Hagerstown District Court Building

36 West Antietam Street

Hagerstown, MD 21740

Energy Audit Report

Prepared for:

Maryland Department of General Services (DGS)

Prepared by:

UMD Smart and Small Thermal Systems (S2TS)

March 4, 2021

Project Team

The UMD Smart and Small Thermal Systems team conducted this audit on behalf of the Maryland Department of General Services (DGS), in accordance with Governor Hogan's Executive Order 01.01.2019.08 Energy Savings Goals for State Government. The UMD S2TS team consisted of energy auditors Katherine Schwartz and Soumya Agrawal who were supervised by Dr. Amir Shooshtari & Dr. Michael Ohadi.

Acknowledgment

The UMD S2TS team would like to acknowledge Mr. James Stayer at Hagerstown District Court and Facilities Management staff for their help and cooperation during the walkthroughs and for answering our questions. We would also like to thank Mr. Tony Myers for his help in coordinating the walkthroughs and assisting with useful information.

Executive Summary

This energy audit supports Governor Hogan's Executive Order 01.01.2019.08 - Energy Savings Goals for State Government. 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, and summarized their findings in this report. This report identifies actionable energy-saving opportunities to increase the building's energy efficiency.

Major findings:

- The system for the entire building operates 24/7 in order to maintain temperature for Data room and security personnel
- The existing chillers are oversized by 77%
- The existing natural gas boilers are oversized by 395%

List of recommended energy efficiency measures (EEM):

<u>EEM 1</u> - Lighting Upgrades

- LED fixtures
- Lighting controls

<u>EEM 2</u> - Chiller Upgrade including,

- New air-cooled reciprocating chillers with variable speed compressors and compressor fans for efficient part-load operation
- A chiller plant control package

<u>EEM 3</u> - Boiler Upgrade including,

- New high efficiency, gas-fired condensing type boilers

<u>EEM 4</u> - Optimize Schedule and Setpoint Temperature

- Reduce the operating hours of HVAC system

See page 17 for more details on the list of ECMs.

List of Additional Building Observations and Recommendations

- Data room
- Outdoor unit insulation issue
- Green Wall

See page 20 for more details on the list of Additional Building Observations and Recommendations.

Savings associated with following all the recommendations:

- Annual utility cost reduction of 35% resulting in $12,953 energy savings out of a total 2020 energy spend of $32,621.
- Annual electricity consumption reduction of 33.8% resulting in $9,500 savings out of a total 2020 electricity spend of $25,703.
- Annual natural gas consumption reduction of 38.3% resulting in $3,453 savings out of a total 2020 natural gas spend of $11,630.

See page 18 for more details on cost savings calculations.

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 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 Hagerstown Court building is the District Court of Maryland for Washington County located at 36 West Antietam St, Maryland. The building was originally constructed in 2000 and it is a two-story building with an overall area of 27,500 sq. ft. Fig. 1 shows the overview of the Hagerstown District Court.

Fig. 1: Hagerstown District Court

Utility use and cost for calendar year 2020 was as follows:

Electricity	266,320 kWh	$20,991
Natural Gas	8,000 therms	$11,630
Water	114 Mgal	$3,976

The building houses primarily the office spaces, conference rooms, courtrooms, and judges' chambers. Level 1 houses the Commissioner's office, a holding area, and other office spaces. Level 2 houses courtrooms, judges' chamber and office spaces. The first floor houses mechanical systems such as the chillers, boilers, and Air Handling Unit (AHUs 1). Since the commission of the building, there have been no major renovation projects.

The facility exemplifies a typical courthouse in function and floor plan layout. The building occupancy schedule is from 7:30 AM to 5 PM on weekdays (Monday to Friday) and commissioner's area till 11 PM. The security personnel work 24 hours in the building. Based on discussions with the Facilities personnel, the building HVAC system operates 24 hours a day.

The building consumes energy from two energy commodities: electricity and natural gas. Both electricity and natural gas are metered and supplied by utility companies (Electricity: Hagerstown light Department; Natural Gas: Columbia Gas of Maryland).

Building HVAC Description

The chilled water is supplied by an air-cooled reciprocating chiller (*Carrier 30 GN-080*) with a capacity of 81.9 tons (288 kW). The chiller pumps that serve the chiller can operate with the chiller on or off, and they normally pump consistently. Two constant speed pumps (*Bell & Gossett Series 1510*) supply the chilled water throughout the facility. The pumps are rated at 5 HP each & supply 196 GPM (12.4 L/s). The supply temperature from the chillers to the AHU was 44F (6.7°C) and the return temperature was approximately 54F (12.2°C). Fig. 2 shows the chiller installed in the chiller yard at the rear of the building. The chiller is original to the building construction (2000).

Fig. 2: Chiller Unit

The hot water is supplied by two gas-fired boilers (*A.O. Smith LB-750*) each with a capacity of 675 MBH (198 kW). The combustion air to the boilers and the exhaust from the boilers is routed to the vent on the backside of the building. Two constant speed pumps (*Bell & Gossett series 80*) supply the hot water throughout the facility. The hot water is supplied to the AHU coils, VAV reheat coils, and cabinet unit heaters. Fig. 3 shows the boiler installed in the boiler room on the first floor. The boiler is original to the building construction (2000).

Fig. 3: Boiler Unit

There is one AHU in the building which serves most of the building needs. AHU 1 serves the majority of the first floor, and the entire second floor. These areas include the courtrooms, lobbies, judges' chambers, holding areas, and office spaces on both levels. The air handling unit is equipped with a hot water preheat coil, a chilled water-cooling coil, and supply fans that are controlled by variable speed drives. The air handling unit has a corresponding return air fan mounted in the ductwork; which is controlled by a variable speed drive.

According to the facility manager, the air flow is sometimes too much on the automatic setting, and he uses a manual override to adjust. Supply air is delivered to each space via variable air volume (VAV) terminal reheat units. Fig. 4 shows an AHU in the first-floor mechanical room.

Fig. 4: AHU in Mechanical Room

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

Table 1: HVAC design specifications summary

AIR HANDLING UNIT SCHEDULE

DESIG	DUTY	FAN SECTION: CFM	FAN SECTION: MIN. OA CFM	FAN SECTION: TSP INCH H_2O	FAN SECTION: ESP INCH H_2O	FAN SECTION: MOTOR BHP	FAN SECTION: MOTOR HP	FAN SECTION: RPM	FAN SECTION: WHEEL DIA INCH	COOLING SECTION: EAT °F DB	COOLING SECTION: EAT °F WB	COOLING SECTION: LAT °F DB	COOLING SECTION: LAT °F WB	COOLING SECTION: TOTAL MBH	COOLING SECTION: SENS MBH	COOLING SECTION: GPM @ 45°F EWT 55°F LWT	COOLING SECTION: MAX H_2O PD FT H_2O	COOLING SECTION: MIN TOTAL FACE AREA	COOLING SECTION: MAXIMUM FACE VEL FPM	COOLING SECTION: No OF COILS	COOLING SECTION: MAX FIN SPACING FIN/IN	COOLING SECTION: MAXIMUM AIR PD IN H_2O	COOLING SECTION: MIN ROWS
AHU-1	BUILDING AIR-CONDITIONING	25,000	6,750	5.25	2.20	28.0	40	1410	30	81.1	68.5	55.0	54.0	979	705	196	15	49.63	504	2	12	1.0	4

ΔP LISTED INCLUDES FINAL FILTER PRESSURE DROPS OF 0.5" FOR F-1 AND 1.0" FOR F-2 (1.5" TOTAL).

