Rockville District Court Building

191 E Jefferson Street

Rockville, MD 20850

Energy Audit Report

Prepared for:

Maryland Department of General Services (DGS)

Prepared by:

UMD Smart and Small Thermal Systems (S2TS)

Dec 9, 2020

Project Team

The UMD S2TS team consisted of Soumya Agrawal, Thirumalesha Gudluru & Sorochukwu Okam supervised by Dr. Amir Shooshtari & Dr. Michael Ohadi.

Acknowledgment

We would like to acknowledge Ms. Nicole Leary and Mr. Buddy Long at Rockville District Court and Facilities Management staff for their help and cooperation during the walkthroughs and for answering our questions. We would also like to thank Mr. Tony Myers for his help in coordinating the walkthroughs and assisting with useful information.

Executive Summary

This energy audit supports Governor Hogan's Executive Order 01.01.2019.08 - Energy Savings Goals for State Government. The UMD S2TS team divided the audit into three phases: Building Comprehension, Energy Model Development, and Energy Efficiency Measure analysis. The team carried out a facility walkthrough, analyzed the utility data and building plans to evaluate the energy usage of the building, and summarized their findings in this report. This report identifies actionable energy-saving opportunities to increase the building's energy efficiency.

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 Rockville Court building is the District Court of Maryland for Montgomery's County located at 191 East Jefferson Street, Rockville, Maryland. The building was originally constructed in 2011 and it is a six-story building with an overall area of 167,000 sq.ft. It has 6-floor levels, and a penthouse roof housing the mechanical equipment. Fig. 1 shows an overview of the Rockville District Court.

Fig. 1: Rockville District Court

The building houses primarily the office spaces and conference rooms (on level 2 and 3), courtrooms, and judges' chambers (on levels 4, 5 and 6). Level 1 houses the Commissioner's office, a holding area, and other office spaces. The first-floor houses mechanical systems such as the chillers, boilers, and condensing unit (1-2). The roof houses Air Handling Units (AHUs 1- 4), cooling towers, and condensing unit (3-9). 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 our discussions with the Facilities personnel, the building HVAC system operates 24 hours with the same temperature during occupied and unoccupied hours.

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: WGL Energy; Natural Gas: Washington Gas).

Savings Opportunities:

- High EUI in the facility

- The existing chillers are oversized by 90%

- The existing natural gas boilers are oversized by 160%.

I. 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 from their implementation.

Savings associated with following all the recommendations:

- Annual utility cost reduction of 7.7% resulting in $45,530 utility savings
- Annual electricity consumption reduction of 10% resulting in $48,300 savings
- Annual natural gas consumption increased by 3% resulting in $2,770
- Annual savings obtained by resolving high EUI issue - electricity consumption reduction by 31% and natural gas consumption reduction by 60%. Estimated total savings of $210,421.

List of recommended energy efficiency measures (EEM):

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

- LED fixtures
- Lighting controls

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 a longer rated life which would mean fewer costs associated with replacing them.

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

EEM 2 - Chilled Water Temperature Variation

- Increase chilled water temperature
- Install Chilled Water reset_

The designed chilled water for the Air Handling Unit is 42 °F. Increasing this temperature by 2 °F can reduce the load on the compressor and help in energy saving. We can further increase saving by installing Chilled water reset which can reduce even more electricity consumption during unoccupied hours when the building load drops drastically. As a rule-of-thumb, each 1°F increase in the chilled-water temperature reduces the energy consumption of the chiller by an amount from 1 percent to 1.5 percent. [12]

EEM 3 - AHU Fan Upgrades

- Install high-efficiency motors

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

There are four AHUs in the building which serves most of the building needs. The AHUs are located on the roof. The four AHUs serve all the floors of the building with different sections of each floor assigned to each AHU. 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. 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.

AHU arrangement on the roof.

<u>EEM 4</u> - Install a Vestibule

- Vestibule installation to reduce air infiltration

As per Facility Management, about 1000 people arrive in the building by 12 noon. The entrance door will be opened the same number of times. Since the entrance of the building is conditioned, frequent opening of the door increases the load on the AHU. The security guard in that area also has a complaint of frequent discomfort in terms of insufficient heating.

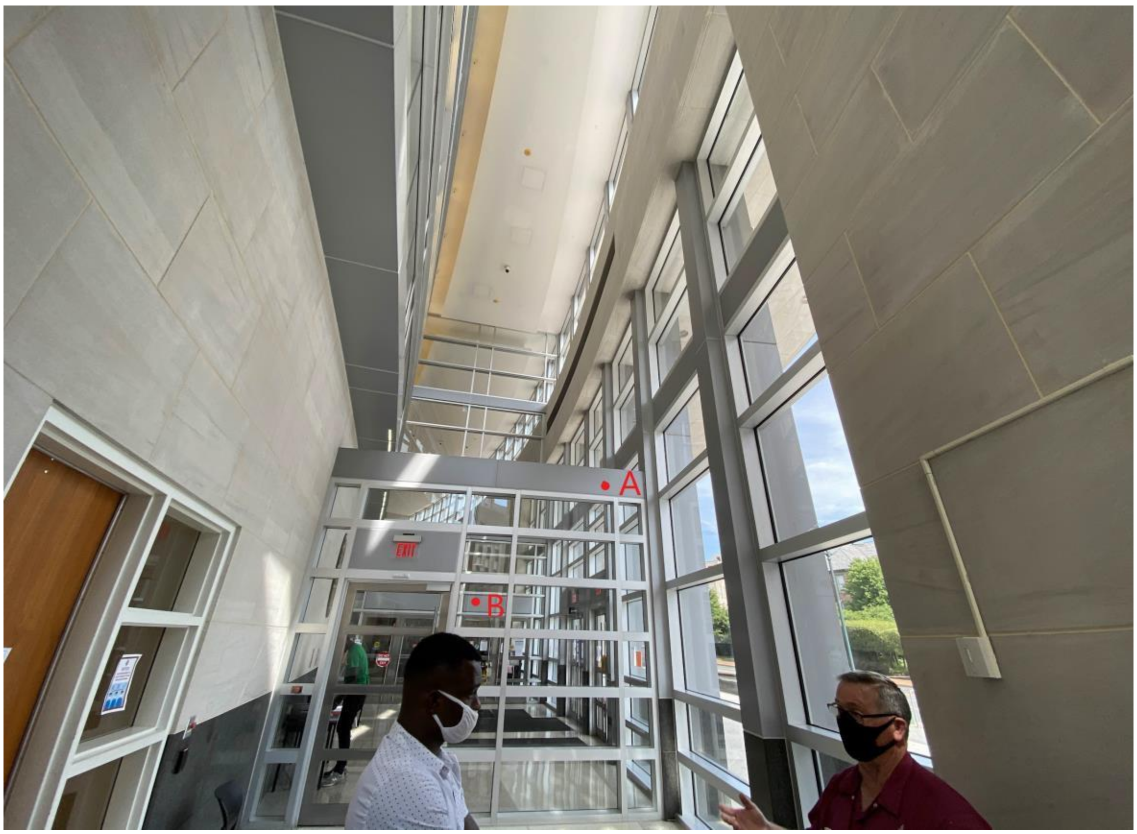


Fig. 13: Entrance of the building with dividing it into a commissioner's area and the entire building

The entrance of the building serves as the entrance for the Commissioner's area as well as the entrance for the entire building. In Fig. 13, it is visible that there is no infiltration in the entrance for the entire building as it is covered by a glass panel (extended till the roof of the space) but the Commissioner's area entrance is open to outside air infiltration which results in insufficient conditioning of the space.

