Hyattsville District Court Building

4990 Rhode Island Avenue
Hyattsville, MD 20781

Energy Audit Report

Prepared for:
Maryland Department of General Services (DGS)

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

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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 Thirumalesha Adarsh Gudluru, Soumya Agrawal & Sorochukwu Okam who were supervised by Dr. Amir Shooshtari & Dr. Michael Ohadi.

Acknowledgment

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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 existing chillers are oversized by 133%
- The existing natural gas boilers are oversized by 507%
- There is no Centralized Building Control System to monitor the building systems.

List of recommended energy efficiency measures (EEM):

EEM 1 - Chiller Upgrade including,

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

EEM 2 - Building Envelope Upgrades

- Retrofitting the roof insulation in the building

EEM 3 - Lighting Upgrades

- LED fixtures
- Lighting controls

EEM 4 - Boiler Upgrade including,

- New high efficiency, gas-fired condensing type boilers

EEM 5 - AHU Fan Upgrades

- Install high-efficiency motors

See page 15 for more details on the list of ECMs.

Savings associated with following all the recommendations:

- Annual utility cost reduction of 25.8% resulting in $35,810 utility savings
- Annual electricity consumption reduction of 27.7% resulting in $33,671 savings
- Annual natural gas consumption reduction of 12.3% resulting in $2139.2 savings

See page 17 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 Hyattsville Court building is the District Court of Maryland for Prince George's County located at 4990 Rhode Island Ave, Hyattsville, Maryland. The building was originally constructed in 1994 and it is a three-story building with an overall area of 83,000 sq. ft. It has 3-floor levels, a basement, and a penthouse roof housing the mechanical equipment. Fig. 1 shows the overview of the Hyattsville District Court.

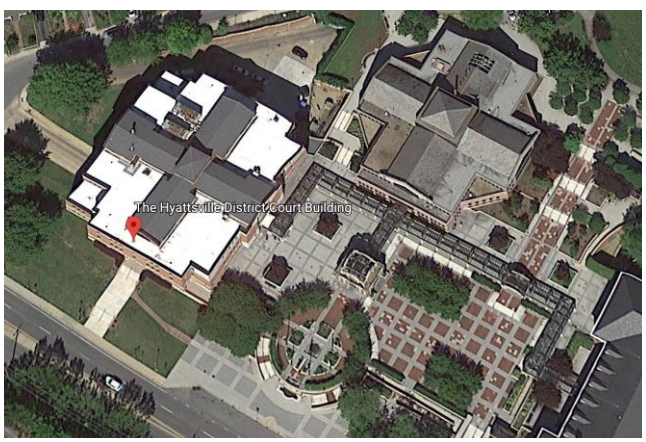

Fig. 1: Hyattsville District Court

The building houses primarily the office spaces, courtrooms, and judges' chambers (levels 2 and 3). Level 1 houses the Commissioner's office, a holding area, and other office spaces.

The basement has other spaces such as a telephone room, a storage space, a generator room, and a mechanical room. The penthouse roof houses mechanical systems such as the chillers, boilers, and Air Handling Units (AHUs 1-4). AHU 5 is in the basement. 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). Based on discussions with the Facilities personnel, the building HVAC system takes a lot of time to recover and hence, cannot be started again on time. For this reason, the building maintains constant operating conditions 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: *Constellation New Energy and Potomac Electric Power Co*; Natural Gas: *WGL Energy and Washington Gas*).

Building HVAC Description

The chilled water is supplied by two rooftop air-cooled rotary screw chillers (*Trane Model: RTA1554XG01AD1BFQ*) with a capacity of 155 tons (545 kW) each. Three constant speed pumps (*Taco Model: FE3010E2HIF2LOA*) supply the chilled water throughout the facility. The pumps are rated at 15 HP (11.18 kW) each & supply 375 GPM (23.7 L/s). The supply temperature from the chillers to the AHUs was 44F (6.7°C) and the return temperature was approximately 56F (13.3°C). The chillers are manually operated. The original design plan indicates the chillers to be operated in a lead-lag configuration with the lead chiller running until the demand on the system is too great for the chiller to meet, at which point the lag chiller initiates until the demand is met. Fig. 2 shows the rooftop chiller unit.

Fig. 2: Rooftop chiller unit

The hot water is supplied by two gas-fired boilers (*Kewanee Catalog# KW4.0-192-G*) each with a capacity of 1749 MBH (513 kW). The louvers in the boiler room supply the combustion air to the boilers and the exhaust from the boilers is routed to the roof. Two constant speed pumps (*Taco Model: FE3008E2GIF2LOA*) 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 unit in the rooftop boiler room.

Fig. 3: Boiler Unit

There are five AHUs in the building which serves most of the building needs. The four AHUs (1-4) are located in the penthouse and one AHU (5) is located in the basement. AHU 1 serves the north side of levels two and three while AHU 2 serves the south side of levels two and three. These include the courtrooms, lobbies, judges' chambers, libraries, and office spaces on both levels. AHU 3 serves the north side of level one while AHU 4 serves the south side. These include conference rooms, holding areas, and other office spaces. The AHU 5 located in the basement serves spaces within the basement level. The four main air handling units are each equipped with a hot water preheat coil, a chilled water-cooling coil, and supply fans that are controlled by variable speed drives. Each air handling unit has a corresponding return air fan mounted in the ductwork; each return air fan is also controlled by a variable frequency drive.

