Hargrove District Court Building

700 E Patapsco Ave.
Baltimore, MD 21225

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 (S2TS) team is managed by the Maryland Department of General Services (DGS) Office of Energy and Sustainability (OES) and collaborates with multiple state agencies. The UMD S2TS team consisted of Oluwaferanmi Kolade Akinpelu and Soumya Agrawal supervised by Dr. Amir Shooshtari & Dr. Michael Ohadi.

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Executive Summary

Governor Hogan's Executive Order 01.01.2019.08 - Energy Savings Goals for State Government was issued in July 2019 to signal the administration's desire to improve the energy efficiency of state-owned buildings, to reduce their environmental impact, and to save taxpayers' money. The executive order set the energy savings goal at 10% savings over a 2018 baseline by 2029. The executive order requires DGS to audit 2 million square feet of State facilities annually, and to present the audit reports to each building's owner. The executive order goes on to state that:
Each unit of state government that occupies the space audited shall, to the fullest extent practicable, implement the measures identified in the audit.

The UMD S2TS team divided the audit into three phases: Building Comprehension, Energy Model Development, and Energy Efficiency Measure analysis. The team carried out a facility walkthrough, analyzed the utility data and building plans to evaluate the energy usage of the building, and summarized their findings in this report. This report identifies actionable energy-saving opportunities to increase the building's energy efficiency.

Building Description

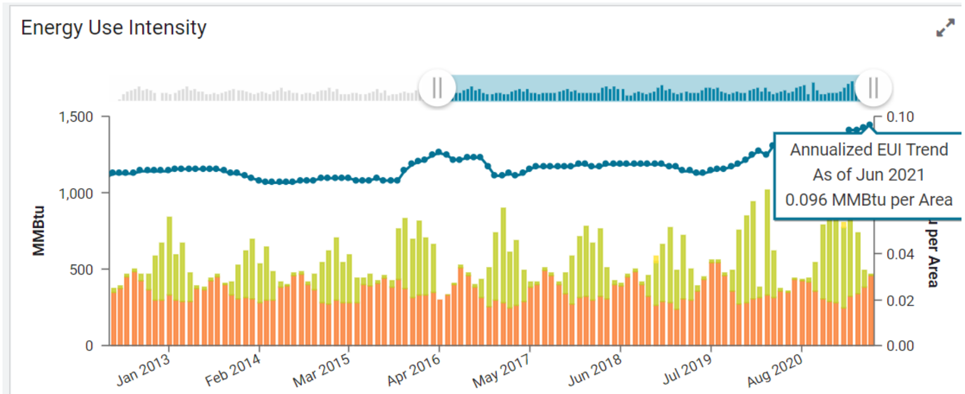
The Hargrove Court building is the District Court of Maryland for Baltimore City County located at 700 E Patapsco Ave, Baltimore, MD 21225. The building was originally constructed in 2003 and is a three-story building with an overall area of 84,730 sq.ft. Fig. 1 shows an overview of the Hargrove District Court.

Fig. 1 Hargrove District Court

The building houses primarily the office spaces and conference rooms on level 1 (ground floor). Level 2 houses courtrooms, judges' chambers, and office spaces. The penthouse houses a mechanical room including the Air Handling Unit (AHU) 1 & 2 and the basement houses holding cells and mechanical systems such as AHU 3, HVU, chillers and boilers.

The facility exemplifies a typical courthouse in function and floor plan layout. The building occupancy schedule is from 7:00 AM to 7:00 PM on weekdays (Monday to Friday) and the Commissioner's office works 24 hours. Based on our discussions with the Facilities personnel, the building HVAC system operates from 5:00 AM to 6:00 PM.

The building consumes energy from three energy commodities: electricity, solar, and natural gas. The electricity, solar panel and natural gas are metered and supplied by utility companies (Electricity and Natural Gas: BG&E & Solar Panel: Longroad Energy). The Solar panel installed on the roof of the building is managed only by Longroad Energy, a renewable energy developer company. Collectively from the grid and solar panel, the building annual average electricity consumption **is 1,241 MWh and** the building annual average natural gas consumption is **24,501 therms**. The annual average utility cost of the building is **$148,110.**



I. Energy Efficiency Measures

After the baseline energy model was validated, a series of actionable proposals aimed at increasing the building's energy efficiency were identified and simulated to estimate the energy and cost savings that will result from their implementation.

Savings associated with following all the recommendations:

- Annual utility cost reduction of 16.7% resulting in $23,178 utility savings
- Annual electricity consumption reduction of 18.4% resulting in $22,300 savings
- Annual natural gas consumption increased by 4.0% resulting in $878

List of recommended energy efficiency measures (EEM):

<u>EEM 1</u> – Retrofit AHU OSA Damper

- Reduce the OSA of AHU to a minimum of 15%

Fixing/Upgrading the dampers of the AHU can further help in making the system more energy efficient. From the BAS in the Hargrove building, the current AHUs have about 40% OSA. If the OSA can be reduced to a minimum of 20%, the electric consumption decreases due to the reduce electric demand of the pump and ventilation.

<u>EEM 2</u> - Lighting Upgrades

- LED fixtures
- Lighting controls

The building currently employs fluorescent lighting. Most of the building is served by T8's and occupancy sensors. 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 a longer rated life which would mean fewer costs associated with replacing them. This work would need to be contracted out as the lights would need to be retrofitted to fit LEDs. Lighting control options further enhance the energy-saving potential of LED lighting. During the retrofit controls such as daylight saving, occupancy, dimming can be integrated into the lighting system to yield energy savings. Transitioning towards LED lighting along with controls could yield electricity savings of around 50% - 60% of total lighting consumption.