HEATING SECTION: EAT °F	HEATING SECTION: LAT °F	HEATING SECTION: MBH @180°F EWT	HEATING SECTION: GPM @20°F ΔT	HEATING SECTION: MAXIMUM H_2O PD FT H_2O	HEATING SECTION: MAXIMUM AIR PD IN H_2O	HEATING SECTION: MIN TOTAL FACE AREA	HEATING SECTION: MAXIMUM FACE VEL FPM	HEATING SECTION: No OF COILS	HEATING SECTION: MAX FIN SPACING FIN/IN	HEATING SECTION: MIN ROWS	ELECTRICAL VOLTS/PHASE/HERTZ	REMARKS	BASIS OF DESIGN
53.0	65.0	324	32.4	10	0.25	43.46	575	2	10	2	460/3/60	SEE FILTER SCHEDULE THIS SHEET	BUFFALO MODEL K240

BOILER DUTY

DESIGNATION :	B-1 AND B-2
FUEL :	NATURAL GAS
INPUT (BTUH) :	750,000
OUTPUT (BTUH):	675,000
EWT (°F) :	160
LWT (°F) :	180
FLOW (GPM) :	66
PRESSURE DROP (FT H_2O) :	10
VENT :	6
INLET DIA (IN) :	4

REMARKS : 90% EFF., CONDENSING TYPE, DIRECT/SEALED VENT

BASIS OF DESIGN : A.O. SMITH LB-750

SPLIT SYSTEM AC UNIT – DUTY

INDOOR UNIT DESIG:	FCU-1
OUTDOOR UNIT DESIG:	CU-1
INDOOR UNIT FAN SECTION:	
TOTAL AIR (CFM) :	700
OUTSIDE AIR (CFM) :	120
ESP (IN) :	0.50
MOTOR HP:	1/4
ELECTRICAL(V/PH/HZ):	120/1/60
INDOOR UNIT COOLING COIL(DX):	
EAT(°F DB):	78.5
EAT(°F WB):	65.2
TH (MBH):	21.0
SH (MBH):	17.0
SST (°F):	45
OUTDOOR UNIT:	
COMPRESSOR RLA:	10.7
COMPRESSOR LRA:	56.0
FAN MOTOR HP:	1/6
ELECTRICAL(V/PH/HZ):	208/1/60
SEER:	10
INDOOR UNIT MFR/MODEL NO.:	MAGIC AIR 24 BVX
OUTDOOR UNIT MFR/MODEL NO.:	CARRIER 38 CKC-024

REMARKS: FIELD INSTALLED FACTORY RECHARGED (R-22) RS AND RL PIPING IN ACCORDANCE W/ FACTORY PREPARED REFRIGERANT PIPING DRAWINGS. PROVIDE FACTORY INSTALLED ELECTRICAL DISCONNECT SWITCH FOR FCU-1. INTERLOCK AND CONTROL WIRING SHALL BE PROVIDED BY THIS CONTRACTOR. PROVIDE 1 SET OF SPACE FILTERS.

UNIT HEATER SCHEDULE

DESIG (UH)	NOMINAL CFM	CAP MBH @180°F EWT	GPM @20°F ΔT H_2O	MAXIMUM H_2O PD FT H_2O	MOTOR HP	RPM	ELECTRICAL VOLTS/PHASE/HERTZ	BASIS OF DESIGN
UH-1	950	47.0	5.3	5.0	1/20	900	120/1/60	VULCAN HV-72
UH-2	210	6.8	0.7	5.0	9 WATTS	1350	120/1/60	VULCAN HV-108A
UH-3	1600	78.4	8.8	5.0	1/20	900	120/1/60	VULCAN HV-120

CABINET UNIT HEATER SCHEDULE

DESIG (CUH)	NOMINAL CFM	CAP MBH @180°F EWT	GPM @20°F ΔT H_2O	MAXIMUM H_2O PD FT H_2O	MOTOR HP	RPM		ELECTRICAL VOLTS/PHASE/HERTZ	BASIS OF DESIGN
						HIGH	LOW		
CUH-1	230	24.0	2.0	5.0	1/15	1050	875	120/1/60	VULCAN F-1000-02
CUH-2	230	17.9	0.5	5.0	1/15	1050	875	120/1/60	VULCAN F-1000-02

PUMP SCHEDULE

DESIG	DUTY	TYPE	GPM	HEAD FEET H_2O	SUCTION X DISCHARGE	MOTOR		RPM	EFFICIENCY %	ELECTRICAL VOLTS/PHASE/HERTZ	BASIS OF DESIGN
						BHP	HP				
P-1	HEATING WATER	B	96	65	2-1/2"x2-1/2"	2.8	5	1750	58	480/3/60	BELL & GOSSETT SERIES 80
P-2	STAND-BY FOR P-1	B	96	65	2-1/2"x2-1/2"	2.8	5	1750	58	480/3/60	BELL & GOSSETT SERIES 80
P-3	CHILLED WATER	A	~~196~~	55	3"x2-1/2"	~~3.5~~	5	1750	~~73~~	480/3/60	BELL & GOSSETT SERIES 1510
P-4	STAND-BY FOR P-3	A	196	55	3"x2-1/2"	3.5	5	1750	73	480/3/60	BELL & GOSSETT SERIES 1510
CP-1	COIL CIRCULATING	B	32	10	1-1/4"x1-1/4"	–	1/4	1750	41	120/1/60	BELL & GOSSETT SERIES 60

AIR COOLED CHILLER DUTY	
DESIGNATION :	ACC-1
CAPACITY (TONS) :	81.9
MAX INPUT (KW) :	93.6
GPM :	196.3
EWT (°F) :	54
LWT (°F) :	44
MAX EVAP ΔP (FT)	15
REFRIGERANT :	R-22
AMBIENT TEMPERATURE (°F) :	95
FOULING FACTOR :	.00025
COMPRESSORS :	
NUMBER	1 @ 46.8 RLA/253 LRA 1 @ 34.6 RLA/173 LRA 1 @ 65.4 RLA/345 LRA
TYPE	RECIPROCATING
UNLOADING	-
CONDENSER :	
COIL FACE AREA (SF) :	128.3
NO. COIL ROWS	3
CONDENSER FANS :	
NUMBER	6 @ 1 HP
DIAMETER	30"
RPM	1140
TOTAL AIR FLOW	51,000
ELECTRICAL :	460 V/3ø/60HZ
REMARKS :	
BASIS OF DESIGN : CARRIER 30 GN-080	

There are multiple hot water unit heaters installed in the facility to provide supplemental heating. The commissioner's area is a unique space where it is the only area in the building that is intended to operate till 11 PM. The area is therefore served by a split system AC unit (Carrier 38CKC-024) with a capacity of 2 tons. The HVAC system works 24 hours at a single setpoint temperature 65 F for the majority of the building. Manual adjustments are made based on tenant feedback, and some individual spaces are kept at 70-75 F. During the unoccupied hours, the building is still occupied by the security personnel.

