Benson Gymnasium

at the Maryland School for the Deaf

301 S. CARROLL STREET, FREDERICK, MD 21701

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 Michael Ohadi, within the Center for Environmental Energy Engineering at the University of Maryland, College Park (UMD), is performing this project, which is managed by the Maryland Department of General Services (DGS) Office of Energy and Sustainability and collaborates with multiple state agencies. Principal investigator and project Director is Dr. Michael Ohadi. Project Deputy Director is Dr. Amir Shooshtari. The UMD S2TS team members who contributed to the present building audit project included Alibek Bekenov, Ji Bae, and Dr. Roxana Family.

Acknowledgment

We would like to acknowledge the building manager Robert Trice at the Maryland School for the Deaf in Frederick, 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. David St. Jean for his leadership, insights, and overall guidance of the project. We are also grateful to Mr. Tony Myers for his diverse help including coordinating the walkthroughs, assisting with gathering of the relevant technical information for the buildings studied, review of the reports and feedback, among others.

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, to reduce their environmental impact, and to 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, divided the audit into three phases: Building Comprehension, Energy Model Development, 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 profile 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 Benson Gymnasium is located at 301 S. Carroll street, Frederick, Maryland. The Gymnasium is one of the sixteen buildings in the Maryland School for the Deaf, Frederick Campus. The building was constructed in 1975 and is a one-story building with an overall area of 42,731 square feet as specified by the facility manager. The same area is indicated in the EnergyCap system. The total area, indicated in the building plan, constitutes 45,509 square feet. Considering that approximately 3000 square feet are non-conditioning zones, this area is close to the value mentioned above. Fig. 1 shows an overview of the building. Table 1 shows the average annual utility consumption and cost for calendar years of 2018 to 2020.

Fig. 1: Aerial view of Benson Gymnasium [1].

The building primarily houses the Gymnasium, Natatorium, Recreation room, classroom, office spaces and storages. The basement level consists of a swimming pool, along with a mechanical room - containing equipment such as boilers, pumps, water heaters. The mezzanine room with all 7 AHUs is on the partial second floor, between the gymnasium and the natatorium. RTUs are located on the rooftop.

As per our discussions with the Maintenance Supervisor, the building occupancy schedule is from 7 AM to 6 PM on weekdays (Monday to Friday) with a break for holidays from June to August. The building’s HVAC systems operate 24 hours a day, during the school year, at temperature setpoints - between 75°F & 80° F for cooling and between 65°F & 70°F for heating.

The building consumes energy from two primary energy sources: electricity and natural gas. The electricity consumption is metered and supplied by Potomac Edison, while the natural gas is metered and supplied by Washington Gas. Based on data from EnergyCAP, the building's annual average electricity consumption is 355.6 MWh and annual average natural gas consumption is 51,207 Therms. Annual average utility cost of the building, excluding water, is $65,453.

Average annual utility use and cost for calendar years 2018-2020

Electricity	355.6 MWh	$ 33,331
Natural Gas	51207 Therms	$ 32,122

We have not included a Water Usage Intensity analysis, because recent utility data is not available on the EnergyCAP database for water usage (only partial data up to 2015 year is available), and utility bill information was not provided outside of EnergyCAP for this building. We recommend installing water meters to measure and bill each unit's actual water use.

Benchmarking Results Summary

Parameter	Benson Gymnasium Value	Standard Value	Reference
Energy Star Score (1-100)	8	75	EnergyStar Portfolio Manager
Site EUI (kBtu/sf)	148.2	123	Commercial Buildings Energy Consumption Survey (CBECS)
Utility Cost Per Area ($/sf)	1.95	1.84	Commercial Buildings Energy Consumption Survey (CBECS)

The overall Energy Star score of 8 indicates that the building is performing significantly below the median energy performance. The EUI value of 148.2 was obtained using EnergyStar Portfolio Manager. Based on the CBECS average data for sport facilities, the Benson Gym building currently has an Energy Usage Intensity higher than the average (148.2 vs. 123). The utility cost per area is higher than the average value (1.95 vs. 1.84). This means when compared to other reference sport facilities, the Benson Gym is performing worse than typical Gymnasium in the United State and that there may be additional opportunities to increase the overall energy efficiency of the facility.

Building Observations:

- Air Handling Units (AHUs) are original to the building, which was built in 1975, and are used only for heating.
- Different types of cooling equipment serve only 40% of the building area: RTUs serve gymnasium, window AC units serve locker rooms, gym and uniform storages, PTAC units serve offices and classrooms. Areas such as the recreation room, natatorium, corridors, lobby and toilets do not have their own cooling systems.
- The interior lighting of the building is provided by fluorescent lamps. They are not controlled by occupancy sensors.
- Single glazed windows are installed throughout the building, and they are original glass windows to the building.
- Most of the appliances in the building are not Energy Star certified.
- Water meters were not installed, actual data of water usage is not available.

Electrification Opportunities:

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 [20]. 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

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. 11, from above), 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 CO2 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 CO2 emissions for an electric heat pump is less than that of a natural gas boiler.

VRF System

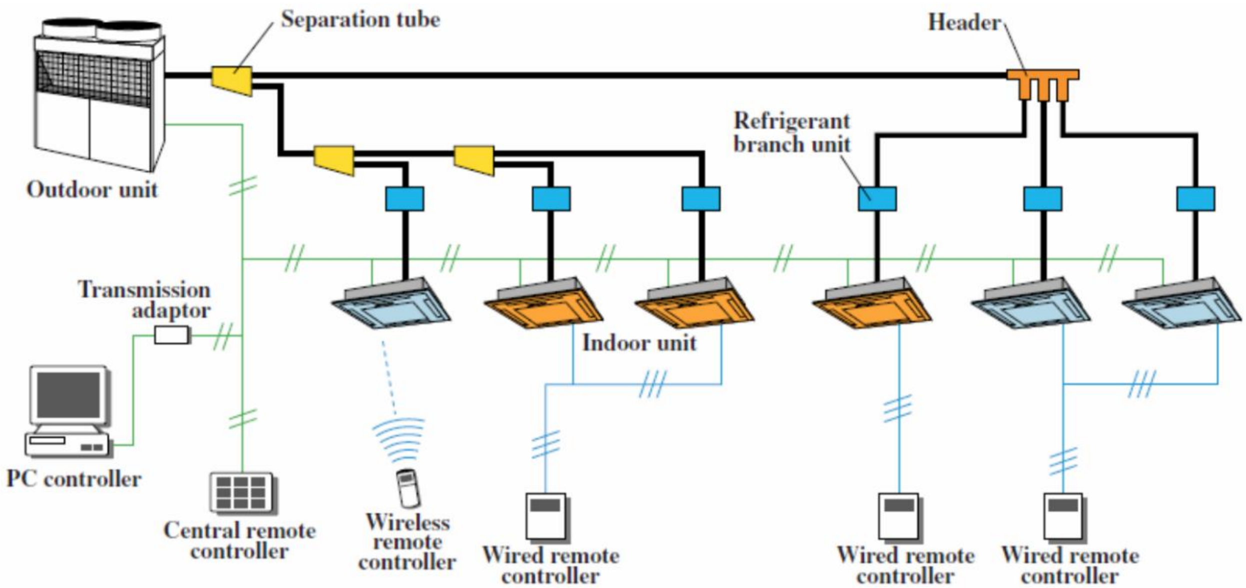
- **Replace the existing HVAC system with variable refrigerant flow (VRF) system.**