Currently, the variable frequency drives are ramped up and down manually rather than responding to system pressure loads as indicated in the original construction plans. Supply air is delivered to each space via variable air volume (VAV) terminal units or, in the case of courtrooms, fan powered VAV terminal units. The fifth air handling unit is a constant volume unit. It is equipped with hot water heating and chilled water cooling, but the supply fan is not controlled by a variable speed drive, and it does not have a return fan. Fig. 4 shows an AHU in the penthouse mechanical room.

Fig. 4: AHU in Penthouse

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								
MARK	LOCATION	SERVES	SUPPLY AIR					REMARKS (PROTOTYPE)
			MIN. O.A. AIR CFM	TOTAL S.A. CFM	EXT. S.P. (INCH WG)	FAN MOTOR		
						HP	V/PH/HZ	
AHU-1	PENTHOUSE	NORTH 2ND/3RD	10,000	20,000	2.00	20	460/3/60	McQUAY MSL 141 (35% ANGULAR FILTERS)
AHU-2	PENTHOUSE	SOUTH 2ND/3RD	10,000	20,000	2.00	20	460/3/60	McQUAY MSL 141 (35% ANGULAR FILTERS)
AHU-3	PENTHOUSE	NORTH 1ST	2,500	10,000	2.00	10	460/3/60	McQUAY MSL 122 (35% ANGULAR FILTERS)
AHU-4	PENTHOUSE	SOUTH 1ST	2,500	10,000	2.00	10	460/3/60	McQUAY MSL 122 (35% ANGULAR FILTERS)
AHU-5	BASEMENT	BSMT	400	1,200	1.50	3/4	460/3/60	McQUAY LSL 103 FC
FCU-1	TEL. RM. B010	MAIN TEL. RM.	50	865	0.50	1/3	115/1/60	McQUAY SHB-081B
RAF-1	PENTHOUSE	AHU-1	--	16,600	1.50	10	460/3/60	TRANE MODEL Q, SIZE 36
RAF-2	PENTHOUSE	AHU-2	--	16,840	1.50	10	460/3/60	TRANE MODEL Q, SIZE 36
RAF-3	PENTHOUSE	AHU-3	--	8200	1.50	5	460/3/60	TRANE MODEL Q, SIZE 27
RAF-4	PENTHOUSE	AHU-4	--	8200	1.50	5	460/3/60	TRANE MODEL Q, SIZE 27

PUMP SCHEDULE									
MARK	LOCATION	SERVES	GPM	TOTAL HEAD (FT.)	MOTOR			MIN PUMP EFFICIENCY	REMARKS (PROTOTYPE)
					HP.	RPM	V/PH/HZ		
HWP-1	BOILER ROOM	BOILER	335	60	7 1/2	1750	460/3/60	75%	BELL & GOSSETT MODEL 1510 3BB OR APPROVED EQUAL.
HWP-2	BOILER ROOM	BOILER	335	60	7 1/2	1750	460/3/60	75%	BELL & GOSSETT MODEL 1510 3BB OR APPROVED EQUAL.
CWP-1	PENTHOUSE	AHU'S	370	75	10	1750	460/3/60	75%	BELL & GOSSETT MODEL 1510 4E OR APPROVED EQUAL.
CWP-2	PENTHOUSE	AHU'S	370	75	10	1750	460/3/60	75%	BELL & GOSSETT MODEL 1510 4E OR APPROVED EQUAL.
CWP-3	PENTHOUSE	AHU'S	370	75	10	1750	460/3/60	75%	BELL & GOSSETT MODEL 1510 4E OR APPROVED EQUAL.

HOT WATER BOILER SCHEDULE											
MARK	LOCATION	SERVES	BOILER TYPE	BOILER HP.	HOT WATER CAPACITY				FIRING RATE	ELECTRICAL DATA	REMARKS (PROTOTYPE)
					WATER TEMP. °F		EDR WATER GROSS. SF	MBH OUTPUT	GAS CFH INPUT	V/PH/HZ	
					ENT.	LVG.					
B-1	BOILER RM	BLDG HTG SYTEM	FIRETUBE 4-PASS	50	160	180	11,150	1674	2095	460/3/60	CLEAVER BROOKS CB50 OR APPROVED EQUAL
B-2	BOILER RM	BLDG HTG SYTEM	FIRETUBE 4-PASS	50	160	180	11,150	1674	2095	460/3/60	CLEAVER BROOKS CB50 OR APPROVED EQUAL

AIR COOLED CHILLER SCHEDULE														
MARK	LOCATION	SERVES	OA TEMP. °F	NOMINAL TONS	EVAPORATOR DATA				CONDENSER FAN DATA			COMPRESSOR DATA		REMARKS (PROTOTYPE)
					GPM	WATER TEMP. °F		MAX. P.D. (FT)	NO. OF FANS	HP	V/PH/HZ	NO.	TYPE	
						ENT.	LVG.							
ACC-1	ROOF	ALL AHU'S	105°F	154.3	370	54	44	15	12	2.8	460/3/60	2	SCREW COMP.	McQUAY AIR COOLED CHILLER MODEL ALS 155A
ACC-2	ROOF	ALL AHU'S	105°F	154.3	370	54	44	15	12	2.8	460/3/60	2	SCREW COMP.	McQUAY AIR COOLED CHILLER MODEL ALS 155A

There are multiple electric unit heaters installed in the facility to provide supplemental heating. Also, curtain heaters are employed at the entrance of level 1 which run on electricity and are turned off at the end of the working hours. The commissioner's area is a unique space where it is the only area in the building that is intended to operate 24 hours a day, 7 days a week. The area is therefore served not only by the main mechanical system (AHU 4) but also by two 3-ton ductless split systems, which are intended to operate when the main air handling units are in unoccupied mode. In the unoccupied mode, the building's mechanical equipment is not shut down but is intended to operate at lower capacities.

