Towson District Court
for Baltimore County

120 E Chesapeake Ave, Towson, MD 21286

Energy Audit Report

Prepared for:

Maryland Department of General Services (DGS)

Prepared by:

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May 26, 2021

Project Team

In accordance with Governor Hogan's Executive Order 01.01.2019.08 Energy Savings Goals for State Government, this project was assigned to the UMD Smart and Small Thermal Systems team by the Maryland Department of General Services (DGS). The UMD S2TS team consisted of Alibek Bekenov, Soumya Agrawal, Ji Bae and Soham Joshi. Project supervisors were Dr. Amir Shooshtari and Dr. Michael Ohadi.

Acknowledgment

We would like to acknowledge Mr. Larry Stinson at the Towson District Court for Baltimore County for his help and cooperation during the walkthrough and for answering our questions. We would also like to thank Mr. David St. Jean for his leadership insights and overall guidance of the project and Mr. Tony Myers for his help in coordinating the walkthrough and assisting with gathering of the relevant technical information for the buildings studied.

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:

- Air Handling Units (AHUs) 3, 4, 5, and 6 are original to the building, which was built in 1994, but their heat transfer coils have been retrofitted.
- The interior lighting of the building is provided by fluorescent lamps. They are not controlled by occupancy sensors since there are none installed.
- Substantial oversizing of boilers and chillers is observed.
- The building has 7.4% energy saving potential when compared to the current baseline.
- Data rooms are not served by separate cooling system.

List of recommended energy efficiency measures (EEM):

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

- LED fixtures.

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

List of Additional Building Observations and Recommendations:

- Adding insulation to refrigerant lines for indoor and outdoor units.

- Separate cooling systems for Data rooms.

- Incorporating interior Green Walls to improve Indoor Air Quality.

See pages 19-21 for more details on the list of Additional Building Observations and Recommendations.

Savings associated with following all recommendations:

- Annual utility cost reduction of 7.4%, amounting to annual savings of $7438.
- Annual electricity consumption reduction of 11.5%, amounting to annual savings of $9421.

See pages 17-18 for more details on cost savings calculations.

Overview

Governor Hogan's Executive Order 01.01.2019.08 - Energy Savings Goals for State Government was issued in July 2019 to signal the Administration's desire to improve the energy efficiency of State-owned buildings to reduce their environmental impact, and to save taxpayers' money. The Executive Order set the energy savings goal at 10% savings over a 2018 baseline by 2029. The Executive Order requires DGS to audit 2 million square feet of State facilities annually, and to present the Audit Reports to each building's owner. The Executive order goes on to state that:

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

The DGS Office of Energy and Sustainability will coordinate with each building owner on financing and implementing the measures identified in this audit report.

Building Description

The Towson District Court for Baltimore County located at 120 E Chesapeake Ave, Towson, Maryland. The building was constructed in 1994 and is a two-story building with an overall area of 60,000 sq. ft.

Fig. 1: Towson District Court for Baltimore County.

The building primarily houses the courtrooms, judges' chambers, office spaces and library/conference rooms on levels 1 and 2.

The basement level consists of a parking garage for vehicles, along with holding cells for people awaiting court trials, storage spaces, smoking room, office spaces and mechanical rooms - containing equipment such as chillers, boilers, pumps, air compressors, AHUs 3, 4, 5, & 6. The parking garage houses 3 unit heaters and the sally port has 1 unit heater. There is 1 cabinet heater on each staircase of level 1, while in the public restrooms on each floor there are 2 such heaters. AHUs 1 & 2 and the Cooling Tower are located on the rooftop.

The building occupancy schedule is from 8 AM to 5 PM on weekdays (Monday to Friday). As per our discussions with the Maintenance Supervisor of the building and our review of the Building Automation System (BAS) configuration, the building's HVAC systems operate 24 hours a day, all around the year, at variable temperature setpoints - between 65°F & 80° F for cooling and between 60°F & 75°F for heating, depending on each zone's requirements and occupancy schedule.

The building meets its energy demands from two commodities: electricity and natural gas, both of which are metered and supplied by utility companies (<u>Electricity and Natural Gas</u>: BG&E, Constellation New Energy, WGL Energy). The building's annual average electricity consumption is 927 MWh and annual average natural gas consumption is 20,033 therms. Annual average utility cost of the building is $103,745.

Building HVAC Description

Chilled water for the cooling coils is supplied by three water-cooled hermetic dual scroll compressor chillers - Water furnace *WCHDM080D4SBBS3B8GXN00NSSS,* with rated capacities of 80 TR (281.3 kW) each. The chillers are controlled by a Building Automation System (BAS). Three variable speed pumps supply the chilled water to cooling coils in all AHUs - 1 to 6. Fig. 2 shows the type of chiller units installed in the basement level mechanical room. The chillers, pumps, piping and VAV units were all replaced within the last year.

Fig. 2: Chiller Unit.

Hot water for AHU coils is supplied by three gas-fired boilers (Lochinvar Power fin PBN1000), each with a capacity of 739 MBH (216 kW). The boilers are controlled by the BAS system as well. 3 constant speed pumps supply hot water to AHU coils, VAV reheat coils, and baseboard & ceiling-suspended unit heaters.

Domestic hot water is supplied by a gas-fired water heater (AO Smith) rated at 199 kBTUh (58 kW). 1 constant speed pump delivers domestic hot water throughout the building. Fig. 3 and Fig. 4 show the boilers and water heater installed in a mechanical room of the basement level. They were replaced in 2014.

Fig. 3: Boiler Units   Fig. 4: Domestic Water Heater

There are 6 AHUs in the building, which serve most of the building needs, with 2 supplementary split DX coil systems and multiple hot water and electrical unit heaters installed throughout the building. AHUs 3, 4, 5 & 6 are in the basement level mechanical rooms, and AHUs 1 & 2 are on the rooftop. AHUs 1 & 2 serve the entire 1st and 2nd floors respectively. AHU 3 serves the detention area, AHU 4 serves the storage, office, and smoking areas, AHU 5 serves the commissioners' office area, and AHU 6 serves the jury room, in the basement.

