VILLAGE OF HASTINGS-ON-HUDSON
MUNICIPAL GREENHOUSE GAS (GHG)
ANALYSIS AND ACTION PLAN
ENERGY AUDIT REPORT

DRAFT REPORT FOR REVIEW AND COMMENT	MARCH 15, 2019

Prepared by

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OLA Project No. NVOH0001.00

TABLE OF CONTENTS

1.0 Executive Summary

Village of Hastings GHG Action Plan Summary

Findings from Study

- Energy Savings Potential: 166.9 kBtu/year
- Cost Savings Potential: $32,289
- CO_2 Savings Potential: 270,429 lb/year

Summary of Recommendations

- LED Lighting Retrofits
- Building Envelope Upgrades
- Condensing Hot Water Boilers
- Geothermal Heat Pumps
- Air Source Heat Pumps
- Solar PV System
- Heating Night Setback
- DHW Heat Pumps

The Village of Hastings-on-Hudson, NY retained OLA Consulting Engineers to develop an action plan to enable the selection of effective projects the Village can take to reduce green house gas (GHG) emissions. The Village received a grant from NYSERDA for the funding of this effort. The focus of the action plan was to concentrate on seven (7) of the Village's buildings and their impact. This assessment was accomplished by first conducting energy audits of the municipal buildings to assess their current energy use, GHG emissions, and then to develop specific actions and projects the Village can consider to reduce energy use.

The approach was to review the building's operations and utility consumption, and perform multiple site visits to review the existing energy using system, and identify the most inefficient systems. As part of this energy audit process, potential energy saving opportunities were developed, cost and emissions savings potential were analyzed, order of magnitude costing developed, and a draft proposed implementation plan presented for the Village to consider. This study is not intended to be used as a design document, but to recommend options to consider in order to improve the operations, energy performance, and GHG emissions of the buildings from an operational/sustainability perspective.

This report discusses a variety of methods that can be used to reduce the energy consumption, while potentially improving performance of the systems. Further detail including short term and long term recommendations is included in the body of this report and the appendices that follow. The insert above provides a brief summary of the types of measures recommended or considered in this report and a savings potential of all the buildings surveyed. Several measures, including EEM's for the Community Center, Hook and Ladder Company, the Ambulance Corps Garage, and the Chemka Pool building have been identified as having a high potential for energy savings and CO_2 reduction, as well as low implementation costs and relatively short payback periods. Other remaining EEM's have been separated into short-term and long-term measures. Short-term measures were determined primarily from the savings potential of the project and cost of implementation. Long-term measures were determined to have a high potential for energy and CO_2 reduction, but likely have high implementation costs and are considered to be significant capital projects. The energy efficiency measure (EEM) summary are summarized in Section 10 of this report and the recommendations for strategic implementation are outlined in Section 11 of this report.

This study elaborates on the proposed energy savings measures, rough costs to implement them, and the payback associated with implementation. OLA anticipates that a final review of the measures with the Village of Hastings will determine a selected approach for implementation and further inform the draft strategic implementation plan.

2.0 Project Site Overview

Table 1 below shows a summary of the seven (7) buildings included in the scope of this energy audit. Figure 1 shows an aerial view of the locations of each building in the Village of Hastings-on-Hudson. The following sections in this report provide a breakdown of the existing conditions and energy usage for each building.

Table 1. Hastings-on-Hudson Energy Audit Building Information

Building	Estimated Floor Area (ft^2)	Building Space Usage
Village Hall	10,595	Mixed Use (Offices, Courtroom, Police Dept.)
Public Library	13,225	Library
James Harmon Community Center	17,000	Mixed Use (Public Assembly, Recreational, Offices)
Hook and Ladder Fire Company	9,000	Fire Station
Ambulance Corps	2,400	Ambulance Garage
Chemka Pool Building	4,200	Mixed Use (Lifeguard station, Locker rooms, Storage)
DPW Garage	12,000	Maintenance / Storage Facility
TOTAL	**68,420**	

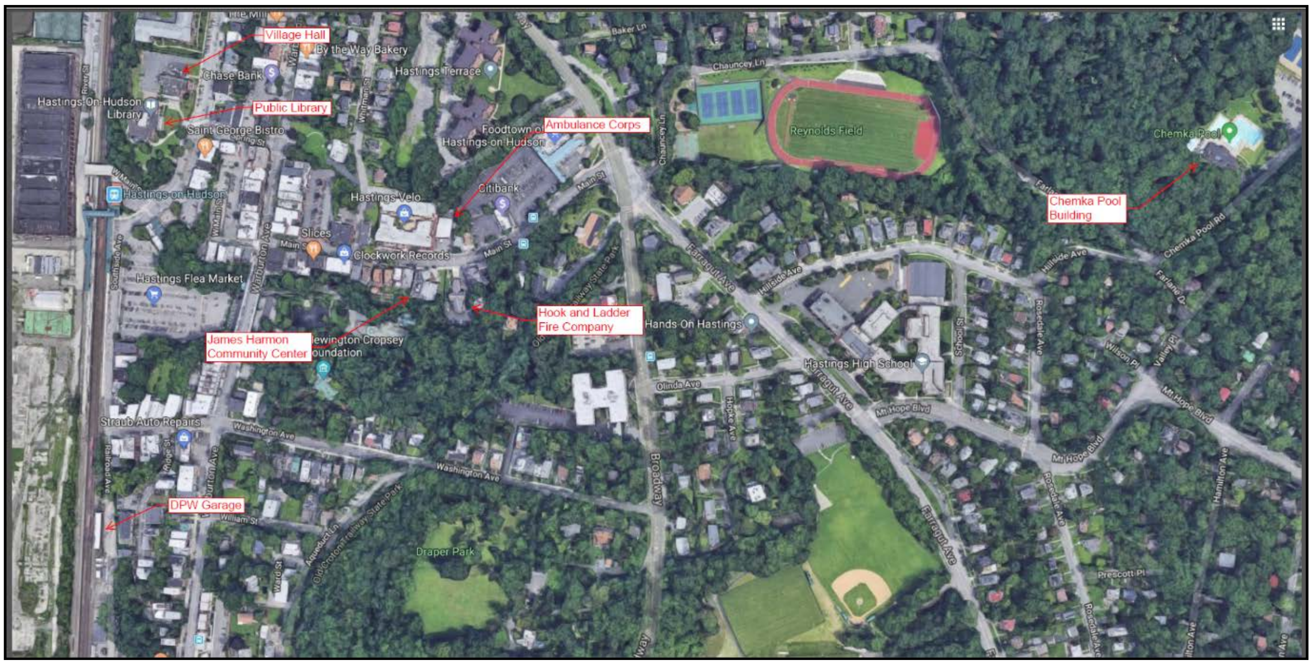

Figure 1. Hastings-on-Hudson site overview

3.0 Project Energy Analysis Approach

3.01 Energy Star and Benchmarking

The EPA's Energy Star Target Finder determines energy performance goals for design projects or existing buildings and provides a method for benchmarking a building's energy use. A rating for actual energy use is determined relative to similar building's average energy consumption on a scale from 0 through 100, with a score of 75 achieving Energy Star status.

Energy Star ratings are based on annual energy use intensity (EUI) measured in terms of kBtu/ft^2. While reducing fuel consumption may not drastically decrease utility costs (relative to higher priced electricity), it will help improve overall energy usage and reduce carbon dioxide emissions. To make a useful comparison for the seven (7) buildings surveyed as part of the energy audit, the energy usage and costs for the building were entered in the Energy Star Target Finder. The results of this benchmark are provided in Table 2 below (see Appendix A for Energy Star Target Finder Input).

Table 2. Energy Star Target Finder Results Summary

Metric	Existing Building Results	Median Property
Village Hall / Library		
Site EUI (kBtu/ft^2)	102.4	86
Greenhouse Gas Emissions (CO_2, lb/year)	363,431	304,238
James Harmon Community Center		
Site EUI (kBtu/ft^2)	107.9	67
Greenhouse Gas Emissions (CO_2, lb/year)	264,683	163,142
Hook and Ladder Fire Company		
Site EUI (kBtu/ft^2)	71.1	110
Greenhouse Gas Emissions (CO_2, lb/year)	76,984	119,050
Ambulance Corps Garage		
Site EUI (kBtu/ft^2)	68.3	83
Greenhouse Gas Emissions (CO_2, lb/year)	22,062	26,456
Chemka Pool Building		
Site EUI (kBtu/ft^2)	89.1	40
Greenhouse Gas Emissions (CO_2, lb/year)	69,872	30,865
Department of Public Works Garage		
Site EUI (kBtu/ft^2)	66.3	64
Greenhouse Gas Emissions (CO_2, lb/year)	101,647	99,208

From the above benchmarking analysis, it can be seen that the Village Hall, Library, and Communtiy Center are the most energy intensive buildings. The other buildings are essentially at or below the median EUI, with the exception of the pool building.

4.0 Village Hall (Municipal Building) and Public Library

4.01 Existing Conditions

The Village Hall and Library are located on the same site at 7 Maple Avenue in Hastings-on-Hudson, NY. The Village Hall is a 2-story, 8,700 square foot municipal building and was built in approximately 1930. Typical spaces on the two (2) above grade floors in the building include a courtroom, offices, conference rooms, and the Village Police Department, which occupies part of the first floor. There is also a cellar level, which contains the boiler room, police department locker rooms, and staff lounge.

The public library is a 2-story, 13,225 square foot building and was built in 1965. An addition was added to the building in 2001. The lower level of the library contains the Orr Community room, Barnes Room, staff lounge, as well as mechanical/electrical rooms and storage spaces. The main floor features the adult library, Picture Book Room, and various offices. Photos 1, 2, and 3 below show an aerial and exterior view of the buildings.

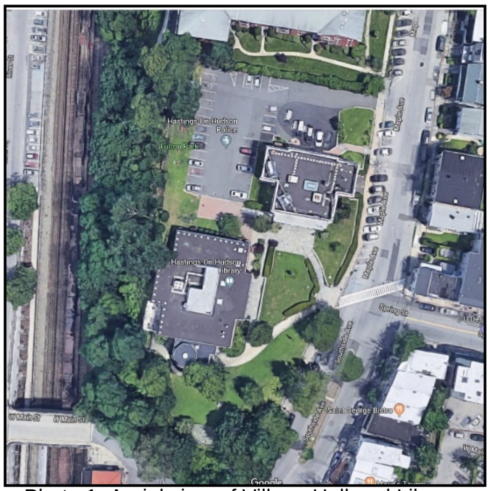

Photo 1. Aerial view of Village Hall and Library

Photo 2. Village Hall exterior

Photo 3. Public Library exterior

Typical building hours for the Village Hall range from 8:30am – 4:00pm Monday through Friday. The building is closed on weekends. However, due to the Police Department presence in the building, the building is occupied 24/7. A breakdown of the building operating hours is shown below in Table 3.

Table 3. Village Hall Operating Hours

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Weekend
8:30am	Building opens	Building opens	Building opens	Building opens	Building opens	Building Closed
4:00pm	Building closes	Building closes	Building closes	Building closes	Building closes	

*Note building is continuously occupied due to Police Department

Normal building hours for the Library range from 9:30am – 8:30pm on Mondays, Tuesdays, and Thursdays, 9:30am – 6:00pm on Wednesdays, 9:30am – 5:00pm on Fridays and Saturdays, and 1:00pm – 5:00pm on Sundays. A breakdown of the building operating hours is shown below in Table 4.