An all-in-one VRF system should be considered as an EEM in order to explore the potential benefits of using this technology for building electrification.

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. 2 shows a schematic VRF arrangement.

A schematic VRF arrangement



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.

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.

Water Management:

Since water data was not available or consistent enough to include a respective table for consumption, direct savings for water efficiency measures were not able to be calculated. The Federal Energy Management Program's - Water Project Screening Tool [22], however, would be a good option to quickly screen for water efficiency opportunities. The tool has easy to use inputs that looks at 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.

Building Automation System:

Benson gym does not have a Building Automation System (BAS).

A centralized control system is essential to achieve an efficient HVAC system and point out any early issue before it transitions to a major setback of the system, thus protecting the facility assets. A BAS system is not only important to manage the occupant comfort but also to effectively operate at reduced capacities and speeds during part-load operation.

Having a building control system plays a part in improving the building efficiency as it will assist the Facility personnel to easily identify any atypical operation of the mechanical system so that the problem can be rectified, and efficient operation restored. Also, a centralized BAS system can help with temperature setback, and changing schedules over unoccupied hours, weekends, and holidays.

EEM 1 - Lighting Upgrades

- Replace all fluorescent and incandescent lights in the building with new LED bulbs and occupancy sensors.

The building mostly employs fluorescent lighting (Fig. 2) with some incandescent lighting, with no occupancy sensors. Most of the building is served by T8 fixtures. Upgrading these fixtures to LED solutions has multiple end-user benefits. Installation of LED lighting, along with occupancy sensors can yield significant energy savings while also reducing the maintenance and labor costs associated with fluorescent and incandescent lighting. LED light fixtures have a longer rated life which would mean fewer costs associated with replacing them.

Lighting control options further enhance the energy-saving potential of LED lighting. During the retrofit, controls such as daylight saving, occupancy sensing operation, and dimming can be integrated into the lighting system to yield energy savings. Transitioning towards LED lighting along with controls could yield electricity savings of around 50% of total annual lighting consumption [2].

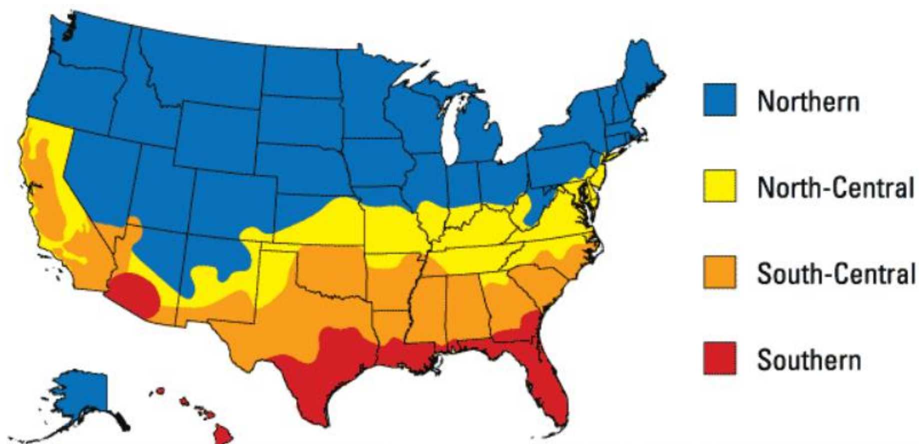
Fig. 2: Fluorescent lamps in the Gym.

<u>EEM 2</u> – Windows Update

- Replace single glazed windows with double glazed tinted windows.

Approximately 30% (or greater in certain cases) of the energy loss occurs through windows and doors [3]. At the moment, the Benson Gym has partially tinted single glazed windows as shown in Fig. 3. Replacing windows with modern energy efficient types will help reduce infiltration and thermal radiation losses from the building. Since the building is located in North Central climate zone, it is recommended to install windows which meet performance criteria certified by the National Fenestration Rating Council (NFRC) [4]: U-factor <= 30 BTU/(h·ft^2·°F) and Solar Heat Gain Coefficient (SHGC) <= 0.40 (Fig. 4). For the Energy Efficiency Model, we employed low emissivity (Low-E glass) double glazed tinted windows with U-factor = 0.33 BTU/(h·ft^2·°F) and SHGC = 0.38, which are close to recommended by NFRC. Low-E glass reduces energy use by as much as 30-50%, especially during hot summer months [3].

Fig. 3: Single glazed windows installed in Benson Gym.



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] Btu/h ft2·°F
[2] Solar Heat Gain Coefficient

Fig. 4: Energy Star qualified windows by climate zones.

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, washers, dryers for small kitchens and other spaces. Fig. 5 shows examples of these types of appliances. Based on the data provided by the facility manager, there are about 40 interior non-HVAC equipment (including pool pump) that consume approximately 16% of electricity. These appliances can be high energy consumers, depending on their energy ratings and age. Replacing the appliances that are more than five years old and are not Energy Star certified, with new Energy Star certified units will result in 10% to 50% savings in electricity consumption each year [5], and savings will expand to the reduction of water consumption as well.

Fig. 5: Examples of Miscellaneous Appliances.

2. **Dehumidifiers and Air Purifiers in Non-Occupied Spaces**

It was observed that there were few standalone dehumidifiers and air purifiers constantly running in spaces that were not occupied due to the fact students were on summer vacation. An example of these types of standalone units are shown in Fig. 6. Although the energy consumption of a single unit may not be significant compared to energy consumption of the building's central HVAC system, having several of these units constantly running throughout the day and night may cause unnecessary energy consumption to accumulate throughout the year to a point where it is noticeable. It is recommended to ensure that these units are used responsibly and only when needed. It is also recommended that a study be conducted to address any humidity or air quality issues in these areas that facilitate the need for the dehumidifiers and air purifiers.

