Borgerding District Court Building

5800 Wabash Ave.

Baltimore, MD 21215

Energy Audit Report

Prepared for:

Maryland Department of General Services (DGS)

Department of General Services

Prepared by:

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Project Team

The UMD Smart and Small Thermal Systems (S2TS) team is managed by the Maryland Department of General Services (DGS) Office of Energy and Sustainability and collaborates with multiple state agencies. The UMD S2TS team consisted of Soumya Agrawal and Ji Bae, supervised by Dr. Amir Shooshtari & Dr. Michael Ohadi.

Acknowledgment

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Executive Summary

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 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, as well as summarized their findings in this report. This report identifies actionable energy-saving opportunities to increase the building's energy efficiency. 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 Borgerding District Court building is located at 5800 Wabash Avenue, Baltimore, Maryland 21215. The building was originally constructed in 1984 and is a two-story building with an overall floor area of 64,050 square feet as specified by the facility manager. The building also includes a basement level. Fig. 1 shows an overview of the building.

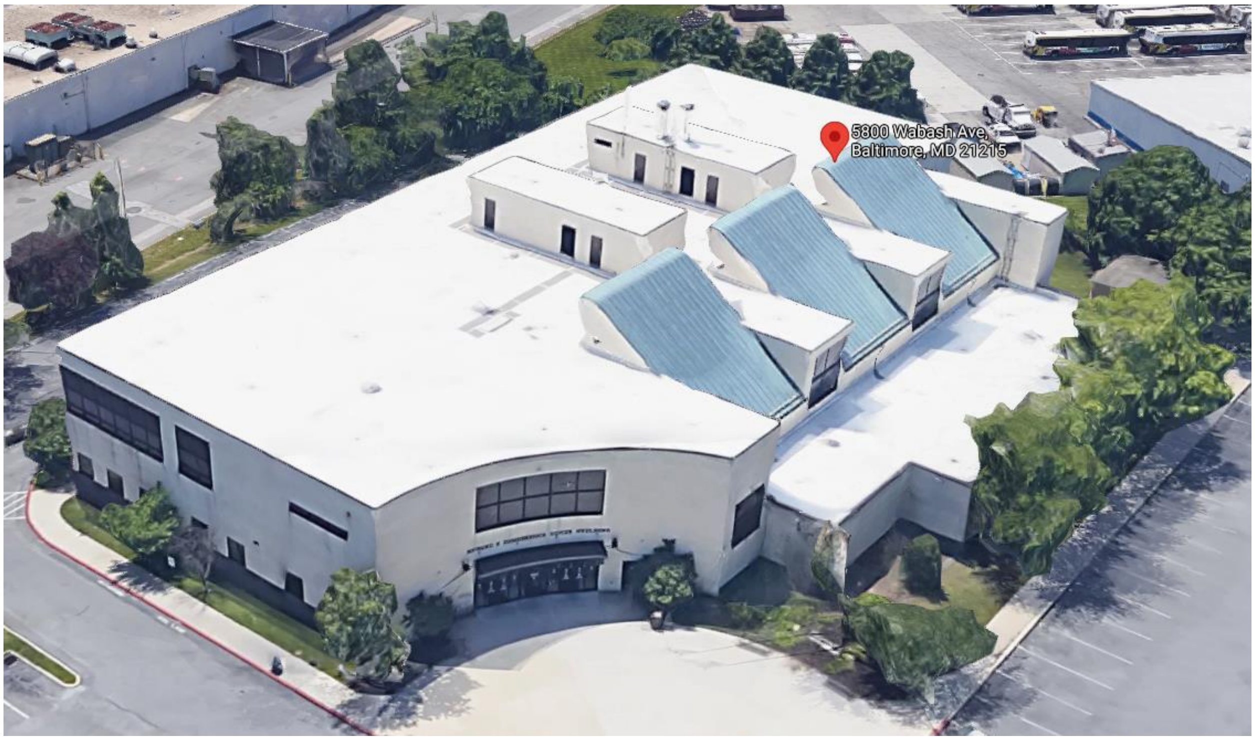

Fig. 1: The Borgerding District Court Building

Average annual utility use and cost for calendar year 2016-2020 was as follows:

Electricity	1,029,227 kWh	$95,965
Fuel Oil #2	11,789 gal	$11,630
Water	671,002 gal	$14,405

The building houses primarily office spaces and courtrooms. The basement consists of a parking garage along with several other miscellaneous spaces such as mechanical rooms, electrical rooms, and office spaces. Level 1 and 2 houses lobbies, reception areas, office spaces, conference rooms, courthouses, corridors, restrooms, elevator rooms, storage rooms, IT rooms, and break rooms.

There are also two penthouses on the roof, which house five of ten air handling units (AHUs) for the building. The other five AHUs are located on the basement floor and first floor of the building. The mechanical room of the building houses two chillers and two boilers. All of these units work to serve and provide the HVAC needs of the entire building.

The facility exemplifies a typical courthouse in function. The entire building is operating on a 9:00am to 5:00pm building schedule on weekdays (Monday to Friday) throughout the year. Likewise, the building HVAC systems operate during all of these hours. The building is controlled by a Metasys BAS from JCI and has a mix consisting of DDC controls and Pneumatic actuators.