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. Currently, in the case of the Hyattsville court building, there is no BAS system employed.

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.

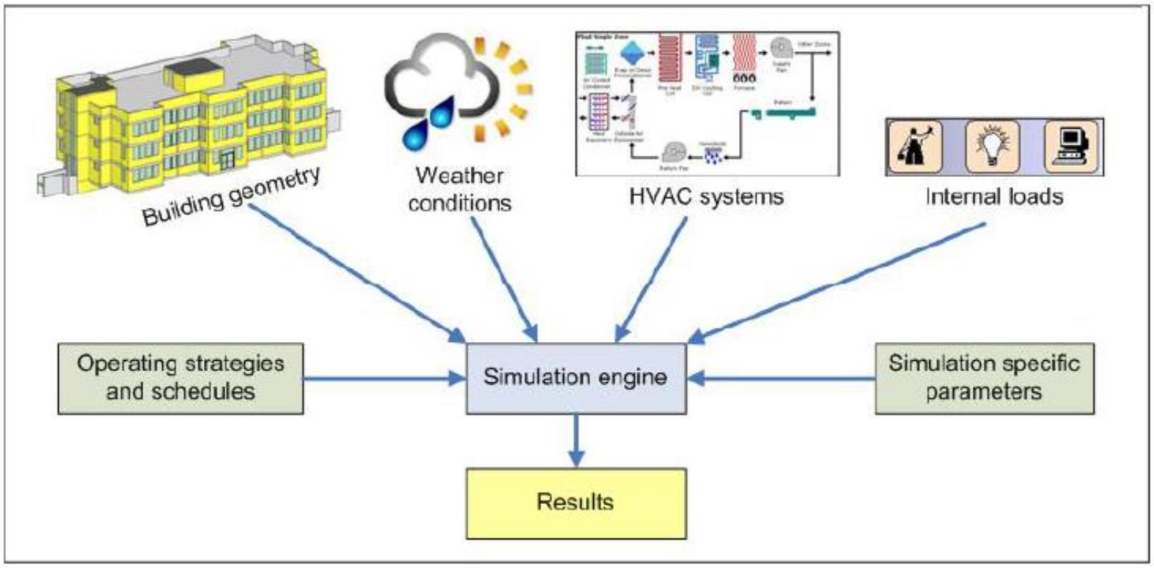

Fig. 5: General data flow of building energy simulation software [3]

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 133 tons and the current chillers are 155 tons each. Even when accounting for redundancies and the original plan of lead-lag configuration, the current chillers are oversized by about 133%. Focusing on the boilers, the total heating load was about 576.2 MBH and the current boilers are 1749 MBH each. Here, the boilers are oversized by about 507% 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 2016-2020 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**
	kWh/yr	kBTU/yr	therms/yr	kBtu/yr	Gal/yr	kBtu/yr	kBtu/SF/Yr
Baseline Energy Usage	1,287,671	4,393,533	22,693.5	2,269,350	543,000	6,662,883	80.3

Fig. 6 and Fig. 7 show the average monthly electricity and natural gas consumption respectively for the years 2016-2020 and provides a number of key insights.