Table 4. Library Operating Hours

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Weekend
9:30am	Building opens	Building opens	Building opens	Building opens	Building opens	Saturday: 9:30am – 5:00pm Sunday: 1:00pm – 5:00pm
5:00pm	-	-	-	-	Building closes	
6:00pm	-	-	Building closes	-	-	
8:30pm	Building Closes	Building Closes		Building Closes		

4.01.1 Existing Heating Systems

Heating for the Village Hall and Library is provided by one (1) dual-fuel fired (natural gas and #2 oil) low-pressure steam boiler. The boiler has a total capacity of 2,452 MBH and is manufactured by Weil McLain (Photo 4). The boiler burner appears to be original to the boiler and has a maximum capacity of 3,103 MBH on natural gas, and 21.5 GPH on oil. It was noted that the boiler is typically run on gas, was installed during a building renovation in 1998, and appears to be in fair condition. Building staff indicated that the boiler is enabled during all hours of the day during the heating season, due to the Hastings Police Department occupying part of the building. A summary of the heating plant is shown below in Table 5.

Table 5. Village Hall Heating Plant Summary

Manufacturer	Type	Capacity (MBH)	Fuel Source	Quantity	Year Installed	Typical Boiler Start/Shutdown Time
Weil McLain	Steam	2,452	Natural Gas / #2 Oil	1	1998	Always active

Photo 4. Steam boiler serving Village Hall

Photo 5. Steam condensate pumps

Low-pressure steam generated by the heating plant serves three (3) different heating zones between the two buildings. The steam system is a two-pipe, pumped return system. Steam condensate is returned to the boilers via a duplex condensate pump (Photo 5), which collects and pumps the condensate back into the boiler. Two of the zones serve the northern and southern halves of the Village Hall, while the third zone supplies hot water to the library via a steam-to-hot water heat exchanger. A description of the heating system for the library is provided below. Steam for the Village Hall is distributed to cast iron steams radiators throughout the building perimeter (Photo 6). Each zone is controlled by its own programmable Honeywell thermostat (Photo 7), which is located on the first floor. The thermostat controlling the northern half of the building is located in the Building Department, while the thermostat controlling the southern half is located in the adjacent Clerk's Office. The thermostats have the ability to automatically adjust temperature setpoint based on a programmed occupancy schedule.

Photo 6. Typical steam radiator

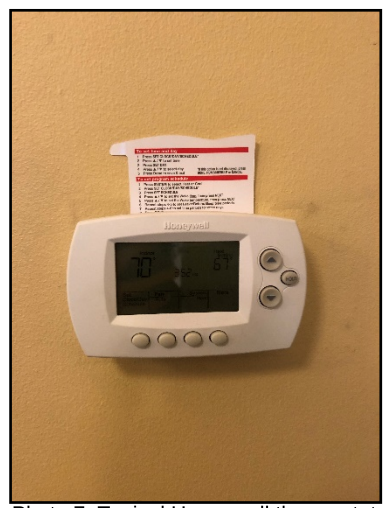

Photo 7. Typical Honeywell thermostat

It was noted that there is a fourth heating zone, which supplies hot water to finned tube radiation in the Police Department locker rooms in the basement of the building by means of a separate heat exchanger and two (2) dedicated hot water pumps (Photos 8 and 9). However officers expressed their desire to keep the space cool, so this zone is no longer in use.

Photo 8. Heat exchanger serving Police locker rooms

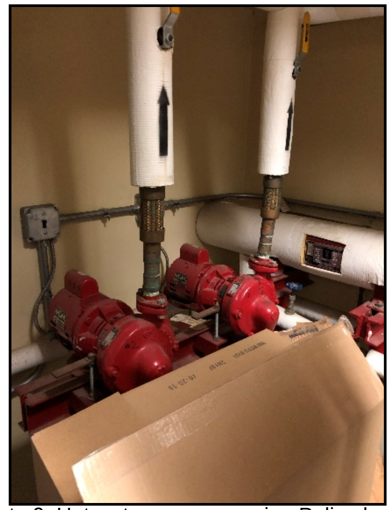

Photo 9. Hot water pumps serving Police locker rooms

Heating for the library is provided by a steam-to-hot water heat exchanger and two (2) dedicated hot water pumps (Photo 10), served by the steam boiler plant at the Village Hall. Hot water generated by the heat exchanger is distributed to perimeter finned tube radiation (Photo 11) and to hot water heating coils located in two (2) AC units and one (1) HV unit serving the building. Each finned tube zone is equipped with an electric control valve and controlled by the Library's building management system (BMS). Heat provided by the AC/HV units and finned tube radiation is controlled by local space temperature sensors, which are all monitored by the BMS. Temperature setpoints for these spaces can be adjusted at the BMS workstation located in the basement electrical room. A full description of the BMS can be found in section 4.01.4.

Photo 10. Hot water pumps serving Library

Photo 11. Typical finned tube radiation

Photo 12. Typical wall mounted temperature sensor

4.01.2 Existing Cooling Systems

Cooling for the Village Hall is provided by a combination of window AC units and packaged terminal AC units (PTAC's) serving offices in the building (Photo 13), a Trane packaged rooftop unit (RTU) serving the second floor courtroom (Photo 14), and two (2) Mitsubishi split AC units serving the Police Department (Photo 15). The RTU and split AC units are all controlled locally by programmable thermostats located in the spaces they serve. It was noted that the packaged RTU serving the courtroom appears to be in poor condition. There are approximately 11 Friedrich window AC units and 2 PTAC's serving the building. Each window AC unit has an approximate capacity of 1.5 tons (18 MBH) of cooling. A summary of the cooling systems at the Village Hall is shown below in Table 6.

Table 6. Village Hall Cooling Plant Summary

Type	Manufacturer	Total Capacity (Tons)	Estimated Total Quantity
Window AC unit	Friedrich	1.5	11
PTAC		1 – 1.5	2
Packaged RTU	Trane	8*	1
Split AC unit	Mitsubishi	1 – 2	2

* Per Village Hall design drawings

Photo 13. Typical window AC unit

Photo 14. Packaged Trane RTU serving courtroom

Photo 15. Split AC unit serving Police Department

Cooling for the Library is provided by a combination of one (1) 40-ton air-cooled Trane chiller (Photo 16), which serves the main floor, Picture Book Room, and Barnes Room via chilled water coils located in AC and HV units, and one (1) City-Multi split AC unit which serves the Orr Community Room on the lower level (Photo 17). A summary of the chiller plant at the Library is shown below in Table 7.

Table 7. Library Chiller Plant Summary

Manufacturer	**Type**	**Total Capacity (Tons)**	**CHWS Temperature (°F)**	**Typical Chiller Start Time**	**Typical Chiller Shutdown Time**
Trane	Air-cooled	40	44	8:00am	7:00pm – 9:00pm

Photo 16. Trane air-cooled chiller

Photo 17. City-Multi condensing unit

Chilled water is supplied to spaces via two (2) chilled water pumps located in the penthouse mechanical room. The chiller itself is located on the roof of the building, adjacent to the penthouse. The chiller is automatically controlled by the BMS (Photo 18) and is set to maintain 44°F chilled water supply temperature (CHWS) during occupied hours (determined based on Library hours). The chiller was installed in the 1990's and appears to be in fair condition, while the chilled water pumps appear to be original to the building (1965). The pumps also appear to be in fair condition.

Cooling for the Orr Community Room is provided by a City-Multi split heat pump and is supplied via ductwork in the space. This unit is locally controlled by a wall-mounted thermostat, and cannot be controlled by the BMS (Photo 19). It was noted that this unit was recently installed during expansion of the community room.

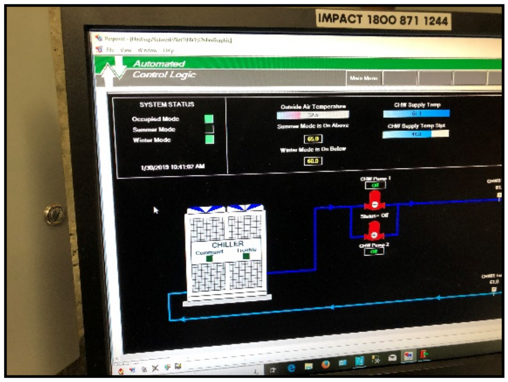

Photo 18. Chiller plant BMS graphic

Photo 19. Thermostat for City-Multi heat pump

4.01.3 Existing Ventilation Systems

Mechanical ventilation for the Village Hall consists of one (1) RTU, which serves the courtroom only. Ventilation for the remainder of the building is provided by opening windows, and through various toilet exhaust fans. Table 8 below shows a summary of the systems serving the Village Hall.

Table 8. Village Hall Mechanical Ventilation System Summary

Unit Tag	Area Served	Motor HP	Max. CFM	100% OA Unit (Y/N)
AC-1	Second Floor Courtroom	2	3,000	No

Mechanical ventilation for the Library consists of two (2) AC units and one (1) Heating and Ventilation (HV) unit that serve all spaces in the building except for the Community Room. HV-1, serving the main floor of the library, is located in the penthouse mechanical room and appears to be original to the building (1965). AC-2, serving the Barnes Room, is located in the ceiling adjacent to the space, and AC-3, serving the Picture Book Room and Director’s Office, is located in a mechanical closet within the space. Both of these units were installed during construction of the new addition. All three (3) of these units are controlled by the BMS. Table 9 below shows a summary of the systems serving the library.

Table 9. Library Mechanical Ventilation System Summary

Unit Tag	Area Served	Motor HP	Max. CFM	100% OA Unit (Y/N)
HV-1	Library Main Floor	10	15,400	No
AC-2	Barnes Room	1	1,925	No
AC-3	Picture Book Room and Director’s Office	¾	1,300	No

4.01.4 Existing Control Systems

Heating at the Village Hall is controlled by two (2) Honeywell wall-mounted programmable thermostats, which control zone valves on the main steam header. The thermostats are set to maintain an occupied and unoccupied heating setpoint, based on a schedule programmed into the thermostats by the building staff. Cooling at the building is all controlled locally via manual switches for window AC units, and thermostats for the split AC units and packaged RTU serving the courtroom.

The library contains a central BMS, which automatically monitors and controls the heating and cooling systems at the building. Heating via the steam-to-hot water heat exchanger is set to maintain 172°F hot water supply temperature (HWST) during occupied hours, while the central chiller plant is set to maintain 44°F chilled water supply temperature (CHWS). The AC / HV units serving the building each have their own BMS graphic (Photo 20), and appear to be controlled based on space temperature setpoint. If the space temperature is above / below setpoint, the BMS will open the associated chilled / hot water valve on the unit until space setpoint is achieved. It was noted that HV-1 appears to have multiple zone dampers, which are also controlled by the BMS and modulate the amount of airflow supplied to each space in order to help meet space setpoint.