The building consumes energy from two energy commodities: electricity and fuel oil #2. The electricity consumption is metered and supplied by BGE. The fuel oil #2 is purchased a few times per year based on the needs of the building from Mansfield Oil. The building's annual average electricity consumption is 1,029 MWh, and the annual average fuel oil #2 consumption is 11,739.6 gallons. Annual average utility cost of the building is $139,210.

Savings Opportunities:

- There are currently traditional fluorescent lights serving the entire building.
- There are no occupancy sensors installed.
- There are several areas of deterioration in the pipe insulation.
- Most windows are operable and can be freely opened by occupants.
- Boilers have passed their useful life and their replacement with newer, more efficient units may be warranted.

I. Energy Efficiency Measures

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

Savings associated with following all the recommendations:

- Annual utility cost reduction of 9.3% resulting in $11,420 annual utility savings.
- Annual electricity consumption reduction of 9.0% resulting in $9,341 annual savings.
- Annual fuel oil #2 consumption reduction by 10.9% resulting in $2,079 annual savings.

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

- Replace all fluorescent lights in the building with new LED bulbs. Occupancy sensors shall also be installed for all spaces so that lights can be ensured to be off during unoccupied building hours.

The building mostly employs fluorescent lighting, and most of the building is served by T8's. Currently, occupancy sensors do not exist in this building.
Upgrading the light fixtures to LED solutions has multiple end-user benefits. LED lighting can yield significant energy savings while also reducing the maintenance and labor costs associated with fluorescent lighting. LED light fixtures have a longer rated life which would mean fewer costs associated with replacing them. This work would need to be contracted out as the lights would need to be retrofitted to fit LEDs. Lighting control options further enhance the energy-saving potential of LED lighting. During the retrofit controls such as daylight saving, occupancy, dimming can be integrated into the lighting system to yield energy savings. Transitioning towards LED lighting along with controls could yield electricity savings of around 50% - 60% of total lighting consumption.

<u>EEM 2</u> - Non-Operable Windows

- Convert all operable windows to non-operable windows so that occupants cannot leave windows open and cause an increase in the infiltration rate.

The building currently has operable windows that occupants can easily access and open. Opening windows can greatly increase the infiltration rate, which results in more energy consumed by the building's HVAC system. In the winter, opened windows might bring in additional cold air that will need to be heated. Likewise, in the summer, opened windows might bring in additional hot air that will need to be cooled. In order to mitigate these risks, it will be beneficial to convert all operable windows to non-operable windows so that occupants will not be able to open them. This will minimize the infiltration rate of the building and allow energy to be saved for the building's HVAC system. In order to define these conditions in the energy model, a standard value for neutral-average infiltration rate given by Trace 3D Plus was used for the condition of operable windows.

Then, this infiltration rate was decreased in the model to be able to generate data showing decreases in energy consumption due to the use of non-operable windows.

Fig 11. Existing Operable Windows

<u>EEM 3</u> - Boiler Replacements

- Replace both oil-fired boilers with newer, more efficient boilers as they have passed their useful life and replacements are warranted.

The hot water is supplied by two oil-fired boilers (Peerless 0-720FDA-WUP) each with a capacity of 2,271.3 MBH. These two boilers work in lead-lag operation and are controlled by the Building Automation System as well. Two identical hot water pumps with single-speed drives work together simultaneously to supply hot water to the AHU heating coils and variable-air-volume (VAV) reheat coils. The boilers were installed in 1984 when the building was originally constructed.

The existing boilers in the building were installed when the building was first constructed in 1984. These boilers have passed their useful life and their replacements are warranted. It will be beneficial to replace both oil-fired boilers with newer, more efficient boilers as this will increase the efficiency of the boilers as well as the hot water system as a whole. The benefits of replacing these boilers will be seen in the utility data for fuel oil #2 cost and consumption as both will decrease by carrying out this EEM.

Boilers				
Designation	**Location**	**Fuel**	**Output MBH**	**Model**
Boiler #1	Basement Mechanical Room	No. 2 Oil	2,271.3	Peerless 0-720FDA-WUP
Boiler #2	Basement Mechanical Room	No. 2 Oil	2,271.3	Peerless 0-720FDA-WUP

Fig. 3 shows the boiler units installed in the mechanical room.

Fig. 3: Boiler Unit

Additional Building Observations and Recommendations

1. Replacement of Pipe and Pipe Insulation

There are several areas in the building where pipe and pipe insulation have been deteriorated due to age and wear. This will cause a decrease in the efficiency of the hot water system as this will cause heat of the hot water to escape from the pipes before reaching the heating coil. It will be beneficial to replace pipe and pipe insulation where deterioration is evident in order to reobtain the lost efficiency of the hot water system, which will allow for properly maintaining the hot water supply temperature. This will allow the air handling units and VAV boxes to perform more efficiently when operating in heating mode.

Fig. 13 shows the Pipe and Pipe Insulation Deterioration.