To reduce this infiltration in the Commissioner's area entrance, we would like to suggest a horizontal glass panel from point A to point B which will enclose the entrance of the building, hence resulting in the decrease of the infiltration. Thus, the load on the AHU will decrease and comfortable conditions can be maintained in that space.

To make it more efficient and further reduce the air infiltration, an air curtain system can be installed. There are conventional air curtain systems that could be considered. [23]

Air Curtain System

<u>Building specific recommendation</u> - High EUI issue

- Zone reconfiguration / Modify temperatures during unoccupied hours (*page 25*)

Additional Building Observations and Recommendations

Building Automation System

As described earlier, the Rockville District Court Building has a Centralized Building Control System to monitor the building systems. At the time of the initial walkthrough, the Building Control System at the Rockville court building had not been functional for the past 2-3 years. As the Energy Audit process was being carried out for the building, the Control system was in the process of being rectified. Based on follow-up meetings with the building personnel, the Building Control System would be back to full functionality by mid-December 2020. The BAS upgrade is being carried out by RMF engineering.

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 BAS 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 plays a part in improving the building efficiency as it will assist the facility personnel to easily identify any atypical operation of the mechanical system so that the problem can be rectified, and efficient operation restored.

Some issues which were observed during the initial walkthrough were; a pipe being broken down due to the extreme cold temperature on the 2nd floor in ACC Large Record Room and heating issues in the office area on the 2nd floor. Therefore, getting the control system back to full function would be very helpful to monitor the systems and handle any failures. Also, a centralized BAS system can help with temperature setback, and changing schedules over unoccupied hours, weekends, and holidays.

Proper implementation of the BAS system would result in about 10-25% of energy savings for the whole building [24]. According to the Metropolitan Energy Coalition (MEPC), a BAS system produces savings ranging from $0.20 to $0.40/square foot for most buildings. The total savings would vary according to the type of equipment, the technology applied, and the building size [25]. Based on the above range, the estimated savings for the facility would be in the range of $33,400 to $66,800/yr.

High EUI of the Facility

During the EEM analysis, a point of concern was the high EUI of the Rockville court building. The EUI was on the higher side when compared to the other DGS facilities (Fig. 15). Further analysis yielded the information that the EUI has been constantly on the higher side for the past 8 years (Fig. 16). Discussions with the building personnel led the team to a possible reason for the issue. In fact, it was noted that the building AHUs are always on even during the unoccupied hours because of the commissioner's area and the security area on level 1. Due to the 24/7 nature of these two spaces and their conditioning needs, the AHUs remain on. The core issue identified is the current zone configuration, as every level of the building is served by all the AHUs in the building, all of them are required to be on at all times.

To find a solution to the problem using zone reconfiguration, the team remodeled the building with one floor per one AHU unit. The proposed remodel included the first floor being served by AHU 1, second floor by AHU 2, third floor by AHU 3, and fourth, fifth and sixth floor by AHU 4 (since these floors are mainly composed of courthouses). After implementing this remodel in the software, the results included 31% (1482 MWh) saving in electricity and 60% (62221 therms) saving in natural gas annually. But, with the implementation of this kind of remodel in real life, there will be a heavy capital investment required to change the serving floors by the AHUs. So, the proposed realistic solution for this problem (since the temperature in any room can be controlled by the BAS system), is that the temperature can be changed for the floors second to sixth during unoccupied hours such that the air dampers of the VAV boxes on that floors remain closed for those unoccupied hours.

Agency	Agency Rank	Bldg. Rank	Building Name (Independently Metered only)	Utility Costs	MMBtu	Sqft	EUI	Primary Use	Year Built	CBECS Ref. EUI	Building Performance Database EUIs - Climate Zone			
											Mean	Min.	Median	Max.
DGS	5	1	Rockville DC/MSC	$637,444	26,234	167,000	157.09	Courthouse	2011	92.2	225	29	186	1189
DGS	5	2	WilliamDonaldSchaefer-6 St. Paul	$1,050,246	33,508	305,400	109.72							
DGS	5	3	Wabash - Borgerding DC/MSC	$130,680	5,409	52,824	102.39	Courthouse		92.2				
DGS	5	4	Towson DC	$100,444	5,069	52,000	97.48	Courthouse		92.2				
DGS	5	5	Westminster DC/MSC	$96,579	4,125	43,000	95.94	Courthouse		92.2				
DGS	5	6	Essex/Rosedale DC/MSC	$53,060	2,100	22,975	91.41	Courthouse		92.2				
DGS	5	7	Silver Spring - L. Leonard Ruben DC	$192,146	7,273	79,596	91.37	Courthouse		92.2				
DGS	5	8	OPD - 201 St. Paul Street	$102,210	2,783	32,000	86.96							
DGS	5	9	Bel Air - Mary Risteau DC/MSC	$274,203	11,604	140,000	82.88	Courthouse		92.2				
DGS	5	10	South Baltimore - Hargrove DC/MSC	$176,894	6,721	84,730	79.32	Courthouse		92.2				
DGS	5	11	Peoples Resource Center - 100 Community Place	$262,563	12,237	155,900	78.49	Office		77.8				
DGS	5	12	Centreville - Carter Hickman DC/MSC	$75,764	2,772	37,783	73.37	Courthouse		92.2				
DGS	5	13	Leonardtown - Joseph P. Carter DC/MSC	$163,697	5,661	77,920	72.65	Courthouse		92.2				
DGS	5	14	2100 Guilford - Parole & Probation	$164,601	6,012	82,953	72.47							
DGS	5	15	Civic Plaza - 200 W BALTIMORE St	$505,988	15,600	217,700	71.66							
DGS	5	16	Glen Burnie - George M. Taylor DC/MSC	$175,115	6,948	97,104	71.55	Courthouse		92.2				
DGS	5	17	Ellicott City DC/MSC	$138,720	5,309	75,300	70.50	Courthouse		92.2				
DGS	5	18	Arbutus/Catonsville DC/MSC	$54,243	2,179	32,657	66.73	Courthouse		92.2				
DGS	5	19	Hyattsville DC/MSC	$158,505	5,362	82,000	65.40	Courthouse		92.2				
DGS	5	20	Hilton Height Community Center - 510 N Hilton	$47,805	1,383	22,900	60.39							
DGS	5	21	Shillman Building	$330,056	9,564	160,000	59.78							
DGS	5	22	Denton - John Hargreaves DC/MSC	$68,428	1,788	31,798	56.24	Courthouse		92.2				
DGS	5	23	Elkton DC/MSC	$148,265	6,725	126,700	53.08	Courthouse		92.2				
DGS	5	24	Hagerstown - J. Louis Boublitz DC/MSC	$32,295	1,430	27,240	52.49	Courthouse		92.2				
DGS	5	25	Prince Frederick - Louis L. Goldstein DC/MSC	$113,399	3,669	73,000	50.26	Courthouse		92.2				
DGS	5	26	Hilton Height Community Center - 530 N Hilton	$10,588	425	8,750	48.54							
DGS	5	27	Jessup State Complex	$88,623	6,011	126,800	47.41							
DGS	5	28	Salisbury - Paul Martin DC/MSC	$228,011	10,182	224,343	45.38	Courthouse		92.2				
DGS	5	29	Annapolis Post Office	$12,022	839	22,994	36.49	Office		77.8				