AHUs 3, 4, 5 & 6 have supply fans powered by constant speed motors, rated at 1 HP, 3 HP, 0.75 HP and 2 HP, respectively. Variable Speed motors with 20 HP power each control supply fans in AHUs 1 & 2 systems. All AHUs are equipped with a hot water preheat coil, a chilled-water cooling coil. In addition, AHUs 3 & 5 have DX (refrigerant) cooling coils. AHUs 1 & 2 have corresponding return air (exhaust) fans mounted in the ductwork; each return air fan is controlled by a variable speed motor. Supply air is delivered to each space via ducts, variable air volume (VAV) terminal units & diffusers.

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

Table 1: HVAC design specifications summary.

AIR HANDLING UNIT SCHEDULE

UNIT	SERVICE	LOCATION	SUPPLY FAN CFM	SUPPLY FAN O.A. CFM	SUPPLY FAN T. S.P. (IN W.G.)	SUPPLY FAN RPM	SUPPLY FAN HP–V/PH/HZ	EXHAUST FAN CFM	EXHAUST FAN S.P. (IN W.G.)	EXHAUST FAN RPM	EXHAUST FAN HP–V/PH/HZ	COOLING TOT/SENS MBH	COOLING EAT(DB/WB)	COOLING GPM	COOLING WPD (FT)	COOLING APD (IN W.G.)
AHU–3	GROUND FLR.	GROUND FLR.	1200	825	2.75	2400	1–480/3/60	–	–	–	–	68.8/41.6	88.8/74.0	12	1.0	.75
AHU–4	GROUND FLR.	GROUND FLR.	2930	[illegible]/700	3.25	1800	3–480/3/60	–	–	–	–	118.7/85.5	79.8/66.4	20	3.1	1.00
AHU–5	GROUND FLR.	GROUND. FLR.	1100	100	2.0	2060	3/4–480/3/60	–	–	–	–	30.4/26.0	76.8/64.0	5.5	.75	.35
AHU–6	GROUND FLR.	GROUND FLR.	1750	750	3.1	1800	2–480/3/60	–	–	–	–	102.6/63.8	83.6/69.6	17.5	2.5	.50

HEATING MBH	HEATING EAT (°F)	HEATING GPM	HEATING WPD (FT)	HEATING APD (IN W.G.)	NOTES	MANUFACTURER & MODEL NO.
82.1	21.8	8.2	.75	.10	1,2	TRANE – CLIMATE CHANGER #03 – VERTICAL DRAW–THRU
126.9	55	12.7	.40	.20	1,2 ,5	TRANE – CLIMATE CHANGER #06 – VERTICAL DRAW–THRU
47.6	55	4.8	.30	.10	1,2	TRANE – CLIMATE CHANGER #03 – VERTICAL DRAW–THRU
94.7	50	9.5	.20	.10	1,2	TRANE – CLIMATE CHANGER #06 – VERTICAL DRAW–THRU

GAS FIRED HOT WATER BOILER SCHEDULE

UNIT	FUEL	OUTPUT HTG. CAP. (MBH)	MAX. PRESS. DROP (FT. WATER)	E.W.T. °F	L.W.T. °F	AIR INTAKE (IN.)	VENT SIZE (IN.)	NOTES	MANUFACTURER & MODEL NO.
HWB–1	NAT. GAS	880	10	180	200	14	10	1	LOCHINVAR POWERFIN PBN1000
HWB–2	NAT. GAS	880	10	180	200	14	10	1	LOCHINVAR POWERFIN PBN1000
HWB–3	NAT. GAS	880	10	180	200	14	10	1	LOCHINVAR POWERFIN PBN1000

NOTES:

1. PROVIDE MANUFACTURERS RECOMMENDED COMBINATION EXHAUST/AIR INTAKE THRU–WALL VENT. NO SUBSTITUTIONS WILL BE PERMITTED FOR AIR INTAKE OR EXHAUST VENTS.

DOMESTIC WATER HEATER SCHEDULE

UNIT	STORAGE CAP (GALS)	INPUT (MBH)	RECOVERY (GPH @ 100 TEMP. RISE)	NOTES	MANUFACTURER & MODEL NO.
GWH–1	100	199	181	1,4	A.O. SMITH BTC–200

NOTES:

1 NAT. GAS FIRED
2 PROPANE FUEL
3 FUEL OIL
4 ELECTRICAL–110V/1PH/60AZ

COOLING TOWER SCHEDULE

UNIT DESIG.	CAP. MBH	GPM	ELECTRICAL FAN HP–V/PH/HZ	ELECTRICAL SUMP HEATER KW–V/PH/HZ	NOTES	MANUFACTURER & MODEL NO.
CT–1	3450	690	40–480/3/60	9–480/3/60	1,2,3	BALTIMORE AIR COIL VTL 245–P

1. ENTERING COOLING TOWER SUPPLY WATER AT 95°F; LEAVING WATER AT 85°F; 95/78 EAT (DB/WB °F)
2. APPROX. OPERATING WEIGHT 9000 LBS.
3. PROVIDE ROOF MOUNTED CURB. SEE DETAIL ON M–9.

Summaries of specifications for the AHUs 1 & 2, chillers & boilers installed in the building are shown in Table 2, 3 & 4, respectively.

Table 2: AHUs 1 & 2 specifications summary.

Unit	Service	Location	Supply Fan			Exhaust Fan			Manufacturer & Model #	Year of Installation
			CFM	Type	HP-V/PH/HZ	CFM	Type	HP-V/PH/HZ		
AHU-1	First floor	Roof	17100	VFD	20-460/3/60	14960	VFD	15-460/3/60	TRANE - Climate Changer CSAA030UBL00	2015
AHU-2	Second floor	Roof	18500	VFD	20-460/3/60	16700	VFD	15-460/3/60	TRANE - Climate Changer CSAA030UBL00	2015

Table 3: Chiller specifications summary.

Designation	CH1	CH2	CH3
Manufacturer	Water furnace		
Model No.	*WCHDM080D4SBBS3B8GXN00NSSS*		
Year of Installation	2020		
Capacity	80 Tons	80 Tons	80 Tons
Compressor Type	Dual Scroll	Dual Scroll	Dual Scroll
Cooling Method	Water-Cooled	Water-Cooled	Water-Cooled

Table 4: Boiler specifications summary.