Fig. 6: Typical Air Purifier in Non-Occupied Space.

3. Green Walls

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 the comfort levels. Indoor living wall solutions provided by LiveWall could be considered for the lobby space [6].

4. Smart Power Strips

Smart power strips can reduce energy waste, prolong 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 in order to reduce annual electricity consumption. The payback period of a smart power strip is around 1.1 years [7].

All power strips in the building shall be replaced with smart power strips, equal to ones provided by Tricklestar or similar brands. The contractor shall provide pricing for provision of smart power strips as well as for their installation in accordance with existing power connection setups for each room in the building.

5. Variable Frequency Drives

The existing HVAC system currently does not have variable frequency drives installed and integrated with them. Variable frequency drives (VFD) modulate the frequency of fans and pumps in order to control the speed of these components so that they are not operating at a higher load than needed.

This allows for improvements in energy efficiency of the HVAC systems. VFD controlled fans have been shown to significantly reduce energy consumption by up to 70% [8]. Installing VFDs is a low-cost option for improving the efficiency of the HVAC units.

Savings associated with the above-referenced recommended EEMs:

- Annual total utility cost reduction of 19.7% resulting in $16,426 annual utility savings.
- Annual electricity consumption reduction of 48.3% resulting in $16,050 annual savings.

Energy Efficiency Measure Savings

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 2. The table also includes the predicted savings of implementing all the EEMs simultaneously, and this section is labeled as “Combined EEM’s.” Note that the savings predicted by the “Combined EEM’s” do not equal the sum of each individual EEM. This is an expected result of the interaction between multiple model parameters in a dynamic whole building energy simulation. The ability to model multiple energy efficiency measures simultaneously is another powerful feature of the whole building energy modeling. For the values in the summary table, the calculations are performed using the current chiller and boiler capacities.

Table 2: 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 - Lighting Upgrades	233	51908	99	-1737	29.8	-3.5	9880	-1737	8143
EEM 2 - Windows Upgrade	270	48058	62	2113	18.6	4.2	6170	2113	8283
Combined	172	49795	161	376	48.3	0.7	16050	376	16426

***** *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 331.9 MWh and 50,171 Therms, respectively.

The total annual utility cost of electricity (331.9 MWh) and natural gas (50,171 Therms) is $83,371. The observed annual utility savings after implementing the EEMs can reduce the annual utility cost by $16,426, which is equivalent to 19.7%.

Table 3a: Carbon Footprint Analysis

Energy Efficiency Measures (EEM)	Projected Energy Savings		Carbon dioxide Reduction *	
	Electricity (MWh/yr)	Natural gas (Therms/year)	Electricity (lbs/year)	Natural gas (lbs/year)
EEM 1 - Lighting Upgrades	99	-1737	72420	-283131
EEM 2 - Windows Upgrade	62	2113	45226	344419
Combined	161	376	117647	61288

Table 3b: Carbon Footprint Reduction Results

Energy Efficiency Measures (EEM)	Carbon Dioxide	
	From Electricity (lbs/year)	From Natural gas (lbs/year)
Without Combined Savings	243,356	8,177,873
With Combined Savings	125,710	8,116,585

* *The above values are based on the State of Maryland estimates of 733 lb of CO2 emissions per every MWh of Electricity based on 2019 data [9] and 163 lb of emissions per every therm of natural gas [10].*

The Carbon footprint analysis shown in Tables 3a and 3b 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. Based on the current average annual utility data, carbon dioxide emissions are 243,356 lbs per year from electricity and 8,177,873 lbs per year from natural gas. With the combined savings from the proposed EEM's, carbon dioxide emissions would become 125,710 lbs per year from electricity and 8,116,585 lbs per year from natural gas.

As a result, implementation of the EEMs would result in a reduction of 178,935 lbs (Electricity and Gas combined) of carbon dioxide emissions per year, that equals to 2%. 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 afterwards) due to use of cleaner fuels and renewable energy sources. See Fig. 7 for more detail.

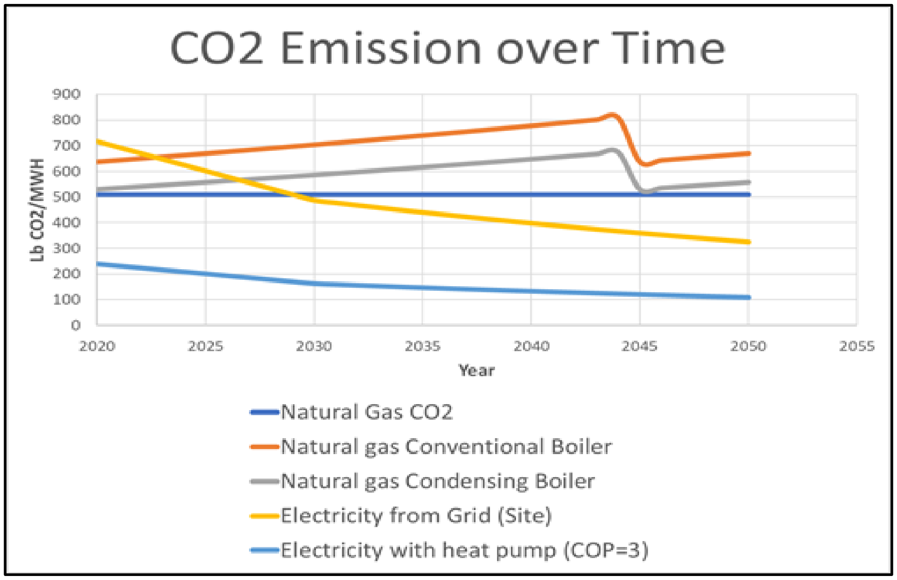
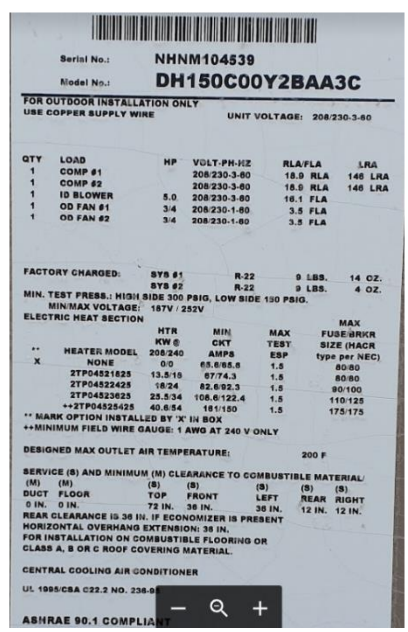


Fig. 7: CO2 emission over time (source: DGS).