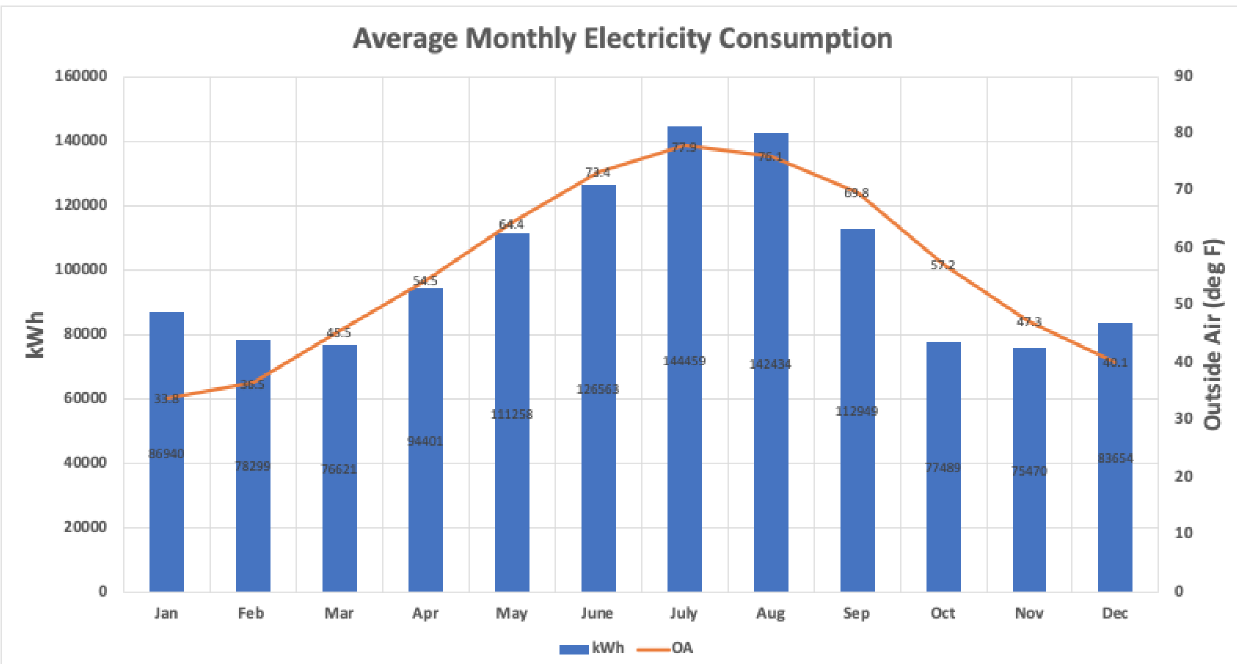

Fig. 6: Average Monthly Electricity Consumption [7]

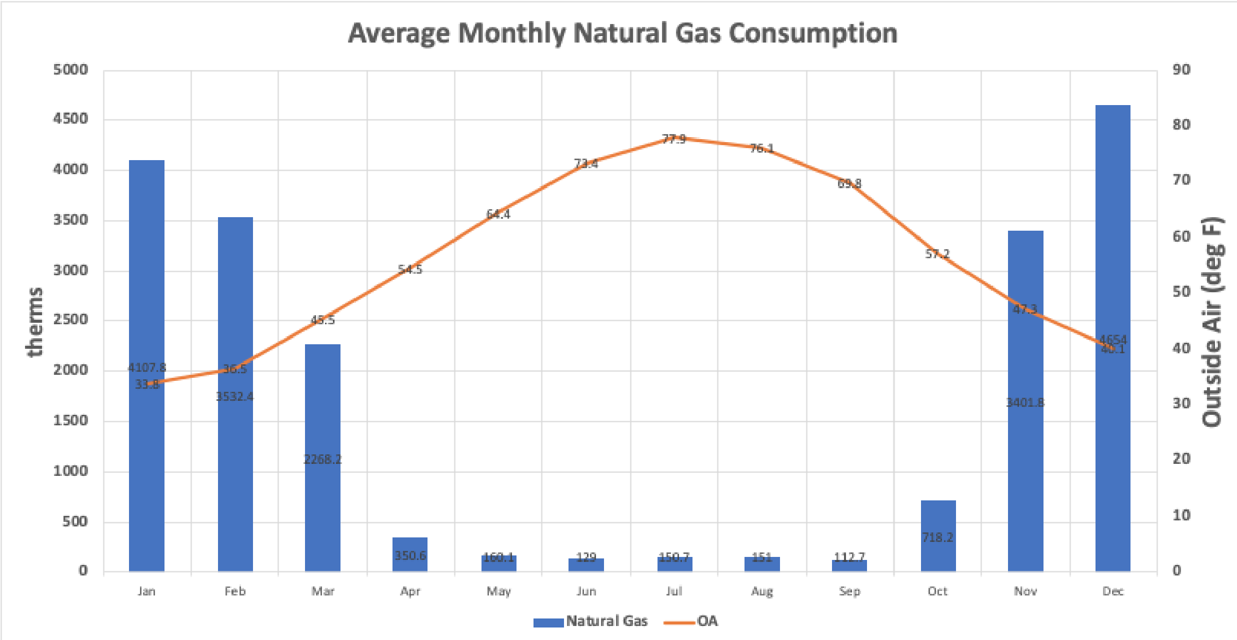

Fig. 7: Average Monthly Natural Gas Consumption [7]

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)	54	-	EnergyStar Portfolio Manager
Site EUI (kBtu/sf)	73.8	101.2	EnergyStar Portfolio Manager
CBECS ($/sf)	1.79	1.84	(Electricity + Natural Gas)/Bldg sq.ft area

The score of 73.8 was obtained using EnergyStar Portfolio Manager while utility analysis yielded a value of 80.2. Based on the benchmarking analysis, the Hyattsville Court Building currently has an Energy Usage Intensity less than the average public courthouses across the country (73.8 vs 101.2). The CBECS score is also less than the average value for commercial offices (1.78 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.