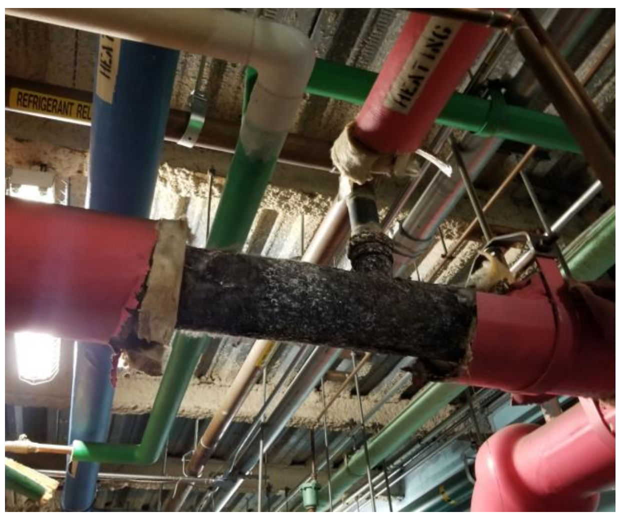

Fig 13. Pipe and Pipe Insulation Deterioration

2. Green Wall

Green walls in the lobby area of the facility could be considered to further condition the air in the space. A drip free indoor living wall option (for water containment) can be considered in the lobby. Green/living walls contribute to indoor air quality. They naturally provide oxygen, humidity, and reduce particulates and volatile organic compounds. Additionally, studies have indicated plants enable more productivity among the building occupants while also ensuring the comfort levels. Indoor living wall solutions provided by LiveWall could be considered for the lobby space [13].

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, and this section is labeled as "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 result of the interaction between multiple model parameters in a dynamic whole building energy simulation. The ability to model multiple energy efficiency measures simultaneously is another powerful feature of the whole building energy modeling. For the values in the summary table, the calculations are performed using the current chiller and boiler capacities.

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)	Fuel oil #2 (MBtu/yr)	Electricity (MWh/yr)	Fuel oil #2 (MBtu/yr)	Electricity (%)	Fuel oil #2 (%)	Electricity ($/yr)	Fuel oil #2 ($/yr)	Total ($/yr)
EEM 1 - Lighting Upgrades	968	2005	67	-85	6.5	-4.4	6742	-845	5897
EEM 2 - Non-Operable Windows	1010	1628	25	291	2.5	15.2	2548	2884	5433
EEM 3 - Boiler Replacements	1035	1787	0	132	0.6	6.9	1	1311	1312
Combined EEM's	942	1710	93	210	9.0	10.9	9341	2079	11420

* The electricity rate considered was $0.10/kWh and for fuel oil no. 2, the rate considered was $9.92/MBtu($1.369/gallon). These rates were estimated based on the utility analysis from EnergyCap.

The annual electricity usage and fuel oil #2 usage derived from the baseline model is 1,035 MWh and 1,920 MBtu, respectively. The total annual utility cost of electricity (1,035 MWh) and fuel oil #2 (1,920 MBtu) is $122,533. The observed annual utility savings after implementing the EEMs can reduce the annual utility cost by $11,420.

Table 5: Carbon Footprint Analysis

Energy Efficiency Measures (EEM)	**Projected Energy Savings**		**Carbon dioxide Reduction**	
	Electricity (MWh/yr)	**Fuel oil #2 (MBtu/yr)**	**Electricity (lbs/year)**	**Fuel oil #2 (MBtu/year)**
EEM 1 - Lighting Upgrades	67	-85	49417	-13910
EEM 2 - Non-Operable Windows	25	291	18679	47482
EEM 3 - Boiler Replacements	0	132	4	21581
Combined EEM's	93	210	68467	34223

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

The above values are based on the State of Maryland estimates of 733 lb of CO_2 emissions per every MWh of Electricity based on 2019 data [11] and 163 lb of emissions per every therm of fuel oil #2 [12]. Implementation of the EEMs would result in a reduction of 186,808 lbs of carbon dioxide emissions per year.

However, it must be noted that the CO_2 emission per MWh for the grid electricity source is projected to continue to drop over time (with a rate of 23 lbs/MWh per year until 2030 and 8 lbs/MWh per year afterwards) due to use of cleaner fuels and renewable energy sources.

See Fig. 12 for more detail.