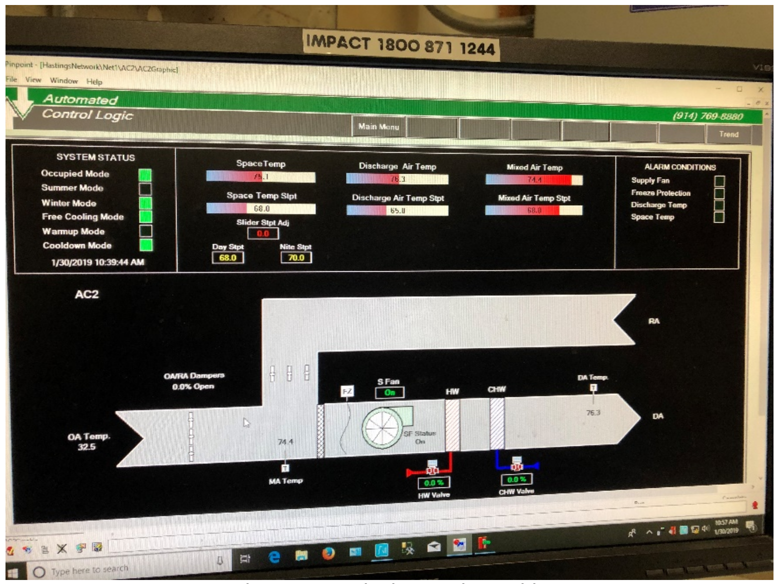

Photo 20. Typical AC unit graphic

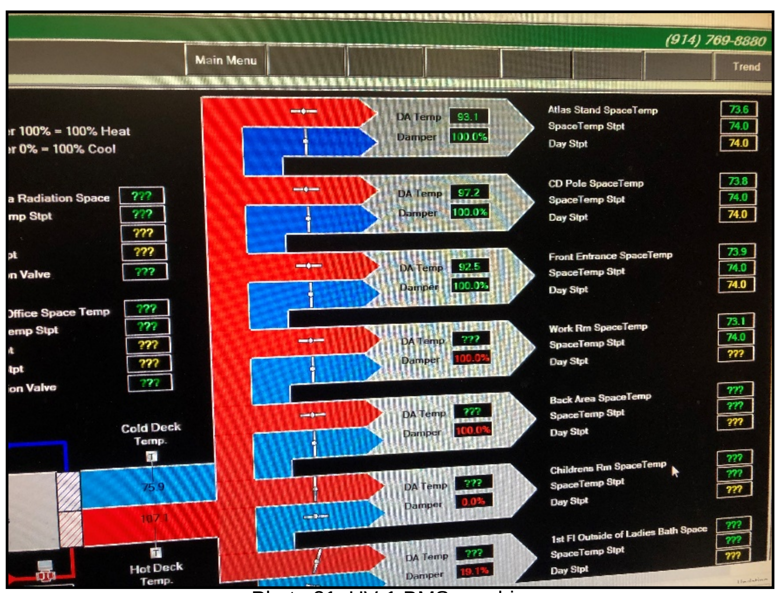

Photo 21. HV-1 BMS graphic

4.01.5 Existing Domestic Water System

Domestic hot water (DHW) at the Village Hall is generated by a combination electric A.O. Smith water heater and storage tank (Photo 22). The DHW heater has a total capacity of 6 kW and a storage capacity of 80 gallons. The age of the DHW heater could not be verified but it appears to be in good condition.

Domestic hot water at the Library is generated by a combination electric American water heater and storage tank (Photo 23). The DHW heater has a total capacity of 4.5kW and a storage capacity of 40 gallons. The DHW heater was installed in 2017 and appears to be in good condition. A summary of the DHW systems serving the two buildings is shown below in Table 10.

Table 10. DHW System Summary

Area Served	Manufacturer	Fuel Source	Heating Capacity (kW)	Storage Capacity (Gal)	Quantity	Year Installed
Village Hall	A.O. Smith	Electric	6	80	1	Unknown
Library	American	Electric	4.5	40	1	2017


Photo 22. Electric DHW heater serving Village Hall


Photo 23. Electric DHW heater serving Library

4.01.6 Existing Lighting System

Interior lighting at the Village Hall primarily consists 3-bulb ceiling pendants which contain 13W Fluorescent bulbs, and 2-bulb ceiling pendants containing 28W Fluorescent bulbs. These fixtures are found in all spaces throughout the building (Photos 24 and 25).

Interior lighting fixtures at the Library primarily consists of 12W and 18W LED lamps, which are found on the main floor, Orr Community Room, Barnes Room, Picture Book Room, and offices (Photos 26 and 27). There are additional wall-mounted lighting fixtures on the lower level of the Library that contain 22W Fluorescent lamps (Photo 28).

Photo 24. Typical Village Hall corridor lighting

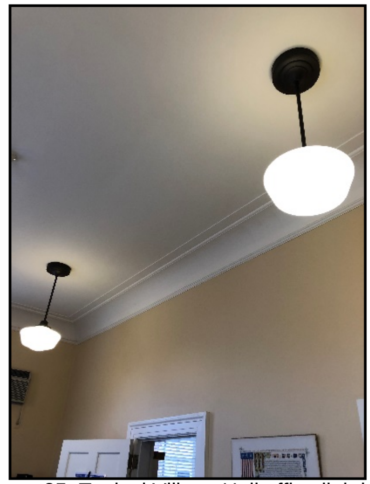

Photo 25. Typical Village Hall office lighting

Photo 26. Typical Library LED lighting

Photo 27. Typical Library LED lighting

Photo 28. Typical Library Fluorescent lighting

4.01.7 Existing Lighting Controls

All interior lighting at the Village Hall and Library is controlled manually by toggle switches. Lighting is turned on at the beginning of each day by building staff and typically remains on until the end of the day. It was noted that both buildings have occupancy sensors installed, however building staff indicated that they were intended to be used for security measures and are no longer in use (Photo 29).

Exterior lighting control at the Village Hall could not be verified during the site visit. Exterior lighting at the Library is controlled by timers (Photo 30).

Photo 29. Typical occupancy sensor

Photo 30. Typical timer for exterior lighting

4.02 Village Hall and Library Analysis of Present Energy Use

A historical energy use analysis was performed for the energy sources at the Village Hall and Library. The following data was analyzed based on 2017-2018 energy consumption and costs. Historical utility bills detailing usage earlier than 2017 were provided, however they were not complete and therefore not included in this analysis. Based on the utility bills provided, OLA was able to calculate a combined site EUI for the two (2) buildings. The Village Hall and Library used approximately 102.4 kBtu/ft^2 site energy and had a combined total energy cost of $58,494 based on 2017-2018 data. OLA could not calculate an average EUI over multiple years due to the limited amount of utility bills provided. Table 11 below provides a summary of the annual energy usage and costs for 2017-2018. Note that all fuel usage, costs, and areas are combined values from both buildings.

Table 11. 2017-2018 Annual Overall Site Energy

Energy Source	Energy Usage	kBtu	Cost ($)	Cost ($) per ft^2	Site EUI (kBtu/ft^2)	CO_2 Emissions (lb/year)
Village Hall Electric (kWh)	125,640	428,684	$16,865	$0.71	18.0	80,410
Library Electric (kWh)	126,720	432,369	$21,847	$0.92	18.2	81,101
Natural Gas (therm)	12,107	1,210,700	$13,515	$0.57	50.8	141,758
#2 Fuel Oil (gal)	2,621	366,940	$6,268	$0.26	15.4	60,907
Total		2,438,692	$58,494	$2.46	102.4	363,431
Gross Area (ft^2)		23,820				

Figure 1 provides the annual site EUI per energy type based on analysis of the utility bills for 2017-2018. Figure 2 provides the annual energy cost summary by energy type from the same average year. Natural gas for heating is the dominant energy source for these two buildings, and is projected to account for 50% of the overall energy consumption of the building. However, natural gas only accounts for 23% of the cost, due to the higher cost of electricity. Figure 3 provides the annual CO_2 emissions breakdown by energy type.

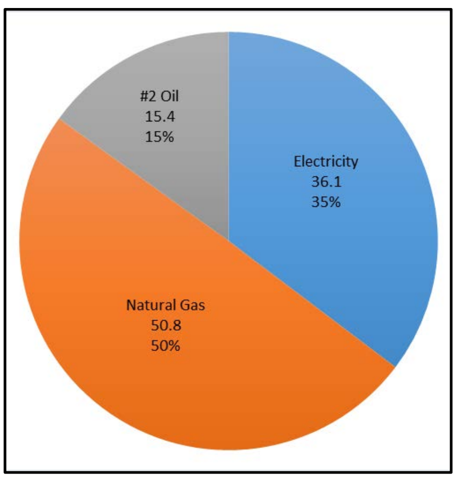

Figure 1. Existing Annual Fuel Type Site EUI Breakdown in kBtu/ft.^{2}

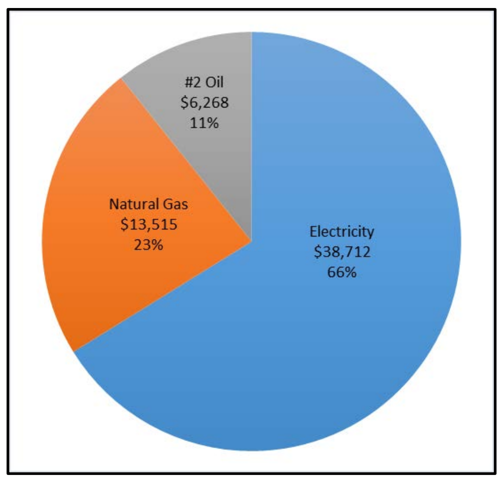

Figure 2. Existing Annual Energy Cost Breakdown

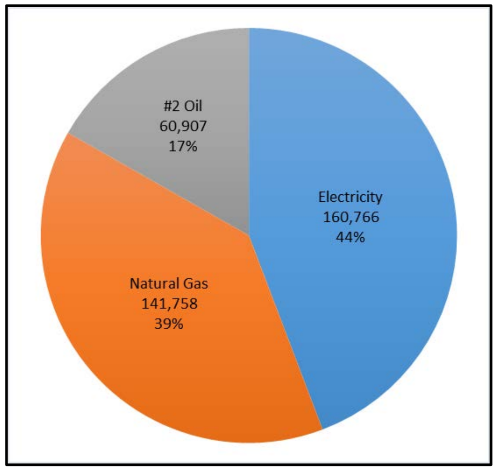

Figure 3. Existing Annual CO_2 Emissions Breakdown in lb/year

4.02.1 Electrical Usage

The historical electric usage for the Village Hall is shown in Figure 4. Peak electricity usage typically occurs during the summer months (May – September), likely due to the need to run the window AC units in order to cool the building. The highest monthly usage recorded during this time was 12,880 kWh during September 2016. It was noted that the usage remains relatively constant throughout the year, likely to the limited amount of window AC units at the building.