Building HVAC Description

Several types of cooling equipment are installed in the building, which serves only 35% of all area. Cooled air for the Gymnasium room is supplied by 4 rooftop units (RTUs) - YORK DH150C00Y2BAA3C- with rated capacities of 152.6 MBH (44.7 kW) each, as specified in the building plan. Fig. 8 shows the RTU installed on the roof in place of a former skylight. All 4 units were mounted in 2004.

Fig. 8: Rooftop Unit.



Storages are cooled by 8 window air conditioners (AC) with a capacity of 5 MBH (1.47 kW) each, based on the information provided by the facility manager (Fig. 9). The average lifespan of the AC window type is estimated at 10 years (according to ASHRAE) [11]. It is recommended to consider the possibility of replacing this equipment.

Fig. 9: Window AC.

Classrooms and office spaces are served by 2 types of Packaged Terminal Air Conditioning (PTAC) units (Fig. 10) with water heating rated at 27 and 18.5 MBH for cooling and 26 and 17 MBH for heating, according to specification in the building plan. Totally, there are 8 units of PTAC. Hot water for this type of AC is provided by boilers. Cooling is generated by own evaporator coils.

Fig. 10: Packaged Terminal Air Conditioners installed in Benson Gym.

Hot water for AHU coils and PTAC as well as for baseboard radiant water heaters is supplied by three gas-fired boilers (Smith 28A Series, Model 28A-S/W-08), each with a capacity of 1700 MBH (498 kW). These boilers (Fig. 11) as well as pumps #4 to #14 were installed in 2007 replacing old ones. In addition to PTAC mentioned above, 8 constant speed pumps (with 5 HP, 1.5 HP, 0.75 HP, 0.5 HP, 0.5 HP, 3 HP, 3 HP, 3 HP) supply hot water to AHU coils and below equipment (as specified in the building plan):

- 3 down blast unit heaters (unit ventilators UV) with a capacity of 52.5 MBH each that serve Recreation room (Fig. 12);
- finned tube radiators that installed in Natatorium
    - along the Eastern wall with a capacity of 800 MBH/ft and a total area of 325 square feet;
    - along the Northern wall with a capacity of 1240 MBH/ft for 42 square feet area and 800 MBH/ft for 65 square feet area;
    - along the Southern wall with a capacity of 1240 MBH/ft for 42 square feet area and 800 MBH/ft for 65 square feet area;
- 1 cabinet heater (27 MBH) and 3 cabinet heaters (11.7 MBH each) that installed in corridor and lobby;
- 2 unit heaters (62 MBH each) which serve Gym storage.

Fig. 11: Boiler Units installed in Benson Gym.

Fig. 12: Unit ventilators (UV) installed in the Recreation room.

Domestic hot water and heated water for the swimming pool in the Natatorium are supplied by 2 gas-fired water heaters (Rinnai, model C199IN) rated at 199 MBH (58 kW). 2 constant speed pumps deliver domestic hot water throughout the building. Fig. 13 shows the type of water heaters installed in a mechanical room of the basement level. They were installed in 2007.

Fig. 13: Domestic Water Heater.

There are 7 AHUs in the building (Fig. 14), which serve most of the building needs. AHUs 1 to 6 are in the mezzanine room on the partial second floor, between the gymnasium and the natatorium. AHU 7 is in the mechanical room of the basement. AHUs 1 to 6 serve the entire 1st floor. AHU 7 serves the basement. All AHUs have supply fans powered by constant speed motors, rated at 1 HP, 3 HP, 3 HP, 0.5 HP, 0.5 HP and 1.5 HP, and are equipped with hot water heating coils. They are used only for heating. Supply air is delivered to each space via ducts and diffusers. AHUs and fans are original to the building which was constructed in 1975.

Fig. 14: AHU7 in the basement (top) and others are in the mezzanine (bottom).

The summary of the design specifications of the building's HVAC system retrieved from the building's mechanical drawings is shown in Tables 4a-4h.

Table 4a: Air Handling Unit specifications summary.

AIR HANDLING UNIT SCHEDULE							
UNIT DESIGNATION		AHU-1	AHU 2&3	AHU-4	AHU-5	AHU-6	AHU-7
SERVING		MEN'S LOCKERS, ETC.	GYMNASIUMS	NATATORIUM	NATATORIUM CLG.	WOMEN'S LOCKERS, ETC.	BSMT. AREA
LOCATION		MEZZ. EQUIP. RM	MEZZ. EQUIP. RM.	MEZZ. EQUIP. RM.	MEZZ. EQUIP. RM.	MEZZ. EQUIP. RM.	BSMT.
CFM		3840	9650	9000	2000	1560	4400
% O.A.		100	25	25	100	100	40
E.S.P. " W.C.		.33	.38	.48	.39	.33	.47
OUTLET VEL. (FPM)		1433	1786	1786	1166	1495	1720
FAN RPM - MOTOR HP		612 - 1	650 - 3	680 - 3	600 - 1/2	1020 - 1/2	670 - 1 1/2
HEATING	TOTAL (MBH)	311.0	339.1	444.9	151.0	126.2	200.2
	ENT. AIR °F.	0	52.5	49.4	0	0	42
	LVG. AIR °F.	75	85.1	95.3	70	75	84
	ENT. WATER °F.	190	190	190	190	190	190
	GPM	32	34	46	16	13	20
	COIL F.V. (FPM)	500	595	555	360	560	565
	COIL P.D. (F.T. W.C.)	3.5	3.3	3.9	5.8	5.6	3.7

Table 4b: Boiler specifications summary.

GAS/OIL-FIRED HOT WATER BOILER								
UNIT NO	LOCATION	GPM	WATER		GAS INPUT (MBH) 3	OUTPUT (MBH) 1	NO.2 OIL GPH	NOTES
			EWT	LWT				
BOILER-1	BOILER ROOM	170	170	190	2482	1700	17.0	2
BOILER-2	BOILER ROOM	170	170	190	2482	1700	17.0	2
BOILER-3	BOILER ROOM	170	170	190	2482	1700	17.0	2

Table 4c: Domestic water heater specifications summary.

DOMESTIC WATER HEATER								
UNIT NO	LOCATION	RECOVERY (GPH)	WATER		GAS INPUT (MBH) 1	STORAGE (GAL)	NO.2 OIL GPH	NOTES
			EWT	LWT				
DWH-1	BOILER ROOM	1200	40	140	1250	200	9.0	1/3 HP BURNER
DWH-2	BOILER ROOM	1200	40	140	1250	200	9.0	1/3 HP BURNER

Table 4d: Roof top unit specifications summary.

