Office of the Chief Medical Examiner of the State of Maryland

900 W Baltimore St.
Baltimore, MD 21223

Energy Audit 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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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 UMD S2TS team consisted of Soumya Agrawal and Ji Bae, supervised by Dr. Amir Shooshtari & Dr. Michael Ohadi.

Acknowledgment

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Executive Summary

Overview

Governor Hogan’s Executive Order 01.01.2019.08 - Energy Savings Goals for State Government 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 S2TS team divided the audit into three phases: Building Comprehension, Energy Model Development, and Energy Efficiency Measure 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 Office of the Chief Medical Examiner building is located at 900 West Baltimore Street, Baltimore, Maryland 21223. The building was originally constructed in 2010 and is a five-story building with an overall floor area of 110,842 sq.ft. Fig. 1 shows an overview of the building.

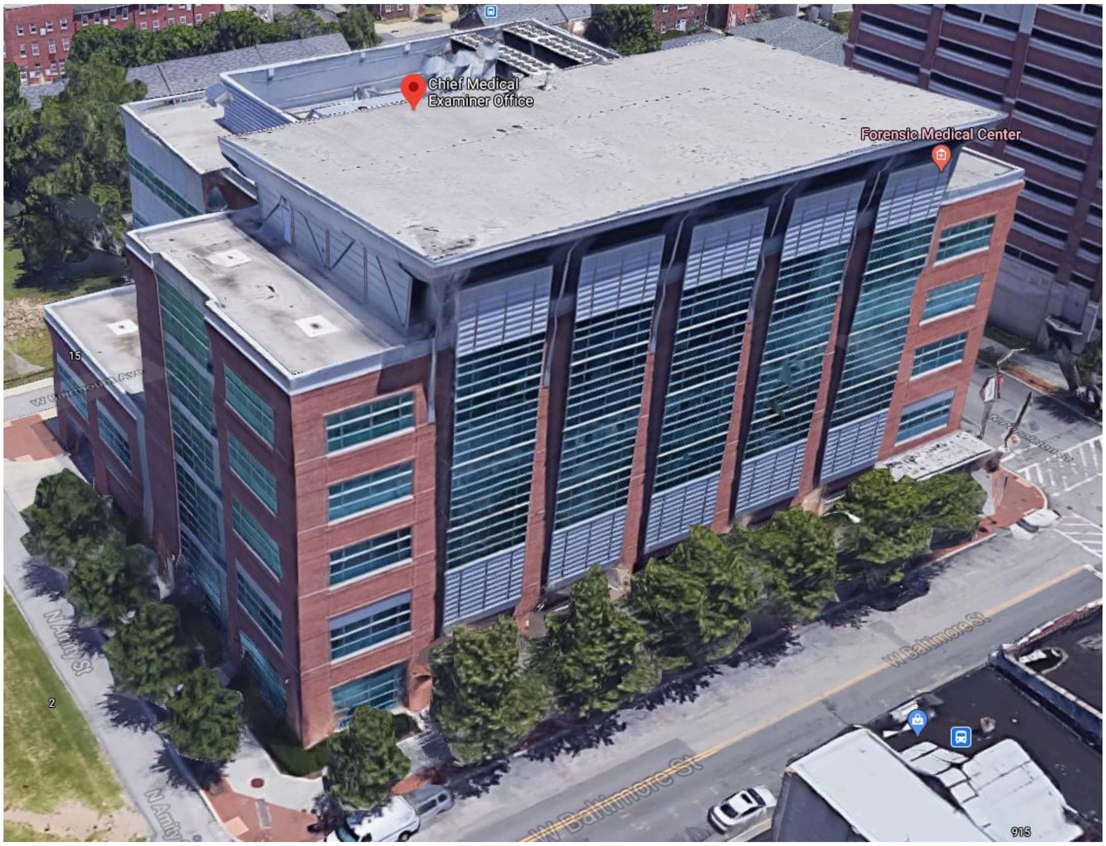
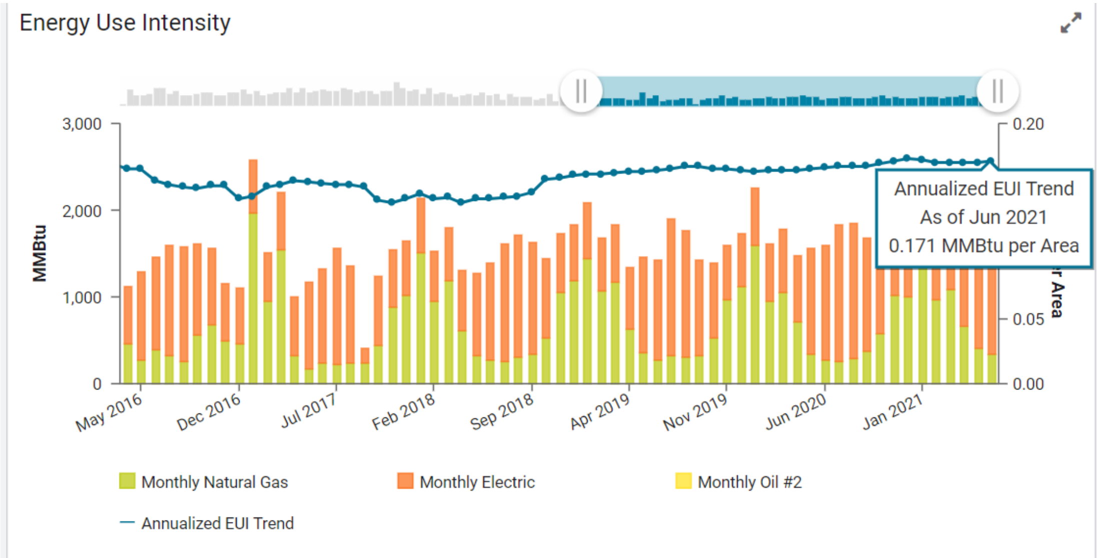


Fig. 1: The Office of the Chief Medical Examiner Building



The building houses primarily office spaces and medical labs. Level 1 consists of a parking garage along with several other miscellaneous spaces such as mechanical and electrical rooms. Level 2 and 3 houses office spaces and medical labs, which include two-story autopsy rooms, biosafety labs, as well as walk-in coolers. Level 4 and 5 house mostly office spaces and conference rooms. There is also a penthouse, which houses five air handling units (AHUs), two chillers, and two boilers. All units work to serve and provide the HVAC needs of the entire building.

The facility exemplifies a typical medical center in function, but there are also many non-typical specialty spaces in the building that require relatively high HVAC and lighting loads. The entire building is operating on a 24-hour building schedule for every day throughout the year. Likewise, the building HVAC systems operate during all of these times.

The building consumes energy from two energy commodities: electricity and gas. The electricity gas consumption is metered and supplied by a utility company called BGE. The building annual average electricity consumption is 3,219 MWh, and the annual average gas consumption is 82,612 therms. Annual average utility cost of the building is $437,993.