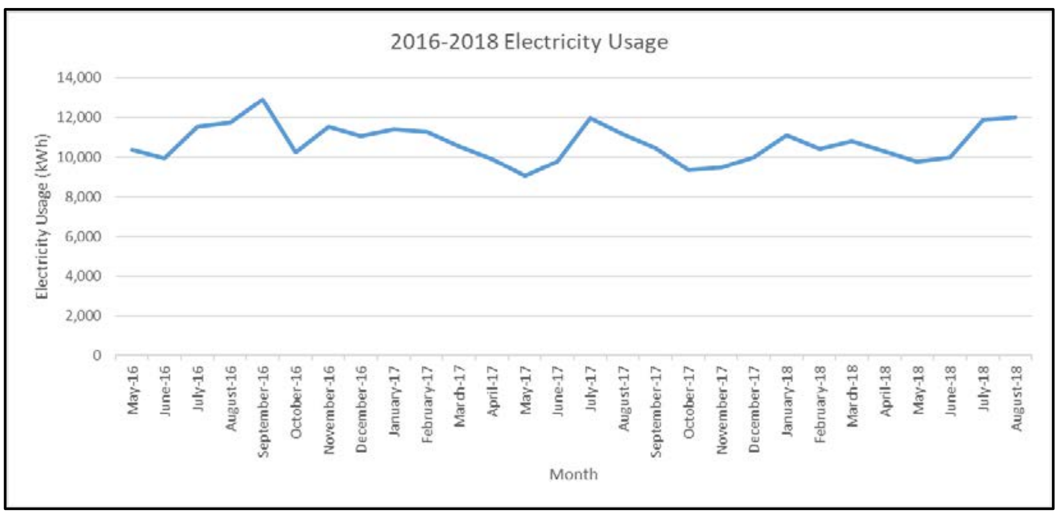

Figure 4. 2016 – 2018 Village Hall Historical Electricity Use

The historical electric usage for the Library is shown in Figure 5. Peak electricity usage typically occurs during the summer months (May – September), likely due to the need to run the air-cooled chiller in order to cool the building. The highest monthly usage recorded during this time was 18,640 kWh during September 2016.

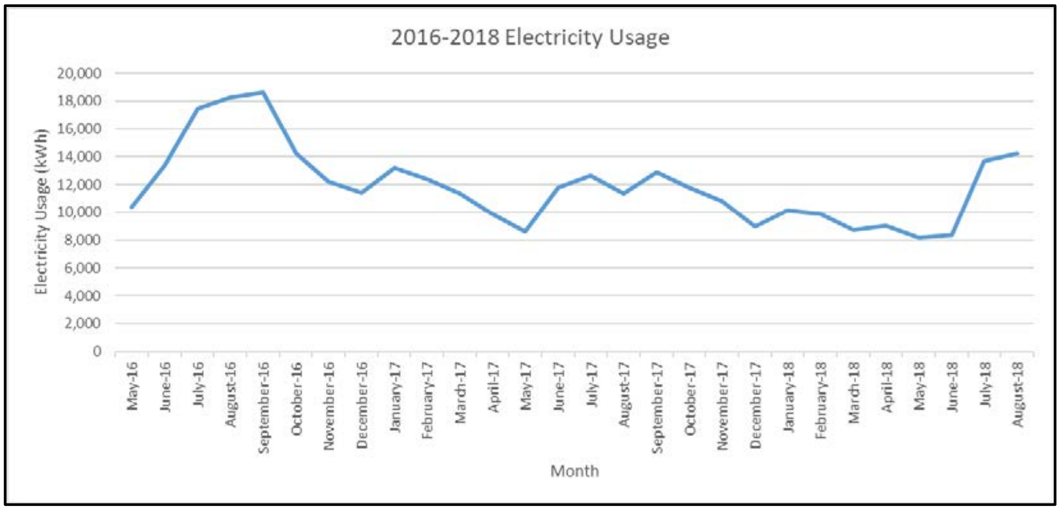

Figure 5. 2016 – 2018 Library Historical Electricity Use

The historical electric demand for the Village Hall is shown in Figure 6. Similar to the historical electricity usage above, the building's peak demand typically occurs between May and September. The highest recorded demand of 38.4 kW occurred in August 2016.

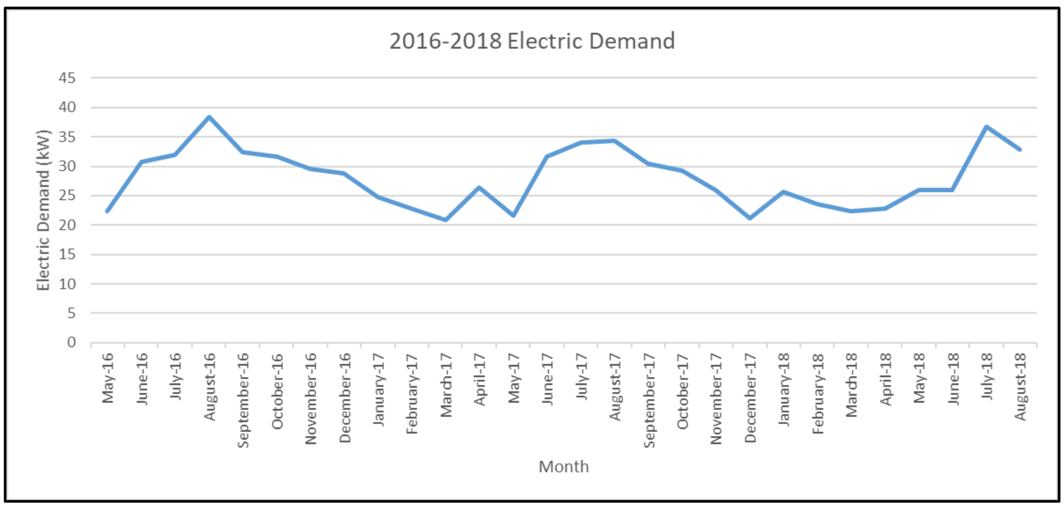

Figure 6. 2016 – 2018 Village Hall Historical Electric Demand

The historical electric demand for the Library is shown in Figure 7. Similar to the historical electricity usage above, the building's peak demand typically occurs between May and September. The highest recorded demand of 64.0 kW occurred in September 2016.

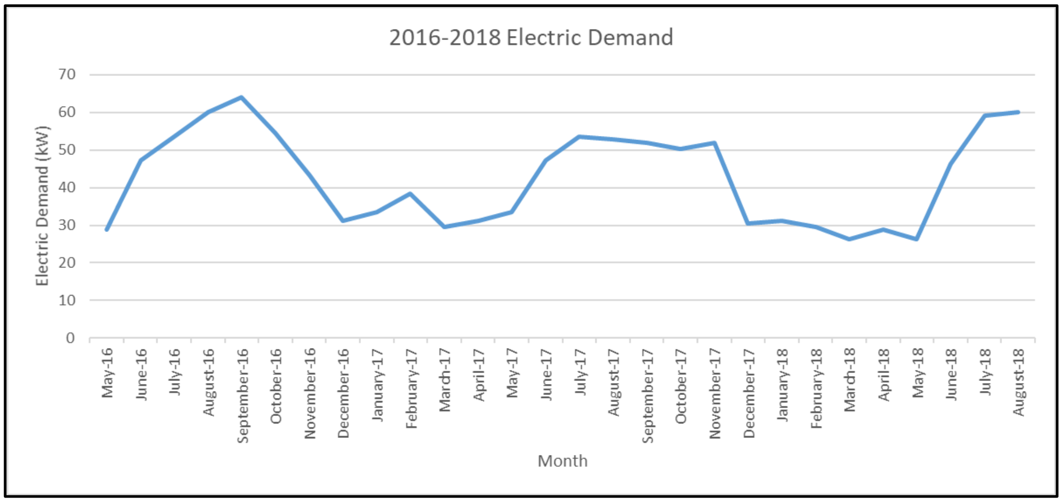

Figure 7. 2016 – 2018 Library Historical Electric Demand

OLA was provided with complete electric utility bills for this analysis, and determined an electricity rate of 0.134 $/kWh for the Village Hall, and an electricity rate of 0.172 $/kWh for the Library based on the bills provided. For the purposes of this study, these rates were used to estimate energy cost savings for the respective building.

4.02.2 Natural Gas Usage

Figure 8 below shows the historical 2017-2018 natural gas usage for the Village Hall and Library. Since these two buildings share a heating plant, and because gas is used for heating only, usage is found to be highest during the winter months. A peak usage of 3,715 therms was recorded in January 2018.

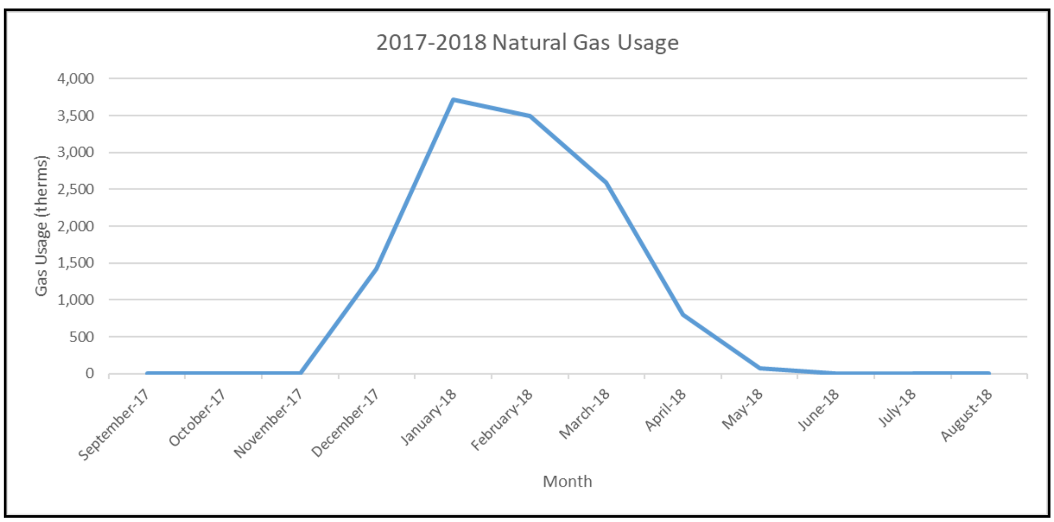

Figure 8. 2017 – 2018 Historical Natural Gas Usage

OLA was provided with complete utility bills for this analysis and determined a natural gas of 1.12 $/therm based on the bills provided. For the purposes of this study, this calculated rate was used to estimate energy cost savings.

4.02.3 #2 Fuel Oil Usage

The historical monthly oil usage for the Village Hall and Library is shown in Figure 9. It was noted that these two buildings stopped using oil for heating in 2017, and only two months of bills from that year were provided. Note that the figure below is a reflection of gallons delivered to the building per month, and not an actual trend of the usage.

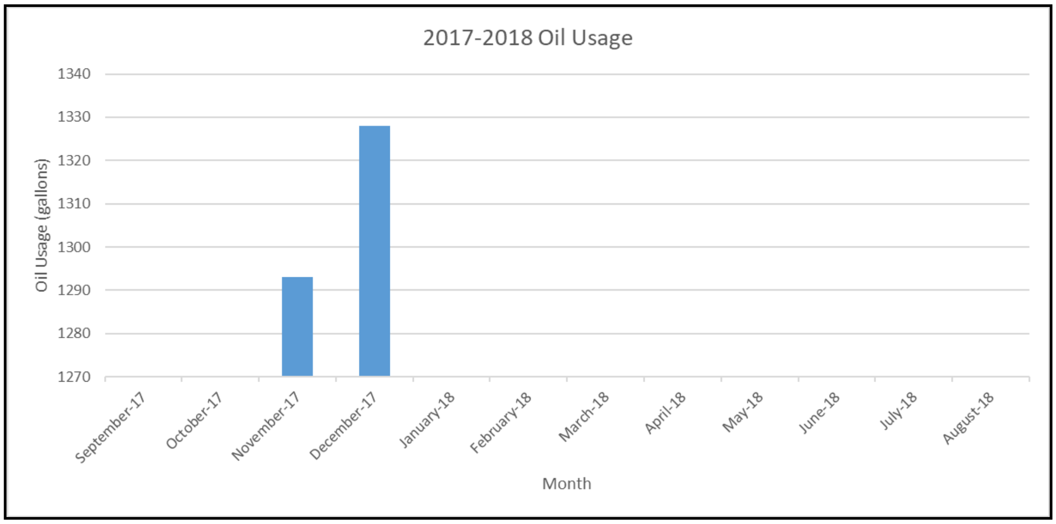

Figure 9. 2017 – 2018 Historical Oil Usage

For the purposes of this study, the provided oil rate of 2.39 $/gallon based on 2017 utility bills was used to estimate energy cost savings.