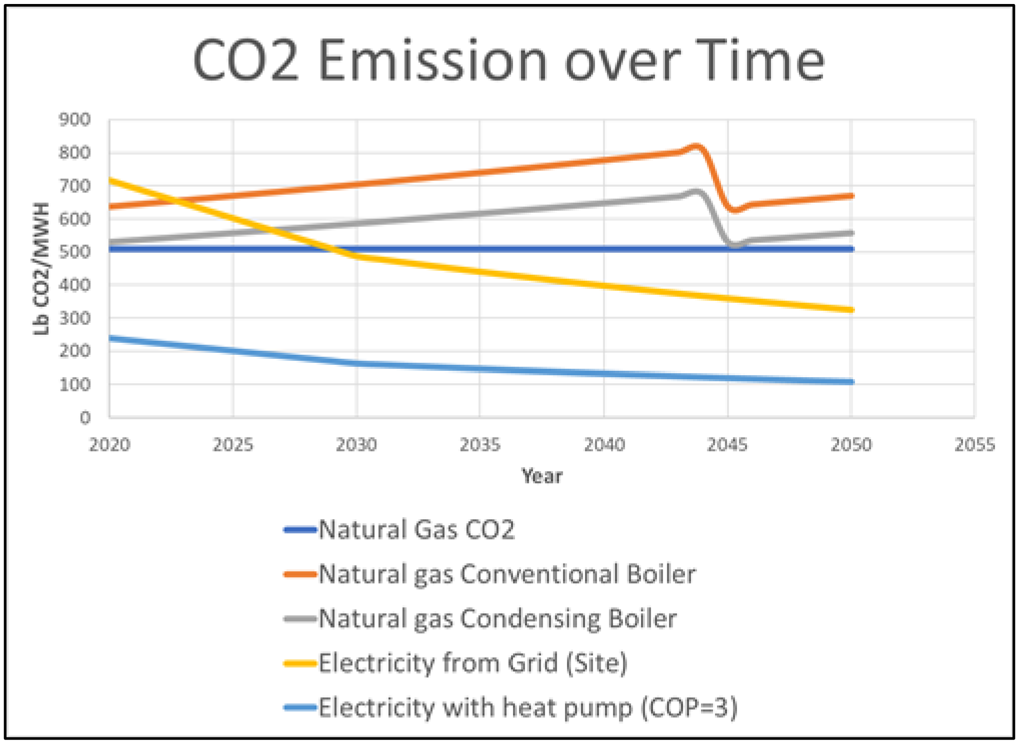

Fig. 12: CO2 emission over time

II. Building HVAC Description

The chilled water is supplied by a centrifugal compressor chiller (York Model YT) with a capacity of 160 tons. The chiller is controlled by the Building Automation System (BAS). Two identical chilled water pumps with single speed drives work together simultaneously to supply the chilled water throughout the facility. Replacement with variable speed motors should be considered for further savings. The chilled water pumps are rated at 10 HP each. There are also two identical condenser water pumps with single speed drives that serve the chilled water system. The condenser water pumps are rated at 15 HP each. The chiller supplies the chilled water to ten air handling units as well as VAV boxes that serve the building. Fig. 2 shows the chiller model installed in the mechanical room. This chiller was installed in 2014 as a replacement for an existing chiller that was installed when the building was originally built. There is also another existing chiller, which was installed when the building was first constructed. This other chiller is a much older unit and only serves as a backup chiller when needed. The cooling tower is located on the basement floor.

Fig. 2: Chiller Unit

Chiller				
Designation	**Location**	**Compressor Type**	**Total Capacity (tons)**	**Model**
Chiller	Basement Mechanical Room	Centrifugal	160	York Model YT

There are ten AHUs in the building serving most of the building needs with supplementary unit heaters installed throughout the facility. Five AHUs are located in the penthouse, and five AHUs are located within the other floors of the building. AHU-2,3,4,5,10 have dedicated return air fans. There are also several VAV boxes throughout the building serving different zones in order to provide temperature control for each of those respective zones. The basement garage parking area is served by an exhaust fan and hot water unit heater.

Table 1: HVAC design specifications summary

Air Handling Units				
Designation	**Serves**	**Cooling Capacity (MBH)**	**Heating Capacity (MBH)**	**Model**
AHU-1	Basement	108	106	McQuay LSL-106
AHU-2	1st Floor Courtrooms	332	177	McQuay MSL-217
AHU-3	2nd Floor Courtrooms	348	223	McQuay MSL-217
AHU-4	Judges’ Chambers	217	122	McQuay MSL-111
AHU-5	Clerk General Offices	178	116	McQuay MSL-111
AHU-6	Storage and Staff Lounges	105	73	McQuay MSL-108
AHU-7	Public Defenders’ Offices	81	46	McQuay MSL-108
AHU-8	Public Defenders’ Offices	92	51	McQuay MSL-108
AHU-9	Commissioners’ Offices	83	54	McQuay MSL-108
AHU-10	Public Concourse	323	327	McQuay MSL-217

Pumps			
Designation	**Service**	**HP**	**Flow Rate (GPM)**
Pump #1	Hot Water	10	340
Pump #2	Hot Water	10	340
Pump #3	Chilled Water	10	330
Pump #4	Chilled Water	10	330
Pump #5	Condenser Water	15	480
Pump #6	Condenser Water	15	480

In addition, there are multiple hot water unit heaters installed in the facility to provide supplemental heating. The building's HVAC system schedule is consistent with the building schedule, and the occupied room setpoint temperatures are around 70°F and 75°F during winter and summer season respectively. Unoccupied room setpoint temperatures are only available for AHU-1 (82°F and 61°F) and AHU-6 (88°F and 64°F) in the BAS.

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 and is performed in 4 steps: 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 rooms, electrical rooms, offices, and 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, as well as occupant behavior.

An archival review of the building’s documentation was conducted alongside the utility analysis before developing the energy model. The referenced documents included the floor plans as well as architectural, mechanical, electrical, and plumbing diagrams. However, there were certain assumptions that had to be made for the unavailable data.

In the final step of building comprehension, access to any Building Automation System (BAS) is sought out and analyzed. In the case of the Borgerding District Court building, the facility has a working BAS system, which was provided by Siemens when the building was first constructed.

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 building simulation software Trane Trace 3D Plus was used.

The early stages of energy model development began after the building walkthrough and utility analysis was completed as well as once the archival review had begun. Fig. 4 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 inputted in the simulation engine, which then simulates the energy consumption in the building.