Fig. 15: The EUI calculated in this table are from FY18 (July 17 to July 18)

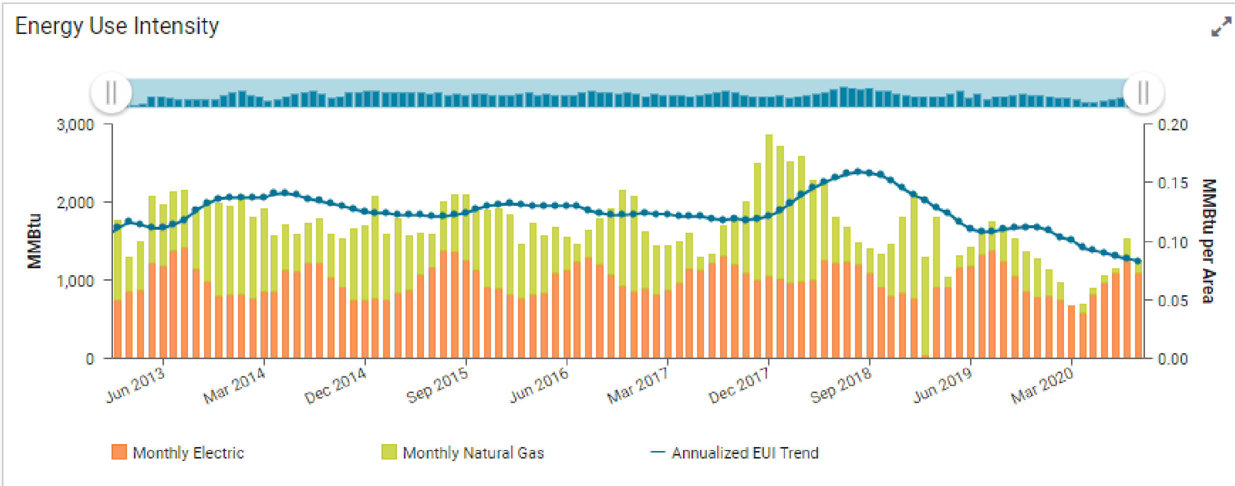


Fig. 16: EUI trend of Rockville from energy cap software from year 2013 to 2020.

Energy Efficiency Measure Savings

The Energy Efficiency Measures discussed above were simulated into the baseline energy model and the expected savings resulting from the implementation of these measures are summarized in the table below (Table 4). The table also includes the predicted savings of implementing all the EEMs simultaneously, labeled the "Combined EEM's." Note that the savings predicted by the "Combined EEM's" do not equal the sum of each individual EEM. This is an expected consequence of the interaction between multiple model parameters in a dynamic whole building energy simulation. The ability to model multiple energy efficiency measures simultaneously is another powerful feature of the whole building energy modeling.

Table 4: Energy and Cost Savings Summary

Energy Efficiency Measures (EEM)	**EEM Simulated**		**Projected Energy Savings**		**Projected Energy Savings Percentage**		**Utility Savings***		
	Electricity (MWh/yr)	**Natural Gas (therm/yr)**	**Electricity (MWh/yr)**	**Natural Gas (therm/yr)**	**Electricity (%)**	**Natural Gas (%)**	**Electricity ($/yr)**	**Natural Gas ($/yr)**	**Total ($/yr)**
EEM 1 - Lighting Upgrades	**4571**	**106500**	**282**	**-2670**	**5.8%**	**-2.6%**	**28200**	**-2670**	**$25,530**

EEM 2 - Chilled water temperature variation	**4754**	**103830**	**99**	**0**	**2.0%**	**0.0%**	**9900**	**0**	**$9,900**
EEM 3 - AHU Fan Upgrades	**4747**	**103910**	**106**	**-80**	**2.2%**	**-0.1%**	**10600**	**-80**	**$10,520**
Combined EEM's	**4370**	**106600**	**483**	**-2770**	**9.9%**	**-2.7%**	**48300**	**-2770**	**$45,530**
EEM 4 - Install a Vestibule**	**-**	**-**	**1**	**1485**	**-**	**-**	**100**	**1485**	**$1,585**

***** 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 EEM 4 cannot be implemented in eQuest, hence separate analysis and calculation were carried out for this measure.

Table 5 shows the calculations required for obtaining the projected energy savings for EEM 4 [13]. Energy-saving with installing a vestibule is calculated by flow normalized climate factor times time-of-day multiplier times average entrance operating hours per day times the difference of infiltration in current and proposed condition.

Table 5: Vestibule calculation

Assumed Parameters for Calculation	**Value**	**Unit**
Average door use rate(People per hour)	361	-
Pressure factor	0.18	(in. of water)$^{0.5}$
Area of Door	49.9	ft^2
Time-of-day multiplier	0.83	
Average entrance operating hours per day	9	h/day

Flow Normalized Climate Factor	0.00761	MMBtu·day/h/cfm
cooling fraction multiplier	0.01	
heating fraction multiplier	0.99	
Calculated Conditions	**Value**	**Unit**
Airflow Coefficient in Current Condition	1060	(cfm)/ft2 /(in. of water)$^{0.5}$
Airflow Coefficient in Proposed Condition	766	(cfm)/ft2 /(in. of water)$^{0.5}$
Infiltration in Current Condition	9522	cfm
Infiltration in Proposed Condition	6880	cfm

The annual electricity usage and natural gas usage derived from the Baseline model is 4853 MWh and 103830 therm, respectively. The total annual utility cost of electricity (4853 MWh) and natural gas (103830 therms) is $589,130. The observed annual utility savings after implementing the EEMs can reduce the annual utility cost by 7.7%. As specified earlier, the EEM 4 is not included in the annual energy consumption and savings calculation due to eQuest not being able to simulate this specific EEM. Also, the annual energy savings for this EEM cannot be included in the combined EEM calculation. The expected savings for EEM 4 is about 2% but the primary reason for this measure is to reduce the air infiltration.