4.02.4 Utility Rates and Costs

The Village Hall and Library are each served by one (1) electric meter and one (1) common gas meter located at the Village Hall. An estimated blended electric rate for each of the two buildings and a common gas rate were determined based on monthly usage and monthly charges. Table 12 below shows a breakdown of the utility rates for each fuel source.

Table 12. Utility Rates

Utility	Unit	2016/17	2017/18
Electric (Village Hall)	$/kWh	$0.125	$0.134
Electric (Library)	$/kWh	$0.150	$0.172
Natural Gas (common)	$/therm	-	$1.12
Fuel Oil #2 (common)	$/Gallon	-	$2.39

4.02.5 Energy Utilization

Figure 10 below shows the breakdown of energy intensity (kBtu/ft^2) by end use type. The results confirm that fuel consumed to run the heating plant accounts for the largest portion of the site energy use and cost.

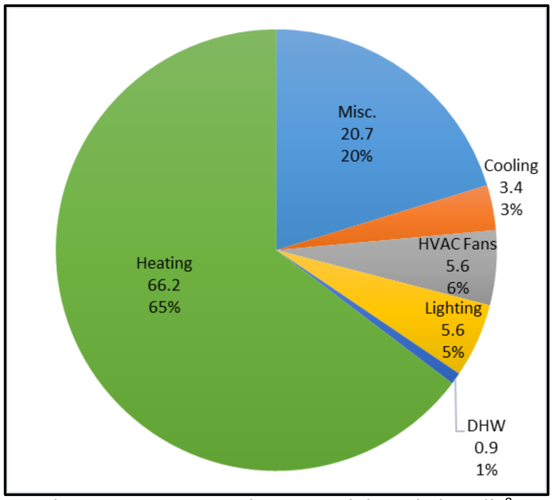

Figure 10. Energy End Use Breakdown in kBtu/ft.^{2}

4.03 Energy Efficiency Measures (EEMs)

Short Term EEM's

4.03.1 EEM 1 – Village Hall LED Lighting Retrofit and Lighting Controls Upgrade

This measure investigates the impact on energy consumption of reduced lighting power density utilizing high efficiency LED lighting technology and retrofit products throughout the building. The new LED lighting will result in a reduced lighting power density and potential for high savings. All of the typical 13W and 28W compact fluorescent lighting, as well as the 32W T8 fluorescent lighting in the basement of the building could be replaced with LED retrofit products. The existing lighting power density of the Village Hall is estimated to be 0.52 W/ft^2. The resulting lighting power density of the entire facility is estimated to be in the range of 0.26 W/ft.^{2} after a complete retrofit.

In addition, installing occupancy sensors could result in further energy reduction. This building currently has no form of automatic lighting controls installed. The occupancy sensors would automatically turn lights on and off depending on whether the space is occupied. This measure will prevent lights from staying on for extended periods of time while the spaces are not being used.

Figure 11. Proposed Philips LED fixture

Figure 12. Typical occupancy sensor

4.03.2 EEM 2 – Library Lighting Controls / Daylighting Upgrades

This measure investigates the energy reduction associated with installing occupancy lighting control sensors and photocells for natural daylighting. This building currently has no form of automatic lighting controls installed. The occupancy sensors would automatically turn lights on and off depending on whether the space is occupied. This measure will prevent lights from staying on for extended periods while the spaces are not in use. The photocells will dim and/or turn the lights off in a space based on the current level of daylight measured by the photocell. We estimate the following spaces/zones would be ideal for occupancy and/or daylighting sensors:

- Main Library Entrance
- Main Library Rear
- Picture Book Room
- Barnes Room
- Director's Office
- Staff Office
- Book Shop
- Staff Lounge
- Restrooms

Long Term EEM's

4.03.3 EEM 3 – Village Hall Upgraded Windows

This measure assesses the energy savings associated with replacing the existing windows with higher thermal performance, high efficiency, low-e double glazing with thermally broken framing (U-0.40 assembly and SHGC 0.45). Although there was found to be considerable energy savings with this measure, the high cost to replace the glazing in each building results in a long payback.

4.03.4 EEM 4 – Village Hall Upgraded Wall Insulation

This measure assesses the energy savings associated with improving the thermal performance of the walls of the Village Hall by adding R-7.5 insulation throughout the building. Although there was found to be considerable energy savings with this measure, the high cost to implements these envelope improvements results in a long payback.

4.03.5 EEM 5A – Heating Plant Upgrades: High Efficiency Gas-Fired Hot Water Boilers

This project would eliminate the existing gas fired steam boiler and convert the Village Hall to a hot water system utilizing new gas-fired, high efficiency condensing boilers as the primary source of heating. The low cost of natural gas will reduce operating costs compared to oil. In general, hot water heating systems are more efficient than steam heating system. Installing a hot water boiler plant will allow the building to move away from the obsolete steam heating system along with their associated system losses and higher maintenance issues and costs. This project would necessitate a complete replacement of the heating distribution system. Current best achievable hot water boiler efficiency is in the range of 90% – 91%. Note that the new system would still serve the hot water heating system at the library.

Figure 13. Aerco condensing boiler

4.03.6 EEM 5B – Geothermal Heat Pumps for Village Hall

An alternative to EEM 5A would be to disconnect the steam heating system from the Village Hall and heat/cool the building using geothermal water source heat pumps. As there is available space in the parking lot for a well field, it is estimated that about 30 geothermal wells could be installed. Utilizing a closed loop geothermal system would remove the high energy costs of natural gas and #2 oil for heating and provide an overall energy use intensity (EUI) reduction and cost savings due to high heat pump operating efficiencies. We estimate the building has enough space for a 30 – 40 ton well field, which could potentially satisfy the entire Village Hall heating and cooling loads. Each zone in the building would be retrofitted with console units, which would provide heating and cooling to the spaces they serve (picture below). Note that the hot water heating system for the Library would remain in place, since the well field would not likely be able to support both buildings. Savings for this measure were calculated based on the existing steam boiler still serving the library.

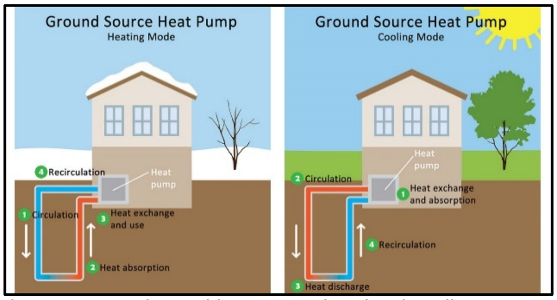

Figure 14. Geothermal heat pump heating / cooling process


Figure 15. Water Furnace console heat pump

4.03.7 EEM 5C – Air Source VRF Heat Pumps for Village Hall

Another alternative to EEM 5A and 5B would be to remove the existing steam heating system and convert the Village Hall to a more traditional air source heat pump system with variable refrigerant flow (VRF). Air source heat pumps typically offer high heating and cooling efficiencies, which could result in an overall EUI reduction and cost savings. Indoor units would be installed where appropriate, providing heating and cooling to the spaces they serve. Note that the hot water heating system for the Library would remain in place. Savings for this measure were calculated based on the existing steam boiler still serving the library.

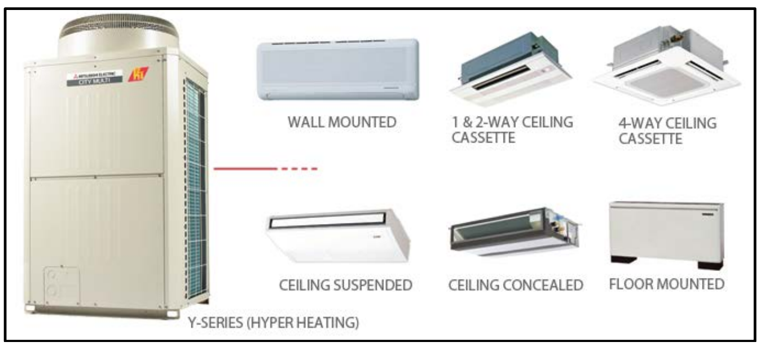

Figure 16. City-Multi VRF heat pump units

4.03.8 EEM 6 – Roof-Mounted Solar Photovoltaic (PV) System for Library

As there is available space on the roof of the library, the installation of solar electric PV panels has been reviewed. It is estimated that about 2,000 ft^2 of roof is available for solar panels. The general orientation of the building is favorable for solar collection, and there are no nearby tall buildings or trees that could potentially cause shading. This makes the library a good candidate for solar PV, and this upgrade would provide significant energy savings toward electricity usage. We estimate the library would have enough roof space for a 30 – 40 kW PV system, which could potentially provide up to 33% of the building's current annual electricity usage.

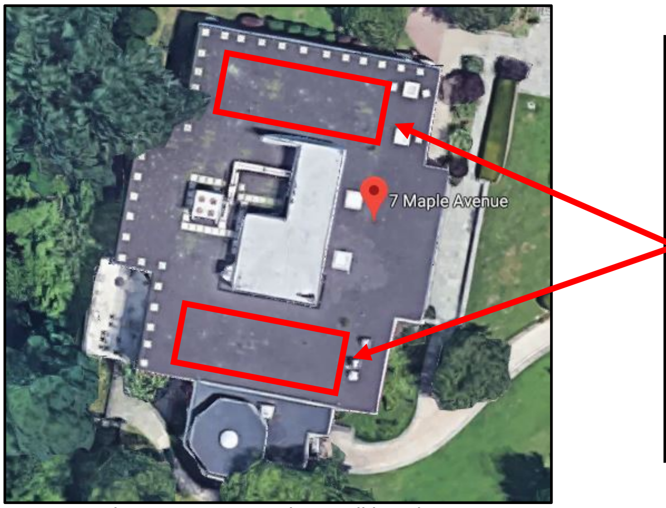

Figure 17. Proposed PV cell locations

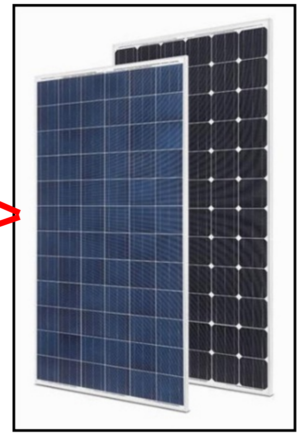

Figure 18. Typical PV cell

4.03.1 EEM 7 – Library AHU Replacement

HV-1, serving the main floor of the Library, appears to be original to the building and although still in fair condition is beyond its useful life and should be replaced. We recommend replacing the unit with a new variable air volume (VAV) air-handling unit with VAV boxes replacing each of the existing zone dampers. The new unit would be equipped with supply and return fan variable frequency drives (VFD's), which would allow the fans to modulate speed based on the building load. Allowing the fans will modulate to a minimum speed would reduce fan energy costs and provide an overall energy savings compared to the existing HV-1.