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 and electrical rooms, offices, courtrooms, and basement units. 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, and occupant behavior.

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

In the final step of building comprehension, access to any Building Automation System (BAS) is sought out and analyzed. In the case of Hagerstown MSC, the facility has a working BAS system (installed in 2010).

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 free building simulation software eQuest-3.65 was used. eQuest utilizes the DOE-2.3 simulation environment developed and provided by the Department of Energy and the Lawerence Berkeley National Laboratory. The software is qualified for commercial building tax deductions and has been widely used in comprehensive building energy analysis for over 20 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, and once the archival review had begun. Fig. 1 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 input in the simulation engine which then simulates the energy consumption in the building.

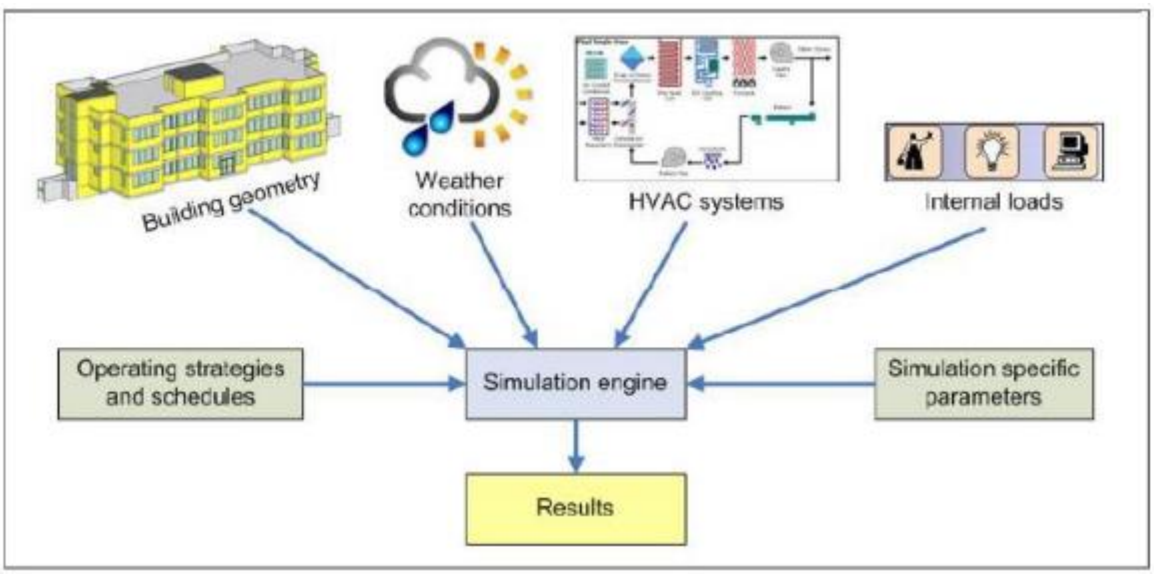

Fig. 5: General data flow of building energy simulation software [3]

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 [4]. ASHRAE also provides registrants with function-specific Advanced Energy Design Guides for achieving additional energy savings up to 50% [5]. 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 eQuest modeling output results (DOE-2 Simulation Results Viewer), it was found that the total cooling load (sensible + latent) was about 47.4 tons. The current chiller is 81.9 tons and the split AC system is 2 tons. Therefore, total capacity is 83.9 tons. Even when accounting for redundancies and the original plan of lead-lag configuration, the current chillers are oversized by about 77%. Focusing on the boilers, the total heating load was about 273 MBH and the current boilers are 675 MBH each. Here, the boilers are oversized by about 395% when compared to the building heating needs. A point of note to be considered is that the systems may be oversized to accommodate for redundancies, higher demand due to weather conditions, and other factors. Usually having some degree of redundancy is recommended; for facilities such as Data Centers and Hospitals, having a redundancy of N+1 or 2N is recommended due to the essential services being carried out at these sites.

Utility Analysis and Benchmarking

Utility data from 2019-2020 were retrieved through the State of Maryland's EnergyCap tool, which collects and stores energy consumption data for the vast majority of 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, were converted to units of kBTU using conversion factors provided by the US DOE and shown in Table 2 [6].

Table 2: Utility Analysis and EUI Summary Calculation

	Electricity		**Natural Gas**		**Water**	**Total Site Energy**	**Site EUI**
	MWh/yr	kBTU/yr	therms/yr	kBtu/yr	Gal/yr	kBtu/yr	kBtu/SF/Yr
Baseline Energy Usage	272	928,064	8327	832,700	104,150	1,760,764	64.02

Fig. 6 and Fig. 7 show the average monthly electricity and natural gas consumption respectively for the years 2019-2020 and provides a number of key insights.

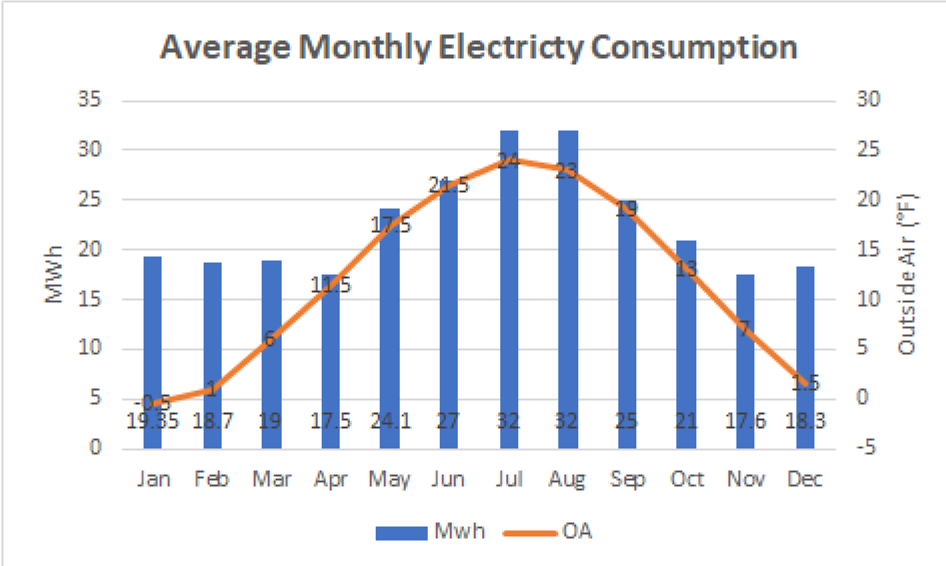

Fig. 6: Average Monthly Electricity Consumption [7]