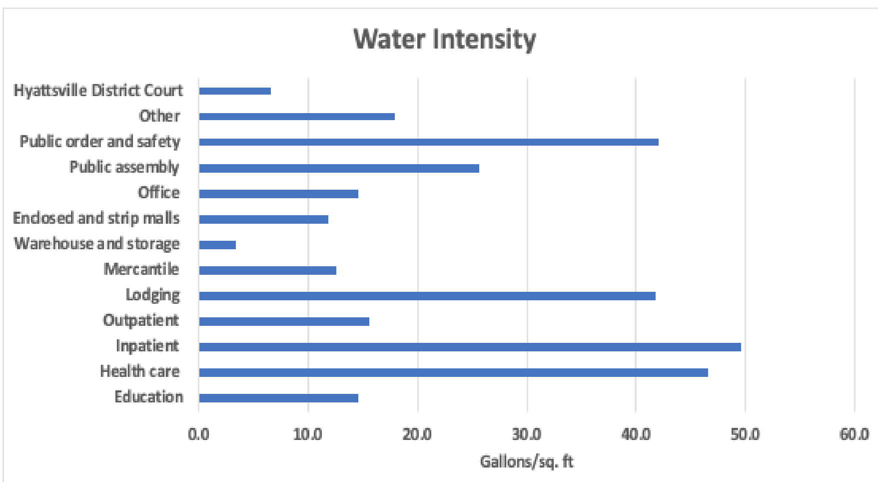

Fig. 8: Water Intensity (Gallons per sq. ft) [11]

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 Hyattsville District Court with a sq. ft area of 83,000 has a water intensity value of 6.54 gallons/sq. ft.

Energy Modeling

Baseline Energy Model

The physical structure of the Hyattsville Court Building was developed 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 5 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.

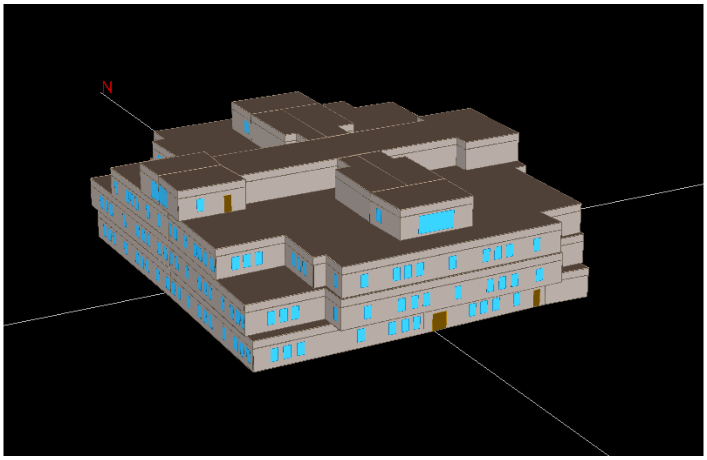

Fig. 9: Building energy model rendered in eQuest

The energy model had a total of 29 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.

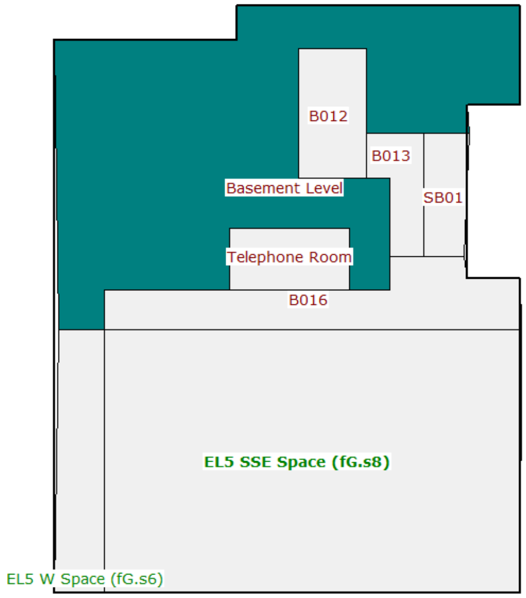

Fig. 10: Model thermal zone design (Basement)

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.