5.0 James Harmon Community Center

5.01 Existing Conditions

The James Harmon Community Center is a 4-story, 17,000 square foot multi-use building located at 44 Main Street in Hastings-on-Hudson, NY and was constructed in 2007. The building contains three (3) above grade floors, as well as a basement level. The lower level contains the Youth Center, the first floor contains offices and the community room, and the second floor contains the TV / Media center and various offices. Photos 31 and 32 show an aerial and exterior view of the building.

Photo 31. Aerial view of Community Center

Photo 32. Community Center exterior

Typical building hours for the Community Center range from 9:00am – 4:30pm Monday through Thursday, and 9:00am – 1:00pm on Fridays. It was noted that the Recreation Department is officially closed on weekends, however the building occasionally allows residents to rent out the large community room on the first floor for parties and events on Saturdays. The Youth Services center on the lower level is also open to students on weekends. A breakdown of the building operating hours is shown below in Table 12.

Table 12. Community Center Operating Hours

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Weekend
9:00am	Building opens	Building opens	Building opens	Building opens	Building opens	Building occasionally open on Saturdays
1:00pm	-	-	-	-	Building closes	
4:30pm	Building closes	Building closes	Building closes	Building closes	-	

5.01.1 Existing Heating Systems

Heating for the Community Center is provided by one (1) gas-fired hot water boiler manufactured by Weil McLain (Photo 33). The boiler has a gross output capacity of 991 MBH, and is equipped with a Power Flame burner that has a maximum capacity of 1,232 MBH. It was noted that the boiler appears to be in good condition. A summary of the heating plant is shown below in Table 13.

Table 13. Community Center Heating Plant Summary

Manufacturer	Type	Capacity (MBH)	Fuel Source	Quantity	Year Installed	Typical Boiler Operating Time
Weil McLain	Hot Water	991	Natural Gas	1	2007	3:30am – 7:00pm

The boiler is automatically controlled by the building's digital building management system (BMS), and typically initiates occupied mode at approximately 3:30am Monday through

Friday during the heating season (Photo 34). The boiler then cycles on/off in order to achieve the BMS hot water supply temperature setpoint of 165°F. It was noted that the boiler operates in unoccupied mode from 7:00pm – 3:30am Monday through Friday. According to the BMS, the boiler is not active during weekends.

Photo 33. HW boiler serving Community Center

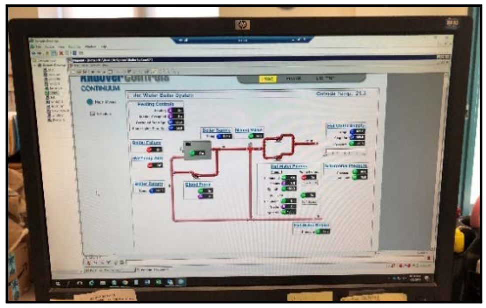

Photo 34. Hot water system BMS graphic

Hot water generated by the boiler is distributed throughout the building via two (2) 3 HP hot water pumps (Photo 35) and serves various perimeter radiation (Photo 36) as well as hot water coils located in the four (4) RTU's and one (1) HV unit serving the building. It was noted that the hot water pumps are equipped with variable frequency drives (VFD's) and have the ability to modulate speed based on heating demand.

Photo 34. Hot water pumps

Photo 35. Typical finned tube radiation

Heating for each space in the building is controlled remotely by the BMS through wall-mounted temperature sensors (Photo 36). Since the majority of spaces in the building are served by variable air volume (VAV) boxes, each temperature sensor typically monitors one zone and an associated finned tube radiation valve grouped with that specific zone. It was noted that space temperature setpoints can be adjusted via the BMS workstation located in the Recreation Department on the first floor of the building. A description of the BMS can be found in section 5.01.4.

Photo 36. Typical temperature sensor

5.01.2 Existing Cooling Systems

Cooling for the Community Center is provided by a total of four (4) packaged Carrier rooftop units (RTU's) equipped with DX cooling. Cold air is generated by the RTU's and then supplied to spaces throughout the building via individual VAV boxes. Cooling setpoints for each space are controlled by the BMS and monitored by wall-mounted temperature sensors. A summary of the cooling capacities for each RTU is provided in section 5.01.3.

5.01.3 Existing Ventilation Systems

Mechanical ventilation for the Community Center consists of the four (4) Carrier RTU's (Photo 37) and one (1) Magic Aire HV unit (Photo 38) that serve the entire building. The four RTU's are all located on the roof of the building, while the HV unit is located in the basement. There are also various corresponding exhaust fans that serve these spaces (Photo 39).

It was noted that three (3) of the RTU's (RT-1, RT-2, RT-4) serve multiple spaces and contain VAV boxes. All of these systems are controlled by the BMS. Table 14 below shows a summary of the major systems serving the building.

Table 14. Community Center Mechanical Ventilation System Summary

Unit Tag	Area Served	Cooling Capacity (Tons)	Heating Capacity (MBH)	Motor HP	Max. CFM	100% OA Unit (Y/N)
RT-1	Second Floor	6	48.2	3	2,100	No
RT-2	First Floor	5	42.2	2	1,750	No
RT-3	Community Room	25	414.4	10	10,000	No
RT-4	Lower Level	20	138.8	5	6,000	No
HV-1	Basement	-	24	1/3	1,000	Yes


Photo 37. Typical RTU serving Community Center


Photo 38. HV-1 serving Community Center


Photo 39. Typical exhaust fan serving Community Center

5.01.4 Existing Control Systems

All of the HVAC systems at the Community Center are controlled by the building's BMS. The BMS has system summary pages for the hot water system, four (4) RTU systems, and one (1) HV unit system. There are also individual VAV graphics for each of the VAV boxes in the building.

Hot water heating is primarily controlled based on hot water supply temperature. The hot water system is currently set to maintain a constant hot water supply temperature of 165°F. The BMS graphic of the hot water system also allows the user to monitor various control points such as return water temperature, hot water pump status and speed, and system differential pressure (Photo 40).

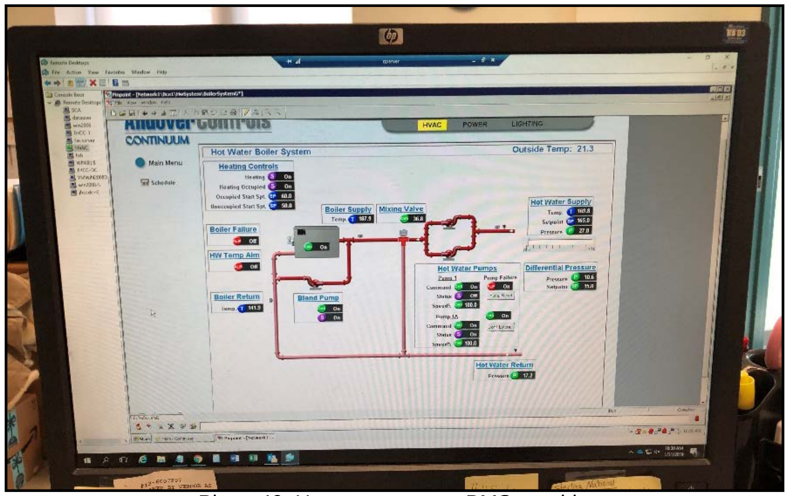

Photo 40. Hot water system BMS graphic

The four (4) RTU's serving the building appear to be controlled by discharge air temperature or static pressure, depending on the unit. Each RTU has its own BMS graphic, where the user can monitor various points such as fan status, damper position, temperature setpoints, and static pressure (Photo 41). It was noted that HV-1, serving the basement, appears to be controlled based on discharge air temperature and does not have the same control points as the RTU's as it is a less complex system (Photo 42).

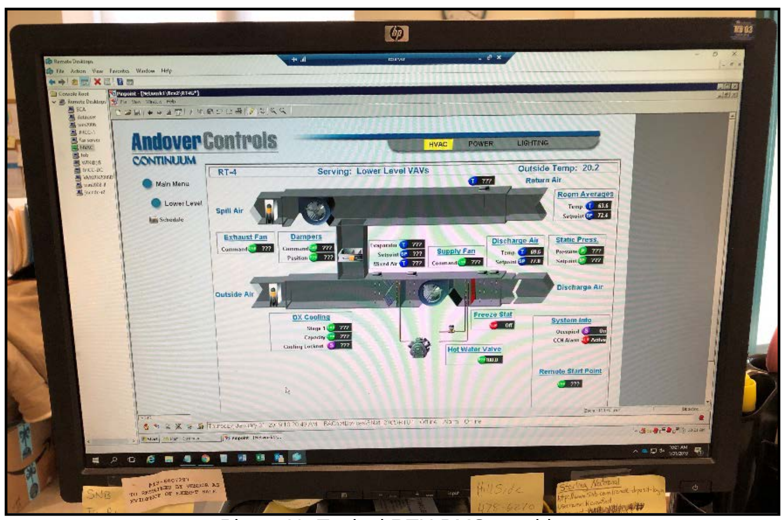

Photo 41. Typical RTU BMS graphic

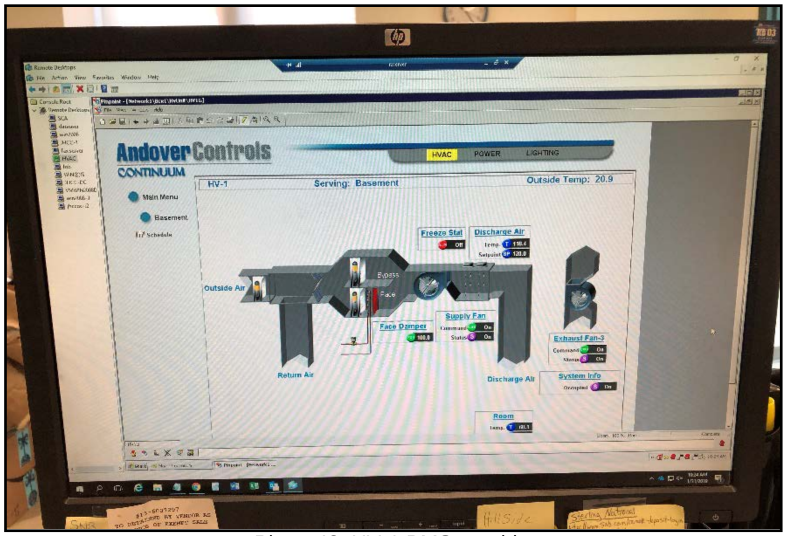

Photo 42. HV-1 BMS graphic

The spaces in the building are separated into zones by VAV boxes on every floor. Each VAV box has an associated wall-mounted temperature sensor, and controls the amount of airflow supplied to the space based on whether it needs heating or cooling. Each VAV box also has its own BMS graphic, where the user can monitor various parameters including damper position and airflow and temperature setpoints (Photo 43). If a VAV box has an associated finned tube radiation zone, the radiation valve status is shown on the graphic as well.