PACKAGED ROOFTOP UNIT SCHEDULE															
UNIT No.	AREA SERVED	FAN						COOLING							ELECTRICAL
		S.A. C.F.M.	OUTDOOR AIR		E.S.P.	H.P.	R.P.M.	TOTAL M.B.H.	SENSIBLE M.B.H.	E.A.T.		L.A.T.			V/PH/HZ
			IAQ MIN. C.F.M.	IAQ MAX. C.F.M.						DB °F	WB °F	DB °F	WB °F		
RTU–1	GYMNASIUM	4750	715	1125	0.50	5	1079	152.6	116.7	79.5	65.9	56.8	55.3		208/3/60
RTU–2	GYMNASIUM	4750	715	1125	0.50	5	1079	152.6	116.7	79.5	65.9	56.8	55.3		208/3/60
RTU–3	GYMNASIUM	4750	715	1125	0.50	5	1079	152.6	116.7	79.5	65.9	56.8	55.3		208/3/60
RTU–4	GYMNASIUM	4750	715	1125	0.50	5	1079	152.6	116.7	79.5	65.9	56.8	55.3		208/3/60

Table 4e: Unit ventilators specifications summary.

UNIT VENTILATOR SCHEDULE						
DESIG.	CFM@ 600 RPM	% O.A.	TOTAL MBH	GPM	P.D. FT.	REMARKS
UV-1	1250	10	52.5	1.6	1.5	SEE NOTE 2 BEL.

Table 4f: Cabinet Heater and Unit Heater specifications summary.

CABINET AND UNIT HEATER SCHEDULE						
DESIG.	CFM	MBH	GPM	P.D. FT.	RPM	REMARKS
CH-1	350	27	3	1.45	750	RECESS, WALL MTD.
CH-2	280	11.7	1	.28	750	SEMI-RECESSED - 4" WALL MTD.
CH-3	280	11.7	1	.28	750	RECESS, WALL MTD.
UH-1	1140	62	8	.46	1150	DOWN-BLAST TYPE

Table 4g: Air conditioner specifications summary.

PACKAGED AIR CONDITIONING UNITS								
DESIG.	COOLING CAPACITY BTUH.	HEATING CAPACITY BTUH	SUPPLY AIR-CFM	OUTSIDE AIR-CFM	FAN RPM	HEATING WTR-GPM	HTG. COIL P.D. FT.	REMARKS
AC-1	27,000	26,000	700	100	1050	2.0	2	REMOTE MTD. WALL THERMOSTAT (MASTER)
AC-2	18,500	17,000	500	75	720	1.7	.5	REMOTE MTD. WALL THERMOSTAT. ABOVE

Table 4h: Pump specifications summary.

PUMP SCHEDULE						
Nº	SERVING	GPM	FT. HD.	RPM	HP.	ELEC.
1	SWIMMING POOL	510	45	1750	10	208V-3φ-60
2	H.W. GENERATOR	162	10	1750	1	208V-3φ-60
3	AIR HANDLING UNITS	202	34	1750	5	208V-3φ-60

UNIT NO	TYPE	LOCATION	SERVICE	FLUID	GPM	HEAD	TEMP	MOTOR HP	RPM
PUMP-4	CM	BOILER ROOM	HEATING WATER	WATER	55	38	190	1-1/2	1760
PUMP-6	D	BOILER ROOM	HEATING WATER	WATER	25	40	190	3/4	1750
PUMP-7	D	BOILER ROOM	HEATING WATER	WATER	11	36	190	1/2	1750
PUMP-8	D	BOILER ROOM	HEATING WATER	WATER	15	35	190	1/2	1750
PUMP-9	J	BOILER ROOM	HWR	WATER	5	26	110	1/3	1750
PUMP-10	D	BOILER ROOM	HEATING WATER	WATER	170	40	190	3	1750
PUMP-11	D	BOILER ROOM	HEATING WATER	WATER	170	40	190	3	1750
PUMP-12	D	BOILER ROOM	HEATING WATER	WATER	170	40	190	3	1750
PUMP-13	J	BOILER ROOM	HWR	WATER	5	15	140	1/8	1725
PUMP-14	N	BOILER ROOM	FLOOR DRAINS	WATER	10	15	190	1/2	1750

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, and courtrooms. 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, there were certain assumptions that had to be made for the unavailable data.

Energy Model Development and Validation comparison

The energy model was developed as follows: simulation software was selected, a baseline model was developed, the model was calibrated, and the results were validated. For this project, the building simulation software 1Trane 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. 15 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.

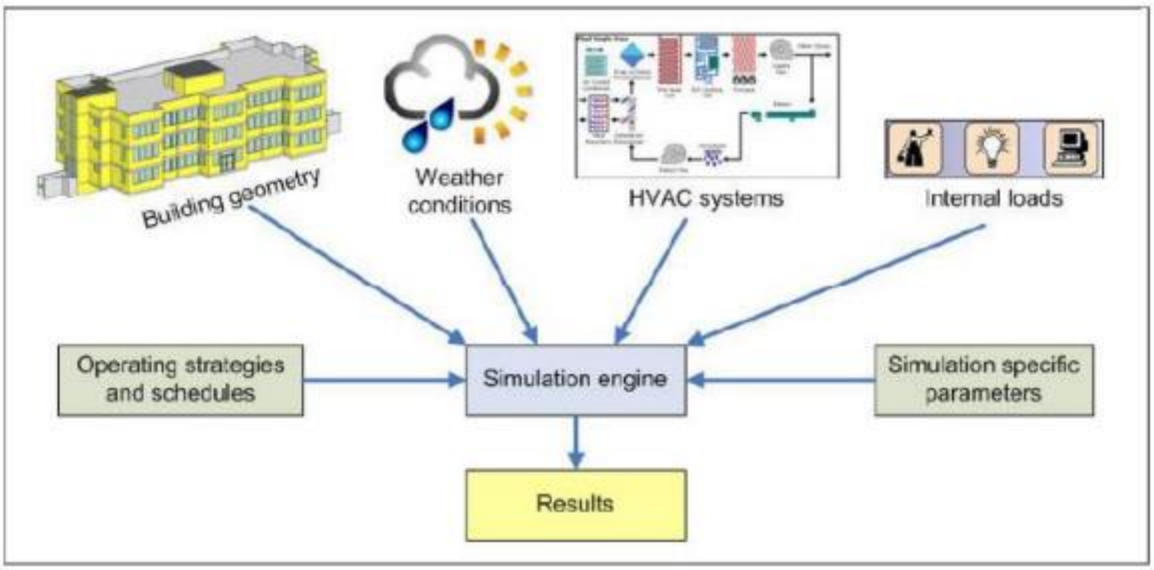


Fig. 15: General data flow of building energy simulation software [12].