Designation	BLR1	BLR2	BLR3
Manufacturer	Lochinvar Power-fin		
Model No.	PBN1000		
Year of Installation	2014		
Input (MBH)	999	999	999
Output (MBH)	850	850	850
Net AHRI Rating (MBH)	739	739	739
(M) / (B) / (F) Thermal Efficiency	85%	85%	85%
M Indicates 5:1 Turndown, Category IV B Indicates 2:1 Turndown, Category I F Indicates 100% On/Off Fire, Category I			

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 firsthand 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 integrity of the 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 this case, 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.

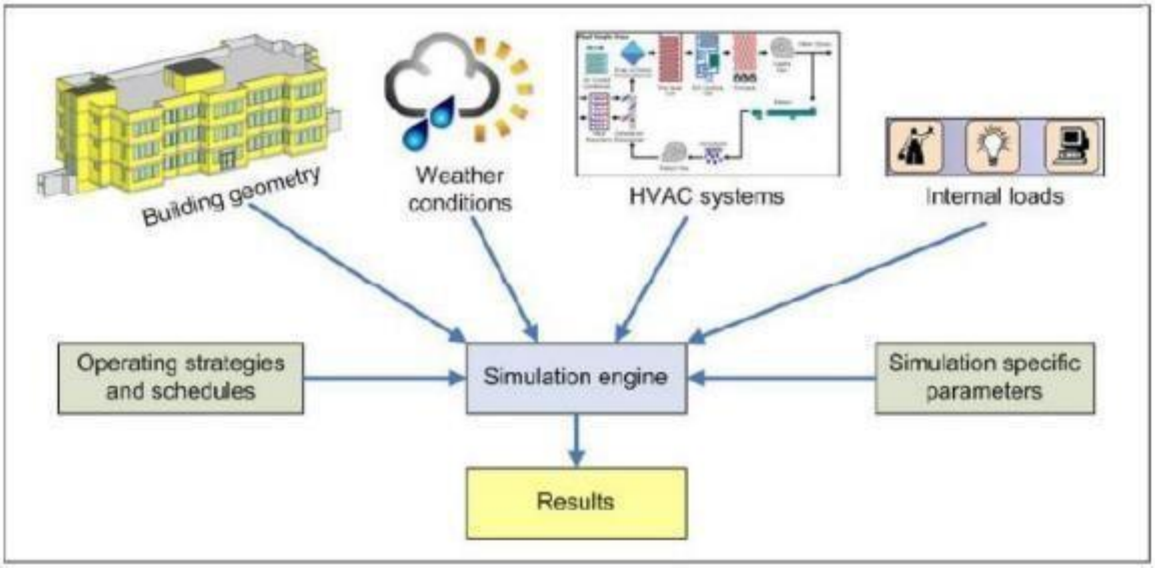

Fig. 5: General data flow of building energy simulation software. [2]

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 86 tons. The current chillers (3 in total) are rated at 80 tons each and the DX coil condensing units (2 in total) have a total estimated capacity of 5 tons. Therefore, the total installed capacity is 245 tons. Hence, the total installed capacity of the current chillers and DX coil condensing units is oversized by about 92%, assuming a redundancy of (N+1) was configured in the design. Focusing on the boilers, the total heating load was about 498 MBH and the current boilers are rated at a maximum net capacity of 739 MBH each. Therefore, combined capacity of the 3 boilers is 2217 MBH. Hence, the boilers are oversized by about 197%, compared to the building's heating needs, even when assuming a redundancy of (N+1), where N is the required number of units. For the highly mission critical facilities (such mission critical data centers, hospitals, and other mission critical facilities) one may use (2N) or (2N+1) redundancy, which is not the case for this building. However, even under (2N+1) redundancy a 50% unnecessary oversizing is observed.

Utility Analysis and Benchmarking

Utility data from 2016 to 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. Monthly energy consumption data for the electricity and natural gas were obtained in the units of kWh and therms, respectively, then converted to units of kBTU using conversion factors provided by the US DOE, and they are shown in Table 5 [5].

Table 5: Utility Analysis and EUI Summary Calculation.

	Electricity		**Natural Gas**		**Total Site Energy**	**EUI**
	MWh/yr	kBTU/yr	therms/yr	kBTU/yr	kBTU/yr	kBTU/sq.ft./Yr
Baseline Energy Usage	941.4	3,212,190	21063	2,106,300	5,318,490	88.64

Fig. 6 and Fig. 7 show the average monthly electricity and natural gas consumption respectively for the years 2016-2019 and provide a few key insights.

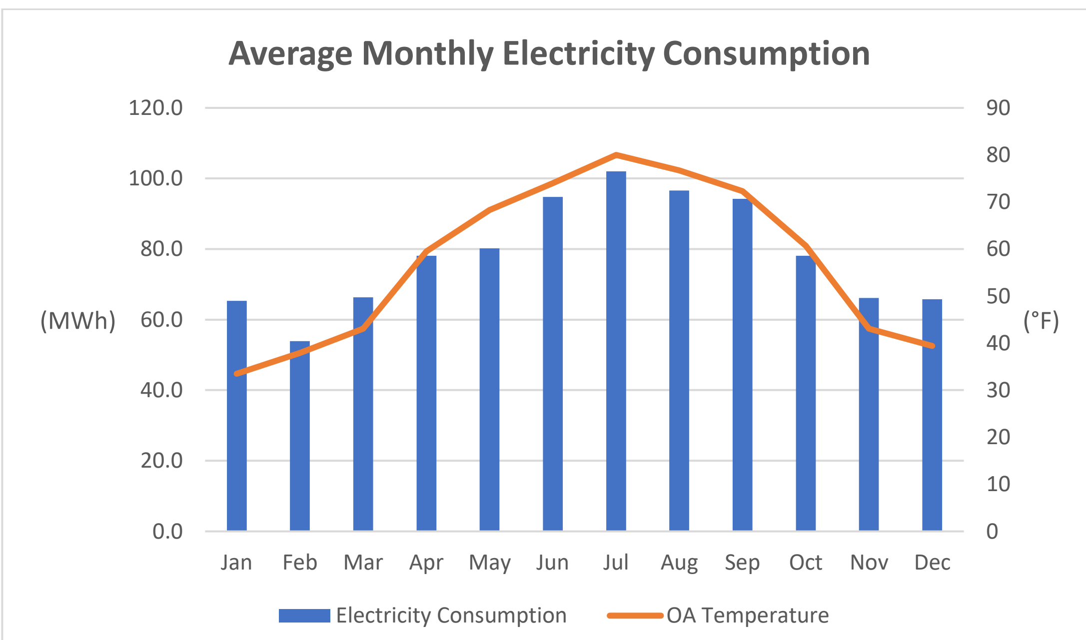

Fig. 6: Average Monthly Electricity Consumption [6]