Table 6: Carbon Footprint Analysis

Energy Efficiency Measures (EEM)	Projected Energy Savings		Carbon dioxide Reduction	
	Electricity (MWh/yr)	Natural Gas (therm/yr)	Electricity (lbs/year)	Natural Gas (lbs/year)
EEM 1 - Lighting Upgrades	282	-2670	206,706	-30,972
EEM 2 - Chilled water temperature variation	99	0	72,567	0
EEM 3 - AHU Fan Upgrades	106	-80	77,698	-928
Combined EEM's	483	-2770	354,039	-32,132
EEM 4 - Install a Vestibule	1	1485	733	17,226

The above carbon footprint analysis 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 321,907 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. 17 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 Rockville 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).

II. Building HVAC Description

The chilled water is supplied by two water-cooled centrifugal compressor chillers (*McQuay Model: E2612CE2-C*) with a capacity of 300 tons (1055 kW) each which they run alternatively each month. Usually, one chiller runs at a time but when the demand increases the other chiller is turned on as well. The chillers are controlled by the BAS system. Two variable frequency drive pumps (Bell & Gossett 1510) supply the chilled water throughout the facility. The pumps are rated at 15 HP (11.18 kW) each & supply 530 GPM (33.4 L/s). The supply temperature from the chillers to the AHUs is 42F (5.6°C) and the return temperature is approximately 56F (13.3°C). Fig. 2 shows the chiller unit installed in the first floor boiler room. The chillers are original to the building construction (2011).

Fig. 2: Chiller Unit

The hot water is supplied by three gas-fired boilers (Fulton VTG) each with a capacity of 2680 MBH (785 kW). The ventilation fan in the boiler room supplies the combustion air to the boilers. The boilers are controlled by the BAS system as well. Two variable frequency drive pumps (Bell & Gossett 1510) 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 first floor boiler room. The boilers are original to the building construction (2011).

Fig. 3: Boiler Unit

The Rockville Court Building also has hydronic radiant floor heating in the Lobby area of the first floor. The lobby area is divided into three parts with 3 Radiant Heating systems (RHS) having capacities of 20,030 MBH, 52,720 MBH, and 40,000 MBH. When the temperature drops below 55F, this RHS system turns on. Based on the utility analysis, there is a separate natural gas meter for the RHS system with an average annual consumption of 574 therms.

Table 1: HVAC design specifications summary

Air Handling Unit Schedule											
Designation	Location	Serves	Supply Air		Motor	Cooling			Heating		
			Min OA CFM	Total SA CFM	HP	EAT °F	LAT °F	GPM@ 42°F EWT 56°F LWT	EAT °F	LAT °F	GPM@ 180°F EWT 160°F LWT
AHU-1	Penthouse	All Floors	10950	36500	50	81	54	200	25	60	70
AHU-2	Penthouse	All Floors	10950	36500	50	81	54	200	25	60	70
AHU-3	Penthouse	All Floors	10950	36500	50	81	54	200	25	60	70
AHU-4	Penthouse	All Floors	10950	36500	50	81	54	200	25	60	70

Fan Coil Unit Schedule							
Designation	Fan			Outdoor Fan		Cooling	Heating
	Duty	CFM	HP	CFM	HP	MBH	MBH
FC-1	Commissioner	1800	0.75	3600	0.5	60	110
FC-2	Main IT/Telephone	2150	1	3600	0.5	60	-
FC-3	Shared Computer	2150	1	3600	0.5	60	-
FC-4	Computer Room	1200	0.25	1500	0.125	24	-
FC-5	Elevator Room	2150	1	1500	0.125	60	-
FC-6	Elevator Room	2150	1	1500	0.125	60	-
FC-7	Elevator Room	2150	1	1500	0.125	60	-
FC-8	Elevator Room	2150	1	1500	0.125	60	-
FC-9	Elevator Room	2150	1	1500	0.125	60	-

Pump Schedule					
Designation	Duty	GPM	Head Feet WG	Motor HP	RPM
CWP-1	Condenser Water	900	40	15	3550
CWP-2	Condenser Water	900	40	15	3550
CHP-1	Chilled Water	530	60	15	1750
CHP-2	Chilled Water	530	60	15	1750
HWP-1	Primary Heating Water	500	60	15	1750
HWP-2	Primary Heating Water	500	60	15	1750
CP-1	Coil Circulation	70	10	0.75	1750
CP-2	Coil Circulation	38	2	0.25	1750

Boiler Schedule							
Designation	Duty	Rating				Fuel Consumption	
		Boiler HP	Output MBH	EWT	LWT	Gas Type	CFH
B-1	Heating Water	80	2680	160	180	Natural gas	3000
B-2	Heating Water	80	2680	160	180	Natural gas	3000
B-3	Heating Water	80	2680	160	180	Natural gas	3000

Chiller Schedule								
Designation	Refrigerant	Capacity (Tons)	GPM		Water Temperature			
					Evaporator Shell		Condenser Shell	
			Evaporator Shell	Condenser Shell	Entering	Leaving	Entering	Leaving
CH-1	R-134A	300	530	900	56	42	85	95
CH-2	R-134A	300	530	900	56	42	85	95

Radiant Heating System Schedule						
Designation	Capacity MBH	GPM	Inlet Temp	Outlet Temp	Heat Exchanger	
					HP	GPM
RHS-1	20,300	2.2	130	110	1	13
RHS-2	52,720	5.6	130	110	-	-
RHS-3	40,000	4.3	130	110	-	-

There are multiple electric unit heaters installed in the facility to provide supplemental heating. The commissioner's area is a unique space that is intended to operate 24 hours a day, 7 days a week. The area is therefore served by the Fan Coil Unit-1.

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.

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 energymodels.

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.

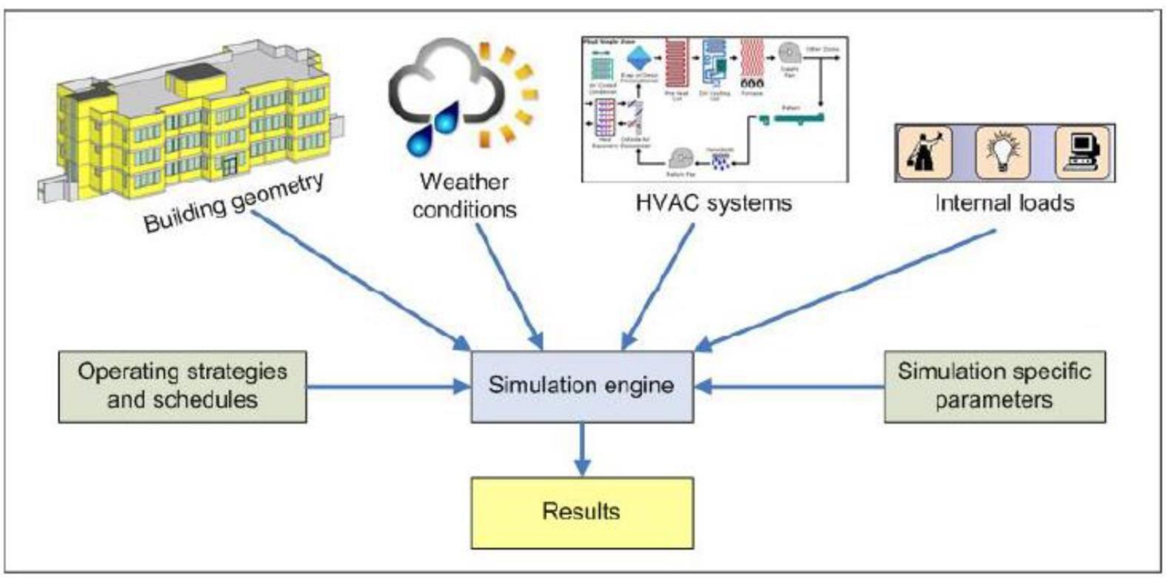


Fig. 5: General data flow of building energy simulation software. [2]