<u>EEM 3</u> - Pump Upgrade

- Change the Pump controls to variable speed drive (VSD)

Pumping systems account for nearly 20% of the energy used by electric motors in the building. The control pump speed running in the Hargrove building is constant. Therefore, if the pump speed can be reduced and still operate as effectively, less energy is imparted to the fluid and less energy is needed to be throttled. The speed can be controlled by a variable speed drive (VSD). The VSD is the preferred option because it varies the flow needs on a regular basis. This is the most efficient method of flow control, and it does not waste any of the shaft input energy.

Pumps			
Designation	**Service**	**Type**	**Flowrate (GPM)**
P-CW-1	Chilled water pump	End Suction	632
P-CW-2	Chilled water pump (Stand-By)	End Suction	632
P-HW-3	Hot water pump	End Suction	330
P-HW-4	Hot water pump (Stand-By)	End Suction	330
P-HW-5	Hot water pump (Circulation)	In-Line	29

<u>EEM 4</u> - Chiller Replacement

- Replace the chiller with a more energy efficient model.

The chiller in the Hargrove building is 18 years old and in most cases the life of a rotary screw chiller is ranges 20-25 years. The chiller was installed when the building was built and its efficiency (2.90 COP) was quite low for today's chillers. If the chiller were to be replaced, the electric demand will decrease to about 5%, saving $5800. In the future, after replacing the chillers, the HVAC system schedule can be optimized to further saving more energy.

The chilled water is supplied by a packaged air-cooled helical rotary compressor chiller (Trane Model RTAA300) with a capacity of 300 tons (1055.1 kW). The chiller is controlled by the Building Automation System (BAS). Two constant speed pumps supply the chilled water throughout the facility. The pumps are rated at 20 HP (14.9 kW) each. The chiller supplies the chilled water to AHUs. Fig. 2 shows the chiller unit installed on the roof. The chiller was installed in 2003.

Fig. 2 Chiller Unit

Chiller		
Designation	**Tons**	**Type**
CH-1	300 Tons	Rotary Screw

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. For the values in the summary table, the calculations are performed using the current chiller and boiler capacities.

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 - Retrofit AHU OSA Damper	**1213**	**20252**	**2**	**2517**	**0.2%**	**11.1%**	**220**	**2517**	**2,737**
EEM 2- Lighting Upgrades	**1098**	**23842**	**117**	**-1073**	**9.6%**	**-4.7%**	**11680**	**-1073**	**10,607**
EEM 3 - Pump Upgrade	**1152**	**23349**	**63**	**-580**	**5.2%**	**-2.5%**	**6310**	**-580**	**5,730**

EEM 4 – Chiller Replacement	**1115**	**22769**	**100**	**0**	**8.2%**	**0**	**10000**	**0**	**10,000**
Combined EEM's	**992**	**21891**	**223**	**878**	**18.4%**	**3.9%**	**22300**	**878**	**23,178**

***** 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 1215 MWh and 22,769 therm, respectively. The total annual utility cost of electricity (1215 MWh) and natural gas (22,769 therms) is $138,769. The observed annual utility savings after implementing the EEMs can reduce the annual utility cost by 16.7%.

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 Hargrove 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 (Rooftop 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).

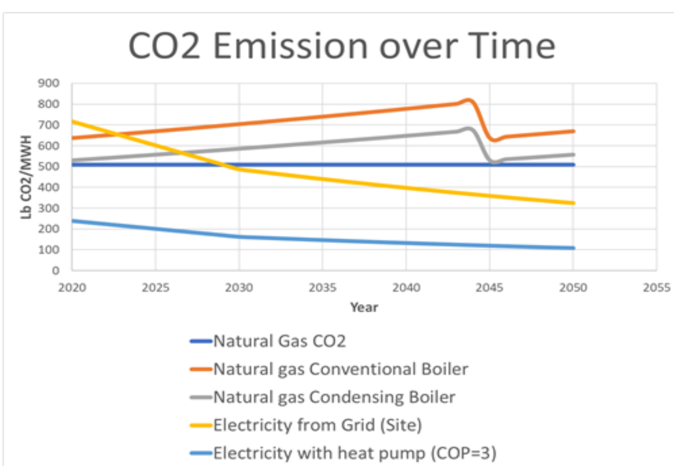
The proposed EEMs must pass a cost-effectiveness test to be eligible for a custom rebate incentive. To evaluate rebate incentives for the proposed EEMs, the target kWh savings would be 1.5 to 2 times the dollar cost of the project. (Example: if the project cost is $100,000, the target savings would be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

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 - Retrofit AHU OSA Damper	2	2517	1613	29197
EEM 2- Lighting Upgrades	117	-1073	85614	-12447
EEM 3 - Pump Upgrade	63	-580	46252	-6716
EEM 4- Chiller Replacement	100	0	73300	0
Combined EEM's	223	878	163459	10185

The above carbon footprint analysis shown in Table 5 is estimated for a specific efficiency wherein the equipment degradation would result in an increase of carbon dioxide emissions both for the upgrade and baseline equipment.

The above values are based on the State of Maryland estimates of 733 lb of 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 173,644 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. 12 below for more detail.



Additional Building Observations and Recommendations

Thermostat in the garage

- Install Thermostat (linked with the BAS) in the garage

The thermostat is used to control the temperature of a space. Therefore, the thermostats should be placed in the area they are serving to maintain a comfortable temperature in the space. In the garage of the Hargrove building, when the HVU is turned on, it is hardly monitored. Additionally it is turned on manually, therefore it could run for hours without actually needing the system to be operating. If the thermostat is placed in the garage area, it can control the HVU and maintain a comfortable temperature in the space. Subsequently, the thermostat should be linked to the BAS to allow for further accessibility which will ultimately save more energy. Fig. 14 shows a thermostat that could be placed in the garage of the building.