Savings Opportunities:

- The autopsy rooms are currently using a large quantity of Metal Halide lights, which emit a high amount of heat as well as consume a lot of energy.
- There are currently no LED lights installed in the building.
- There are PSC motors installed in some of the evaporators and condensers serving the walk-in coolers on the second and third floor.

Savings associated with following all the recommendations:

- Annual utility cost reduction of 5.7% resulting in $26,080 utility savings.
- Annual electricity consumption reduction of 7.4% resulting in $27,100 savings.
- Annual natural gas consumption increased by 1.1% resulting in $1,020 loss.

List of additional building observations and recommendations:

1. Disinfecting Lights
2. Lighting Certifications
3. UV-C Germicidal Lamps
4. Green Wall

I. 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 Upgrades

- Replace all non-variable speed fan motors with variable-speed fan motors for the existing evaporators and condensers serving the walk-in coolers on the 2nd and 3rd floors. The associated room numbers are 209, 211, 236, 238, 337, 338. Include all controls necessary to allow modulation of the variable speed fan motors and integrate the controls to the existing Building Automation System.

The HVAC upgrades involve making improvements to the split systems serving the walk-in refrigerators and freezers located on the second and third floors. The associated room numbers are 209, 211, 236, 238, 337, and 338. The HVAC upgrades include the replacement of non-variable speed fan motors in the existing evaporators and condensing units with variable speed fan motors, such as EC motors or equivalent. The variable speed fan motors will help in reducing energy consumption by reducing the speed of the fan motor when cooling requirements are lower and will also help in reducing run-time as well as load on compressors. These fan motor replacements will allow for energy savings of up to 25% according to the existing equipment manufacturer's product data, depending on whether fan motor replacements are made for only the evaporator, for only the condenser, or for both. Please see the following link for additional details: https://t-rp.com/products/technology/smartspeed/. Along with these fan motor replacements, all necessary controls that allow for the modulation of the variable speed fan motors shall be included. Smart defrost controls shall be included as well. All of the controls mentioned above (including remote monitoring, automatic temperature tracking, as well as alarms of walk-in refrigerators and freezers) shall be integrated to the existing Building Automation

EEM 2 – Lighting Upgrade

- Replace Metal Halide and fluorescent lights in the building with new LED bulbs, including all 2x4 surface troffers and high/low bay lights. Rooms to be included in the lighting upgrade shall be the autopsy rooms, biosafety labs, 3rd floor labs, and office areas.
- New LED bulbs shall have a minimum efficacy of 110 lumens per watt.
- Ensure each new light fixture in the autopsy rooms provide a minimum light intensity of 800 foot-candles for a table height of 34 inches.

Several rooms shall have the existing Metal Halide or fluorescent lighting replaced with LED bulbs. These light fixtures include 2x4 surface troffers as well as high bay lights. This particular EEM shall consider lighting upgrades and energy consumption savings for four different areas, which are the autopsy rooms, biosafety labs, 3rd floor labs, and office spaces. In particular, the autopsy rooms have a high quantity of Metal Halide lights, which emit high amounts of heat. This causes the existing air handlers to provide a lower supply air temperature (50 degrees) in order to maintain the 65-to-68-degree room temperature required during the operation of autopsies, which occurs 12 hours per day. Furthermore, since these air handlers also serve the other spaces on the second and third floors, there are overcooling issues with many of these spaces. Replacing the Metal Halide lights with LED's will mitigate these issues as well as increase the efficacy of the light fixtures. As stated by the facility manager, the high bay light fixtures in the autopsy rooms were originally designed for a light intensity of 800 foot-candles each at a table height of 34 inches. Over the course of three years, the facility manager has also stated that the light intensity of these high bay light fixtures has degraded to only 450 foot-candles each. Therefore, all new high bay light fixtures shall each provide a light intensity of 800 foot-candles at a table height of 34 inches as originally designed. Also, the minimum efficacy for all new light fixtures shall be 110 lumens per watt, which is a standard efficacy value for LED light bulbs. This efficacy number is consistent with typical 4-foot linear tubes [12]. Furthermore, the replacement lights shall be DLC or Energy Star certified as well as comply with the Maryland Green Purchasing Committee Approved Specification [13].

Additional Building Observations and Recommendation

Disinfecting Lights

All autopsy rooms and biosafety labs shall have the existing Metal Halide and fluorescent lighting replaced with disinfecting LED lights provided by Vital Vio or similar according to the manufacturers' recommendations with all necessary lighting controls related to the operation of disinfection, including an enhanced cleaning mode that allows the lights to emit a higher dosage of antimicrobial light wavelengths when the space is not occupied. UV lights can be harmful to the human eyes and skin, and Vital Vio provides disinfecting lights with light wavelengths between 400 to 420 nm. This is in the light wavelength range for visible light, which does not cause any harm to humans while disinfecting [16].

UV-C Germicidal Lamps

UV-C germicidal lamps shall also be provided for the existing air handling units on the 4th and 5th floors so that the return air can be disinfected before recirculating back into the spaces served by the respective unit. There are several methods for installing UV-C germicidal lamps, and the most popular ones include in-duct and coil-level UV-C systems. Currently, the common practice for an in-duct UV-C system is to provide an average irradiance in the order of 1,000 to 10,000 $\mu W/cm^2$, and the system should be installed in a location that can provide a minimum of 0.25 second of UV exposure. In the case of a coil-level UV-C system, the common practice is for coil surface irradiance levels to be between 50 to 100 $\mu W/cm^2$ [17].

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 the comfort levels. Indoor living wall solutions provided by LiveWall could be considered for the lobby space [18].

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

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 the table below (Table 4). 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 4: Energy and Cost Savings Summary

Energy Efficiency Measures (EEM)	EEM Simulated		Projected Energy Savings		Projected Energy Savings Percentage		Utility Savings*		
	Electricity (MWh/yr)	Natural Gas (therm/yr)	Electricity (MWh/yr)	Natural Gas (therm/yr)	Electricity (%)	Natural Gas (%)	Electricity ($/yr)	Natural Gas ($/yr)	Total ($/yr)
EEM 1 - HVAC Upgrades	3643	92512	20	-500	0.5%	-0.5%	2000	-500	1500
EEM 2a - Lighting Upgrades (Autopsy Rooms)	3541	93482	122	-1470	3.3%	-1.6%	12200	-1470	10730
EEM 2b - Lighting Upgrades (Biosafety Labs)	3627	92622	36	-610	1.0%	-0.7%	3600	-610	2990
EEM 2c - Lighting Upgrades (3rd Floor Labs)	3625	93782	38	-1770	1.0%	-1.9%	3800	-1770	2030
EEM 2d - Lighting Upgrades (Office Spaces)	3606	93632	57	-1620	1.6%	-1.8%	5700	-1620	4080
Combined EEM’s	3392	93032	271	-1020	7.4%	-1.1%	27100	-1020	26080

***** 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 3,663 MWh and 92,012 therms, respectively. The total annual utility cost of electricity (3,663 MWh) and natural gas (92,012 therms) is \$458,312. The observed annual utility savings after implementing the EEMs can reduce the annual utility cost by \$26,080.