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 316 tons and the current chillers are 300 tons each. Even when accounting for redundancies and the original plan of lead-lag configuration, the current chillers are oversized by about 90%. Focusing on the boilers, the total heating load was about 3087 MBH and the current boilers are 2680 MBH each. Here, the boilers are oversized by about 160% 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 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 2012-2019 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 [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	3955	13,494,460	94,107	9,410,700	2,080,000	22,905,160	137.2

Fig. 6 and Fig. 7 show the average monthly electricity and natural gas consumption respectively for the years 2012-2019 and provides a number of key insights.

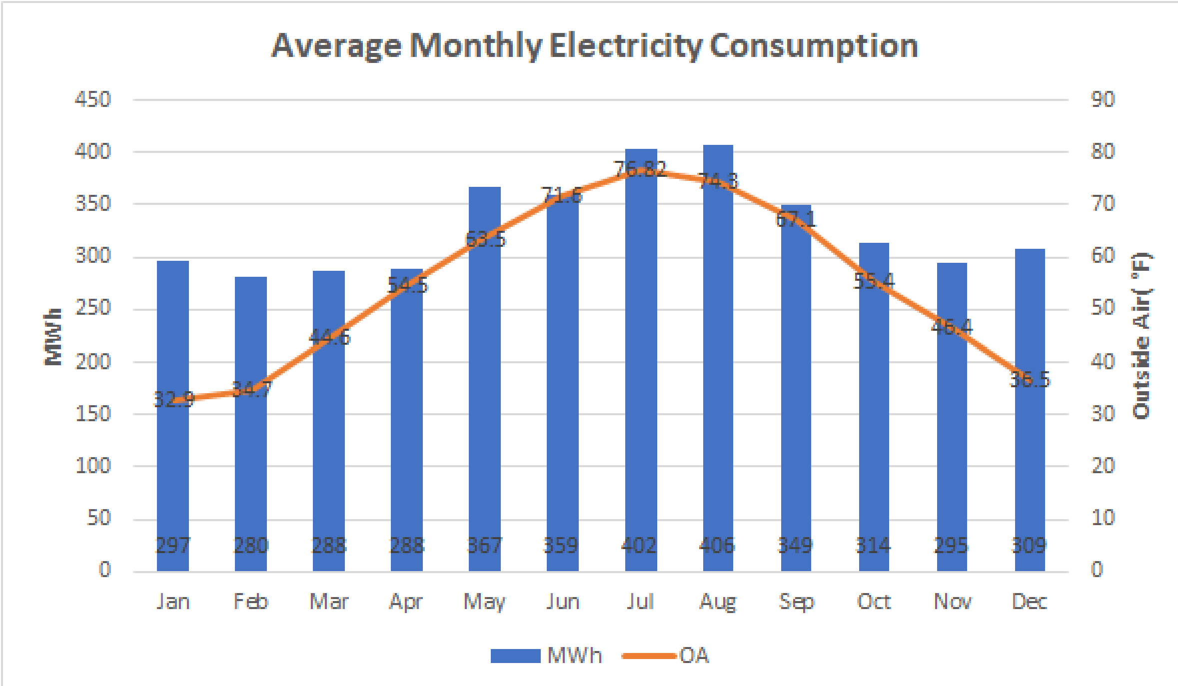


Fig. 6 Average Monthly Electricity Consumption [6]

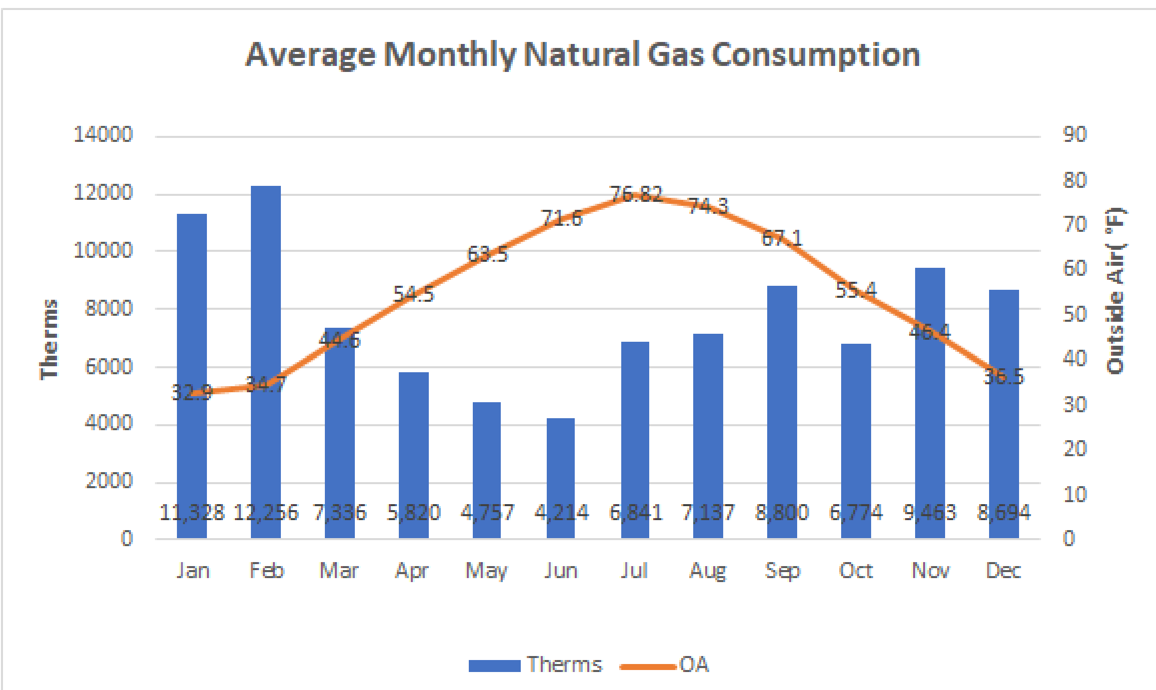


Fig. 7 Average Monthly Natural Gas Consumption [6]

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. 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 increasing or decreasing trendline to derive upon. 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 [7]. The Commercial Buildings Energy Consumption Survey (CBECS) database data was also used to evaluate the energy profile of the facility [8]. This comparison provides an opportunity to determine the scope of improving overall energy efficiency.