Thermostats in the Garage

Green Wall

- Green Wall

Green walls in the lobby area of the facility could be considered to further condition the air in the space. A drip free indoor living wall option (for water containment) can be considered in the lobby. Green/living walls contribute to indoor air quality.

They naturally provide oxygen, humidity, and reduce particulates and volatile organic compounds. Additionally, studies have indicated plants enable more productivity among the building occupants while also ensuring the comfort levels. Indoor living wall solutions provided by LiveWall could be considered for this lobby space [16](Fig. 15).

Fig. 15: Lobby Area

- **Outside Air Damper is not working properly.**

II. Building HVAC Description

The hot water is supplied by two forced draft gas fired boilers (Byran Boilers HECL-210) each with a capacity of 1,785 MBH (523.13 kW). The boilers are controlled by the BAS system as well. Two constant speed pumps 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 installed in the building. The boilers were installed in 2003.

Boiler Unit

The air that returns from the spaces in the building passes back to the packaged rooftop unit (RTU). There is only one RTU which also uses outdoor air and mixes it with the return air in order to produce fresher air flowing back to the spaces in the building. The RTU connects directly to a ductwork system that distributes the conditioned air through the space and returns it to the packaged rooftop unit. The RTU is located on the roof and the overall cooling size of the RTU is 10 tons and the overall heating size of the RTU is 350kbtu. It is also important to note that the RTU serves the east side of the first floor. Pic below shows the RTU unit installed in the building. The RTU was installed in 2003.

RTU Unit

There are three AHUs and one HVU in the building which serves most of the building needs, with supplementary hot water units installed throughout the facility. The first and second AHUs are located in the penthouse and the third AHU is located in the basement. The HVU is located in the basement. The first AHU serves the ground floor, the second AHU serves the second floor, the third AHU serves the basement, and lastly, the HVU serves the garage which is in the basement floor. The three AHU and HVU are each equipped with a hot water preheat coil, but only the three AHU and the RTU are equipped with a chilled water cooling coil (supplied from the chiller), and supply fans that are controlled by variable speed motors. AHU 1-2 has a corresponding return air fan mounted in the ductwork; each return air fan is also controlled by a constant speed motor. Supply air is delivered to each space via variable air volume (VAV) terminal units.

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

TAG	TYPE	LOCATION	AREA SERVED	COOLING COIL DATA																SUPPLY FAN DATA			
				CAPACITY		AIR DATA		EAT (°F)		LAT (°F)		WATER/30% PROPYLENE GLYCOL MIX DATA				COIL DATA		T.S.P. IN. WC	E.S.P. IN. WC	hp	rpm
				TOTAL MBH	SENSIBLE MBH	SUPPLY cfm	MIN O.A. CFM	EDB	EWB	LDB	LWB	EWT °F	LWT °F	gpm	P.D. FT. W.C.	FACE AREA, SF	FACE VELOCITY, fpm				
AHU-1	HORIZONTAL DRAW-THRU	PENTHOUSE	GROUND FLR.	776	558	16000	4720	82.1	67.5	54.0	53.5	42	54	148	26.0	39.3	458	5.9	1.30	25	1491
AHU-2	HORIZONTAL DRAW-THRU	PENTHOUSE	SECOND FLR.	1845	1031	28510	13,000	89.6	74.8	53.9	53.7	42	54	350	24.0	49.4	526	5.9	1.50	40	1463
AHU-3	HORIZONTAL DRAW-THRU	BASEMENT	BASEMENT FL.	293	145.5	4000	3625	91.0	77.0	54.0	53.9	42	54	50	11.5	6.8	500	4.0	0.75	3	1987
HVU-1	HORIZONTAL DRAW-THRU	BASEMENT	GARAGE	–	–	7650	7650	–	–	–	–	–	–	–	–	–	–	1.5	.5	10	1500

PRE-HEAT / HEATING COIL DATA							OPERATING WEIGHT LBS	DIMENSIONS			MANUFACTURER AND MODEL NUMBER (OR EQUAL)
CAP. MBH	AIR DATA			HOT WATER DATA				LENGTH	WIDTH	HEIGHT	
	F.V., fpm	EDB °F	LDB °F	EWT °F	gpm	P.D. ft w.c.					
820	519	13	55	180°F	82	6.5	5500	20'-8"	8'-0"	5'-2"	TRANE MODEL MCC-35
1184	545	13	55	180°F	118	9.1	8800	20'-8"	10'-0"	6'-2"	TRANE MODEL MCC-50
284	393	13	85	180°F	29	1.0	1350'	14'-0"	4'-0"	2'-8"	TRANE MODEL MCC-8
328	500	13	55	180°F	32	2.0	3000	14'-0"	6'-2"	3'-8"	TRANE MODEL MCC-17

PACKAGED GAS HEAT/ELECTRIC ROOF TOP UNIT SCHEDULE

TAG	SERVICE	LOCATION	EER	INLET/OUTLET FLOW TYPE	COOLING COIL DATA: CAPACITY NOMINAL TON	CAPACITY TOTAL MBH	CAPACITY SENSIBLE MBH	AIR DATA SUPPLY CFM	AIR DATA MIN O.A. CFM	EAT (°F) EDB	EAT (°F) EWB	LAT (°F) LDB	LAT (°F) LWB
RTU-1	FIRST FLOOR EAST HALF	ROOF	9.0	DOWN FLOW	27.5	304.2	224.0	8430	1760	81.5	67.2	57.4	55.8