Table 5: Carbon Footprint Analysis

Energy Efficiency Measures (EEM)	**Projected Energy Savings**		**Carbon dioxide Reduction**	
	Electricity (MWh/yr)	**Natural Gas (therm/yr)**	**Electricity (lbs/year)**	**Natural Gas (lbs/year)**
EEM 1 - HVAC Upgrades	20	-500	14660	-5801
EEM 2a - Lighting Upgrades (Autopsy Rooms)	122	-1470	89426	-17056
EEM 2b - Lighting Upgrades (Biosafety Labs)	36	-610	26388	-7078
EEM 2c - Lighting Upgrades (3rd Floor Labs)	38	-1770	27854	-20537
EEM 2d - Lighting Upgrades (Office Spaces)	57	-1620	41781	-18796
Combined EEM’s	271	-1020	198643	-11835

The above carbon footprint analysis shown in Table 5 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 [14] and 11.6 lb of emissions per every therm of Natural Gas [15]. Implementation of the EEMs would result in a reduction of 186,808 lbs of carbon dioxide emissions per year.

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. 12 for more detail.

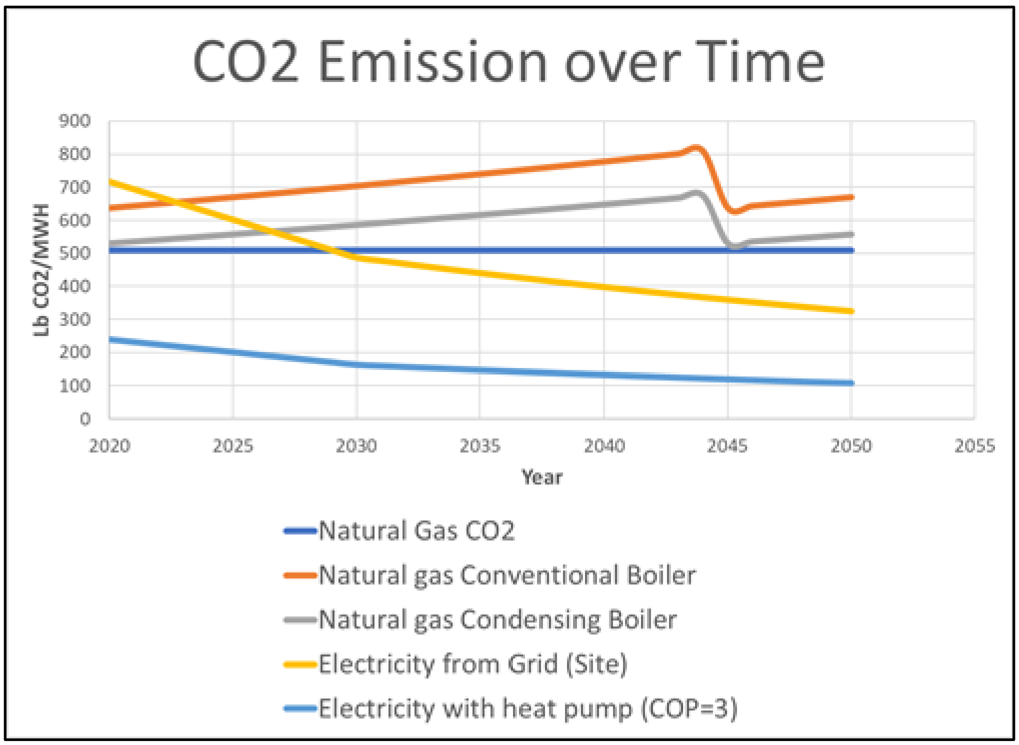


Fig. 12: CO_2 emission over time

II. Building HVAC Description

The chilled water is supplied by two air-cooled screw compressor chillers (McQuay AGS400DS) with a capacity of 390 tons each as well as a dry cooler (Liebert) with a capacity of 40 tons. The chillers are controlled by the Building Automation System (BAS). Two identical chilled water pumps with variable frequency drives work together simultaneously to supply the chilled water throughout the facility. There is also one identical stand-by pump for backup purposes. The pumps are rated at 40 HP each. The chillers supply the chilled water to five air handling units (AHUs) that serve the building. Fig. 2 shows the chiller model installed in the penthouse. The chillers were installed in 2010 when the building was originally constructed.

Fig. 2: Chiller Unit

The hot water is supplied by two gas-fired boilers (Cleaver Brooks CBLE) each with a capacity of 8,369 MBH. These two boilers work in lead-lag operation and are controlled by the Building Automation System as well. Two identical hot water pumps with variable frequency drives work together simultaneously to supply the hot water to the AHUs in the penthouse, and there is also an identical stand-by pump for backup purposes.

A separate reheat pump with a variable frequency drive works to supply the hot water to the variable-air-volume (VAV) reheat coils and FCU heating coils in the building. There is also an identical stand-by reheat pump for backup purposes. Fig. 3 shows the boiler unit installed in the penthouse. The boilers were installed in 2010 when the building was originally constructed.

Fig. 3: Boiler Unit

There are five AHUs in the building serving most of the building needs with supplementary unit heaters installed throughout the facility. All five AHUs are located in the penthouse, and they all serve different floors of the building. AHU-1,2,3 work together simultaneously to serve the 1st, 2nd, and 3rd floors. AHU-4 serves the 4th floor, and AHU-5 serves the 5th floor. Each AHU is equipped with a chilled water cooling coil and a hot water heating coil. These coils are served by the chillers and boilers of the building as previously mentioned. The AHUs also include premium efficiency supply fan motors with variable frequency drives. Supply air from these AHUs are delivered to each space via the corresponding VAV terminals units. AHU-1,2,3 have dedicated return air fans and are also equipped with variable frequency drives. There are also several split systems serving the walk-in coolers on the second and third floors. Some of the fans in the evaporators and condensers for these split systems have PSC motors while the others have EC motors.

A summary of the design specifications of the existing building HVAC system retrieved from the building's mechanical drawings is shown in Table 1.