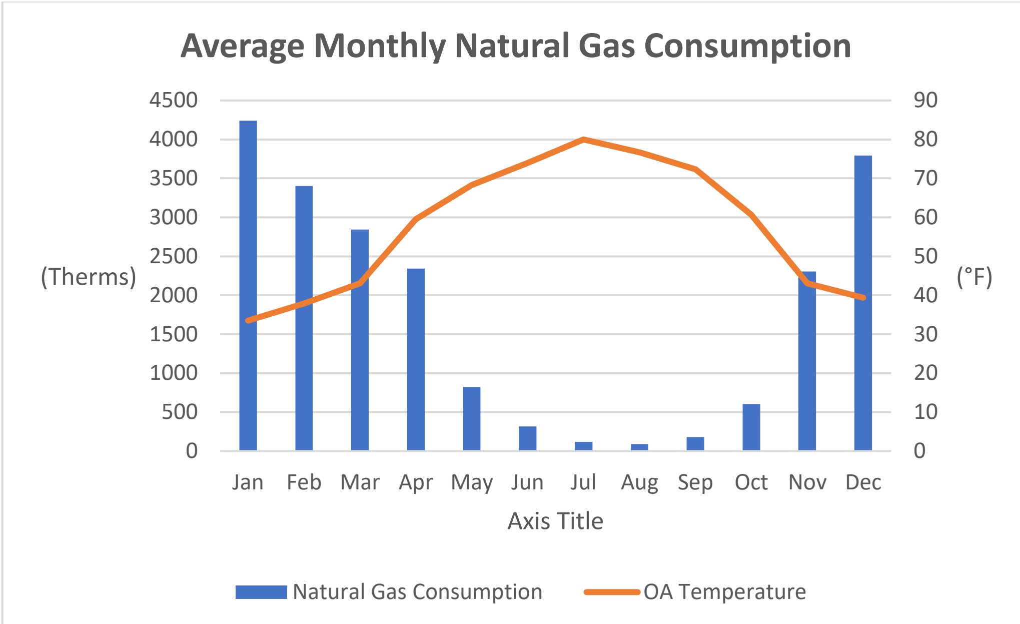

Fig. 7: Average Monthly Natural Gas Consumption [6]

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 humidification 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 and natural gas utility bills which were further supplemented with the facility data (such as floor area, building use, occupancy, etc.). Table 6 provides a summary of the result of benchmarking analysis using both the EnergyStar Portfolio Manager and the CBECS database. This table also compares the obtained value with the standard EnergyStar and CBECS score for a public courthouse [9].

Table 6: Benchmarking Results Summary.

Parameter	**Value for Towson District Court**	**Benchmark Reference**	**Reference**

Energy Star Score (1-100)	42	-	EnergyStar Portfolio Manager
Site EUI (kBTU/sq.ft.)	88.6	101.2	EnergyStar Portfolio Manager
CBECS ($/sq.ft.)	1.73	1.84	(Electricity + Natural Gas Utility Costs)/Building floor area

The overall Energy Star Score of 42 indicates that the building is performing below median energy performance. An Energy Usage Intensity (EUI) value of 88.6 was obtained using EnergyStar Portfolio Manager and utility analysis (2016-2019). Based on the benchmarking analysis, the Towson District Court has an EUI that is less than that of the average public courthouse (88.6 vs 101.2). The $/sq.ft. value is also lower than the CBECS average value for commercial offices (1.73 vs 1.84). This means that when compared to other courthouses, the Towson District Court is performing well and there might be fewer opportunities to increase the overall energy efficiency of the facility.

We have not included a Water Usage Intensity analysis, because sufficient utility data is not available on the EnergyCAP database for water usage (only 2 months worth of data is visible), and utility bill information was not provided outside of EnergyCAP for this building.

Energy Modeling

Baseline Energy Model

The physical structure of the Towson District Court & MSC was modeled in eQUEST. Initially, AutoCAD 2021 was used to create CAD drawing (.dwg) files based on PDF scans of the architectural plans. 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 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.