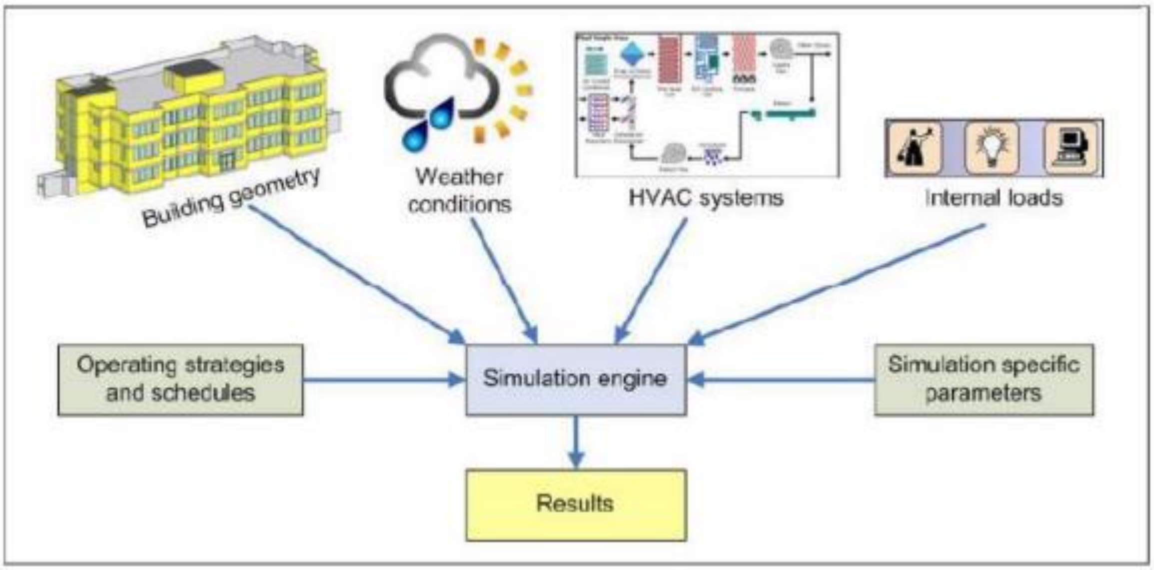

Fig. 4: General data flow of building energy simulation software. [1]

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 [2]. ASHRAE also provides registrants with function-specific Advanced Energy Design Guides for achieving additional energy savings up to 50% [3]. When possible, these energy conservation measures were analyzed by the energy model of the building.

Load Calculations

The building load calculations were analyzed to determine and evaluate whether the existing building HVAC system is properly sized based on the calculated total design cooling load.

The capacity of the existing chiller is 160 tons, and the total combined capacity of all of the existing air handling units is 156 tons. Therefore, it was determined that the total cooling capacity for the building's existing HVAC system is 160 tons according to the existing equipment. As previously mentioned, there is another existing chiller that serves as a backup unit, although it is a much older unit. The Trane Trace 3D Plus energy model calculated the site peak cooling load to be 198 tons, which is higher than the building's existing HVAC system's total cooling capacity. The discrepancy can be due to several factors such as changes in the building conditions, changes in the building use, as well as human error. However, the team has determined that the building was modeled as accurately as possible and that the discrepancy was small enough to be able to complete the energy audit for this building.

As for the boilers, the calculated site peak heating load from the energy model was 1,511 MBH and the capacity of the current boilers are 2,271.3 MBH each. With the combined capacity of both boilers, the boilers seem to be oversized when compared to the heating needs of the building as calculated in the model. The oversizing (though seemingly excessive) appears to figure in the redundancy practice for boilers, typical (N+1). The boilers are controlled in lead-lag operation.. In addition, the boilers may be oversized to accommodate for redundancies, higher demand due to unexpected extreme weather conditions, as well as many other factors. Usually having some degree of redundancy is recommended, typical (N+1) for boilers, depending on the nature of the building and its mission.

Utility Analysis and Benchmarking

Utility data from 2016-2020 were retrieved through the State of Maryland's EnergyCAP tool, which collects and stores energy consumption data from most facilities in the State of Maryland. Monthly energy consumption data for the electricity and fuel oil #2 were collected in the units of kWh and gallons, respectively. Then, these values were converted to units of kBtu using conversion factors provided by the US DOE and shown in Table 2 [4].

Table 2: Utility Analysis and EUI Summary Calculation

	Electricity		**Fuel Oil #2**		**Water**	**Total Site Energy**	**EUI**
	MWh/yr	kBTU/yr	Gal/yr	kBtu/yr	Gal/yr	kBtu/yr	kBtu/SF/Yr
Baseline Energy Usage	1,029	3,514,218	11,739	1,630,327	671,002	5,144,545	80.32

Fig. 5 shows the average monthly electricity consumption for the years of 2016 to 2020 as well as provide a number of key insights.