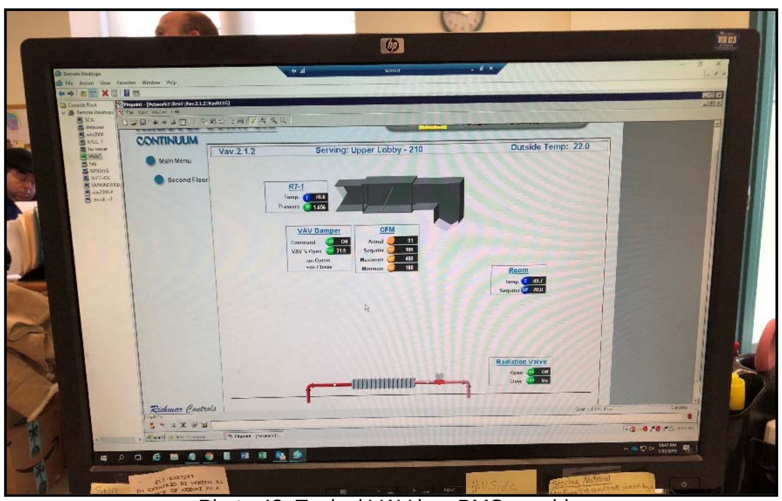

Photo 43. Typical VAV box BMS graphic

5.01.5 Existing Domestic Water Systems

Domestic hot water (DHW) is generated by a combination gas-fired PVI DHW heater and storage tank (Photo 44). The DHW heater has a total capacity of 140 MBH and storage capacity of 125 gallons. The domestic hot water loop is controlled by an aquastat and is set to supply 110°F throughout the building. A summary table of the DHW system is shown below in Table 15.

Table 15. DHW System Summary

Manufacturer	Fuel Source	Heating Capacity (MBH)	Storage Capacity (Gal)	HWS Temperature (°F)	Quantity	Year Installed
PVI	Natural Gas	140	125	110	1	2007

Photo 44. PVI DHW heater and storage tank

5.01.6 Existing Lighting System

Interior lighting fixtures primarily consist of 32W T8 LED and Fluorescent lamps, which are in all spaces throughout the building (Photos 45 and 46). The lobby and community room have additional ceiling pendants and wall-mounted fixtures that all contain fluorescent lamps (Photos 47 – 49). It was noted that the Community Center is in the process of converting all fixtures to LED lamps.

Photo 45. Typical 32W T8 lighting fixtures in offices

Photo 46. Typical 32W T8 lighting fixtures in Youth services

Photo 47. Lobby ceiling pendants and wall-mounted light fixtures

Photo 48. Community room ceiling pendants

Photo 49. Community room wall-mounted light fixtures

5.01.7 Existing Lighting Controls

Interior lighting is primarily controlled by ceiling-mounted occupancy sensors in each space (Photo 50). Lighting in the community room is controlled manually.

Exterior lighting is controlled by a timer located in the basement electrical room (Photo 51).

Photo 50. Typical occupancy sensor

Photo 51. Timer for exterior lighting

5.02 Community Center Analysis of Present Energy Use

A historical energy use analysis was performed for the energy sources at the Community Center. The following data was analyzed based on 2016-2018 energy consumption and costs. Based on the utility bills provided, OLA was able to calculate a combined site EUI for the building. The Community Center used approximately 107.9 kBtu/ft^2 site energy and had a total energy cost of $43,027 based on 2016-2018 data. Table 16 below provides a summary of the annual energy usage and costs for 2016-2018.

Table 16. 2016-2018 Annual Overall Site Energy

	Energy Usage	kBtu	Cost ($)	Cost ($) per ft^2	Site EUI (kBtu/ft^2)	CO_2 Emissions (lb/year)
Electric (kWh)	209,400	714,473	$30,700	$1.81	42.0	133,399
Natural Gas (therm)	11,213	1,121,250	$12,327	$0.73	65.9	131,284
Total		1,835,723	$43,027	$2.53	107.9	264,683
Gross Area (ft^2)		17,000				

Figure 19 provides the annual site EUI per energy type based on analysis of the utility bills for 2016-2018. Figure 20 provides the annual energy cost summary by energy type from the same average year. Natural gas for heating is the dominant energy source for this building, and is projected to account for 61% of the overall energy consumption of the building. However, natural gas only accounts for 29% of the cost, due to the higher cost of electricity. Figure 21 provides the annual CO_2 emissions breakdown by energy type.

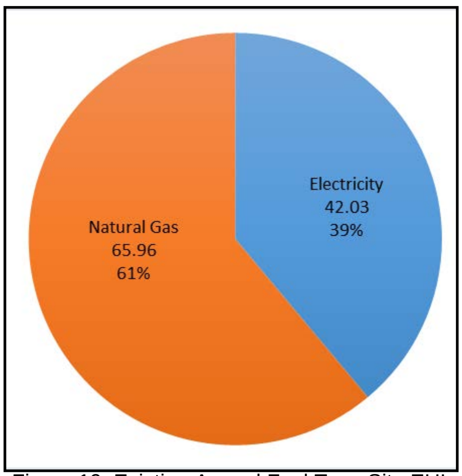

Figure 19. Existing Annual Fuel Type Site EUI Breakdown in kBtu/ft.^{2}

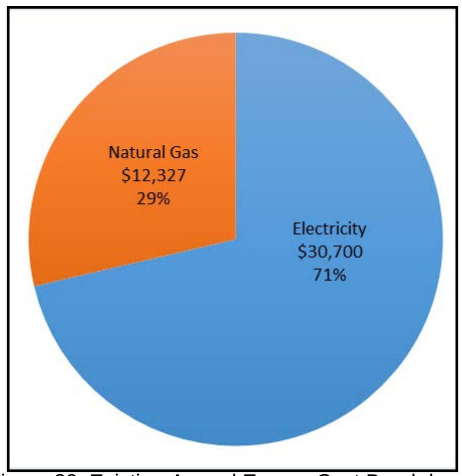

Figure 20. Existing Annual Energy Cost Breakdown

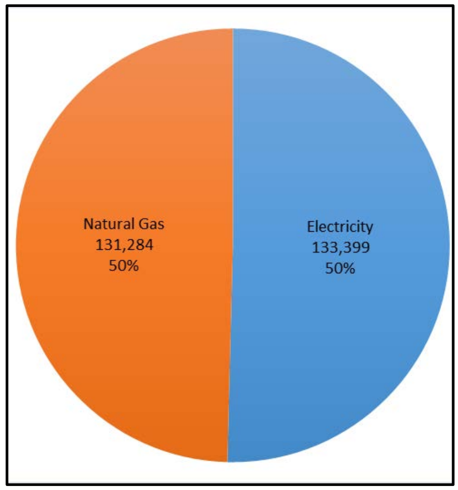

Figure 21. Existing Annual CO_2 Emissions Breakdown in lb/year

5.02.1 Electrical Usage

The historical electric usage for the Community Center is shown in Figure 22. Peak electricity usage typically occurs during the summer months (May – September), likely due to the need to run the window AC units in order to cool the building. The highest monthly usage recorded during this time was 21,680 kWh during August 2018.

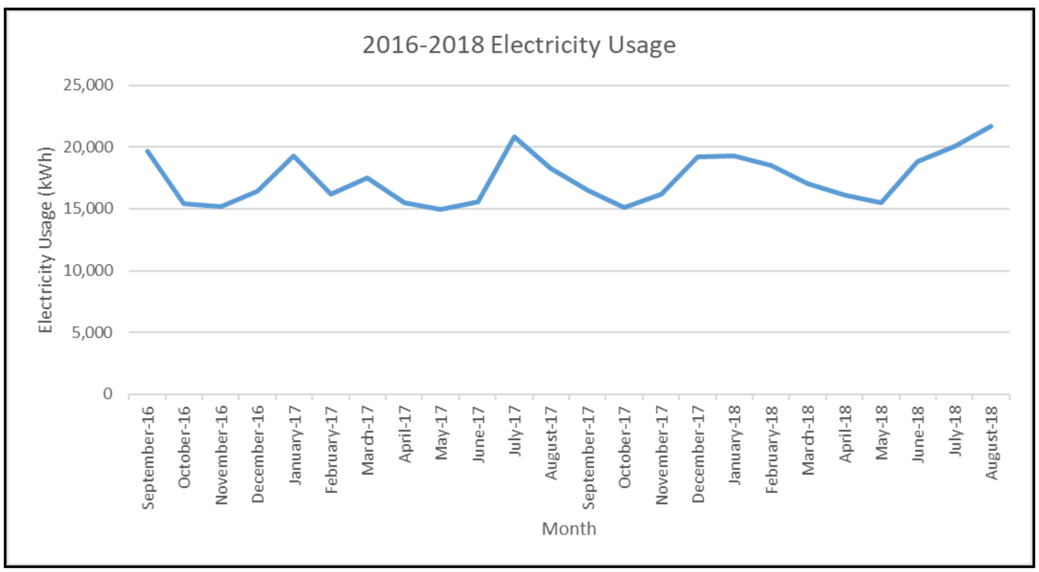

Figure 22. 2016 – 2018 Historical Electricity Use

The historical electric demand is shown in Figure 23. Similar to the historical electricity usage above, the building's peak demand typically occurs between May and September. The highest recorded demand of 81.6 kW occurred in September 2016.

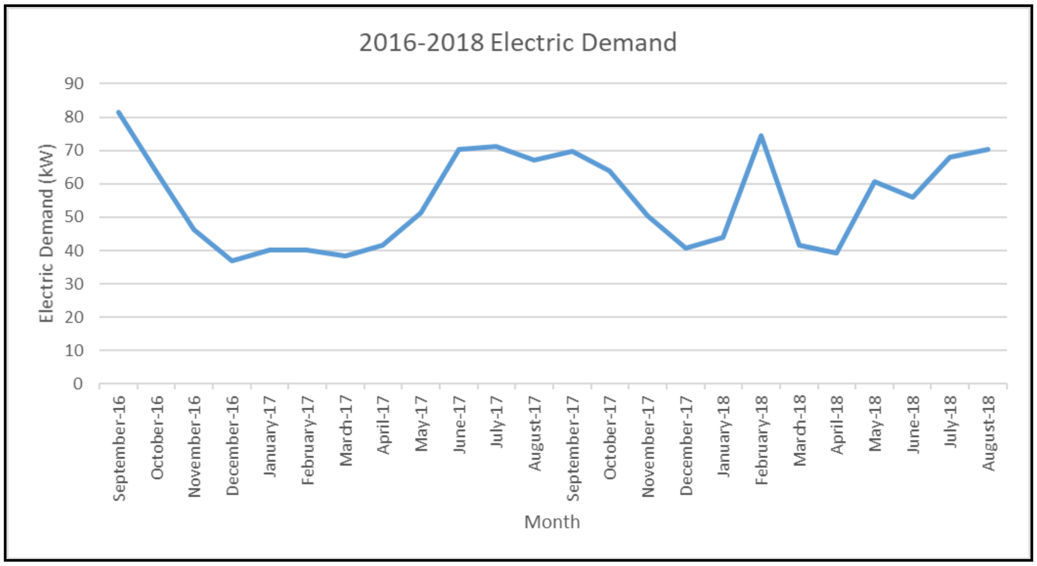

Figure 23. 2016 – 2018 Historical Electric Demand

OLA was provided with complete electric utility bills for this analysis, and determined an electricity rate of 0.147 $/kWh based on the bills provided. For the purposes of this study, this calculated rate was used to estimate energy cost savings.