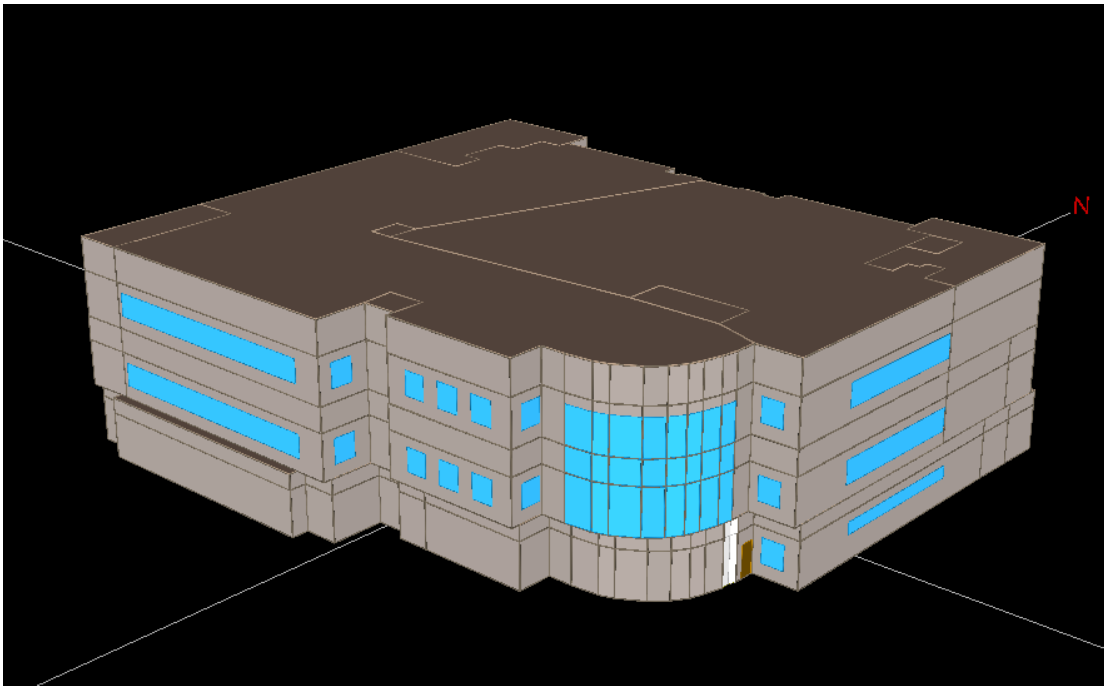

Fig. 8 (a): Building Energy Model rendered in eQUEST (viewed from south-east direction).

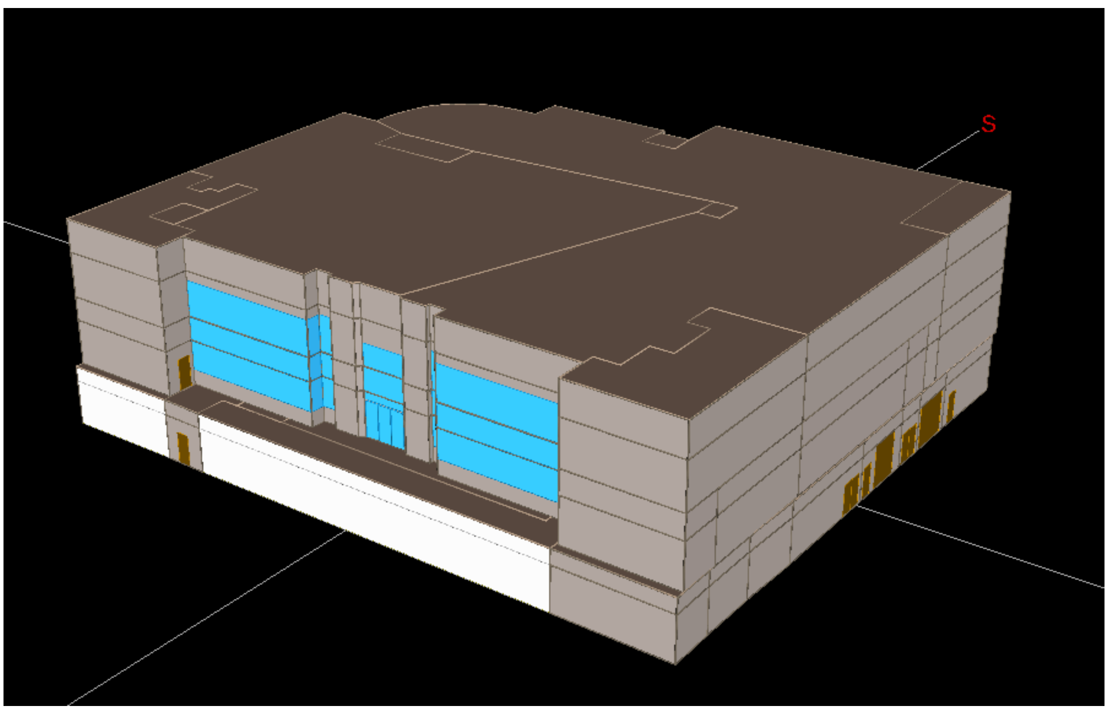

Fig. 8 (b): Building Energy Model rendered in eQUEST (viewed from north-west direction).

The energy model has a total of 50 thermal zones. Each thermal zone represents a space served, or not served, by an AHU on a given floor. Fig. 9 illustrates the thermal zone layout for level 1 -

basement. Each zone was provided with unique VAV terminal specifications, exhaust capacities, and thermostats, if any, derived from the original mechanical drawings.

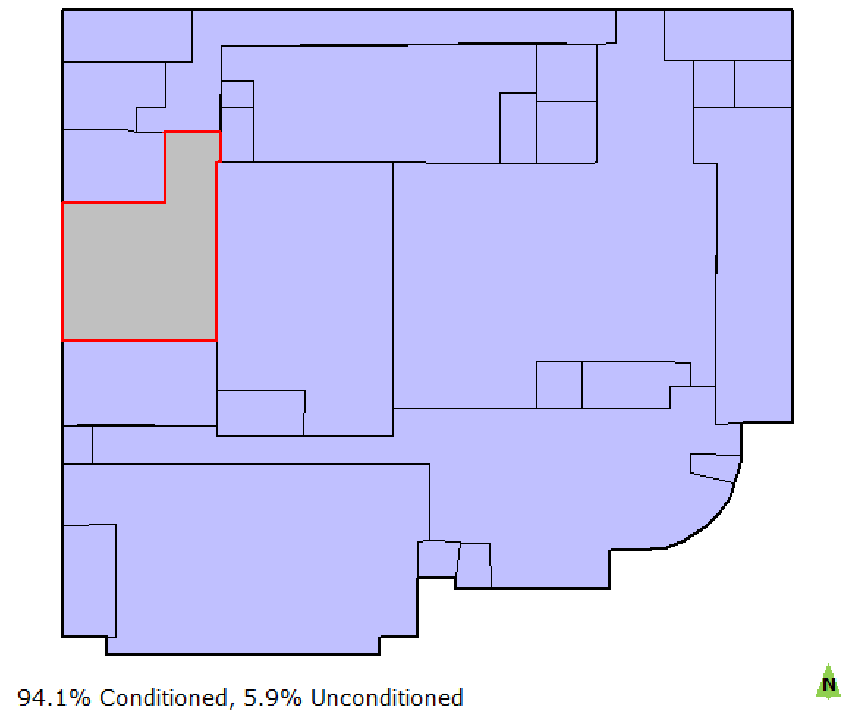

Fig. 9: Model thermal zone design (Level 1 – basement).

The main types of spaces defined - to specify the lighting & plug loads, occupancy, and their associated AHUs, were offices, courtrooms, lobbies, holding areas. These definitions were developed through the process of building comprehension.