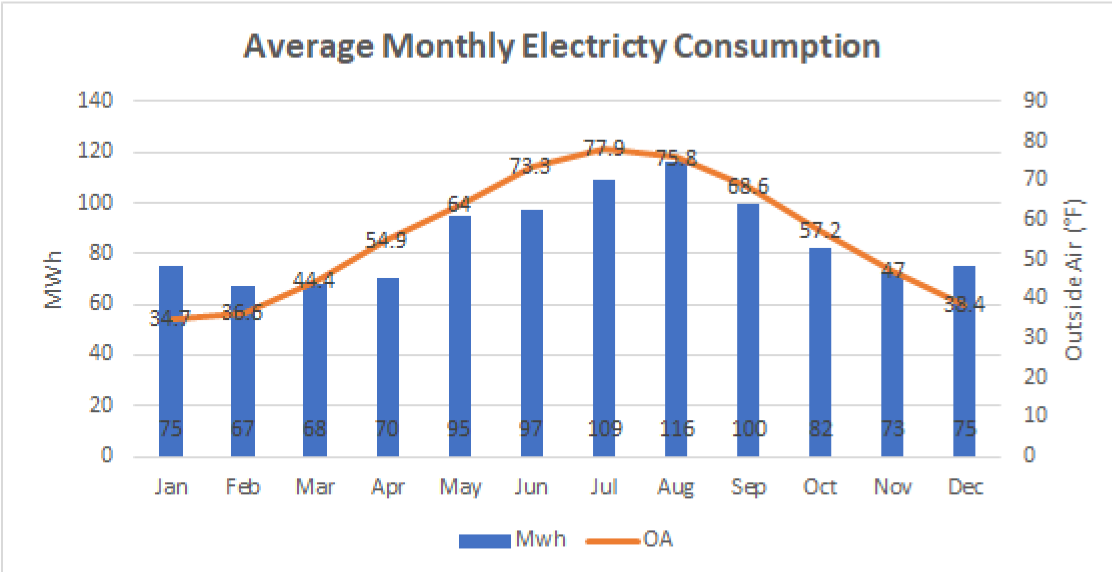

Fig. 5: Average Monthly Electricity Consumption [5]

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. The fuel oil no. 2 is not metered and bought a few times per year. Therefore, it is not possible to get monthly consumption of the fuel oil no. 2. According to the utility data, an average of 11,739.6 gallons of fuel oil no. 2 is consumed every year. Fuel oil #2 consumption is highest during the winter months to provide the required space conditioning. The fuel oil #2 consumption in the summer is due to the reheat operation required to provide adequate dehumidification and occupant comfort.

Energy benchmarking assessment helps to identify the potential opportunities to improve energy efficiency and reduce the associated costs for utilities. To further verify the utility benchmarking calculations, benchmarking was performed using EnergyStar Portfolio Manager [6]. The Commercial Buildings Energy Consumption Survey (CBECS) database data was also used to evaluate the energy profile of the facility [7]. 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. This included electricity, fuel oil #2, and water utility bills. They were further supplemented with the facility data such as floor area, building use, and occupancy. 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 [8].

Table 3: Benchmarking Results Summary

Parameter	Borgerding Value	Standard Value	Reference
Energy Star Score (1-100)	46	-	EnergyStar Portfolio Manager
Site EUI (kBtu/sf)	79.3	101.2	EnergyStar Portfolio Manager
CBECS ($/sf)	2.01	1.92	(Electricity + Fuel Oil #2)/Bldg sq.ft area

The overall Energy Star score of 46 indicates that the building is performing above the median energy performance. The EUI value of 79.3 was obtained using EnergyStar Portfolio Manager. Based on the benchmarking analysis, the Borgerding District Court building currently has an Energy Usage Intensity less than the average public courthouses (79.3 vs 101.2). The CBECS score is slightly higher than the average value for commercial offices (2.01 vs 1.92). This means when compared to other reference courthouses, the Borgerding District Court building is performing similar to typical courthouses in the United State and that there may be additional opportunities to increase the overall energy efficiency of the facility.