In the case of EnergyStar Portfolio Manager, the facility utility data was fed to the Portfolio Manager. These included electricity, natural gas, and water utility bills 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**	**Standard Value**	**Reference**
Energy Star Score (1-100)	32	-	EnergyStar Portfolio Manager
Site EUI (kBtu/sf)	143.5	101.2	EnergyStar Portfolio Manager
CBECS ($/sf)	3.57	1.84	(Electricity + Natural Gas)/Bldg sq.ft area

The value of 143.5 was obtained using EnergyStar Portfolio Manager while utility analysis yielded a value of 137.2. Based on the benchmarking analysis, the Rockville Court Building currently has an Energy Usage Intensity more than the average public courthouses (143.5 vs 101.2). The CBECS score is also more than the average value for commercial offices (3.57 vs 1.84). This means when compared to other reference courthouses there might be more opportunities to increase the overall energy efficiency of the facility. But the above analysis just provides an insight into the opportunities as the reason for the higher values might indicate the current inefficient operation of the facility such as the recorded high EUI issues (discussed below).

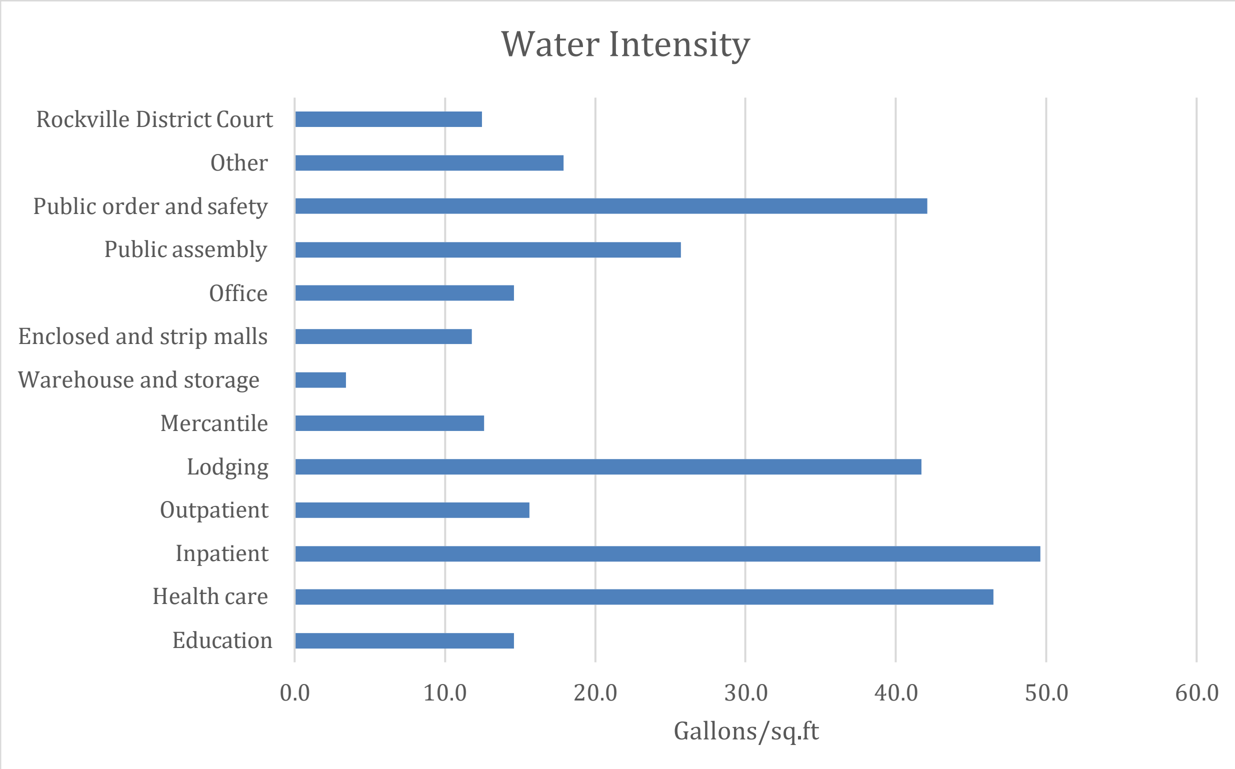


Fig. 8 Water Intensity (Gallons per sq. ft) [10]

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 Rockville District Court with a sq. ft area of 167,000 has a water intensity value of 12.45 gallons/sq. ft.

Energy Modeling

Baseline Energy Model

The physical structure of the Rockville 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 8 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.

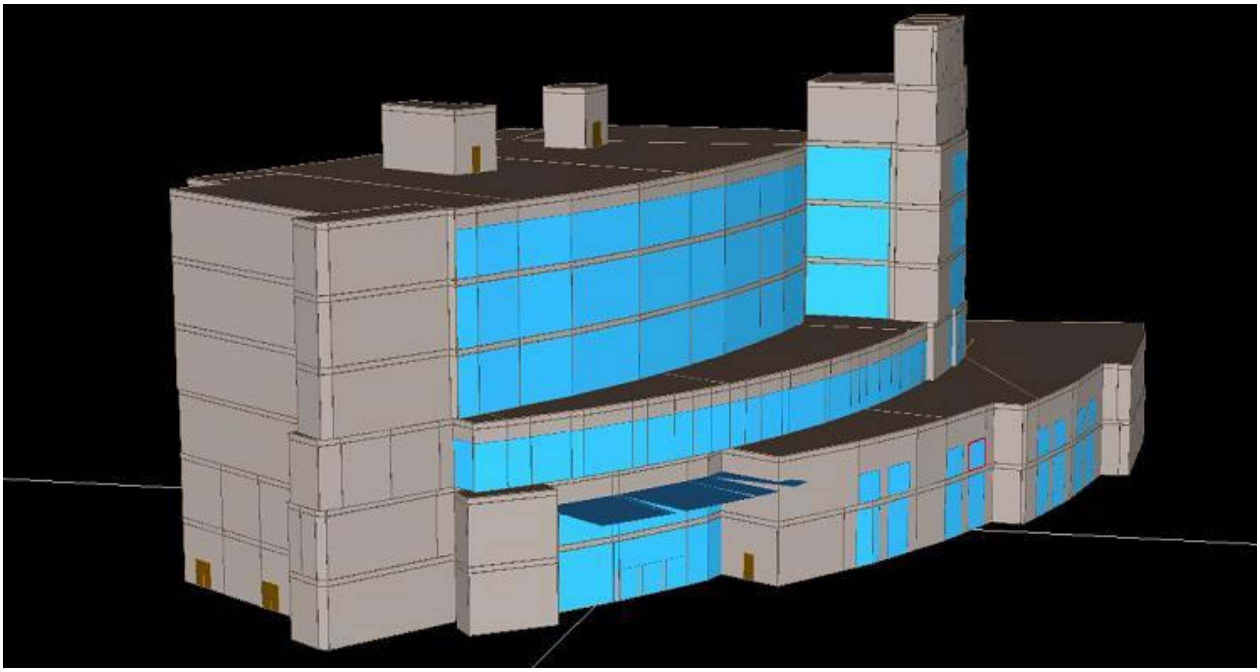
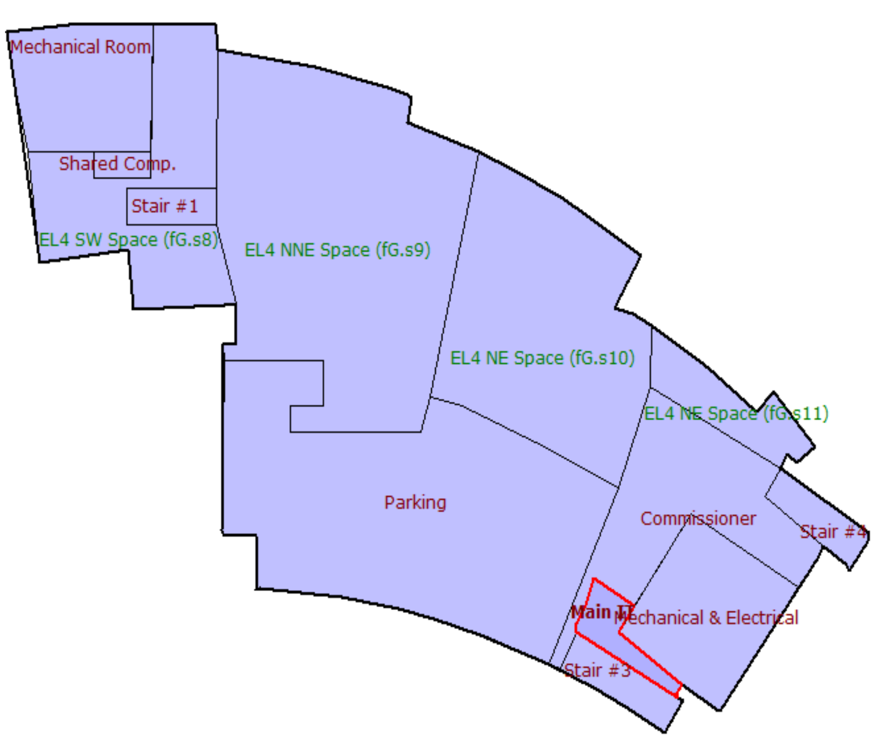