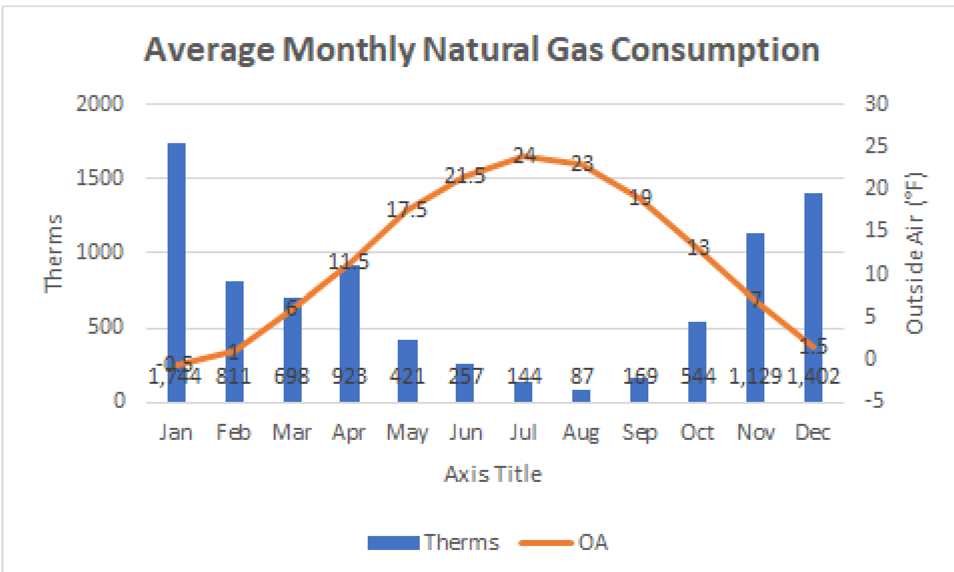

Fig. 7: Average Monthly Natural Gas Consumption [7]

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. However, in the summer months, there is some natural gas consumption due to the reheat operation required to provide adequate dehumidification and occupant comfort. Based on the utility analysis of electricity and natural gas from the EnergyCap software, there is no visible trendline to derive upon. The plots vary year over year significantly and hence, an average estimation was carried out for the annual utility analysis.

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 [8]. The Commercial Buildings Energy Consumption Survey (CBECS) database data was also used to evaluate the energy profile of the facility [9]. 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 which were further supplemented with the facility data (such as sq.ft area, building use, occupancy, etc.). 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 public courthouse [10].

Table 3: Benchmarking Results Summary

Parameter	**Value**	**Standard Value**	**Reference**
Energy Star Score (1-100)	53	-	EnergyStar Portfolio Manager
Site EUI (kBtu/sf)	64	101.2	EnergyStar Portfolio Manager
CBECS ($/sf)	1.29	1.84	(Electricity + Natural Gas)/Bldg sq.ft area

The EUI of 64 kBtu/sf was obtained using EnergyStar Portfolio Manager while utility analysis yielded a value of 64.02 kBtu/sf. Based on the benchmarking analysis, the Hagerstown Court Building currently has an Energy Usage Intensity less than the average public courthouses across the country (64 vs 101.2). The CBECS score is also less than the average value for commercial offices (1.29 vs 1.84). This means when compared to other reference courthouses there might be less opportunities to increase the overall energy efficiency of the facility.

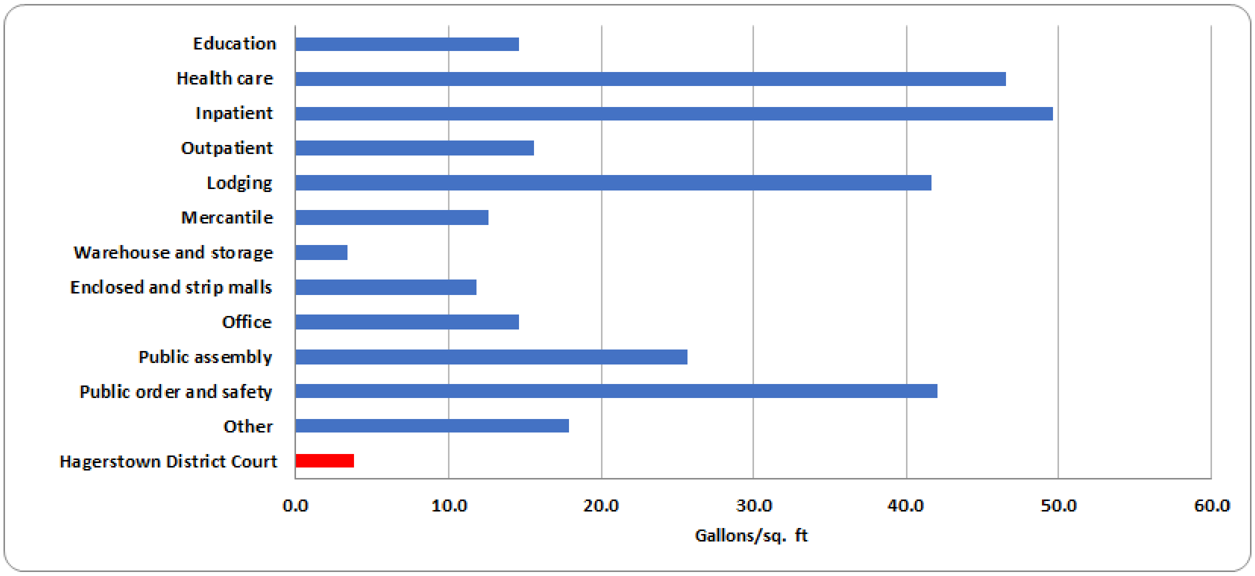

Fig. 8: Water Intensity (Gallons per sq. ft) [11]

The Fig. 8 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 Hagerstown District Court with a sq. ft area of 27,500 has a water intensity value of 3.79 gallons/sq. ft.

Energy Modeling

Baseline Energy Model

The physical structure of the Hagerstown Court Building was modeled in eQuest. Initially, AutoCAD 2020 was used to import the PDF images of the architectural plans and convert them into CAD files (.dwg). These CAD files were then imported into eQuest to generate the initial building geometry. Floor dimensions were calculated using the documented reference scale.

Then, the required zones were modeled into the floor layout and the subsequent HVAC systems were designed. The required information to be fed into the model (such as building envelope construction) was derived from the building plans and during the walkthrough. Certain informed assumptions were made for the unavailable data through physical observations, building plan analysis, and discussions with the facility personnel.

Each of the 2 levels was modeled and zoned separately to make the model as accurate as possible along with implementing the specific fenestration (windows and doors) details. Fig. 9 shows the 3-d representation of the building model as rendered in eQuest.