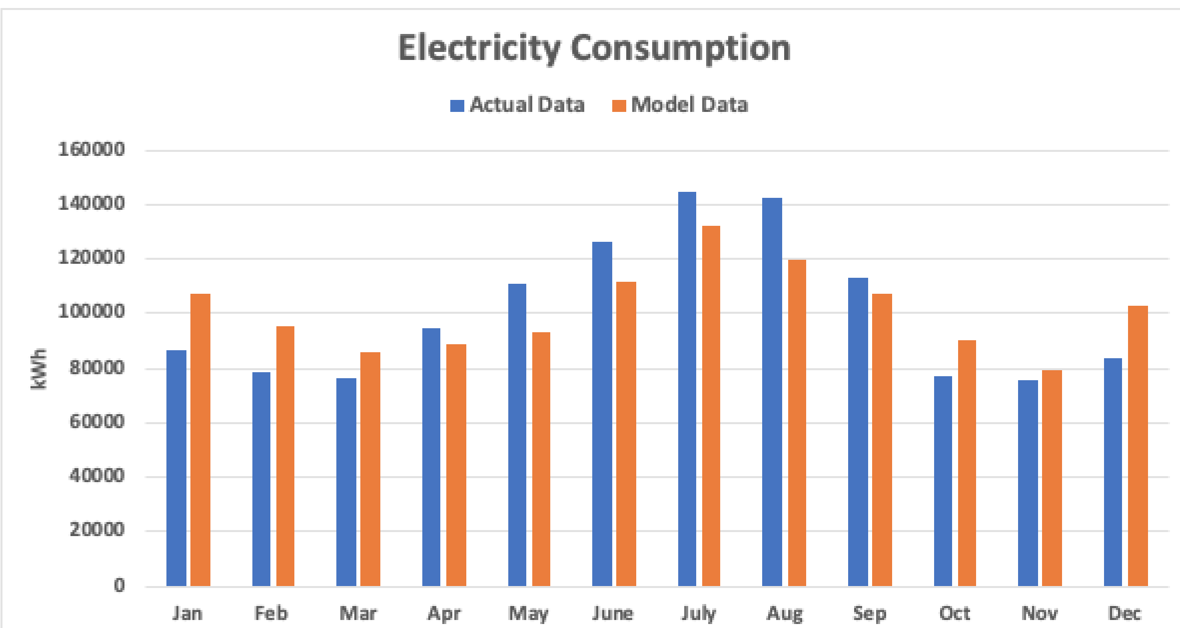

Fig. 11: Monthly electricity consumption comparison

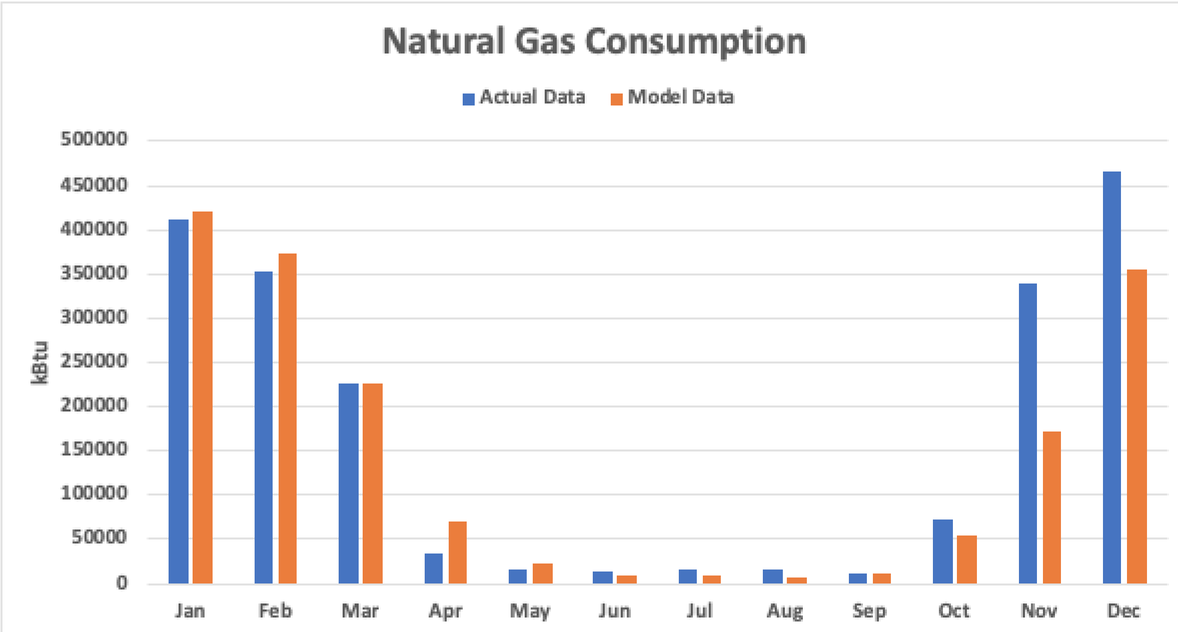

Fig. 12: Monthly natural gas consumption comparison

The predicted monthly energy consumption of the baseline energy model closely matched the average monthly energy reported by utility bills between 2016 and 2020. In the case of electricity consumption, the values deviate by ~0.29% while the natural gas consumption values deviate by ~12.15%. 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 - 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 1994). 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 rotary screw 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 2 - Building Envelope Upgrades

During the walkthrough of the facility, it was observed that some spaces on the first floor (Level 1) were cooler than the rest. Discussions with the facility personnel further explored this observation, where during the winter months these spaces usually run cooler than the other spaces in the level. Further analysis yielded irregular roof insulation in the basement under Level 1.

Building envelope upgrades in the form of retrofitting the roof insulation can help in maintaining the thermal comfort of the building as well as reducing the energy loads on the building HVAC system.

EEM 3 - 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 4 - Boiler Upgrade

The current boilers need to be replaced with new high-efficiency boilers. Based on the research into the current boilers, it was found that the company (Kewanee) has ceased its operation. This would mean further difficulties in locating the required replacement products in case of a failure. The ASHRAE Equipment Life Expectancy Chart states a median life of 24 years for a boiler unit [12].

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 5 - AHU Fan Upgrades

Upgrading the current motors of the AHU fans with high-efficiency ones can further help in making the system more energy efficient. Though the savings achieved will not be much significant, this measure will reduce the failure rate and enable the energy-efficient operation of the AHU fans.

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 - Chiller Upgrade	1056.9	16416	157.2	925.2	12.9%	5.3%	15720	925.2	**$16645**
EEM 2 - Building Envelope Upgrades	1170.1	13244.2	44.0	4097.0	3.6%	23.6%	4400	4097.0	**$8497**
EEM 3 - Lighting Upgrades	1081.5	24119.8	132.6	-6778.6	10.9%	-39.1%	13260	-6778.6	**$6481**
EEM 4 - Boiler Upgrade	1207.8	14855.5	6.3	2485.7	0.5%	14.3%	630	2485.7	**$3116**
EEM 5 - AHU Fan Upgrades	1213.5	17344.0	0.6	-2.8	0.1%	-0.01%	60	-2.8	**$57**
Combined EEM's	877.3	15202	336.7	2139.2	27.7%	12.3%	33671	2139.2	**$35810**

***** 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 1214.1 MWh and 17341.2 therms, respectively. The annual utility cost of electricity (1214.1 MWh) and natural gas (17341.2 therms) is $138,751.2. The observed annual utility savings after implementing the EEMs can reduce the annual utility cost by 25.8%.