Energy Efficiency Measures 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 [13]. ASHRAE also provides registrants with function-specific Advanced Energy Design Guides for achieving additional energy savings up to 50% [14]. When possible, these energy conservation measures were analyzed by the energy model of the building.

Load Calculations

The building load calculations were carried out to determine the building loads and evaluate whether the current systems are undersized or oversized. From the Trane 3D Plus modeling output results, it was found that the total cooling load was about 49 tons. The current RTUs (4 in total) are rated at 12.7 tons each and the wall and window AC units (16 in total) have a total estimated capacity of 17 tons. Therefore, the total installed capacity is 68 tons. Assuming a redundancy of (N+1), the amount of installed RTUs is sufficient if one of them fails. Focusing on the boilers, the total heating load was about 1710 MBH and the current boilers are rated at a maximum net capacity of 1700 MBH each. Therefore, combined capacity of the 3 boilers is 5100 MBH. Boilers meet the building's heating needs, assuming a redundancy of (N+1), where N is the required number of units.

Utility Analysis and EUI Benchmarking

Utility data from 2017 to 2021 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 obtained in the units of kWh and Therms, respectively, then converted to units of kBTU using conversion factors provided by the US DOE [15], and they are shown in Table 5. The corresponding Energy Star scores are given in table 6.

Table 5: Utility Analysis and EUI Summary Calculation.

	Electricity		**Natural Gas**		**Total Site Energy**	**Site EUI**	**Source EUI**
	MWh/yr	kBtu/yr	therms/yr	kBtu/yr	kBtu/yr	kBtu/SF/Yr	kBtu/SF/Yr
Baseline Energy Usage	331.9	1,132,490	50171	5,017,100	6,149,590	144	211

Fig. 16 and Fig. 17 show the average monthly electricity and natural gas consumption respectively for the years of 2017-2021 as well as provide a number of key insights.

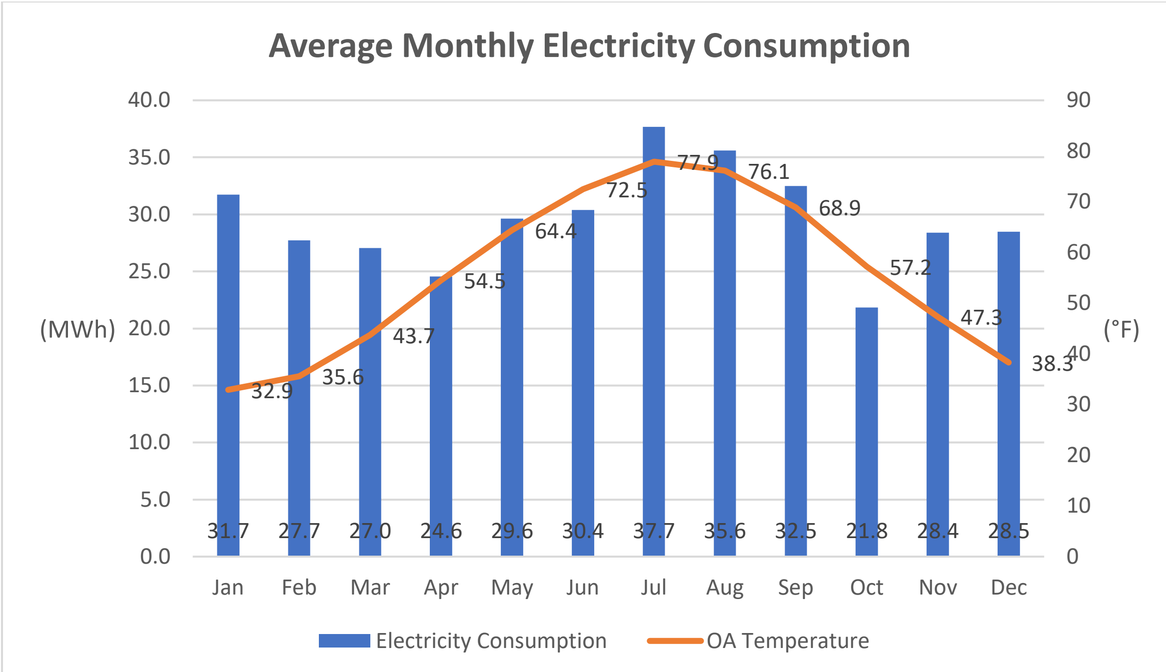


Fig. 16: Average Monthly Electricity Consumption [16].

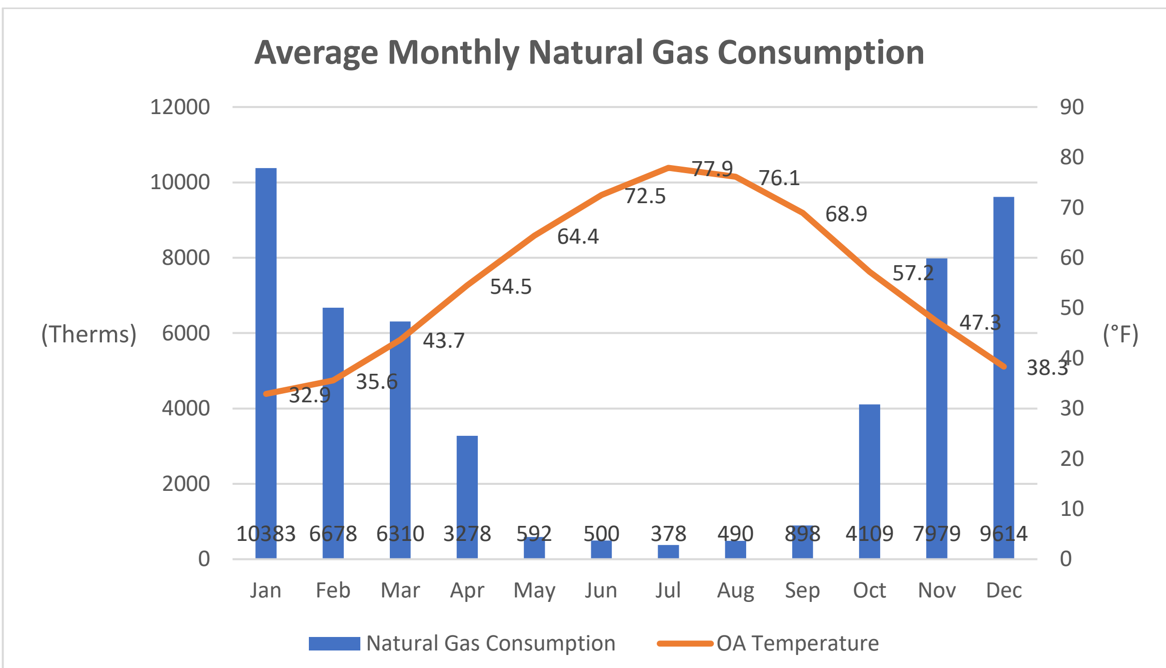


Fig. 17: Average Monthly Natural Gas Consumption [16].