The eQUEST has two modes of data entry: “Schematic Design Wizard” and “Design Development Wizard”. Building envelope and boundary conditions, fenestration, and construction materials, space type definitions, occupancy & schedules, thermal zones, HVAC definitions and temperature set-point schedules, as well as equipment & lighting loads, were all entered using the “Design Development Wizard”.

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. 10 and Fig. 11 show the results of the baseline energy model’s monthly energy consumption as compared to the building’s actual monthly energy consumption data for both electricity and natural gas.

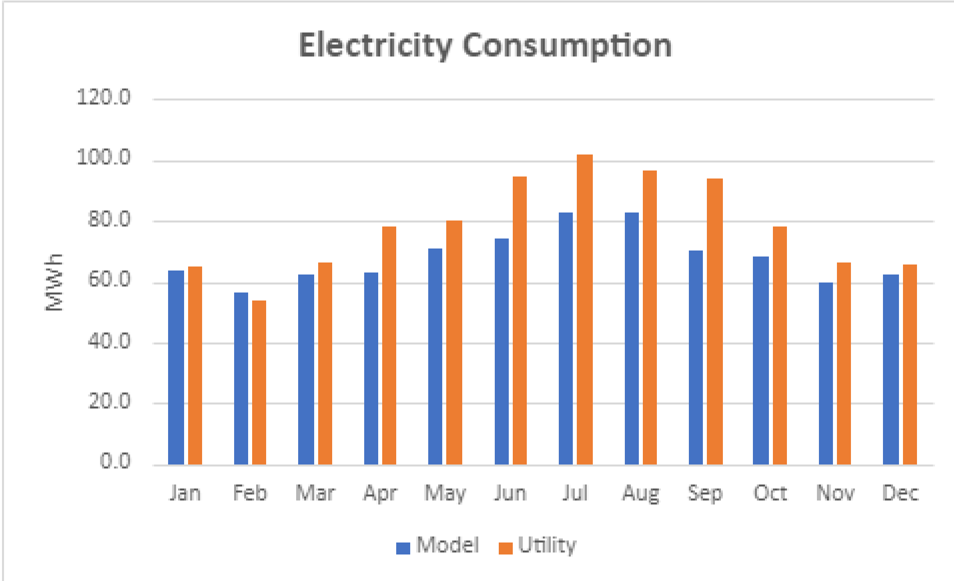

Fig. 10: Monthly electricity consumption comparison.

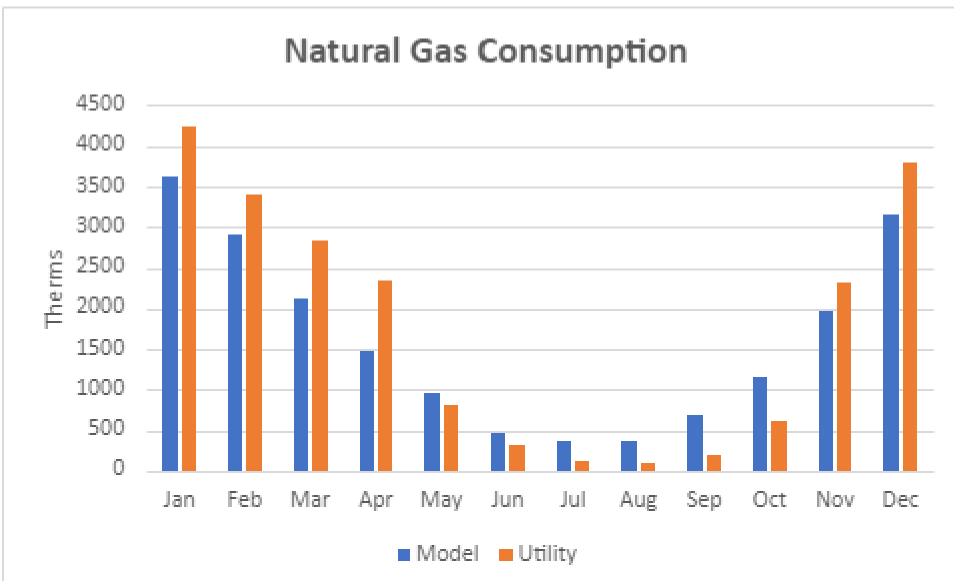

Fig. 11: Monthly natural gas consumption comparison.

The predicted monthly energy consumption from the baseline energy model was in close range of the average monthly energy consumption reported by utility bills between 2016 and 2019. In the case of electricity consumption, the values deviate by ~13.4% annually, while the natural gas consumption values deviate by ~8.7% annually. This meets the ASHRAE calibration requirements as given by Guideline 14-2002 which allows a deviation of up to 15% [11]. The reason for the deviations in electricity and natural gas consumption may be due to discrepancies in the miscellaneous loads, occupancy, and scheduling of the building.

Energy Efficiency Measures

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

EEM 1 - Lighting Upgrades

The building currently employs fluorescent lighting, with no occupancy sensors. Most part of the building is served by T8 fixtures. Upgrading these fixtures to LED solutions has multiple end-user benefits. Installation of LED lighting, along with occupancy sensors can yield significant energy savings while also reducing the maintenance and labor costs associated with fluorescent 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 sensing operation, and dimming can be integrated into the lighting system to yield energy savings. Transitioning towards LED lighting could yield energy savings of around 50% - 60%, in comparison to the existing lighting system.

Energy Efficiency Measure Savings

The Energy Efficiency Measure discussed above was simulated over the baseline energy model and the expected savings resulting from the implementation of these measures are summarized in the table below (Table 7). For the values shown in the summary table, the calculations were performed using the current chiller and boiler capacities.

Table 7: Energy and Cost Savings Summary.

	EEM Simulated		Projected Energy Savings				Utility Savings*		
Energy Efficiency Measures (EEMs)	Electricity (MWh/yr)	Natural Gas (therms/yr)	Electricity (MWh/yr)	Natural Gas (therms/yr)	Electricity (%)	Natural Gas (%)	Electricity ($/yr)	Natural Gas ($/yr)	Total ($/yr)
EEM 1 - Lighting Upgrades	722	21124	94	-1893	11.5	-9.8	9380	-1893	7487

***** 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 815.6 MWh and 19231 therms, respectively. The total annual utility cost of electricity ($81,558) and natural gas ($19231) is $100,789. The observed annual utility savings after implementing the EEMs are 7.4%.