Table 1A: AHU design specifications summary

AIR HANDLING UNIT SCHEDULE

SYMBOL	LOCATION	SERVICE	SUPPLY FAN DATA							
			SUPPLY AIR CFM	MIN. OA CFM	EXT. SP IN.WG.	FAN TYPE	DIA IN.	FAN MOTOR BHP	FAN MOTOR HP	MAX RPM
AHU–1,2,3	PENTHOUSE	LAB AND AUTOPSY	35,000	35,000	4.25	AF	33	48.45	60.00	1600
AHU–4,5	PENTHOUSE	LEVEL 4,5	18000	4,500	3.00	AF	27	16.35	20.00	1950

COOLING COIL DATA														
	AIR								WATER					
QTY	TOTAL MBH	SENS MBH	EAT DB	EAT WB	LAT DB	LAT WB	MAX FV FPM	PD IN WG	GPM	EWT (DF)	LWT (DF)	PD IN WG	ROWS/ FPI
2	3002	1581	90.0	75.0	47.6	47.4	500	1.5	537.3	42.0	54.1		12 / 11
2	559	444	75.7	63.0	53.1	52.3	500	0.6	99.0	42.0	54.3	11.6	5 / 11

HW HEATING COIL DATA										UNIT WEIGHT LBS	BASIS OF DESIGN
AIR					WATER						
TOTAL MBH	EAT DB	LAT DB	MAX FV FPM	PD IN WG	GPM	EWT (DF)	LWT (DF)	PD FT	ROWS/ FPI		
1832	0.00	52.30	500	0.1	122.0	180.0	148.6	21.1	1 / 11	13940	MCQUAY CAH080GDAC
498	50.00	75.30	500	0.1	35.2	180.0	149.6	6.5	1 / 11	10063	MCQUAY CAH040GDAC

RETURN AIR CFM	EXT. SP IN.WG.	TOTAL SP IN.WG.	FAN MOTOR BHP	FAN MOTOR HP	MAX RPM
18000	1.50	0.56	6.50	7.5	1750

Table 1B: Chiller design specifications summary

CHILLER SCHEDULE (AIR COOLED)

UNIT NO.	SERVICE	LOCATION	CAPACITY TONS	COMPRESSOR DATA				
				MAX. INPUT KW	ELECTRICAL DATA V	PH	HZ	CAPACITY REDUCTION %
CH–I, CH–2	AHU'S	PENTHOUSE	390	486	460	3	60	NOTE 6

EVAPORATOR DATA						CONDENSER DATA					VIBRATION ISOLATION DATA			OPERATING WEIGHT (LBS)	REMARKS
EWT (F)	LWT (F)	GPM	No. OF PASS	MAX. PD (FT.)	FOULING FACTOR	AMBIENT	FAN MOTOR QTY/HP				FOULING FACTOR	MOUNTING TYPE	DEFLECTION (IN.)		
54.0	42.0	810	2	37.0	0.00025	95.0	24/4.1				0.0005	TL SPRING	1.5	22485	

Table 1C: Boiler design specifications summary

BOILER SCHEDULE										
			BOILER PERFORMANCE DATA					OIL BURNER DATA		
UNIT NO	SERVICE	LOCATION	NET CAPACITY (MBH)	GPM	EWT (F)	LWT (F)	DESIGN PRESS (PSI)	INPUT GPH	OIL PUMP MOTOR HP	INPUT MBH
B-1,2	HEATING HOT WATER	PENTHOUSE	8,369	600	150	180	150	72.9	1/2	10,206

GAS BURNER DATA				FLUE SIZE (IN.)	BOILER HP	OPERATING WEIGHT (LBS.)	REMARKS
MIN. PRESS. (PSIG.)	PRESS DROP	GAS TRAIN SIZE (IN.)	BLOWER MOTOR HP				
2.4	BY MFG	2	10	20	250	36,000	CLEAVER BROOKS CB LE PROMOMETHEAN

Table 1D: Pump design specifications summary

PUMP SCHEDULE															
			PERFORMANCE DATA					MOTOR DATA			VIBRATION ISOLATION DATA				
UNIT NO	SERVICE	LOCATION	GPM	TDH (FT.)	RPM	SUCT SIZE (IN.)	DISCH SIZE (IN.)	HP	V	PH	MTG. TYPE	DEFLECT (IN.)	BASE TYPE	NOTES	REMARKS BASIS OF SELECTION
CHWP-1	CHILLED WATER	PENTHOUSE	800	125	1750	6	6	40	460	3	SPRING - 1IN	1	INERTIA	1	B&G VSC 6X6X12L
CHWP-2	CHILLED WATER	PENTHOUSE	800	125	1750	6	6	40	460	3	SPRING - 1IN	1	INERTIA	1	B&G VSC 6X6X12L
CHWP-3	CHILLED WATER	PENTHOUSE	800	125	1750	6	6	40	460	3	SPRING - 1IN	1	INERTIA	1	B&G VSC 6X6X12L
HWP-1	HEATING HOT WATER	PENTHOUSE	400	100	1750	4	5	15	460	3	SPRING - 1IN	0.75	INERTIA	1	B&G SERIES 1510-4E
HWP-2	HEATING HOT WATER	PENTHOUSE	400	100	1750	4	5	15	460	3	SPRING - 1IN	0.75	INERTIA	1	B&G SERIES 1510-4E
HWP-3	HEATING HOT WATER	PENTHOUSE	400	100	1750	4	5	15	460	3	SPRING - 1IN	0.75	INERTIA	1	B&G SERIES 1510-4E
RHP-1	REHEAT WATER	PENTHOUSE	200	100	1750	2	3	7.50	460	3	-	0.75	INERTIA	1	B&G SERIES 1531-2E
~~RHP-2~~	~~REHEAT WATER~~	~~PENTHOUSE~~	~~200~~	~~100~~	~~1750~~	~~2~~	~~3~~	~~7.50~~	~~460~~	~~3~~		~~0.75~~	~~INERTIA~~	~~1~~	~~B&G SERIES 1531-2E~~
FPP-1,2,	AHU-4,5	PENTHOUSE	30	60	1750	-	-	3/4	120	1	-	-	-	-	
FOS 1,2	FUEL OIL SUPPLY	LEVEL 1	5	150	1750	1 1/2	1	1/2	120	1	NEOPRENE PAD	-	-	2	SEE SECTION 15192

~~NOTES: 1. MOTORS COMPATIBLE WITH VFD BY DIV 16~~
2. LEAD/LAG ALTERNATOR

Table 1E: Walk-in cooler split system design specification summary

LARKIN DISCUSS, SCROLL AND HERMETIC CONDENSING UNITS (CAPACITY BTU/HR @ 95°F AMBIENT AIR SUCTION TEMPERATURE)