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 - Chiller Upgrade	157.2	925.2	115227.6	10732.3
EEM 2 - Building Envelope Upgrades	44.0	4097.0	32252	47526
EEM 3 - Lighting Upgrades	132.6	-6778.6	97195.8	-78631
EEM 4 - Boiler Upgrade	6.3	2485.7	4617.9	28834
EEM 5 - AHU Fan Upgrades	0.6	-2.8	439.8	-32
Combined EEM's	336.7	2139.2	246801.1	24814.7

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 CO2 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 271,616 lbs of Carbon dioxide emissions per year. However, it must be noted that the CO2 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. 14 for more detail.

Rebate Savings Analysis

To offset the initial capital costs for these upgrades, utility rebate incentive programs can be utilized. Based on the information from Empower MD, as the Hyattsville District Court is >75,000 sq. ft, it comes under the Large Building Tune-up. Custom incentive tracks can be pursued where measures for the existing buildings include HVAC (Roof top units and in-room units), Variable Frequency Drives (Retrofit constant speed fans and pumps with VFDs and Incentive per motor HP controlled), and Prescriptive Lighting. Rebates can be classified into End of Life Replacement (Up to 75% of the incremental costs for the more efficient equipment, capped at $0.28/kWh saved annually) and Retrofit (Up to 50% of the costs for the more efficient equipment, capped at $0.28/kWh saved annually).

The proposed EEMs must pass a cost effectiveness test to be eligible for custom rebate incentive. To evaluate rebate incentives for the proposed EEMs, the target kWh savings would be 1.5 to 2 times the dollar cost of the project. (Example: if the project cost is $100,000, the target savings would be 150,000 kWh)

Additional Building Observations and Recommendations

Building Automation System

The Hyattsville District Court Building does not have a Centralized Building Control System to monitor the building systems. A centralized control system is essential to achieve an efficient HVAC system and point out any early issue before it transitions to a major setback of the system, thus protecting the facility assets. A control system is not only important to manage the occupant comfort but also to effectively operate at reduced capacities and speeds during part-load operation.

Having a building control system will not inherently improve the building efficiency but it will assist the Facility personnel to easily identify any atypical operation of the mechanical system so that the problem can be rectified. As discussed earlier, on account of the building and its HVAC system being old, a control system would be very helpful to monitor the systems and handle any failures that may occur due to the age of the HVAC system. Also, a centralized BAS system can help with temperature setback, and changing schedules over the unoccupied hours, weekends, and holidays.

A study by the Pacific Northwest National Laboratory (PNNL) found that if commercial buildings fully utilized controls nationwide, the U.S. could reduce its energy consumption by the equivalent of what is currently used by 12 to 15 million Americans. 34 different energy efficiency measures were analyzed, most of which rely on various building controls, which when implemented could affect energy use in commercial buildings such as stores, offices, and schools. Researchers at PNNL found the measures could cut the annual commercial building energy use by an average of 29%. This would result in between 4 to 5 quadrillion British Thermal units in national energy savings, which is about 4-5% of the energy consumed nationwide [16].

Of the 34 individual energy efficiency measures that can improve commercial building performance, some include:

- Fixing broken sensors that read temperatures and other measurements
- Turning off power using devices like printers and monitors when a room isn't occupied
- Dimming lights in areas with natural lighting

Combining the individual measures can yield further increase in energy savings.

Hotspots in the Level 3 lobby

During the walkthrough and discussions with the facility personnel, hotspots were observed in the Level 3 lobby. The lobby itself was warmer as compared to other spaces in the building. Stratified air near the ceiling due to a lack of escape space was deduced as a reason. Fig. 13 shows the thermal image of the lobby and the stratification of air is observed. The presence of such hotspots would require additional effort from the HVAC system to handle the heat load, but this additional cooling would then end up causing discomfort to the occupants. Installing a ceiling fan would help with this and spread the load across space, thus reducing the load on the system.

Additionally, a 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].

Fig. 13: Stratification of air at Level 3 lobby

Commissioner's Area

The Commissioner's area in the building is a unique space on account of it being operational 24 hours a day and 7 days a week. The area is currently served by a VRF system. The mechanical plans show that AHU-4 also serves the south side of Level 1, with Commissioner's area being in this space. A recommendation for this space can be to eliminate this zone from the main building HVAC system. This would result in energy savings in terms of developing and distributing chilled water, hot water, and conditioned air to this space. Further downsizing of these systems can also be explored due to a reduction in the load. Additionally, these systems and equipment no longer need to be operated after-hours solely to serve the Commissioner's Area.

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. 14), 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 CO2 emissions. This 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.