According to the utility data, an average of 355.6 MWh 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 51,207 Therms of natural gas is consumed every year.

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 [17]. The Commercial Buildings Energy Consumption Survey (CBECS) database data was also used to evaluate the energy profile of the facility [18]. This comparison provides an opportunity to determine the scope of improving overall energy efficiency.

In the case of 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].

Energy Modeling

The physical structure of the Benson Gym 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. 18 shows the 3-D representation of the building model as rendered in Trane Trace 3D Plus.

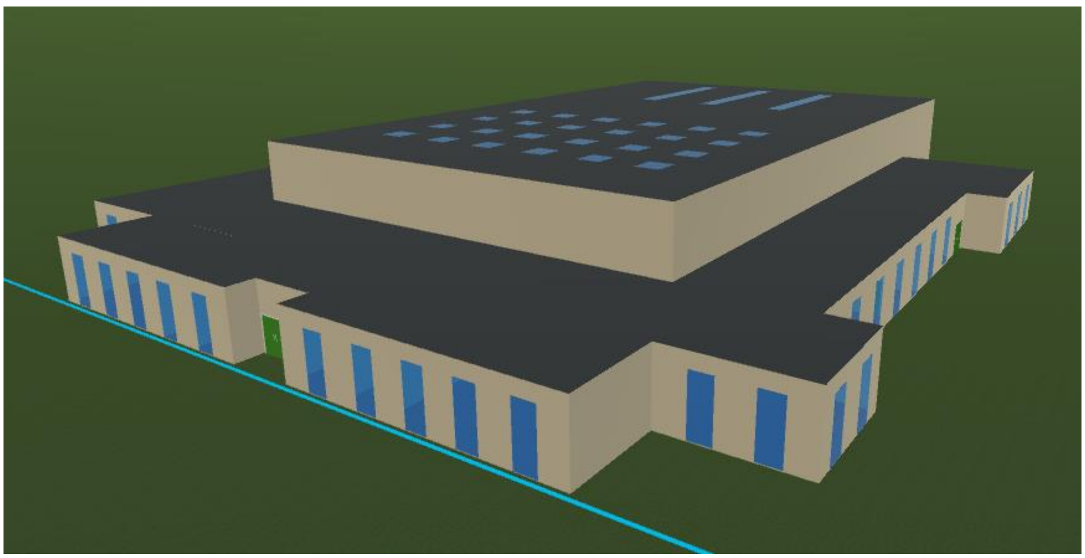


Fig. 18: Building energy model rendered in Trane Trace 3D Plus.

The energy model has a total of 10 thermal zones. Fig. 19 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, boiler and mechanical rooms.

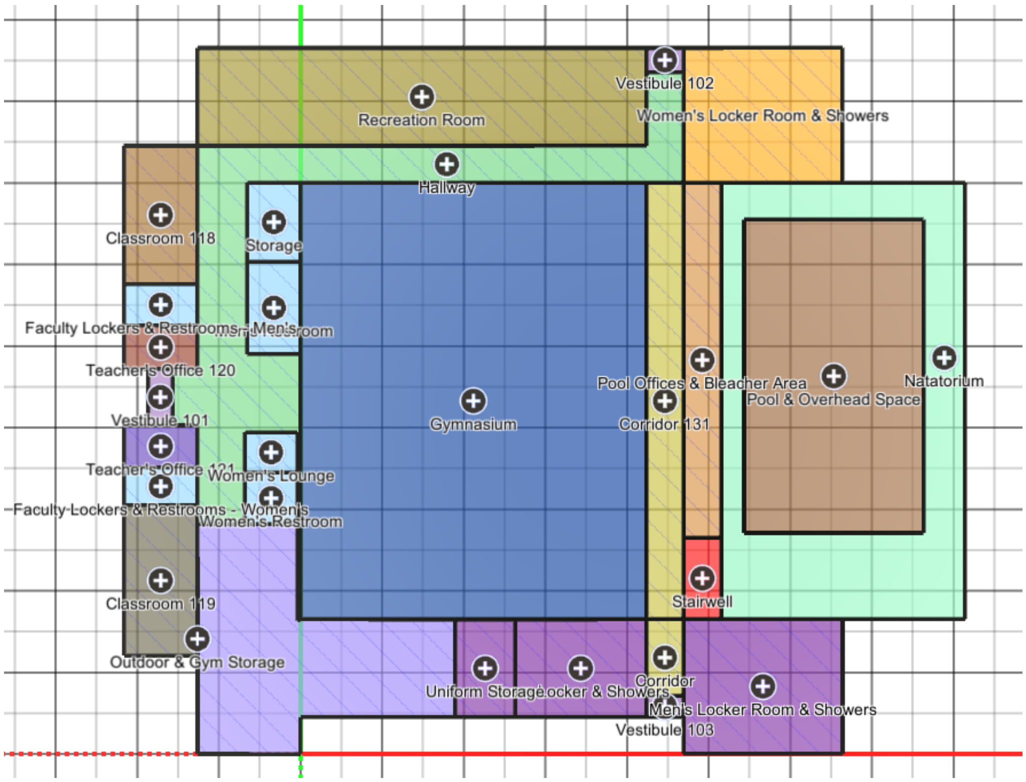


Fig. 19: Model thermal zone design.

The main space types defined to specify the lighting, plug loads, occupancy, and their associated schedules were offices, classrooms, corridors, storage rooms, gymnasium, and natatorium. 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. 20 and Fig. 21 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.