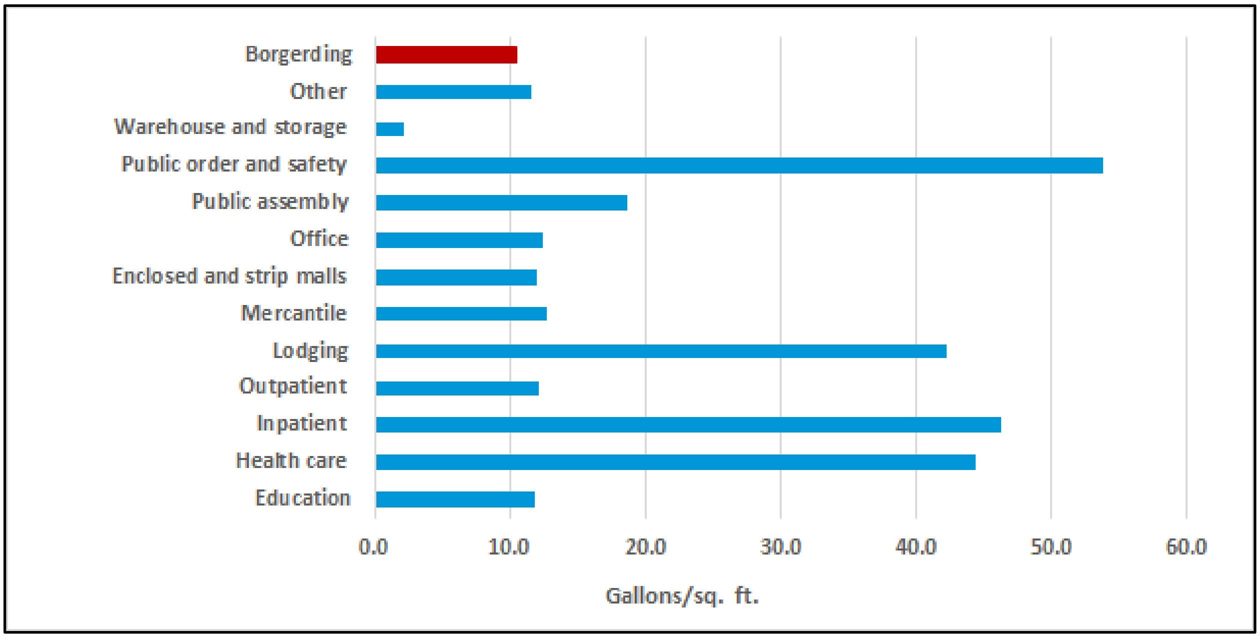

Fig. 6 Water Intensity (Gallons per sq. ft) [9]

Fig. 6 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 Borgerding District Court building has a total floor area of 64,050 square feet and has a water intensity value of 10.5 gallons per square foot, which is relatively low compared to other commercial buildings in the U.S. However, when compared to other courthouses that were reviewed by the S2TS team, this water intensity value is actually on the higher end. This may be explained by the fact that the chiller is cooled by evaporative cooling, which may require the building to consume much more water when compared to other courthouses.

Energy Modeling

Baseline Energy Model

The physical structure of the Borgerding District Court building was developed in Trane Trace 3D Plus. Initially, PDF images of the architectural plans were imported into Trane Trace 3D Plus to generate the initial building geometry. Floor dimensions were calculated by applying proper dimensional scaling based on the documented reference scale. Then, the required zones were modeled into the floor layout, and the subsequent HVAC systems were designed to be selected for the respective zones. The required model information such as building envelope construction was derived from the building plans as well as the data gathered during the building walkthrough. Certain informed assumptions were made for the unavailable data through physical observations, building plan analyses, and discussions with the facility personnel.

All of the spaces in each of the levels of the building were modeled and zoned in order to make the model as accurate as possible. The specific fenestration details such as doors and windows were also implemented. Fig. 7 shows the 3-D representation of the building model as rendered in Trane Trace 3D Plus.

Fig. 7 Building energy model rendered in Trane Trace 3D Plus

The energy model had a total of 10 thermal zones. Each thermal zone represents the space served by an AHU. Fig. 8 illustrates the method by which the thermal zone layout was created. Each zone was provided with unique air terminal unit specifications, exhaust capacities, and thermostats derived from the original mechanical drawings. An unconditioned thermal zone was also considered for spaces, such as stairways, that were assumed as insignificant compared to the model as a whole in order to increase efficiency and create ease of modeling.

Fig. 8 Model thermal zone design (1st floor).

The main space types defined to specify the lighting, plug loads, occupancy, and their associated schedules were offices, lobbies, storage rooms, IT rooms, and corridors. These definitions were developed through the process of building comprehension. Trane Trace 3D Plus has several modes of data entry. Building envelope, boundary conditions, fenestration, construction materials, as well as simplified space type definitions, thermal zones, schedules, plant loops, and basic HVAC definitions were all entered into the software. The occupancy, equipment, lighting, and temperature set-point schedules were implemented as well.

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 fuel oil #2. Utility consumption data were averaged and compared to the Trane Trace 3D Plus simulation results. Fig. 9 and Fig. 10 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 fuel oil #2.

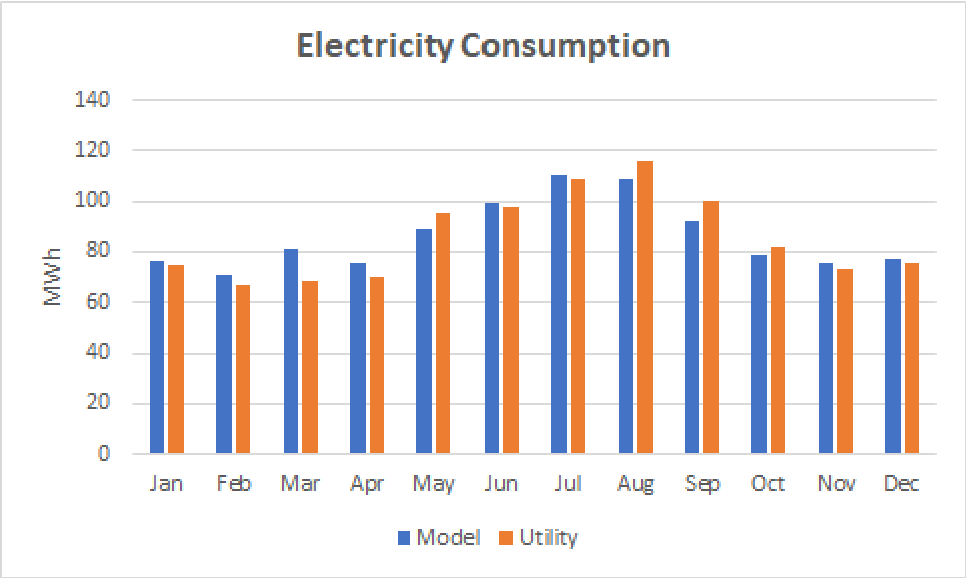

Fig. 9: Monthly electricity consumption comparison.