TAG	EVAPORATOR FAN ESP (IN WG.)	EVAPORATOR FAN HP	EVAPORATOR FAN FLA	EVAPORATOR FAN RPM	COMPRESSOR DATA NO.	COMPRESSOR DATA LRA (EA.)	COMPRESSOR DATA RLA (EA.)	CONDENSER FAN NO.	CONDENSER FAN HP (EA.)	CONDENSER FAN FLA (EA.)	EXHAUST FAN NO	EXHAUST FAN HP (EA.)	EXHAUST FAN FLA (EA.)	GAS HEATING COIL CAPACITY MBH INPUT	GAS HEATING COIL CAPACITY MBH OUTPUT
RTU-1	1.2	10	12.5	700	2	95 14.2	18.1 27.3	3	1.1	3.5	2	1.0	3.1	250	202.5

BOILER–BURNER SCHEDULE

TAG	GAS FIRING RATE MBH	ENTERING WATER TEMP.°F	LEAVING WATER TEMP.°F	BOILER HP	OUTPUT MBH	BOILER EFFICIENCY %	ELECTRICAL DATA BURNER HP	VOLT	PHASE	CYCLE	OPERATING WEIGHT (LBS)	DIMENSIONS (IN.) LENGTH	HEIGHT	WIDTH	MANUFACTURER AND MODEL NUMBER
B-1	2,100	160	180	53	1785	85	1	460	3	60	3000	104	67	34½"	BRYAN BOILERS HECL-210 (OR EQUAL)
B-2	2,100	160	180	53	1785	85	1	460	3	60	3000	104	67	34½"	BRYAN BOILERS HECL-210 (OR EQUAL)

In addition, there are multiple hot water unit heaters installed in the facility to provide supplemental heating. The communication room is an area where a Mini-Split Inverter Heat Pump system AC unit with a capacity of 1.9 tons serves the room for 24 hours. The building's HVAC system works from 5 AM to 6:00 PM at a setpoint temperature of 70°F and 73°F during winter and summer respectively. During the unoccupied hours in winter and summer, the setpoint temperatures are 60°F and 88°F, respectively.

III. Methodology

The project can be generally divided into three phases: Building Comprehension, Energy Model Development, and Energy Efficiency Measure analysis.

Building Comprehension

Building comprehension is the process of data collection and analysis. This can be further divided into 4 categories: Utility analysis, Building walkthrough, Archival review, and monitoring the Building Automation System.

The first objective during the building comprehension phase is to understand the building's energy consumption patterns. Once notable patterns and characteristics of a building's energy consumption are known, they can be compared to available "benchmark" data to assess a building's relative performance.

A building walkthrough was conducted with the facility personnel. The aim was to provide a first-hand examination of all building spaces and equipment as well as establish relationships with people involved in the building's operations. The walkthrough was thorough and included visiting every available space, including mechanical and electrical rooms, offices, courtrooms. A walkthrough is often crucial in revealing operational issues and helping to elucidate building use patterns that cannot be found anywhere else. The building walkthrough revealed data including the integrity of building envelope and mechanical systems, thermal zone temperature controls and setpoints, office and courtroom equipment, construction materials, schedules, 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; but 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 Hargrove MSC, the facility has a working BAS system.

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 Lawrence 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. 5 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.

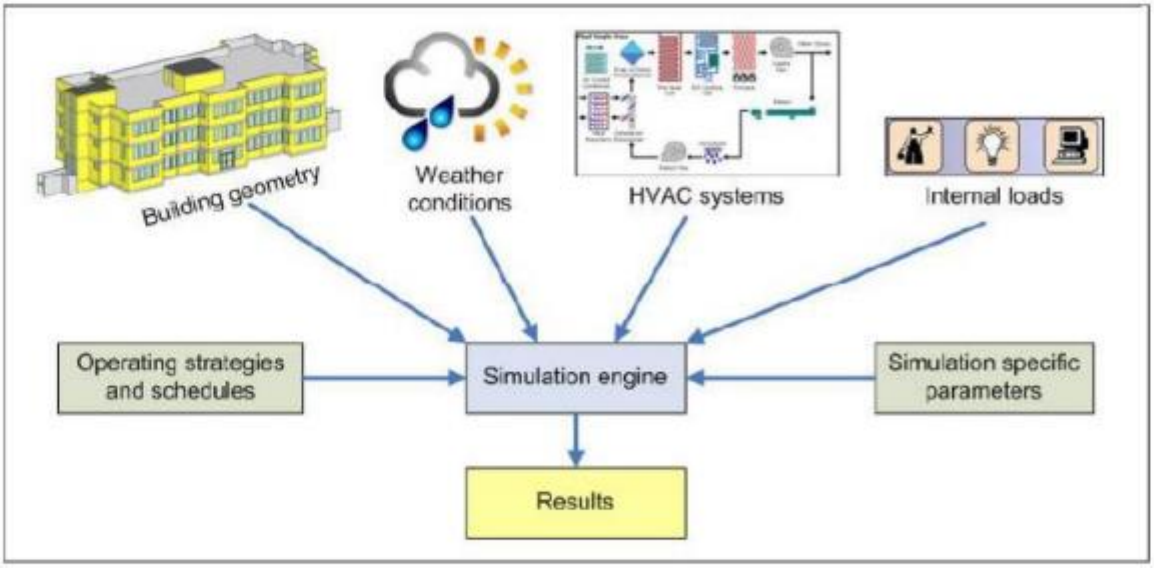


Fig. 5: General data flow of building energy simulation software. [2]

Energy Efficiency Measure Analysis

The energy efficiency measures were selected primarily through data obtained during the building comprehension phase and after reviewing the relevant literature. For example, the ASHRAE Standard 90.1 - 2019: Energy Standard for Buildings Except Low-Rise Residential Buildings provides full-scope strategies and technical guidance for achieving at least 30% energy savings [3]. ASHRAE also provides registrants with function-specific Advanced Energy Design Guides for achieving additional energy savings up to 50% [4]. When possible, these energy conservation measures were analyzed by the energy model of the building.

