or is about to be occupied. Thermostats can be programmed to select the right temperature setpoints for spaces within a facility in compliance with ASHRAE Standard 55 for Thermal Comfort, which delineates the range of temperatures depending on the season and relative humidity levels within a particular zone. This reduces the use of heating and cooling systems during the unoccupied times. Smart thermostats that earn the ENERGY STAR label have been independently certified, based on actual field data, to deliver energy savings. Analysis conducted by Ecobee on their customers' data found that some smart thermostat users saved up to 23% on their heating and cooling costs [17]. For the present case, the installation of smart thermostats can reduce a significant amount of energy in the building. Energy savings as high as 0.18 kWh/sq. ft. [18] can be realized while having relatively shorter payback periods of two years [19].

EEM 5 – Plug and Process Load Reduction (PPL)

- Advanced Power Strips: Advanced power strips 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 advanced power strips to reduce annual electricity consumption. The payback period of advanced power strips is estimated at about 1.1 years [20].
    - All power strips in the building should be replaced with advanced power strips, e.g., similar to the ones provided by Tricklestar or similar brands. The contractor shall provide pricing for the provision of advanced power strips as well as for their installation by existing power connection setups for each room in the building.

Fig. 22: Power strip in M5A office.

    - Replace 10+ years old drinking fountains with Energy Star noncooled drinking fountains.

Fig. 23: Drinking fountain in drill area.

- Equipment EnergyStar upgrades: When the time comes to upgrade plug-in equipment, low-energy or EnergyStar-rated products should be considered at a minimum. Significant energy savings can be achieved by replacing old, inefficient equipment with low-energy or EnergyStar-certified equipment. There are currently several different types of appliances being used throughout the building like refrigerators, microwave ovens, and copy machines as shown in Fig. 24. These appliances can be high energy consumers depending on their energy ratings and age. Replacing all appliances that are more than five years old and are also not Energy Star certified with Energy Star certified ones will result in savings in electricity consumption, and this savings may be shown in water consumption as well. 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. For appliances where the Energy Star rating is unknown, we recommend replacing them with products with energy efficiency ratings that are in the top 25% of their respective markets.

Fig. 24: Sample plug-in equipment in the Fifth Regiment Armory.

EEM 6 – Water Conservation Measures

1) Bathroom Sink Faucets/Accessories

- Replace the older models with new WaterSense labeled faucets to reduce water usage. WaterSense labeled products are 20% more water-efficient than average products with payback periods as short as 2-3 years [21].

2) Toilets and Waterless Urinals

- Many high-efficiency toilets are sold in two parts, with the tank and bowl sold separately. When components combine to make a WaterSense labeled product, tanks should include the words "When used in combination with [bowl model number/name]" in close proximity to the label, and similarly with bowl labeling.
- Waterless urinals are available in the market which use Eco-Trap technology and can last up to 1500 sanitary uses [22].
- A waterless urinal can replace a standard one gallon per flush urinal and save up to 40,000 gallons of water annually [23].

3) Showerheads

- With a WaterSense labeled showerhead, one can save a considerable amount of water. Water-saving showerheads that earn the WaterSense label must demonstrate that they use no more than 2.0 GPM. The WaterSense label also ensures that these products provide a satisfactory shower that is equal to or better than conventional showerheads on the market.

Summary of Energy and Dollar Savings Potential

EEMs	Proposed Solution	Annual Energy Savings Potential	Annual Dollar Savings Potential	Water Savings (Gallons)
Variable Refrigerant Flow (VRF) system	Replacing current HVAC equipment with a Dedicated Outdoor Air System (DOAS) coupled with a Variable Refrigerant Flow (VRF) system	4.86-5.54 kWh/sq. ft. [24]	-	-
Lighting Upgrades	Replacing the CFLs and T8 fluorescent lamps past their useful life with LEDs	-	$0.33/sq. ft. or higher [25]	-
Windows and doors Upgrade	Replacing old single glazed and double-glazed windows and doors with new double-glazed, energy efficient windows and doors	-	$80.75/year/ window [16]	-
SMART Thermostat Installation	Switch from manual controls to Smart Thermostats	0.18 kWh/sq. ft. [18]		
Plug-in Process Load Reduction (PPL)	Advanced Power Strips (APS)	0.2 – 0.7 kWh/day [26]	-	-
Water Conservation	WaterSense Labelled products and Waterless urinals for efficient use of water in the facility.	-	-	Up to 40,000 gallons of water annually [23].