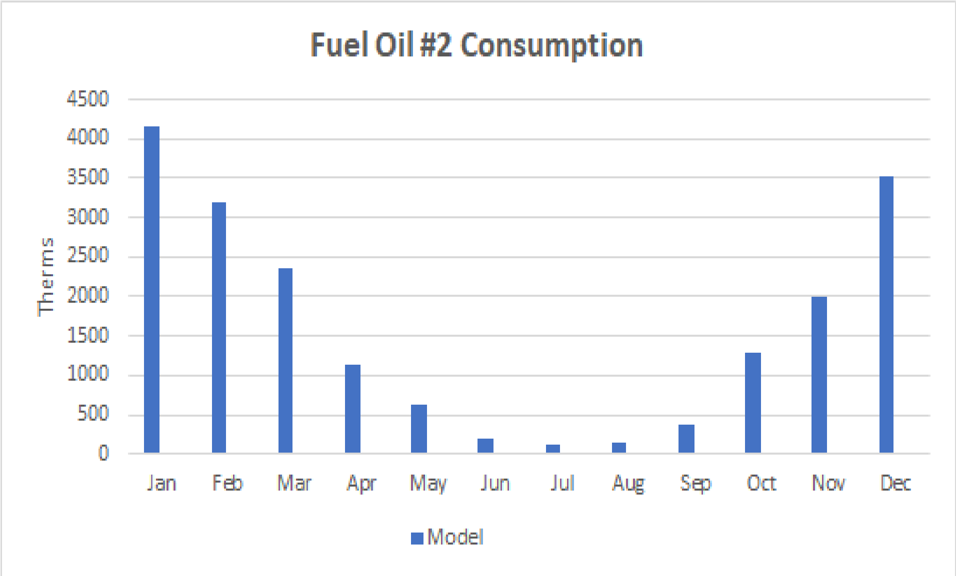

Fig. 10: Monthly fuel oil #2 consumption comparison.

The predicted monthly energy consumption of the baseline energy model closely matched the average monthly energy reported by utility bills between 2016 and 2020. The monthly data for fuel oil #2 consumption does not exist, and comparisons were made in terms of yearly consumption values. In the case of electricity consumption, the values deviate by ~0.6% while the fuel oil #2 consumption values deviate by ~17.7%. The reason for the deviation in the electricity and fuel oil #2 consumption may be due to the discrepancy in the occupancy and scheduling of the building. This is close to the ASHRAE calibration requirements as given by Guideline 14-2002 which allows a deviation of up to 15% [10].

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 [14]. 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 [15].

Electrification

Electrification of end uses will be a key pathway to reducing emissions. Assuming a decarbonized power sector, using electricity for heating, cooling, and hot water needs, instead of burning natural gas or fuel oil, can greatly reduce a building's emissions. Based on DGS data on carbon emissions (Fig. 12, from above), by the year 2029, the carbon emissions in lb/MWh from the electricity grid will be along the same level as the amount from natural gas sources. This downward trend would continue after 2029 with the CO2 emissions from the electricity grid being less than that of natural gas sources. Heat pumps are currently one of the most, if not the most efficient available technology for space heating in the commercial and residential sectors. Although heat pumps have high initial capital costs, high efficiency and minimal maintenance make air source heat pumps a rewarding investment over the long term.

Additionally, the CO2 emissions for an electric heat pump is less than that of a natural gas boiler. Other existing renewable thermal technologies such as geothermal heat pumps or solar water heaters can be installed as fossil fuel-powered replacements. Additional advancements in the heat pump to accommodate even colder conditions can be adopted in the next few years.

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, 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.

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 an oil-fired water heater. A electric water heater can be installed on the roof to provide domestic hot water for the building thus eliminating the need for oil 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 in addition to being backed up with the main power grid 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 [16]. 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 public 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) [17], 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 in order to qualify.

V. Conclusions

The Borgerding District Court building is an interesting facility due to it being a relatively older construction yet operating better than the average levels of a typical courthouses.

The facility would benefit from lighting upgrades on account that it is currently operating with fluorescent light bulbs while the trend for modern buildings are LED's for increasing energy efficiency. Energy Efficient Measures were identified to transition the building system to these newer technologies (such as LED lighting) and make the building energy efficient as a whole. Non-operable windows were also proposed in order to decrease the risk of infiltration to also increase energy efficiency for the building's HVAC system. The expected energy savings resulting from the implementation of these energy efficiency measures will decrease the building's annual electricity consumption by 9.0% and fuel oil #2 consumption will decrease by 10.9%. These savings may not look substantial because most of the energy for this building is consumed by the HVAC system, and the EEM's that were proposed are mostly related to lighting upgrades and construction-related improvements. This is especially the case for the air handling units because these units are operating with a certain percentage of outside air, which require a high amount of energy to condition. According to the model, HVAC accounts for 77.9% of the total building energy consumption, while lighting only accounts for 16.1%. As shown in Table 3, the EUI for the building is already below the average for public courthouses, but there may be potential for more energy savings by performing more large-scale improvements or replacements of the building's existing HVAC systems.

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 public courthouses. This model can be further fine-tuned based on future developments to account for changes in the energy profile of the facility.

VI. References

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