Load Calculations

The building load calculations were carried out to determine 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 was about 229 tons. The current chiller is 300 tons and the Rooftop unit has a capacity of 10 tons. Therefore, the total capacity is 310 tons. The current chillers and condensing units are oversized by about 35%. Subsequently, the total heating load for the boilers was about 1939 MBH and the current boilers are 1,785 MBH each, which works in a lead-lag control arrangement. Here, the boilers are oversized by about 84% 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 example, it is recommended that Data Centers and Hospitals have a redundancy of N+1 or 2N due to the essential services being carried out at these sites.

Utility Analysis and Benchmarking

Utility data from 2016-2019 were retrieved through the State of Maryland's EnergyCap tool, which collects and stores energy consumption data from most facilities in the State of Maryland. The total electric energy (listed in Table 2) usage is from both the grid and the solar panel which the building pays for. 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 [5].

Table 2: Utility Analysis and EUI Summary Calculation

	Electricity		Natural Gas		Water	Total Site Energy	EUI
	MWh/yr	kBTU/yr	therms/yr	kBtu/yr	Gal/yr	kBtu/yr	kBtu/SF/Yr
Baseline Energy Usage	1241	4,234,292	25,401	2,540,100	7,481	6,774,392	80

Fig. 6 and Fig. 7 show the average monthly electricity (from both the grid and solar panel) and natural gas consumption respectively for the years 2016-2019 and provides a number of key insights.

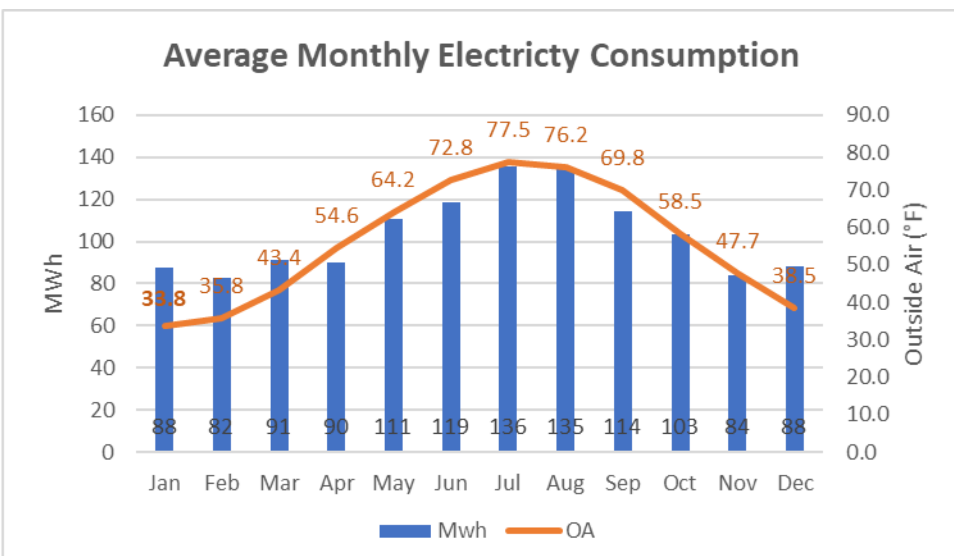


Fig. 6: Average Monthly Electricity Consumption [6]

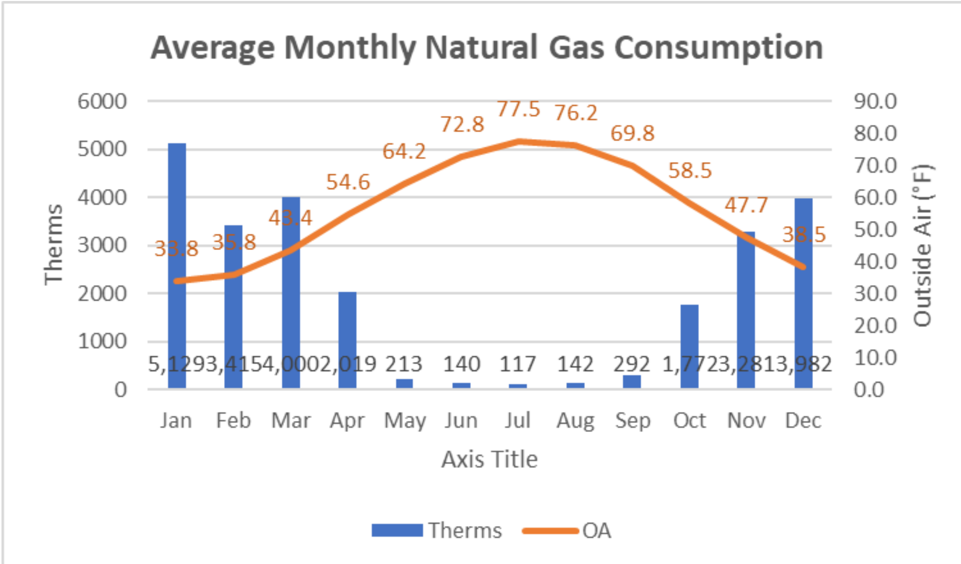


Fig. 7: Average Monthly Natural Gas Consumption [6]

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

Energy benchmarking assessment helps to identify the potential opportunities to improve energy efficiency and reduce the associated costs for utilities. To further verify the utility benchmarking calculations, benchmarking was performed using EnergyStar Portfolio Manager [7]. The Commercial Buildings Energy Consumption Survey (CBECS) database data was also used to evaluate the energy profile of the facility [8]. This comparison provides an opportunity to determine the scope of improving overall energy efficiency.