DESCRIPTION	QTY.	MFG.	MODEL NO.	TEMP.	SUCT. TEMP.	BTUH/HR @ 100°F	CONNECTIONS (ID)		RECEIVER 90% FULL Lbs.	FAN(S)	DIMENSIONS (In.)			NET WT. Lbs.	SOUND DATA dba	POWER SUPPLY			COMPRESSOR		FAN MOTOR			AIR DEFROST		ELEC. DEFROST		DEF. HTR. AMPS	EVAP. FAN AMPS	RECOMM. REFRIGERANT
							LIQUID	SUCTION			L	H	D			Volts	H.P.	Hz	RLA	LRA	QTY.	HP	FLA	MCA	MOPD	MCA	MOPD			
ROOM 209, 211, 238	2 EA.	LARKIN	LDT0751H2D	35°F	25°F	71,930(2)	5/8"	1-3/8"	78	-	36.75	39.25	63.75	985	82	460	3	60	12.6	85	2	1/3	3.8	19.6	30	29.6	40	25	10	R-22
ROOM 236	2	LARKIN	LDT0900L6D	0°F	-10°F	59,280(2)	5/8"	1-3/8"	67	-	36.75	39.25	63.75	1030	82	460	3	60	15	106	2	1/3	3.8	22.6	35	35.6	50	35	13	R-404A
ROOM 337	2	HEATCRAFT	MOS040L64C	0°F	-10°F	21160(2)	1/2"	1-1/8"	20	1	30.25	42.5	29.75	457	70	460	3	60	7.6	41.0	1	1/3	1.9	-	-	24	25	19	9	R-404A
ROOM 338	2	HEATCRAFT	MOS015H24C	35°F	25F	11740(2)	3/8"	7/8"	10	2	28.25	37.75	17.25	221	69	460	3	60	2.2	18.2	2	1/15	1	15	15	-	-	-	-	R-22

LARKIN AIR & ELECTRIC DEFROST MODELS 60 Hz WITH PSC AND EC MOTORS

DESCRIPTION	QTY.	MFG.	MODEL NO.	BTUH/WATTS 10°F TD	FAN		PSC MOTOR	EC MOTOR	DEFROST HEATERS		CONNECTIONS (Inches)				NET WT. Lbs.	DIMENSIONS (In.)		
					CFM	NO.	460v/1	115v/1 - 230v/1	WATTS	460v/1	INLET OD	SUCTION ID	EXT. EQUA.	DRAIN		D	W	H
ROOM 209, 211, 238	4 EA	LARKIN	MMT6-365	36,500(4)	6,900	3	- -	#209, 211: 8.4 (115/1) #238: 4.2 (230/1)	-	-	7/8	1 3/8	1/4 OD	3/4 MPT	200	97.32"	22"	24"
ROOM 236	4	LARKIN	MLT6-260	26,000(4)	4,500	2	2.0	-	5,350	11.6	7/8	1 3/8	1/4 OD	3/4 MPT	153	69.32"	22"	24"
ROOM 337	2	LARKIN	LCE6-200	20,000(2)	3,250	5	2.0	-	4,500	9.8	1/2	1 1/8	1/4 OD	3/4 MPT	101	93.5"	15"	16"
ROOM 338	2	LARKIN	LCA6-135	13,500(2)	2,100	3	-	2.9 (115/1)	-	-	1/2	7/8	1/4 OD	3/4 MPT	67	61.5"	15"	16"

In addition, there are multiple hot water unit heaters installed in the facility to provide supplemental heating. The building's HVAC system schedule is consistent with the building schedule in that it also operates 24 hours each day throughout the entire year. Room setpoint temperatures are around 65°F and 70°F during winter and summer season respectively, and the autopsy rooms are maintained between 65°F to 68°F. AHU-1,2,3 use 100% outside air, while AHU-4,5 use 25% outside air.

III. 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. This can be further divided into 4 categories: 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 labs. 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.

In the final step of building comprehension, access to any Building Automation System (BAS) is sought out and analyzed. In the case of the Office of the Chief Medical Examiner, the facility has a working BAS system, which provided by Siemens when the building was first constructed.

Energy Model Development

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 Trane Trace 3D Plus was used. The software is qualified for commercial building tax deductions and has been widely used in comprehensive building energy analysis for nearly 50 years. It is well regarded for its simple user interface as well as its ability to create working whole-building energy models.

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. 4 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.

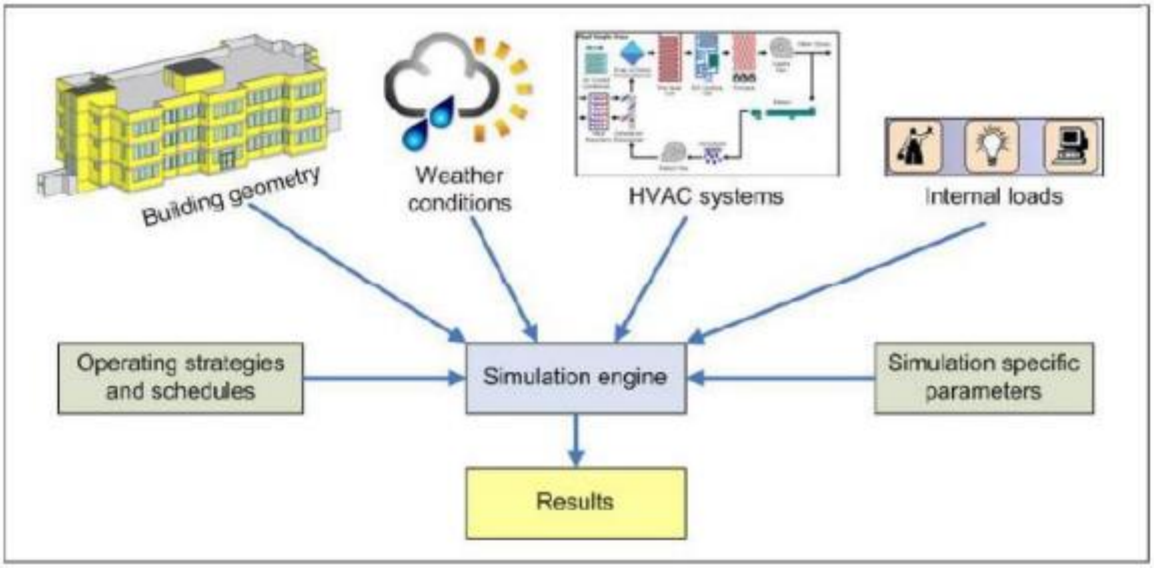


Fig. 4: General data flow of building energy simulation software. [2]

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 [3]. ASHRAE also provides registrants with function-specific Advanced Energy Design Guides for achieving additional energy savings up to 50% [4]. 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 and evaluate whether the existing building HVAC system is undersized or oversized based on the calculated total cooling load. The capacity of the existing chillers is 390 tons each, and the total capacity of all of the existing split systems serving the walk-in coolers is 51 tons. Therefore, the total cooling capacity of the existing building HVAC system is 831 tons. The Trane Trace 3D Plus energy model calculated the site peak cooling load to be 830 tons, which is consistent with the total cooling capacity of the existing building HVAC system. Therefore, it was determined that the existing chillers and split systems are sized for the building fairly accurately.

As for the boilers, the calculated site peak heating load from the energy model was 5,579 MBH and the capacity of the current boilers are 8,369 MBH each. The boilers seem to be oversized by about 200% compared to the heating needs of the building in the model, and one potential reason may be due to the fact that the model underestimates the gas consumption for the month of January as shown in Fig. 11. The heating load calculation is most likely based on this month, which may explain the reason for the discrepancy.