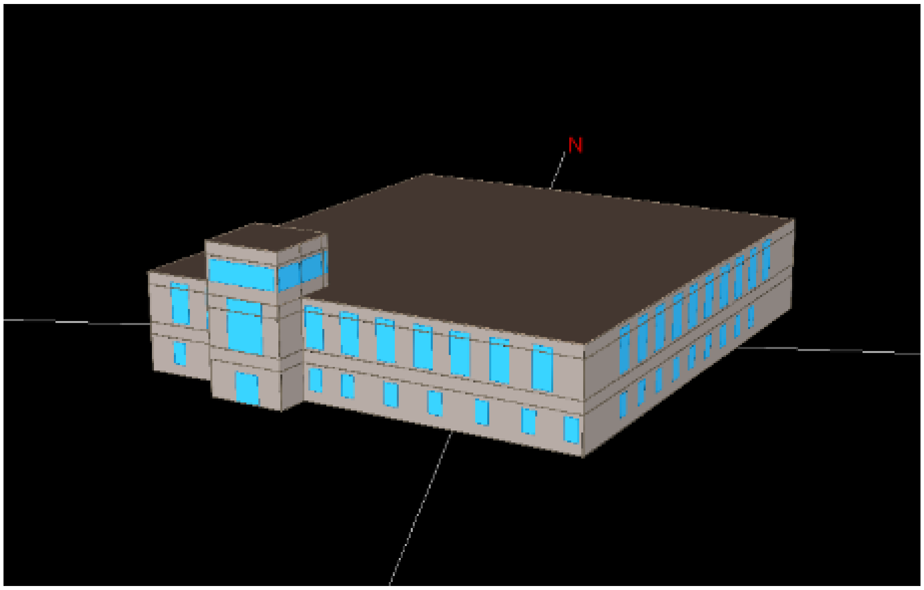

Fig. 9: Building energy model rendered in eQuest

The energy model had a total of 10 thermal zones. Each thermal zone represented the space served, or not served, by an AHU on a given floor. Fig. 10 illustrates the method by which an exemplary thermal zone layout was created. Each zone was provided with unique VAV terminal specifications, exhaust capacities, and thermostats derived from the original mechanical drawings.

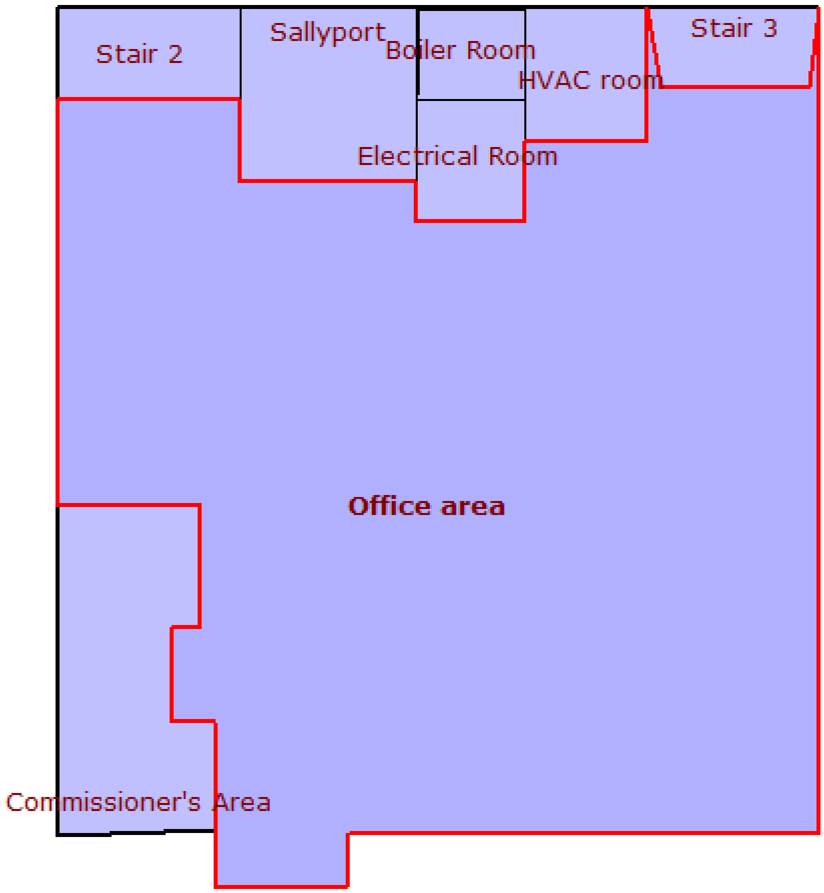

Fig. 10: Model thermal zone design(First floor)

The main space types defined to specify the lighting, plug loads, occupancy, and their associated schedules were offices, courtrooms, lobbies, holding area, and basement units (storage, mechanical, telephone). These definitions were developed through the process of building comprehension.

eQuest has two modes of data entry: “Schematic Design Wizard” and “Design Development Wizard”. Building envelope and boundary conditions, fenestration, and construction materials, as well as simplified space type definitions, thermal zones, schedules, plant loops, and basic HVAC definitions, were all entered using the “Schematic Design Wizard” mode. The model was refined and finalized by switching into “Design Development Wizard” mode after all possible data were entered into the “Schematic Design Wizard”. Advanced occupancy, equipment, lighting, and temperature set-point schedules were implemented using the “Design Development Wizard” mode.

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 eQuest simulation results.

Fig. 11 and Fig. 12 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.