In the case of EnergyStar Portfolio Manager, the facility utility data was fed to the Portfolio Manager. These included electricity (both from the grid and solar panel), 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 [9].

Table 3: Benchmarking Results Summary

Parameter	Value (for Hargrove Building)	Standard Value	Reference
Energy Star Score (1-100)	56	-	EnergyStar Portfolio Manager
Site EUI (kBtu/sf)	78	101.2	EnergyStar Portfolio Manager
CBECS ($/sf)	1.74	1.84	(Electricity + Natural Gas)/Bldg sq.ft area

The overall Energy Star Score indicates 56 which indicates that the building is already performing above median energy performance. The value of 78 was obtained using EnergyStar Portfolio Manager and utility analysis yielded a close value of 80. Based on the benchmarking analysis, the Hargrove Court Building currently has an Energy Usage Intensity less than the average public courthouses (78 vs 101.2). The CBECS score is also less than the average value for commercial offices (1.74 vs 1.84). This means when compared to other reference courthouses the Hargrove MSC is performing well but there are still opportunities to increase the overall energy efficiency of the facility.

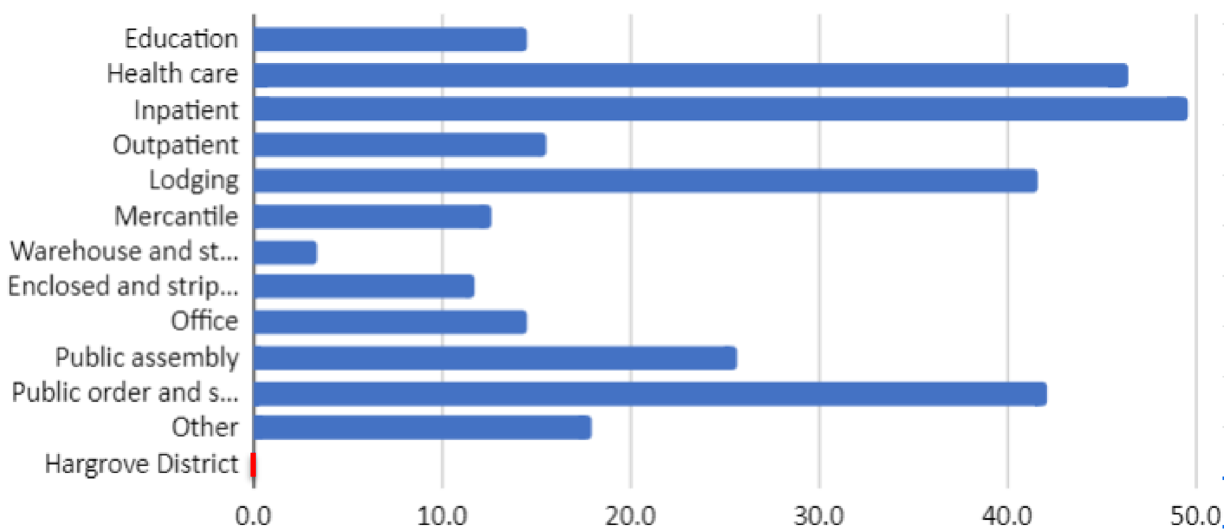


Fig. 8 Water Intensity (Gallons per sq. ft) [10]

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 Hargrove District Court with a sq. ft area of 84,730 has a water intensity value of 0.088 gal/sq. ft.

Energy Modeling

Baseline Energy Model

The physical structure of the Hargrove 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. Afterwards, the required zones were modeled into the floor layout and the subsequent HVAC systems were designed. The required model information (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 3 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. 8 shows the 3-D representation of the building model as rendered in eQuest.

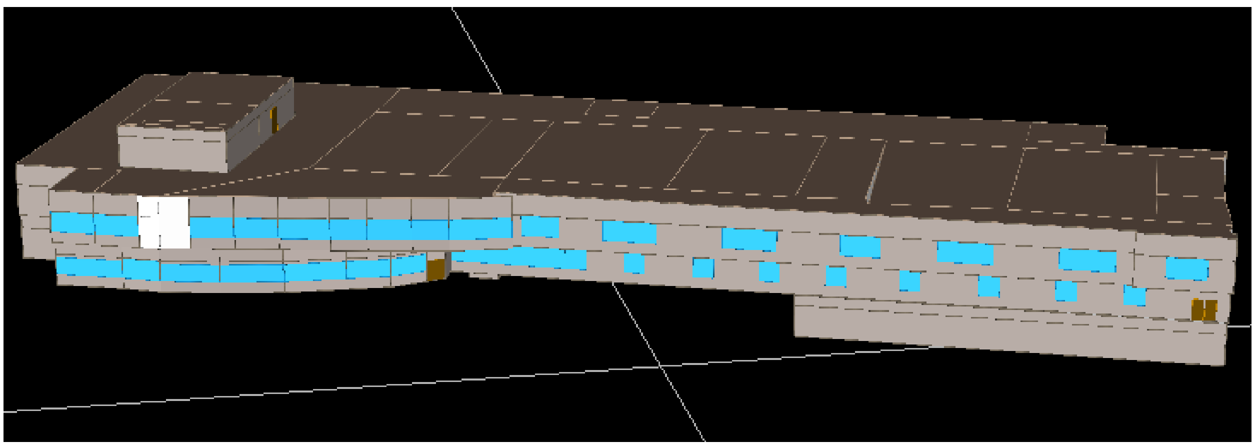


Fig. 9 Building energy model rendered in eQuest

The energy model had a total of 19 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.