Summary Scope of Work

A summary scope of work is provided in the following table. The estimated payback periods are to be used as a general guide and otherwise represent average estimated costs offered in the open domain. With the current inflationary market prices, the numbers will certainly need updating when the implementation of any/all of the respective EEMs is intended.

System Description	**Current System/Issue**	**Proposed System/Solution**	**Comments**
HVAC, RTUs, split and window AC systems	HVAC systems past their useful life and working inefficiently.	Replace the 30 years old equipment with high efficiency equipment such as DOAS and VRF systems with a centralized controller.	DOAS with VRF systems are nearly 25% more efficient than conventional HVAC systems [8]. Due to its high energy savings potential, DOAS/VRF systems can pay for themselves in an estimated five years or less [8].
Lighting	Fluorescent lighting and fluorescent EXIT signs.	Replace with LED lighting and LED EXIT signs along with occupancy sensors and controls for daylight harvesting and dimming.	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 [10].
Windows and Doors	Single glazed windows and doors past their useful life and due for replacement/upgrades	Replace with Low emissivity (Low-E glass) double glazed tinted windows and doors.	Low-E glass reduces energy use by as much as 30-50% [13] and with an average estimated payback of 8.5 years [16].
Smart Thermostat	A system with manual control and temperature setpoints year-round.	Smart Thermostats to control temperature and humidity setpoints for HVAC systems in spaces to match the occupancy schedule.	Smart Thermostats can save up to 23% on heating and cooling costs [17] with an estimated payback period of less than 2 years [19].
Plug and Process Load	Regular power strips, drinking fountains and	Replace with Advanced Power Strips,	Plug-in and process loads (PPLs) can consume up to

Reduction	miscellaneous equipment in the facility.	EnergyStar rated appliances such as vending machines and drinking fountains.	~ 47% of the primary energy in U.S. commercial buildings. APS have payback periods of as short as less than 2 years [20].
Water Conservation Measures	Identify and implement WaterSense opportunities, including leak detection.	WaterSense rated sinks, faucets, and urinals. Leak detection system.	Water-saving techniques by installing WaterSense labeled products that have typically short payback periods of 2-3 years [21].
Renewable Energy	No Solar PV system in place.	Installing Solar Panels for electricity generation.	Based on a 77,350 ft² roof (which represents 50% of the available roof area) a 400-kW solar PV system can produce about 563,553 kWh/year of electricity [27]. The typical payback period of a Solar PV system in Maryland is ~11 years [29].

Future Renewable Energy Scope

The Climate Solutions Now Act of 2022 increases Maryland's target for reducing greenhouse gas emissions to 60 percent below 2006 levels by 2031 and sets a 2045 deadline for achieving net-zero greenhouse gas emissions across the state's economy. It also creates a building energy performance standard for the state that will require most buildings over 35,000 square feet to start reporting their data in 2025 and achieve a 20% reduction in direct emissions (as compared to 2025 levels for average buildings of similar construction) by January 1, 2030, and net-zero direct emissions by January 1, 2040.

Building electrification is a critical part of the path to transition away from fossil fuels and to meet the state's aggressive climate goals. Based on DGS data on carbon emissions by the year 2029, the carbon emissions in lb/MWh from the electricity grid will be along 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.

Transitioning towards an all-electric system for heating, cooling, and hot water needs, instead of burning natural gas or fuel oil can reduce overall energy use, reduce emissions, and ensure that occupants have access to cleaner, healthier, more resilient buildings.

Hot water heaters

- Hot water heaters could be replaced with Heat pump water heaters (HPWHs).

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.

The building has wide open space around it (parking) as well as free space on a higher roof (Fig. 24), where solar PV panels can be installed to provide supplemental electricity. The solar system would need to be provided with a battery system to offset the intermittent availability of sunlight throughout the year at the location. Using the NREL PVWATTS Calculator, an assumption of the system parameters can be made [27]. For example, at the Fifth regiment Armory, by assuming 50% of the total roof area for installation of a Solar PV system, a 400-kW solar system can generate about 563,553 kWh/year of AC energy. This system can be sized appropriately based on the available space at the site, preferably the roof. If the roof space is limited, further space can be explored near the site such as parking spaces or other open spaces. Further opportunities include purchasing renewable electricity from utilities wherein the sourced renewable energy could go hand in hand with the site renewable energy implementation. Rebate incentives can be claimed in the form of Solar Renewable Energy Credit (SRECs) [28], also called alternative energy credits in Maryland. SRECs are created for each 1,000 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, for qualifying.

Fig. 25: Higher roof – free space for solar water heaters and PV panels.

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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