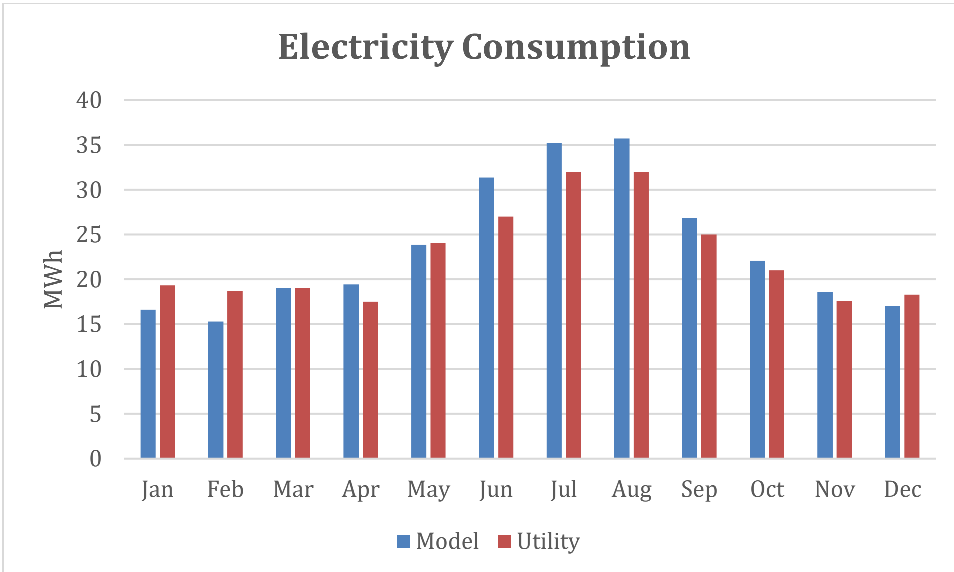

Fig. 11: Monthly electricity consumption comparison

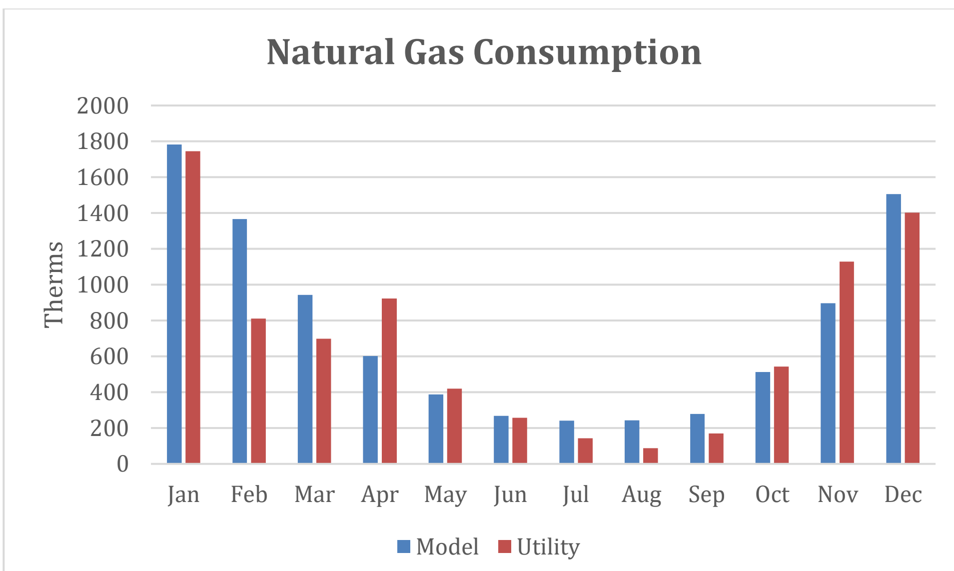

Fig. 12: Monthly natural gas consumption comparison

The predicted monthly energy consumption of the baseline energy model closely matched the average monthly energy reported by utility bills between 2019 and 2020. In the case of electricity consumption, the values deviate by ~3.5% while the natural gas consumption values deviate by ~8.4%.

The reason for the deviation in 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% [12].

Energy Efficiency Measures

After the baseline energy model is 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 upon their implementation.

EEM 1 - Lighting Upgrades

The building currently employs fluorescent lighting. Upgrading these fixtures to LED solutions has multiple end-user benefits. LED lighting can yield significant energy savings while also reducing the maintenance and labor costs associated with fluorescent lighting. LED light fixtures have longer rated life which would mean fewer costs associated with replacing them.

Lighting control options further enhance the energy-saving potential of LED lighting. Controls such as daylight saving, occupancy, dimming can be integrated into the lighting system to yield energy savings. Transitioning towards LED lighting could yield energy savings of around 50% - 60%.

EEM 2 - Chiller Upgrade

The current chillers currently satisfy the cooling needs of the facility, but they are original to the building construction (The building was constructed in 2000). The ASHRAE Equipment Life Expectancy Chart states a median life of 23 years for a packaged chiller unit [13]. Replacing the current chillers is recommended as maintenance issues and costs would keep on rising and the efficiency of the chillers would further degrade over time. Improvements over the years in chiller technology would help in implementing the most energy-efficient solution available.

New air-cooled reciprocating chillers with variable speed compressors and compressor fans for efficient part-load operation can be considered. Pumps with variable speed drives and differential control strategy will allow the pump speeds to match up to the building loads. A chiller plant control package can also be implemented to centralize the operation of the system and maximize the performance of various chiller components.

EEM 3 - Boiler Upgrade

The current boilers satisfy the heating needs of the facility, but they are original to the building construction (The building was constructed in 2000). The ASHRAE Equipment Life Expectancy Chart states a median life of 24 years for a boiler unit [12]. These boilers are nearing the end of their life, and need to be replaced with new high-efficiency boilers.

The existing boilers can be replaced with new high efficiency, gas-fired condensing type boilers. Current industry-standard employs condensing type boilers to significantly reduce the heating plant energy usage by safely operating at lower temperatures and utilizing variable system flow. Pumps with variable speed drives and a differential pressure control strategy will allow the heating water system to more efficiently function at part load conditions.

EEM 4 - Optimize Schedule and Setpoint Temperature

A final EEM that can be implemented for the Hagerstown courthouse is adjusting the schedule for the HVAC system operations in the building. Currently, the HVAC system for the entire building operates 24/7. The critical data rooms require constant operation to maintain system operations. One solution to save energy is to install a VRF system (see *data room)*. The rest of the building can then shift HVAC operation hours so that the entire building HVAC systems do not operate on holidays, weekends, and off-occupancy hours. We understand security personnel occupy the building 24/7, but we suggest that instead of running entire building HVAC systems on full load we run it on part load with different setpoint temperature.

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, labeled the “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 consequence 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.

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 - Lighting Upgrades	257	9515	24	-489	8.5%	-5.4%	2400	-489	**$1911**
EEM 2 - Chiller Upgrade	236	9026	45	0	16%	0%	4500	0	**$4500**
EEM 3 - Boiler Upgrade	279	8203	2	823	0.7%	9.1%	200	823	**$1023**
EEM 4 - Optimize Schedule and Setpoint Temperature	246	5746	35	3280	12.5%	36.3%	3500	3280	**$6780**
Combined EEM’s	186	5573	95	3453	33.8%	38.3%	9500	3453	**$12953**

***** 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 281 MWh and 9026 therms, respectively. The annual utility cost of electricity (281 MWh) and natural gas (9026 therms) is $37,126. The observed annual utility savings after implementing the EEMs can reduce the annual utility cost by 35%.

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 - Lighting Upgrades	24	-489	17592	-5672
EEM 2 - Chiller Upgrade	45	0	32985	0
EEM 3 - Boiler Upgrade	2	823	1466	9547
EEM 4 - optimize Schedule and Setpoint Temperature	35	3280	25655	38048
Combined EEM's	95	3453	69635	40055

The above carbon footprint analysis is estimated for a specific efficiency wherein the equipment degradation would result in 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 109,690 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. 15 for more detail.

Rebate Savings Analysis

This building is located in the service territory of Hagerstown Light Department which does not currently participate in the Empower Maryland Energy Savers Rebate Program. There are currently no utility incentives for energy saving projects available through Hagerstown Light Department.