A point of note to consider is that these boilers work in lead-lag operation. In other words, only one boiler is operating at a time when the heating load is less than the heating capacity of a single boiler, which is the most common case for a given day as the total heating load calculated from the energy model accounts for the peak load in a given year. In addition, the boilers may be oversized to accommodate for redundancies, higher demand due to unexpected extreme weather conditions, as well as many other factors. Usually having some degree of redundancy is recommended. For example, it is recommended that data centers and hospitals have a redundancy of N+1 or 2N due to the essential services being carried out at these sites.

Utility Analysis and Benchmarking

Utility data from 2016-2021 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 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 [5].

Table 2: Utility Analysis and EUI Summary Calculation

	Electricity		**Natural Gas**		**Water**	**Total Site Energy**	**EUI**
	MWh/yr	kBTU/yr	therms/yr	kBtu/yr	Gal/yr	kBtu/yr	kBtu/SF/Yr
Baseline Energy Usage	3,219	10,991,037	82,612	8,259,226	2,051,016	19,250,263	173.67

Fig. 5 and Fig. 6 show the average monthly electricity and natural gas consumption for the years of 2016 to 2021 as well as provide a number of key insights.

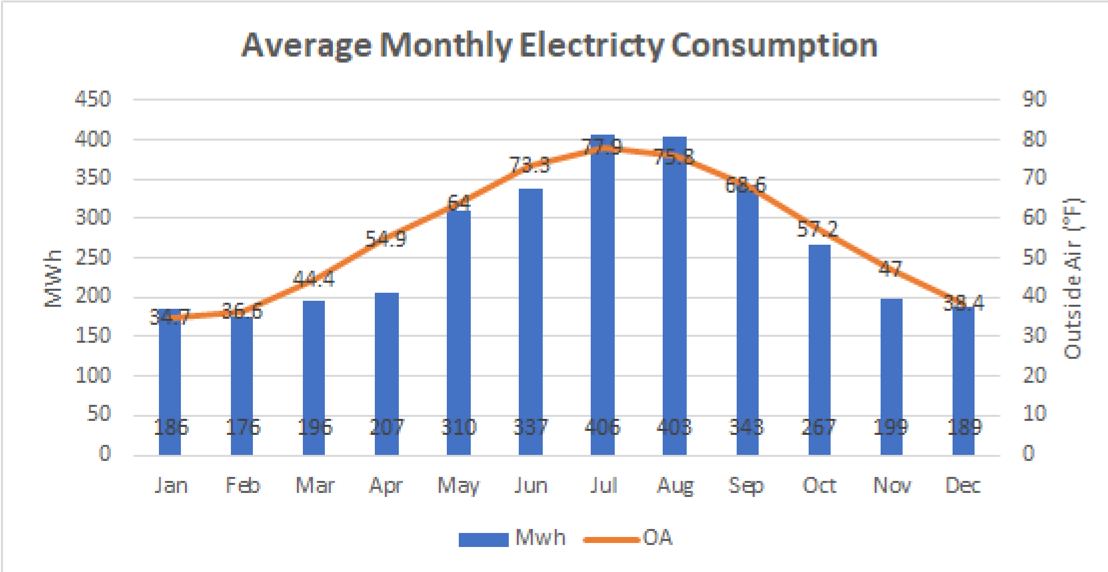


Fig. 5: Average Monthly Electricity Consumption [6]

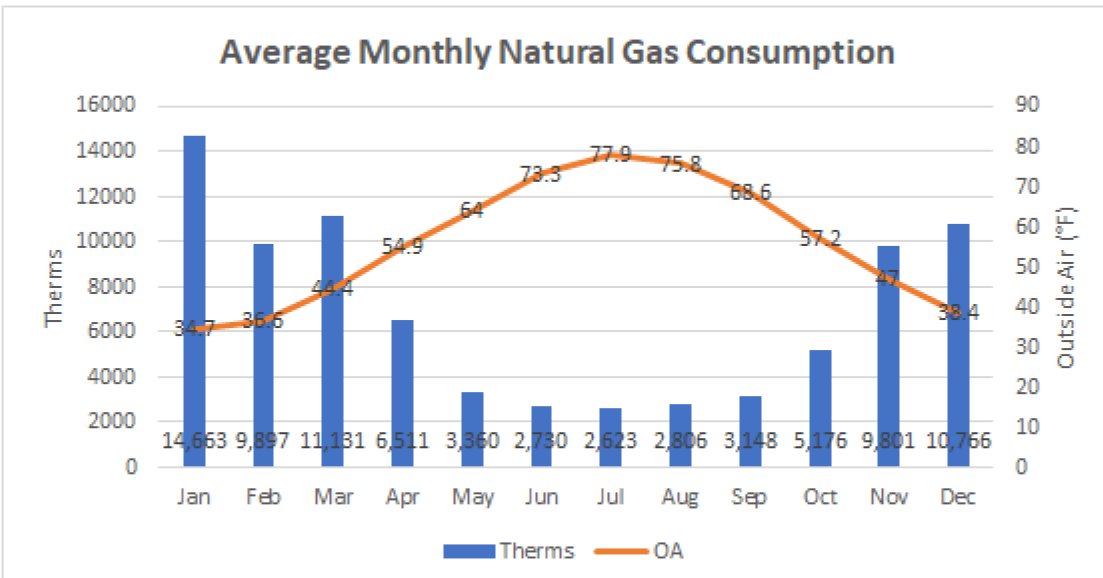


Fig. 6: Average Monthly Natural Gas Consumption [6]

Electricity consumption increases during the summer months due to the space cooling requirements. The use of electric unit heaters results in a slight increase in electricity consumption during the winter months. Natural gas consumption is highest during the winter months to provide the required space conditioning. The natural gas consumption in the summer is due to the reheat operation required to provide adequate dehumidification and occupant comfort.

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 [7].

The Commercial Buildings Energy Consumption Survey (CBECS) database data was also used to evaluate the energy profile of the facility [8]. 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, natural gas, and water utility bills. They were further supplemented with the facility data such as floor area, building use, and occupancy. Table 3 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 a healthcare facility [9].

Table 3: Benchmarking Results Summary

Parameter	OCME Value	Standard Value	Reference
Energy Star Score (1-100)	50	-	EnergyStar Portfolio Manager
Site EUI (kBtu/sf)	173.6	206.7	EnergyStar Portfolio Manager
CBECS ($/sf)	3.6	4	(Electricity + Natural Gas)/Bldg sq.ft area

The overall Energy Star score of 50 indicates that the building is already performing above median energy performance. The value of 173.6 was obtained using EnergyStar Portfolio Manager, and the utility analysis yielded a similar value of 173.67. Based on the benchmarking analysis, the Office of the Chief Medical Examiner building currently has an energy usage intensity value that is less than the average for healthcare facilities (173.6 vs 206.7). The CBECS score is also less than the average value for commercial offices (3.6 vs 4). This means that, when compared to other reference healthcare facilities, the Office of the Chief Medical Examiner building is performing well and there may be fewer opportunities to increase the overall energy efficiency of the facility.