Table 8: Carbon Footprint Analysis.

	Projected Energy Savings		Carbon-dioxide Reductions	
Energy Efficiency Measures (EEMs)	**Electricity (MWh/yr)**	**Natural Gas (therms/yr)**	**Electricity (lbs./yr)**	**Natural Gas (lbs./yr)**
EEM 1 - Lighting Upgrades	94	-1893	68755	-21959

The above values are based on the State of Maryland estimates of 733 lbs. of CO2 emissions per MWh of electricity consumed based on 2019 data [13] and 11.6 lbs. of emissions per therm of natural gas consumed [14]. Implementation of all the EEMs would result in a reduction of 46,796 lbs. of carbon-dioxide emissions per year. However, it must be noted that the CO_2 emissions per MWh for the grid electricity source is projected to continue to drop over time (with a rate of 23 lbs./MWh per year until 2030 and 8 lbs./MWh per year afterwards) due to use of cleaner fuels and renewable energy sources. See Fig. 12 for more details.

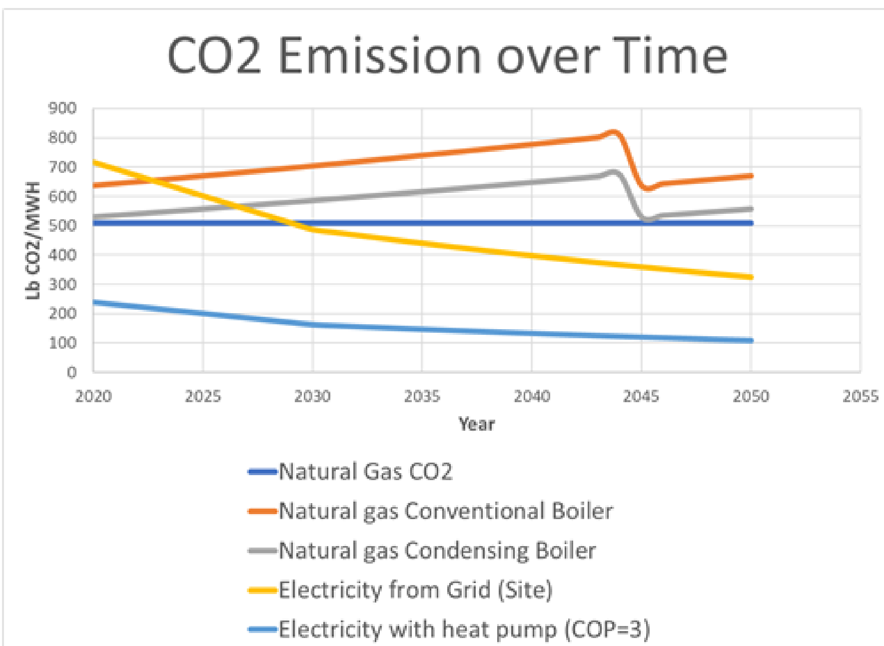

Fig. 12: CO_2 emissions over time.

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, since the Towson District Court is <75,000 sq. ft, it falls under the Small Building Tune-up category. 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 fan and pump motors with VFDs, with incentives per motor HP controlled), and Prescriptive Lighting. Rebates can be classified into End-of-Life Replacement (up to 75% of the incremental costs for more efficient equipment, capped at $0.28/kWh saved annually) and Retrofit (up to 50% of the costs for more efficient equipment, capped at $0.28/kWh saved annually) categories.

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 should be 1.5 to 2 times the dollar cost of the project. (Example: if the project cost is $100,000, then the target savings should be at least 150,000 kWh).

Additional Building Observations and Recommendations

Insulation for refrigerant lines

During our walkthrough of the basement level, we noticed that the lines carrying refrigerant are missing the required insulation. Fig. 13 shows the uninsulated lines.

Fig. 13: Missing Insulation on Refrigerant-carrying lines.

A lack of insulation results in unwanted heat transfer between the tubes and the surroundings, reducing the cooling capacity of the refrigerant by the time it reaches the evaporator coil in the air handling unit. Therefore, adding insulation to the tubes will reduce thermal losses & energy consumption of the DX coil and AHU systems by increasing their cooling efficiency.

Data room

Data rooms are high heat output zones. During our walkthrough, we found that there is no separate cooling system for server rooms. Currently, the entire building HVAC system operates 24/7 so that the data rooms maintain their set point temperature and to minimize the risk of any equipment overheating in the data rooms. Installing a Variable Refrigerant Flow (VRF) system or creating special thermal zones can isolate the data rooms' heating and cooling loads from the rest of the building. This way, the data rooms can be maintained at their fixed setpoints while the rest of the building is maintained at variable setpoints by the HVAC system, according to their occupancy schedules (Fig. 14).

Fig.14: Data rooms in the basement and on the first floor.

Green Wall

Adding Green walls in the lobby area of the building 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 improve indoor air quality.

They naturally provide oxygen, humidity, and reduce particulates and volatile organic compounds. Additionally, studies have indicated plants increase productivity of the building's occupants, while improving their comfort level. Indoor living wall solutions provided by Live Wall could be considered for these areas in the lobby [15] (Fig. 15).

Fig. 15: Areas in the lobby suitable for installation of Green Walls.

Future Scope

Building Decarbonization / Electrification Analysis

In 2018, direct greenhouse gas emissions from the residential and commercial building sector accounted for 12.3% of total U.S. greenhouse gas emissions [16]. Greenhouse gas emissions from this sector vary from year to year, often correlated with the 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. 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 appliances with efficient electric appliances in existing buildings and constructing new buildings as all-electric is the primary approach to building decarbonization [17].

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's data on carbon emissions (Fig. 12, from above), by the year 2029, carbon emissions in lbs./MWh from the electricity grid will be along the same level as that from natural gas sources. This downward trend would continue after 2029 with CO_2 emissions from the electricity grid being less than that of natural gas sources. Heat pumps are currently one of the most, if not the most efficient available technology for space heating in the commercial and residential sectors. Although heat pumps have high initial capital costs, high efficiency and minimal maintenance make air source heat pumps a rewarding investment over the long term. Additionally, the CO_2 emissions for an electric heat pump is less than that of a natural gas boiler. Other existing renewable energy-powered 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 for accommodating colder conditions could be adopted in the next few years.