Additional Building Observations and Recommendations

Data room

Data rooms are a high heat output zone. Currently, the entire building HVAC system operates 24/7 so that the data rooms maintain their set point temperature and to minimize the risk of any equipment overheating in the data rooms. Installing VRF system can isolate the data rooms' heating and cooling from the rest of the building. This way, the data rooms can maintain their setpoints while the rest of the building is controlled by the main HVAC system. (Fig. 13)

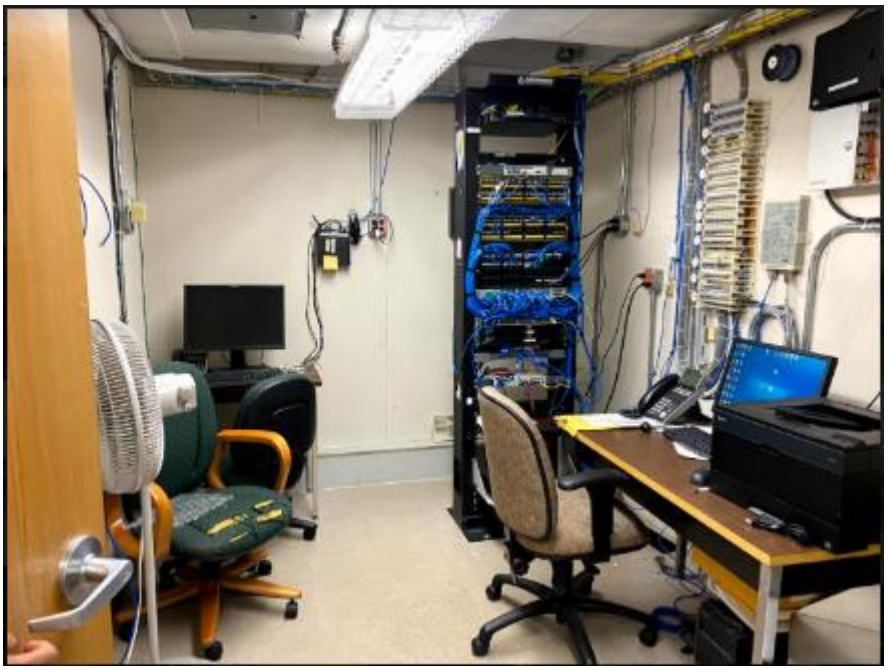

Fig.13: Data room on first floor

Outdoor unit Insulation issues

Another observation during the walkthroughs are the insulation issues of the outdoor units. Improper insulation of the equipment piping results in loss of useful energy which in turn increases the energy usage and makes the whole system inefficient. Proper insulation repairs need to be made to make sure the system runs as per the requirements (Fig.14).

Fig. 14: Uninsulated Pipe of AC split system

Green wall

Green wall in this lobby space 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 reduced 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 this lobby space [17].

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 [18]. 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 [19].

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. 15), 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. The carbon reduction initiatives in Maryland, with the transition to increasingly cleaner grid, results in the downward trend of CO_2 emissions. This trend would continue after 2029 with the CO_2 emissions from the electricity grid being less than that of natural gas sources. Heat pumps are currently one of the most, if not the most efficient available technology for space heating in the commercial and residential sectors. Although heat pumps have high initial capital costs, high efficiency and minimal maintenance make air source heat pumps a rewarding investment over the long term. Additionally, the CO_2 emissions for an electric heat pump is less than that of a natural gas boiler. Other existing renewable thermal technologies such as geothermal heat pumps or solar water heaters can be installed as fossil fuel-powered replacements. Additional advancements in the heat pump to accommodate even colder conditions can be adopted in the next few years.

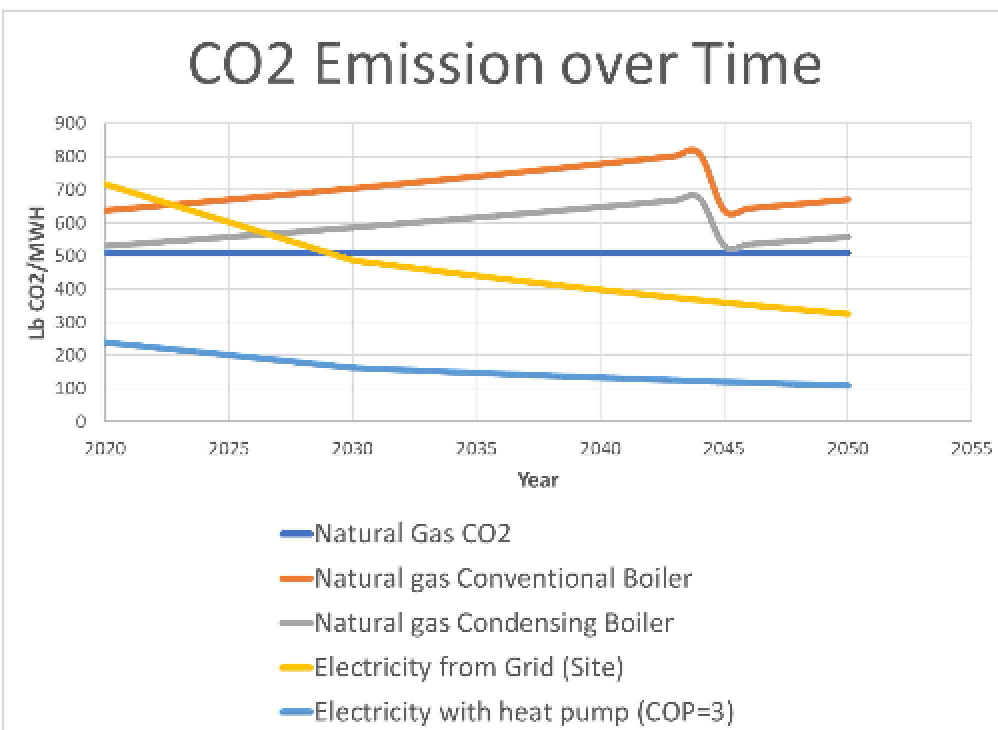

Fig. 15: CO2 emission over time

Energy Efficiency

Buildings undergo several phases over their lifetimes, including design, construction, operation, and retrofits. In each stage, there are opportunities to improve energy efficiency and reduce emissions: designing a building to use more natural lighting or install district heating (similar to central Satellite Central Utility Building (SCUB) units in the UMD campus), sourcing construction materials that have less embodied carbon, changing consumer behavior and electricity usage patterns to reduce energy demand or planning major retrofits over the life of the building. 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.

Electrification Analysis: Hagerstown District Court

Currently, the Hagerstown District Court satisfies its heating and cooling needs using traditional boilers and chillers. The earlier part of the report discussed the upgrade of these systems to more efficient ones and the subsequent energy savings. Here, an all in one Variable Refrigerant Flow (VRF) system is discussed to satisfy the building heating and cooling loads and further explore the scope of building electrification using this technology.

VRF is an air-condition system configuration where there is one outdoor condensing unit 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. 16 shows a schematic VRF arrangement.