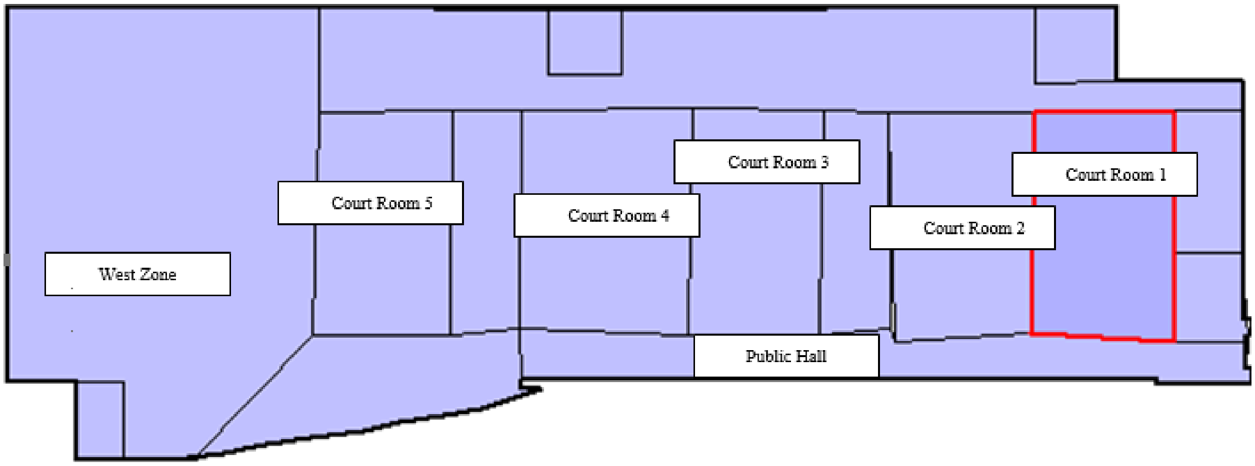


Fig. 10 Model thermal zone design (2nd floor).

The main space types defined to specify the lighting, plug loads, occupancy, and their associated schedules were offices, courtrooms, lobbies, holding areas. 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” model.

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.

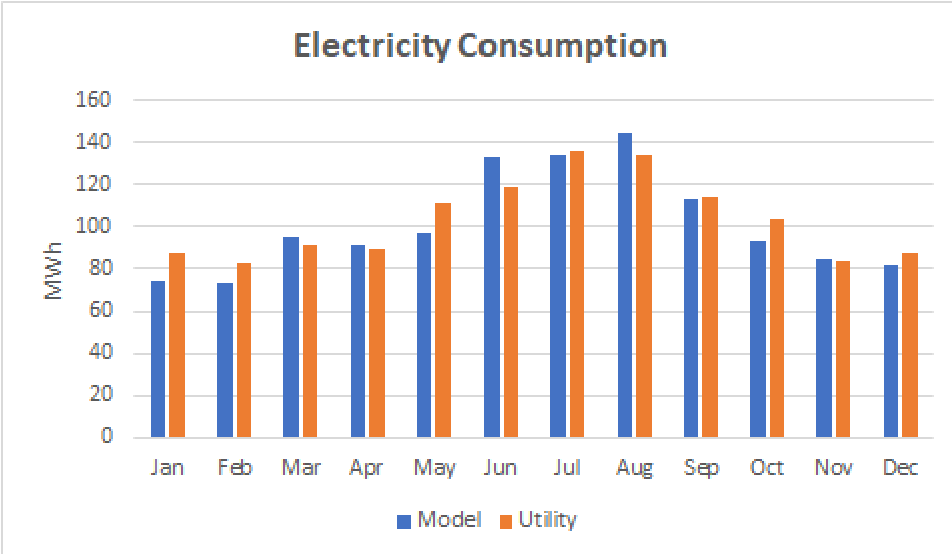


Fig. 11: Monthly electricity consumption comparison.

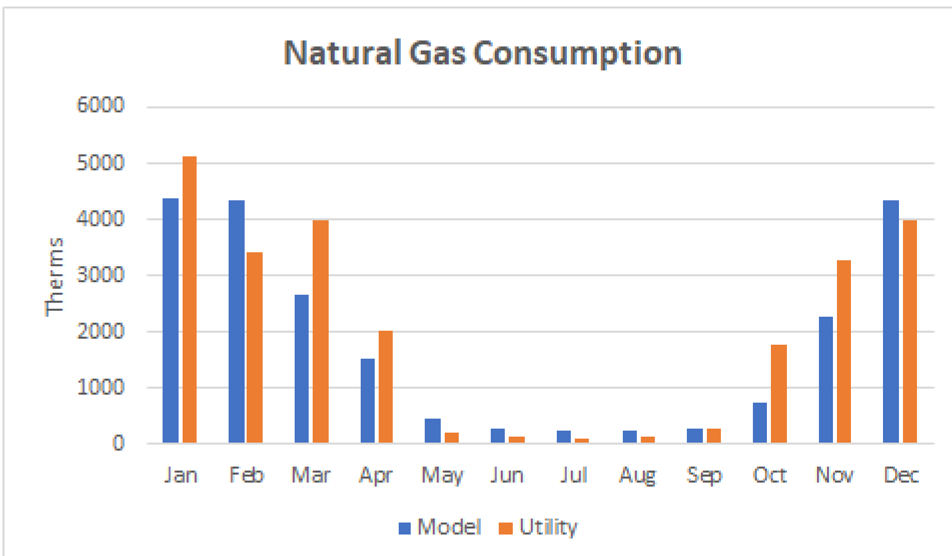


Fig. 12: Monthly natural gas consumption comparison.