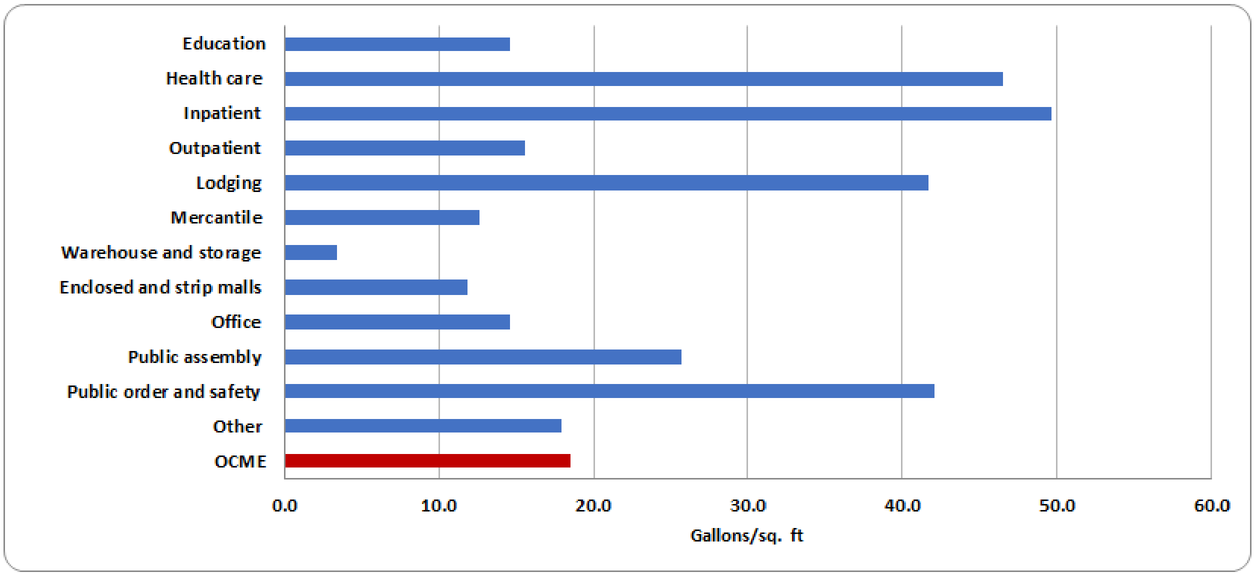


Fig. 7 Water Intensity (Gallons per sq. ft) [10]

Fig. 7 shows the water consumption data from the Commercial Buildings Energy Consumption Survey. The facilities included in the figure consists of commercial buildings greater than 200,000 sq. ft. When compared to these facilities, the Office of the Chief Medical Examiner has a total floor area of 110,842 square feet and has a water intensity value of 18.5 gallons per square foot.

Energy Modeling

Baseline Energy Model

The physical structure of the Office of the Chief Medical Examiner 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 5 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. 8 shows the 3-D representation of the building model as rendered in Trane Trace 3D Plus.

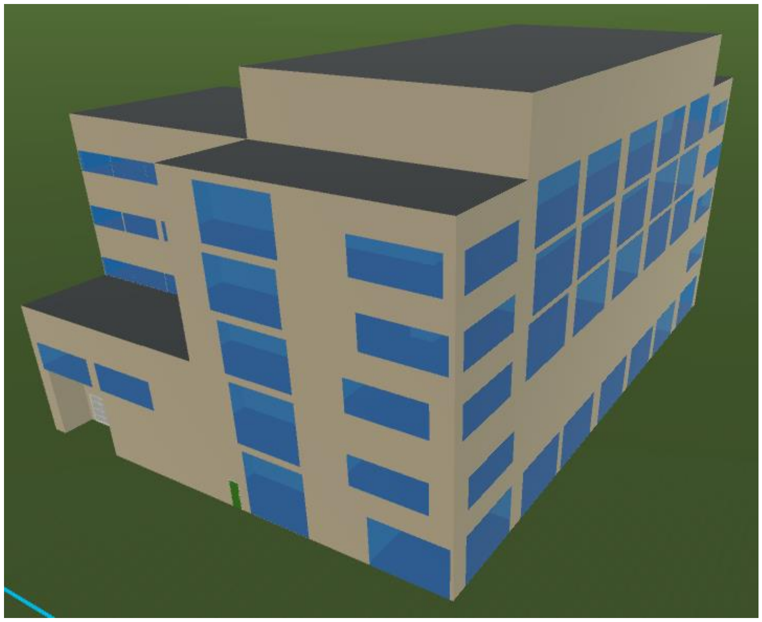


Fig. 8 Building energy model rendered in Trane Trace 3D Plus (south and west façade view)

The energy model had a total of 6 thermal zones. Each thermal zone represented the space served by an AHU or another HVAC system on a given floor. Fig. 9 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.

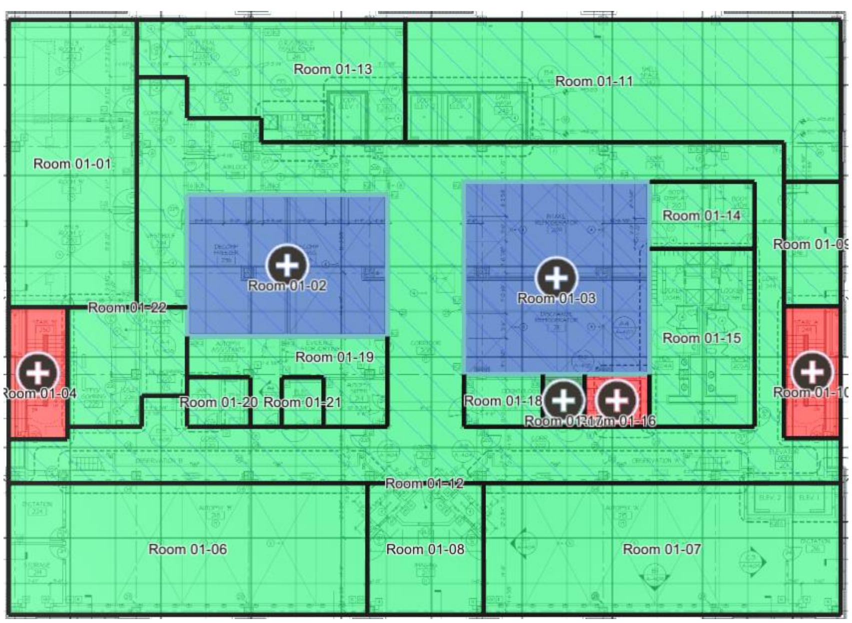


Fig. 9 Model thermal zone design (2nd floor).

The main space types defined to specify the lighting, plug loads, occupancy, and their associated schedules were offices, operating rooms, lobbies, storage rooms, IT rooms, 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. 10 and Fig. 11 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.