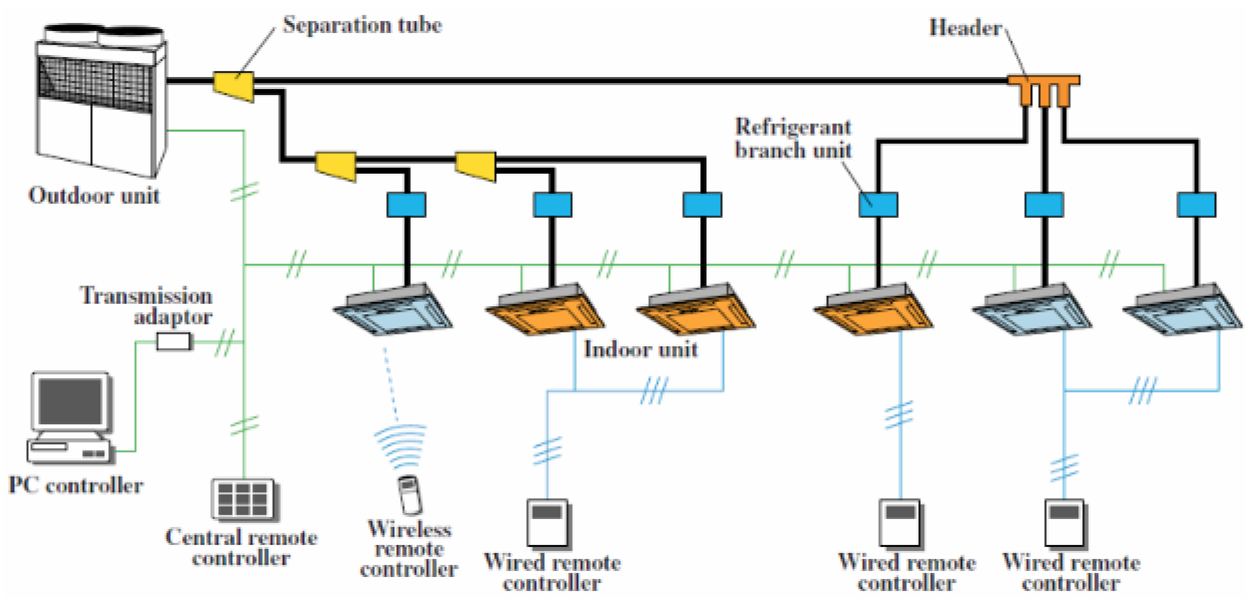

Fig. 16: A schematic VRF arrangement [20]

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.

All in one VRF systems such as the ones offered by Mitsubishi Electric can be considered for the Hagerstown District Court building [21]. The City Multi products (R2 series, Y-series, WR2-series, WY-series) from Mitsubishi are designed for commercial applications. They provide zone control, design flexibility, quiet operation, hyper heating inverter (H2i), personalized comfort control, and simultaneous cooling and heating operations (R2 and WR2-series). The City Multi Controls Network (CMCN) enables control of multiple centralized controllers and can be managed from any networked PC, tablet, or smartphone.

This VRF system could replace the current chillers and boilers 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.

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 eliminating the need for natural gas altogether. Solar thermal systems have been known to be a cost prohibitive option in certain climates, so another alternative may be PV array coupled with a heat pump water heater.

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 [22]. For example, at the Hagerstown District Court, a 10kW system can generate about 13,965 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 courthouse 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) [23], also called alternative energy credits in Maryland. SRECs are created for each 1000 kWh of electricity produced by a qualified alternative energy source. The value of SRECs is measured in $/MWh. [24]. There is no specific size limit, but the systems generally must be connected to the distribution system serving the state in order to qualify.

Initial Scope of Work

	Current System	Proposed System	Comments
Chiller	81.9 tons	~54.5 tons	15% increase of the peak load consumption (47.4 tons), Take next available chiller tonnage available
Boiler	1350 MBH (675 MBH each)	~341.25 MBH	25% increase of the peak load consumption (273 MBH), Take next available boiler MBH available
Lighting	Fluorescent	LEDs	LED along with occupancy, daylight and microphonics sensors

*Redundancy is not considered in the above proposed value in the chiller and boiler.

Conclusions

The Hagerstown District Court Building is an interesting building due to it being an old construction but still operating along the average levels of a public courthouse. The facility would benefit from a HVAC system upgrade. Due to this, Energy Efficient Measures were identified to transition the building system to newer technologies 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 33.8% and natural gas consumption by 38.3%.

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 accurate baseline energy model detailed in this report can provide a number of powerful tools to a diverse range of courthouse facilities. This model can be further fine-tuned based on future developments to account for changes in the energy profile of the facility.

References:

[1] U.S. EIA, "Monthly Energy Review", 2017.

[2] https://www.osti.gov/biblio/941430

[3] Maile, Tobias, Martin Fischer, and Vladimir Bazjanac. 2007. *Building Energy Performance Simulation Tools - a Life-Cycle and Interoperable*. Sanford University, Facil. Eng. (CIFE) Working Pap.. 107.

[4] ASHRAE, Energy Standard for Buildings Except Low-Rise Residential Buildings, I-P Edition ed., Atlanta, GA: ANSI/ASHRAE/IESNA, 2011.

[5] ASHRAE, "ASHRAE Advanced Energy Design Guides," 2017. [Online]. Available: http://aedg.ashrae.org/Default.aspx. [Accessed 2017].

[6] EPA, DOE, "Thermal Energy Conversions," ENERGY STAR, August 2015. [Online]. Available: http://portfoliomanager.energystar.gov/pdf/reference/Thermal%20Conversions.pdf.

[7] https://www.ncdc.noaa.gov/

[8] https://portfoliomanager.energystar.gov/pm/home

[9] https://www.eia.gov/consumption/commercial/data/2012/

[10] https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager/understand-metrics/what-energy

[11] https://www.eia.gov/consumption/commercial/reports/2012/water/

[12] http://www.eeperformance.org/uploads/8/6/5/0/8650231/ashrae_guideline_14-2002_measurement_of_energy_and_demand_saving.pdf

[13] https://www.naturalhandyman.com/iip/infhvac/ASHRAE_Chart_HVAC_Life_Expectancy.pdf

[14] https://www.eia.gov/electricity/state/maryland/

[15] https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references#:~:text=Carbon%20dioxide%20emissions%20per%20therm,one%20therm%20(EIA%202018).

[16] https://buildingretuning.pnnl.gov/publications/PNNL-25985.pdf

[17] https://livewall.com/products/indoor/

[18] https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

[19] https://www.c2es.org/document/decarbonizing-u-s-buildings/
[20] www.seedengr.com/ Variable Refrigerant Flow Systems
[21] https://www.mitsubishipro.com/products/city-multi-vrf/outdoor
[22] https://pvwatts.nrel.gov/pvwatts.php
[23] https://pepco.com/SmartEnergy/MyGreenPowerConnection/Pages/SolarIncentivesRebates.aspx
[24] https://programs.dsireusa.org/system/program/detail/5688