Fig. 9 Building energy model rendered in eQuest

The energy model had a total of 60 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 (1^{st} floor).



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

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

Model Validation

Calibrating the baseline energy model to closely match the actual building energy consumption data is crucial. As discussed in an earlier section: *Utility Analysis and Benchmarking*, the main energy commodities are electricity and natural gas. Utility consumption data were averaged and compared to the eQuest simulation results. Fig. 11 and Fig. 12 show the results of the baseline energy model's monthly energy consumption as compared to the building's actual monthly energy consumption data for both electricity and natural gas.

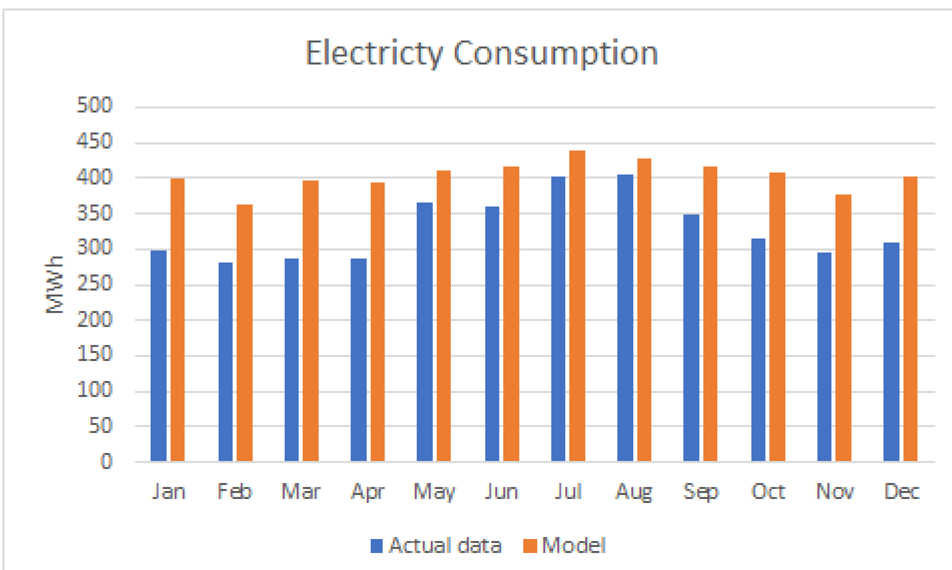


Fig. 11: Monthly electricity consumption comparison.

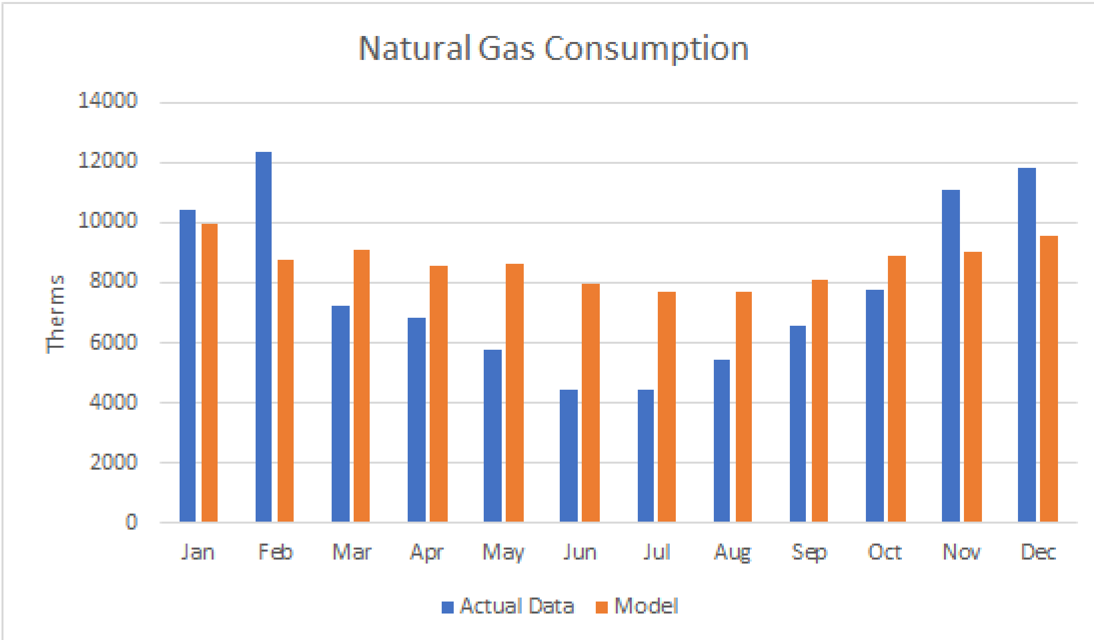


Fig. 12: Monthly natural gas consumption comparison.