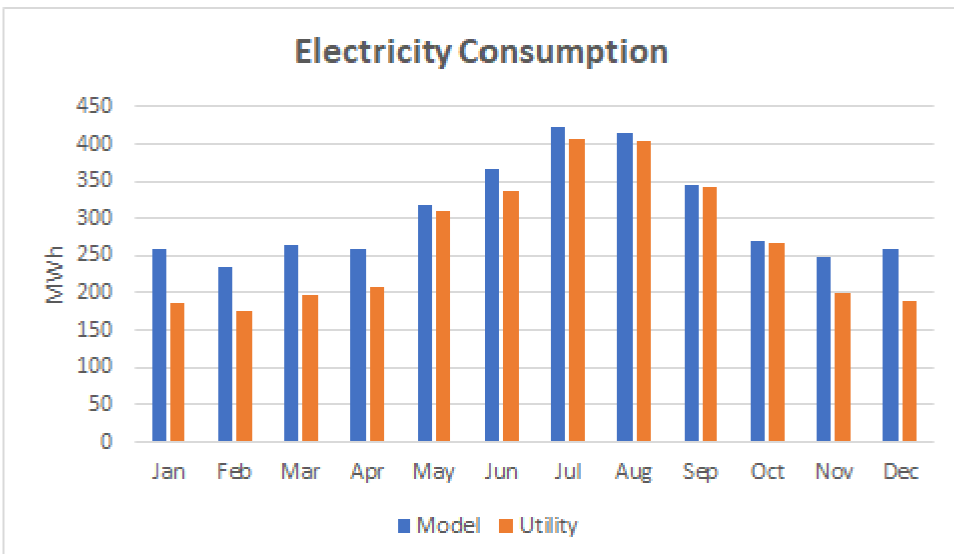


Fig. 10: Monthly electricity consumption comparison.

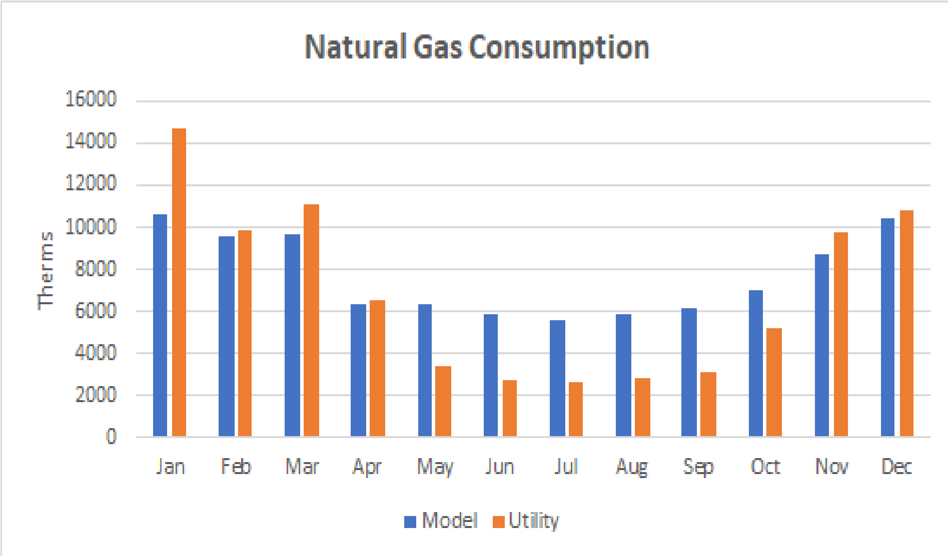


Fig. 11: Monthly natural gas consumption comparison.

The predicted monthly energy consumption of the baseline energy model closely matched the average monthly energy reported by utility bills between 2016 and 2021. In the case of electricity consumption, the values deviate by ~13.8% while the natural gas consumption values deviate by ~11.4%. The reason for the deviation in the electricity and natural gas consumption may be due to the discrepancy in the occupancy and scheduling of the building. This meets the ASHRAE calibration requirements as given by Guideline 14-2002 which allows a deviation of up to 15% [11].

IV. Future Scope

Building Decarbonization / Electrification Analysis

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 [19]. 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.

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.

Substantially 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 [20].

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 fuel oil, can greatly reduce a building's emissions. Based on DGS data on carbon emissions (Fig. 12, 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. 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, 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. 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 further deployment of smart metering.

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.

Currently, the domestic hot water is supplied by a gas-fired water heater. A solar water heater can be installed on the roof to provide domestic hot water for the building thus helping to eliminate the need for natural gas altogether.

Solar PV panels can be installed at the site to provide supplemental electricity to the building. The solar system would need to be provided with a battery 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 [21]. For example, at the Office of the Chief Medical Examiner, a 10kW system can generate about 14,261 kWh/year of electricity. This system can be sized appropriately based on the available space at the site, preferably the roof. But since the available roof space at the healthcare facility is limited, further space can be explored near the site such as parking spaces or other open spaces. Further opportunities include purchasing electricity from Renewable utilities wherein the source 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) [22], also called alternative energy credits in Maryland. 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.

V. Conclusions

The Office of the Chief Medical Examiner building is an interesting facility due to it being a relatively newer construction and operating better than the average levels of a typical hospital. The facility would benefit from a HVAC system upgrade on account of the high cooling and heating needs of the building as well as due to the fact the building is operating on a 24-hour schedule. Energy Efficient Measures were identified to transition the building system to newer technologies (such as LED lighting) and make the building energy efficient as a whole. The expected energy savings resulting from the implementation of energy efficiency measures will decrease the building's annual electricity consumption by 7.8% and natural gas consumption increase by 0.7%. These savings may not look substantial because most of the energy for this building is consumed by the HVAC system, and the EEM's that were proposed are mostly related to lighting upgrades. This is especially the case for AHU-1,2,3 because these units are operating with 100% outside air, which require a high amount of energy to condition. According to the model, HVAC accounts for 41.2% of the total building energy consumption, while lighting only accounts for 20.8%. Also, this building was recently built and is considered a state-of-the-art building. As shown in Table 3, the EUI for the building is already below the average for healthcare facilities, which may explain the relatively lower potential for energy savings.

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 healthcare facilities. This model can be further fine-tuned based on future developments to account for changes in the energy profile of the facility.

Initial Scope of Work

	Current System	**Proposed System**	**Comments**
Walk-In Cooler Split Systems	PSC Fan Motors	EC Motors	Up to 25% increase in system efficiency
Lighting in Autopsy Rooms	Fluorescent and Metal Halide	LEDs	LED along with occupancy, daylight and microphonics sensors
Lighting in Biosafety Labs	Fluorescent	LEDs	LED along with occupancy, daylight and microphonics sensors
Lighting in 3rd Floor Labs	Fluorescent	LEDs	LED along with occupancy, daylight and microphonics sensors
Lighting in Offices	Fluorescent	LEDs	LED along with occupancy, daylight and microphonics sensors
Green Wall	No Green Wall	Install Green Wall	

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