Energy Efficiency

Buildings undergo several phases over their lifetimes, including design, construction, operation, and retrofits. In each stage, there are opportunities to improve energy efficiency and reduce emissions: designing a building to use more natural lighting or install district heating (like 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: Towson District Court

Currently, the Towson District Court satisfies its heating and cooling needs using traditional boilers and chillers. Here, an all-in-one Variable Refrigerant Flow (VRF) system is discussed as an alternative technology to satisfy the building's heating and cooling loads, and further explore the scopes of building electrification.

VRF is an air-conditioning system configuration where there is one outdoor (condenser) unit and multiple indoor (evaporator) units. The term VRF refers to the ability of this system to individually control the amount of refrigerant flowing through every evaporator, enabling the use of multiple 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 through condensers/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.

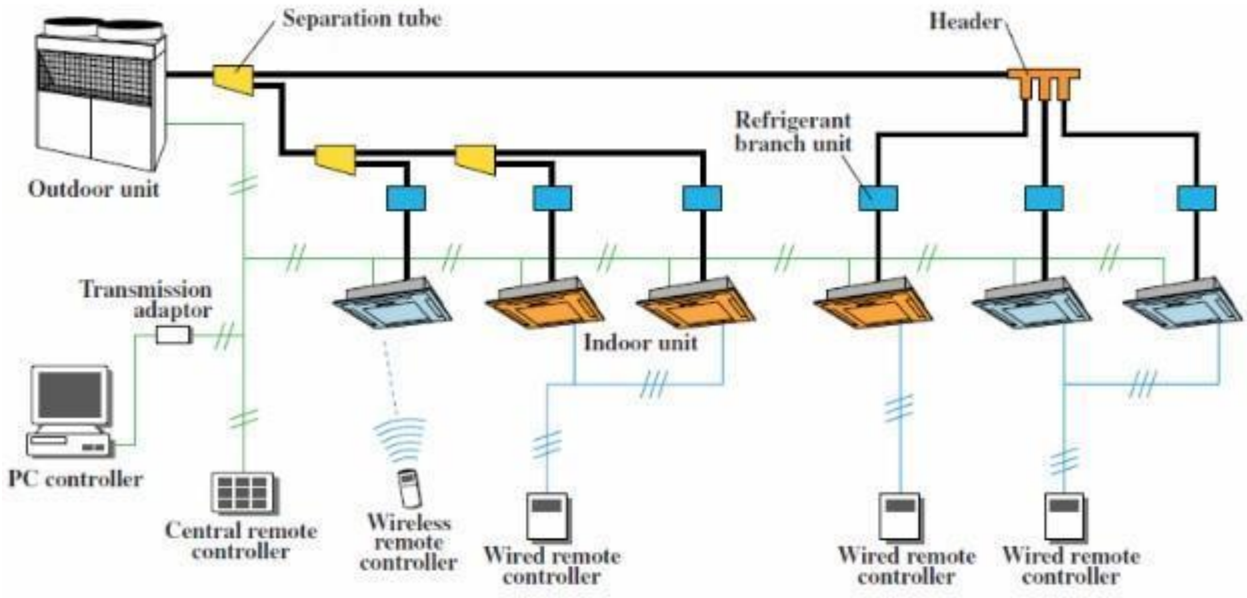

Fig. 16: A schematic VRF arrangement. [19]

There are 2 types of VRF systems: heat pump and heat recovery. VRF heat pump systems permit heating or cooling in all 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 Towson District Court building [19]. 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 it can be utilized from any networked PC, tablet, or smartphone.
A VRF system could replace the current chillers and boilers of the building, and it would also enable progress towards the State of Maryland's future greenhouse gas and environmental goals, starting with 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 [20]. For example, at the Towson District Court, a 50 kW system can generate about 68680 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 renewable electricity from utilities wherein the sourced renewable energy could go hand in hand with the site renewable energy implementation. Rebate incentives can be claimed in the form of Solar Renewable Energy Credit (SRECs) [22], also called alternative energy credits in Maryland. SRECs are created for each 1000 kWh of electricity produced by a qualified alternative energy source. There is no specific size limit, but the systems generally must be connected to the distribution system serving the State, for qualifying.

Initial Scope of Work

	Current System or Specifications	Proposed System or Specifications	Comments
Lighting	Fluorescent lamps	LED lamps	LED lamps, along with occupancy, daylight, and microphonic sensors.

Conclusion

Although the Towson District Court is operating with an EUI lower than that of the average public courthouse, it has a lower than median EnergyStar Score. It was also found that the building's HVAC systems are oversized in comparison to the simulated cooling and heating loads, but most of the equipment has been replaced within last year, with the exception of the boilers - which are 7 years old. Therefore, upgrading lighting systems to newer technologies (such as LED lamps with occupancy sensors) was identified as one of the main energy efficiency measures for this building. Implementation of the measure will decrease the building's annual electricity consumption by 11.5%, and increase the annual natural gas consumption by 9.8%. Natural gas consumption would increase in order to compensate for less heat rejection from LED lamps into the conditioned space. But overall, there will be a reduction of 7.4% in the total utility costs.

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. The presented energy model in this report tries to incorporate the above-mentioned aspects as much as possible with the available information. The baseline energy model detailed in this report can serve as a useful reference for several parameters applicable 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] 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.

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

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

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

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

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

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

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

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

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

[12] https://www.naturalhandyman.com/iip/infhvac/ASHRAE_Chart_HVAC_Life_ Expectancy .pdf

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

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

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

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

[17] https://www.c2es.org/document/decarbonizing-u-s-buildings/

[18] www.seedengr.com/ Variable Refrigerant Flow Systems

[19] https://www.mitsubishipro.com/products/city-multi-vrf/outdoor

[20] https://pvwatts.nrel.gov/pvwatts.php

[21] https://pepco.com/SmartEnergy/MyGreenPowerConnection/Pages/SolarIncentives Rebates.aspx

[22] https://programs.dsireusa.org/system/program/detail/5688