The predicted monthly energy consumption of the baseline energy model closely matched the average monthly energy reported by utility bills between 2016 and 2019. In the case of electricity consumption, the values deviate by ~2% while the natural gas consumption values deviate by ~7%. The reason for the deviation in the electricity and natural gas consumption may be due to the discrepancy in the occupancy and scheduling of the building. This meets the ASHRAE calibration requirements as given by Guideline 14-2002 which allows a deviation of up to 15% [11].

IV. Future Scope

Building Decarbonization / Electrification Analysis

In 2018, the direct greenhouse gas emissions from the residential and commercial building sector accounted for 12.3% of total U.S. greenhouse gas emissions [17]. 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 [18].

Electrification

Electrification of end uses will be a key pathway to reducing emissions. Assuming a decarbonized power sector, using electricity for heating, cooling, and hot water needs, instead of burning natural gas or fuel oil, can greatly reduce a building's emissions. Based on DGS data on carbon emissions (Fig. 12, from above), by the year 2029, the carbon emissions in lb/MWh from the electricity grid will be along the same level as the amount from natural gas sources. This downward trend would continue after 2029 with the CO2 emissions from the electricity grid being less than that of natural gas sources. Heat pumps are currently one of the most, if not the most efficient available technology for space heating in the commercial and residential sectors. Although heat pumps have high initial capital costs, high efficiency and minimal maintenance make air source heat pumps a rewarding investment over the long term. Additionally, the CO2 emissions for an electric heat pump is less than that of a natural gas boiler. Other existing renewable thermal technologies such as geothermal heat pumps or solar water heaters can be installed as fossil fuel-powered replacements. Additional advancements in the heat pump to accommodate even colder conditions can be adopted in the next few years.

Electrification Analysis: Hargrove District Court

Currently, the Hargrove 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.

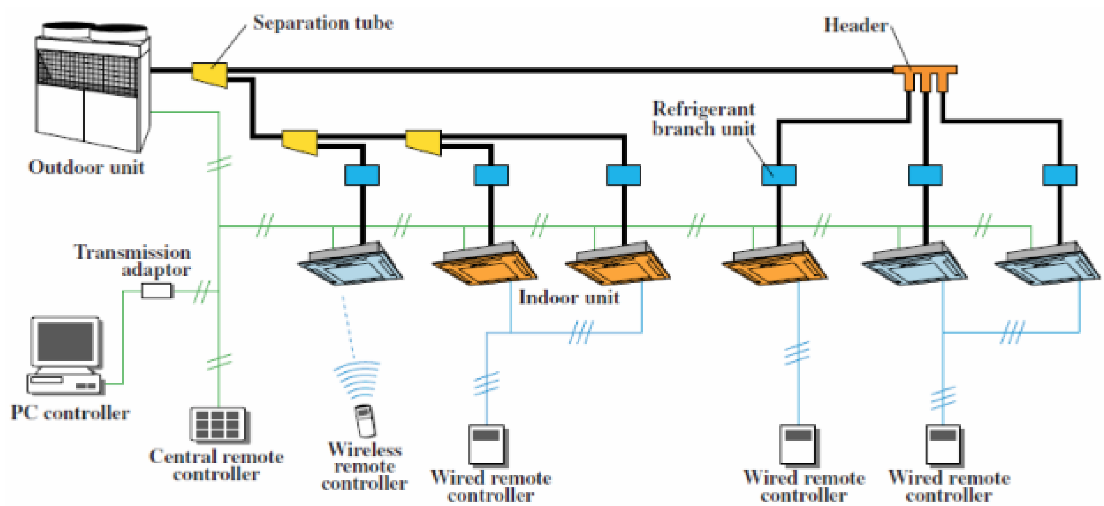


Fig. 16: A schematic VRF arrangement [19]

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 Hargrove District Court building [20]. 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 (reducing the OSA to an acceptable level) (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 helping to eliminate the need for natural gas altogether.

One positive is that Solar PV panels are already installed at the site to provide additional electricity to the building. There are 462 panels, each with 230 watts. This panels were manufactured by Yingli Solar and the yearly average amount of additional energy the solar panel provides to the building is approximately 118 MWh/yr.

V. Conclusions

The Hargrove District Court Building, overall, operates well. The building is not that old, it's only 18 years old.

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.

The facility would benefit from a HVAC system upgrade on account that the AHU OSA is about 40% which should be lower, and the pumps should be variable speed. Energy Efficient Measures were identified to transition the building system to newer technologies (such as LED lighting) and make the building energy efficient as a whole. The expected energy savings resulting from the implementation of energy efficiency measures will decrease the building's annual electricity consumption by 18.4% and natural gas consumption increase by 4.0%

Detailed and accurate building energy auditing and modeling are highly involved processes requiring substantial time, resources, and coordination. Buildings are complex systems whose behavior and energy consumption are often not understood without a thorough investigation of mechanical systems, electrical equipment loads, environmental conditions, and occupant behavior.

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

Initial Scope of Work

	Current System	**Proposed System**	**Comments**
AHU Dampers	40% OSA	~20%	A minimum of 20% OSA of the AHU will reduce the consumption usage.
Pump Upgrade	Constant Speed Drive	Variable Speed Drive	Most efficient method of flow control and it does not waste any of the shaft input energy
Rotary Screw Chiller	2.9 COP	3.9 COP	An increase to the COP will decrease the electric demand to about 5%
Lighting	Fluorescent	LEDs	LED along with occupancy, daylight and microphonics sensors
Green Wall	No Green Wall	Install Green Wall	

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