The predicted monthly energy consumption of the baseline energy model closely matched the average monthly energy reported by utility bills between 2012 and 2019. In the case of electricity consumption, the values deviate by ~22.7% while the natural gas consumption values deviate by ~10.3%. The reason for the deviation in the electricity and natural gas consumption may be due to the discrepancy in the occupancy, window glass configuration and scheduling of the building. The gas consumption meets the ASHRAE calibration requirements as given by Guideline 14- 2002 which allows a deviation of up to 15% [11].

IV. Future Scope

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 [16]. 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.

Building Decarbonization / Electrification Analysis

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 [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 data on carbon emissions (Fig. 17), 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.

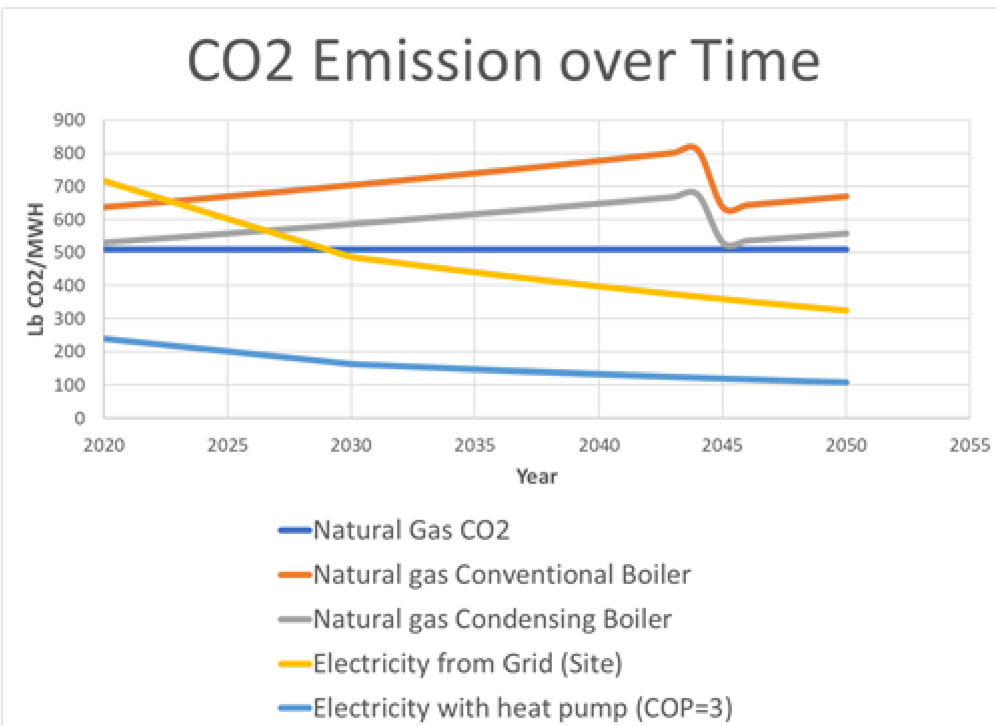


Fig. 17: CO2 emission over time

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: Rockville District Court

Currently, the Rockville District Court satisfies its heating and cooling needs using traditional boilers and chillers. The HVAC system is only 10 years old and working perfectly fine so there is no need for immediate replacement, but this can change in the future accounting for the developments in the building HVAC technologies. 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. 18 shows a schematic VRF arrangement.

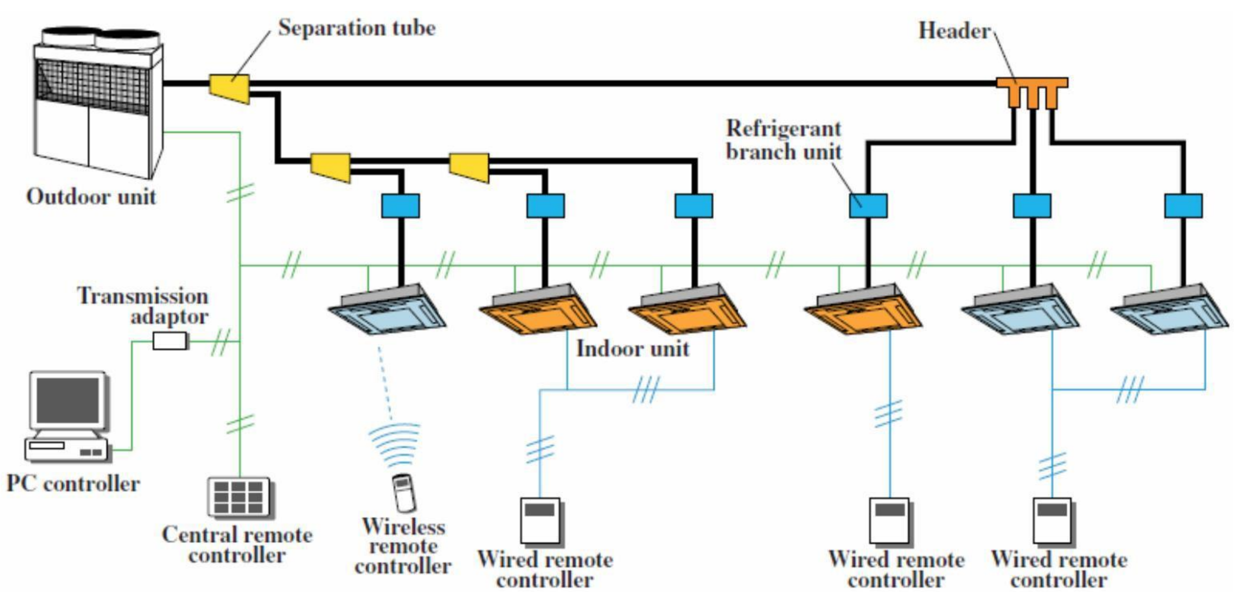


Fig. 18: A schematic VRF arrangement [18]

There are 2 types of VRF systems: heat pump and heat recovery. VRF heat pump systems permit heating or cooling in all 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 Rockville 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 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 [20]. For example, at the Rockville District Court, a 10kW system can generate about 14,200 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) [21], 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 [22]. There is no specific size limit, but the systems generally must be connected to the distribution system serving the state in order to qualify.

V. Conclusions

The Rockville District Court Building is an interesting building due to it being a new construction but still facing some operating issues.

The facility would benefit from general modifications especially the BAS system. 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 10% and natural gas consumption increase by 3%. A further building-specific measure such as improving the High EUI of the facility would result in significant specific savings of electricity consumption reduction by 31% and natural gas consumption reduction by 60%.

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.

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

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

[12] https://tranecds.custhelp.com/ci/fattach/get/566/0/filename/Chilled_Water__Reset%5B1%5D.pdf

[13] https://www.nrel.gov/docs/fy12osti/52290.pdf

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

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

[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

[23] https://www.amazon.com/Awoco-Curtain-Shutoff-Magnetic-SwingING/dp /B07MXN86G4?th=1

[24] https://www.aceee.org/sites/default/files/publications/researchreports/a1701.pdf

[25] https://www.cretech.com/cretech-blog/how-much-might-building-management-tech-save-you/