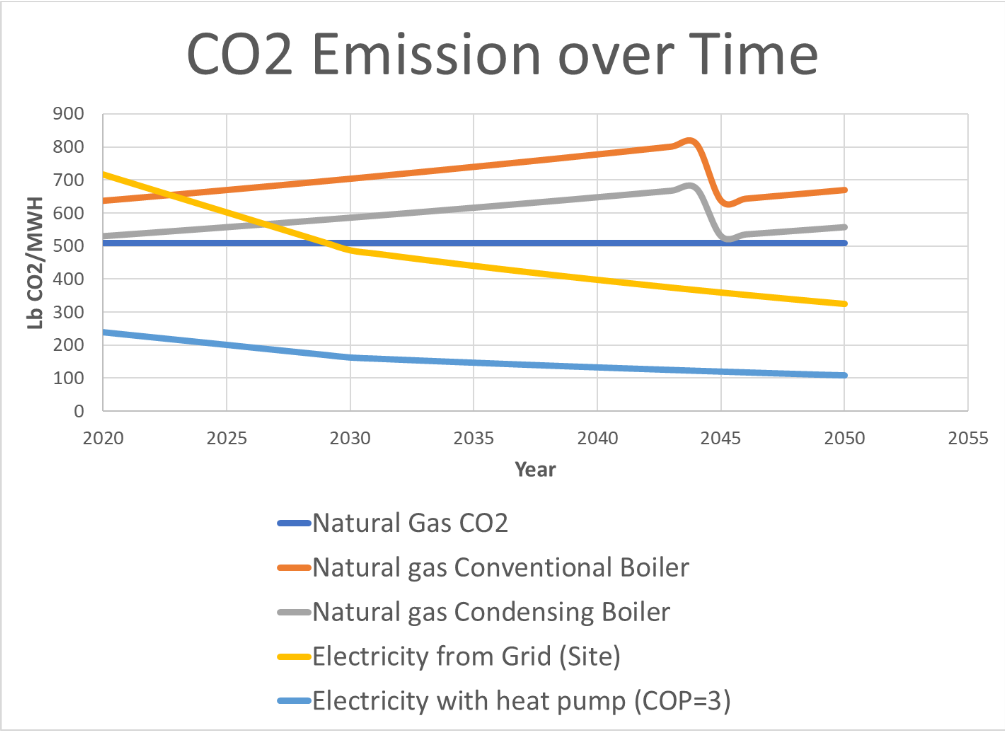

Fig. 14: CO2 emission over time

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: Hyattsville District Court

Currently, the Hyattsville 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. 15 shows a schematic VRF arrangement.

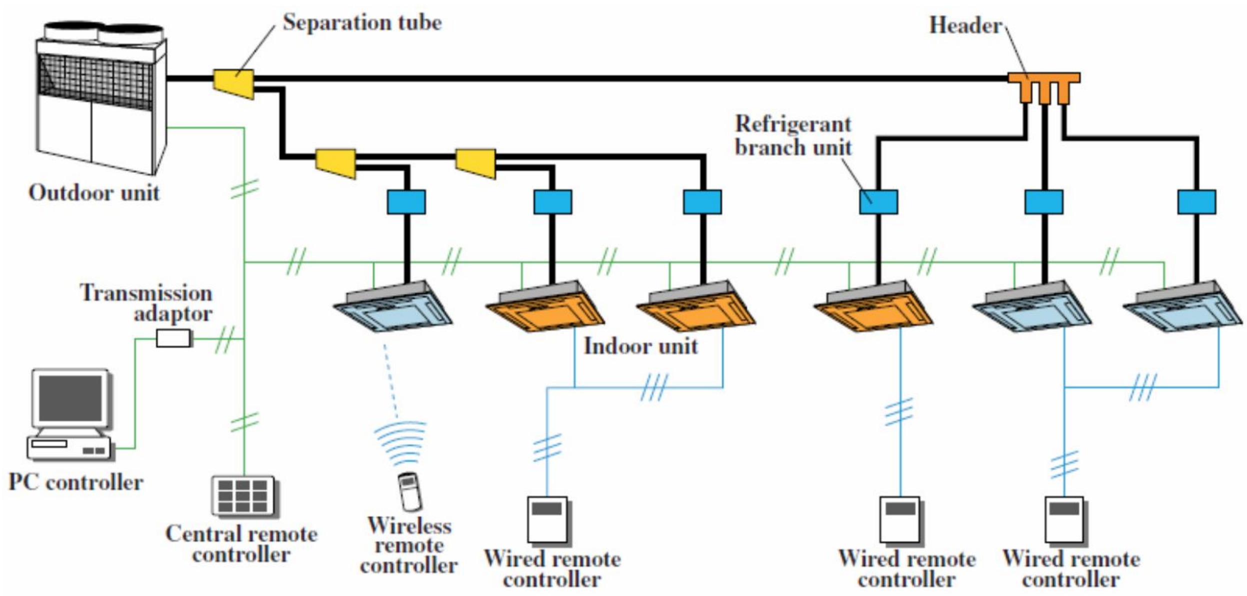

Fig. 15: A schematic VRF arrangement [20]

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 Hyattsville 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 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 Hyattsville District Court, a 10kW system can generate about 14,370 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. According to this incentive program, the eligible technologies of Solar Water Heat and Solar Photovoltaics can be credited at $160/MWh, with a theoretical maximum of $400/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.

Conclusions

The Hyattsville 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 27.7% and natural gas consumption by 12.3%.

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