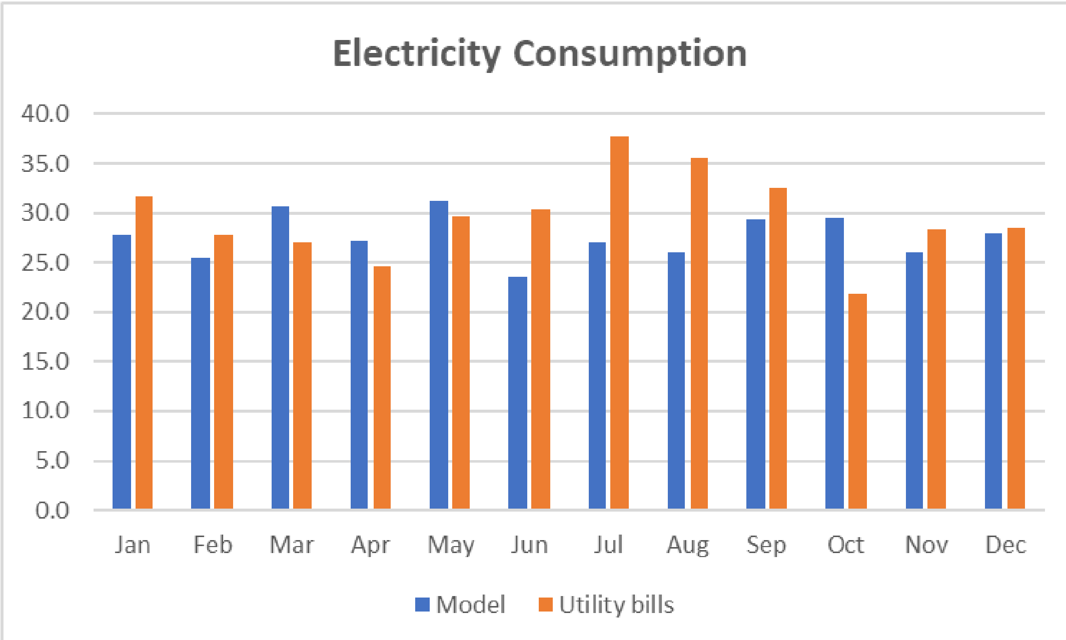


Fig. 20: Monthly electricity consumption comparison.

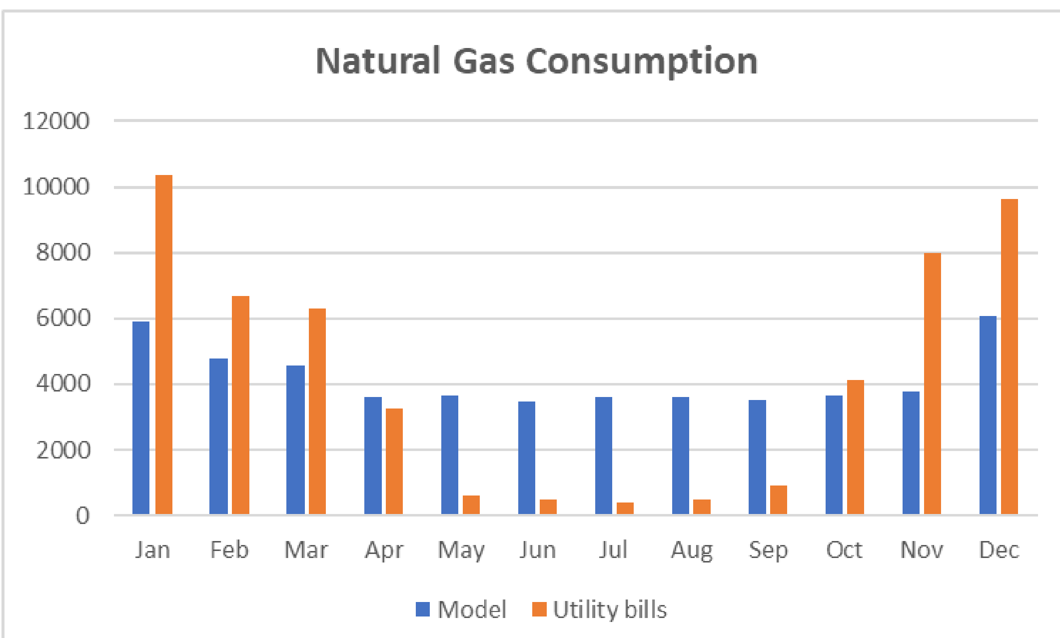


Fig. 21: Monthly natural gas consumption comparison

The predicted monthly energy consumption of the baseline energy model closely matched the trend of the average monthly energy consumption reported by utility bills between 2018 and 2020 except for the electricity and gas consumption in the summer months in particular.
The utility data showed that electricity consumption was relatively high in the summer compared to the predicted data, which indicates that an unnecessary amount of electricity may be being consumed during the summer.

In the case of the modeled electricity consumption in comparison to the actual utility data, the values deviate by 6.7% while the natural gas consumption values deviate by 2%. 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 meet the ASHRAE calibration requirements as given by Guideline 14-2002 which allows a deviation of up to 15% [19]. Therefore, the team has determined that the model is suitable to use for energy analysis and auditing of the Benson Gym building.

Low cost-No cost/Energy Star Recommendations

- ✓ Conduct a nighttime audit to find out what's on afterhours that shouldn't be.
- ✓ Optimize start-up time, power-down time, and equipment sequencing.
- ✓ Install LED exit signs. These signs are brighter, reduce annual electricity costs
- ✓ and can dramatically reduce maintenance by eliminating the need to replace lamps.
- ✓ Install occupancy sensors to automatically turn off lights when no one is present and back on when people return. Storage rooms, back-of-house spaces, meeting rooms, and other low-traffic areas are often good places to start.
- ✓ Plug air leaks with weather stripping and caulking.
- ✓ Repair damaged insulation and replace missing insulation with thicknesses calculated for the operating and ambient conditions of the mechanical system.

Conclusions

The Benson Gymnasium building is an interesting facility due to it being a relatively old construction, absence of a chiller and operating with a variety of cooling equipment only in some rooms.

The facility would benefit from lighting upgrades on account that it is currently operating with fluorescent light bulbs while the trend for modern buildings are LED's 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 facility would also benefit from the replacement of single glazed windows with double glazed tinted ones. The expected energy savings resulting from the implementation of these energy efficiency measures will decrease the building's annual electricity consumption by 48.3% and natural gas consumption by 0.7%.

This is a relatively high number in electricity 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 79% of the total building energy consumption, while lighting only accounts for 5%. Another 16% accounts for Interior Equipment. As shown in Table 6, the EUI for the building is higher than the average for sport 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.

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.

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