5.02.2 Natural Gas Usage

Figure 24 below shows the historical 2016-2018 natural gas usage for the Community Center. Since gas in this building is used for heating only, usage is found to be highest during the winter months. A peak usage of 2,726 therms was recorded in December 2017.

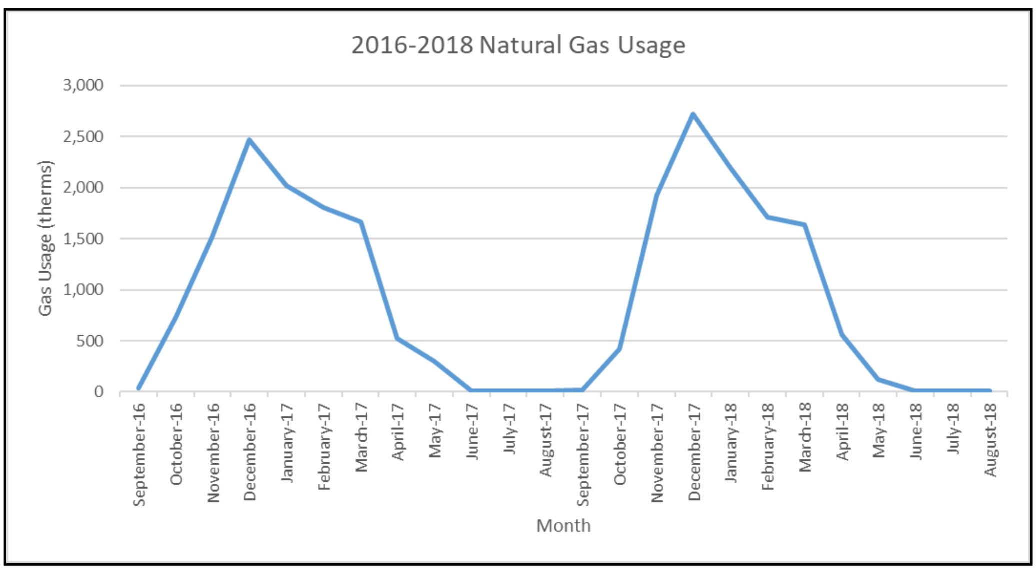

Figure 24. 2016 – 2018 Historical Natural Gas Usage

OLA was provided with complete utility bills for this analysis and determined a natural gas of 1.10 $/therm based on the bills provided. For the purposes of this study, this calculated rate was used to estimate energy cost savings.

5.02.3 Utility Rates and Costs

The Community Center is served by one (1) electric meter and one (1) gas meter. Estimated blended electric and gas rates for the building were determined based on monthly usage and monthly charges. Table 17 below shows a breakdown of the utility rates for each fuel source.

Table 17. Utility Rates

Utility	Unit	2016/17	2017/18
Electric	$/kWh	$0.142	$0.151
Natural Gas	$/therm	$1.05	$1.15

5.02.4 Energy Utilization

Figure 25 below shows the breakdown of energy intensity (kBtu/ft^2) by end use type. The results confirm that fuel consumed to run the heating plant accounts for the largest portion of the site energy use and cost.

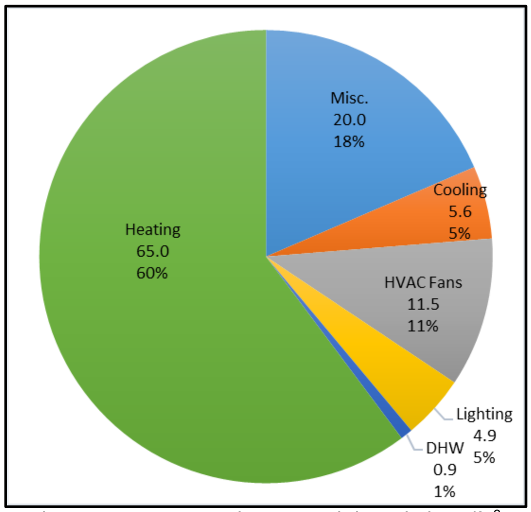

Figure 25. Energy End Use Breakdown in kBtu/ft.^{2}

5.03 Energy Efficiency Measures (EEMs)

Short Term EEM's

5.03.1 EEM 1 – LED Lighting Retrofits

This measure investigates the impact on energy consumption of reduced lighting power density utilizing high efficiency LED lighting technology and retrofit products throughout the building. The new LED lighting will result in a reduced lighting power density and potential for high savings. All of the typical 32W T8 fluorescent lighting throughout the Community Center and the existing wall-mounted fluorescent fixtures in the multi-purpose room could be replaced with LED retrofit products. The existing lighting power density of the building is estimated to be 0.56 W/ft^2. The resulting lighting power density of the entire facility is estimated to be in the range of 0.42 $W/ft.^2$ after a complete retrofit.

5.03.2 EEM 2 – Rescheduling of RTU's

The current operating hours of the HVAC equipment at the Community Center appears to not be synchronized with the actual weekly occupied hours at the building. This measure studies the potential savings from reducing the run hours on the four (4) RTU's serving the building. Adjusting the run hours could provide a significant electricity savings, and reduce the overall site and source EUI.

5.03.3 EEM 3 – Variable Frequency Drives (VFD's) on RT-3 and RT-4

Installing VFD's on RT-3 and RT-4 and making these units variable air volume (VAV) systems would allow the supply and exhaust fans on these units to modulate based on space temperature (or duct static pressure in the case of RT-4). If space temperature setpoint is met, the fans will modulate to a preset minimum speed, thereby reducing fan energy costs while still providing ventilation.

Long Term EEM's

5.03.4 EEM 4 – Heating Plant Upgrades: High Efficiency Gas-Fired Hot Water Boiler

This project would eliminate the existing standard efficiency gas-fired boiler at the community center and install a new high efficiency, condensing boiler for heating. We estimate that the boiler efficiency of the existing heating plant is approximately 81%. Current best achievable hot water boiler efficiency is in the range of 90% – 91% when used to serve an existing building.

Figure 26. Aerco condensing boiler

5.03.5 EEM 5 – Supplemental Domestic Hot Water Heat Pump

Supplementing the existing gas-fired domestic hot water heater with a 125-gallon electric heat pump system should be considered in the future. Providing the building with a high efficient electric heat pump water heater would reduce the site EUI of the building and CO_2 emissions.

Figure 27. Typical residential style DHW heat pump

6.0 Hook and Ladder Fire Company

6.01 Existing Conditions

The Hook and Ladder Fire Company building is a 2-story, 9,000 square foot volunteer fire department located at 50 Main Street in Hastings-on-Hudson, NY and was constructed in the early 1900s. It was noted that the building has been converted for many different purposes and the original construction has been altered significantly over time. The first floor contains the main garage, kitchen, workout room, and lounge area for the fire company, while the second floor contains the chief's office and additional lounge space. There is also a basement level that contains the mechanical equipment serving the building. Photos 52 and 53 shows an aerial and exterior view of the building.

Photo 52. Aerial view of Hook and Ladder Co.

Photo 53. Hook and Ladder Co. exterior

As Hook and Ladder Co. is considered a volunteer fire department, at least one volunteer is present at the building on a daily basis. However, based on observations made during the survey and through interviewing building staff it appears the building is unoccupied at night. Volunteers will typically only occupy the building in the case of a fire call during these hours.

6.01.1 Existing Heating Systems

Heating for the building is provided by one (1) gas-fired hot water boiler manufactured by Weil McLain (Photo 54). The boiler has a gross capacity of 296 MBH. Hot water generated by the boiler is distributed throughout the building via four (4) inline hot water recirculation pumps that separate the building into four (4) separate zones which include the Chief's office, truck room (main garage), bar room, and the second floor lounge space. Each zone contains perimeter finned tube radiation for heating (Photo 55). It was noted that the large majority of hot water piping is uninsulated. A summary of the heating plant is shown below in Table 18.

Table 18. Hook and Ladder Heating Plant Summary

Manufacturer	Type	Capacity (MBH)	Fuel Source	Quantity	Year Installed	Typical Boiler Operating Time
Weil McLain	Hot Water	296	Natural Gas	1		Always active


Photo 54. HW boiler serving Hook and Ladder Co.


Photo 55. Typical finned tube radiation

Each heating zone is controlled by a local wall-mounted thermostat, which controls the finned tube radiation in that particular zone (Photo 56). It was noted that the thermostat controlling the finned tube radiation in the bar room appears to have recently been replaced. Building staff indicated that thermostats are typically kept at a constant temperature setpoint (approximately 70°F) during the heating season.

Photo 56. Typical heating thermostat

6.01.2 Existing Cooling Systems

Cooling is provided by a combination of window AC units and Mitsubishi split AC units (Photos 57 and 58). There are two (2) window AC units, which serve the first floor workout room and second floor lounge space. Each window AC unit has an approximate capacity of 1 – 1.5 tons (12-18 MBH) of cooling. There are also three (3) Mitsubishi split AC units, which serve the bar room and Chief's office respectively. The two (2) units serving the bar room have a capacity of 2.5 tons (24-30 MBH) each, and the unit serving the Chief's office has a total capacity of 3 tons (36 MBH). A summary of the cooling systems serving the building is shown below in Table 19.

Table 19. Hook and Ladder Cooling Plant Summary				
Type	**Area Served**	**Manufacturer**	**Total Capacity (Tons)**	**Total Quantity**
Window AC unit	Workout room, Second Floor Lounge	-	1.5	2
Split AC unit	Bar Room, Chief's Office	Mitsubishi	2.5 – 3	3

Photo 57. Typical window AC unit

Photo 58. Mitsubishi split AC unit serving bar room

6.01.3 Existing Ventilation Systems

Hook and Ladder Co. does not have any mechanical ventilation systems. Ventilation is only provided when opening windows and doors in the building.

6.01.4 Existing Domestic Water Systems

Domestic hot water (DHW) is generated by a combination gas-fired Rheem DHW heater and storage tank, which is located in the basement (Photo 16). The DHW heater has a total capacity of 40 MBH and storage capacity of 50 gallons. A summary of the DHW system is shown below in Table 20.

Table 21. Hook and Ladder DHW System Summary						
Manufacturer	**Fuel Source**	**Heating Capacity (MBH)**	**Storage Capacity (Gal)**	**HWS Temperature (°F)**	**Quantity**	**Year Installed**
Rheem	Natural Gas	40	50	-	1	2003

Photo 59. Rheem DHW heater

6.01.5 Existing Lighting System

Interior lighting primarily consists of 32W T8 fluorescent and round 13W LED light fixtures found in the main garage, chief's office, bar room, and kitchen (Photos 60 and 61). There are additional light fixtures that contain Satco T8 U-tube shaped fluorescent lamps found in the workout room and second floor lounge (Photo 62).

Photo 60. Typical T8 fluorescent lighting

Photo 61. Typical LED lighting

Photo 62. Typical Satco T8 lighting

6.01.6 Existing Lighting Controls

The majority of lighting in the building is controlled manually by toggle switches. However, there is a row of lights in the truck room that is controlled by a wall-mounted occupancy sensor (Photo 63).

Photo 63. Occupancy sensor in truck room

6.02 Hook and Ladder Fire Company Analysis of Present Energy Use

A historical energy use analysis was performed for the energy sources at Hook and Ladder Fire Company. The following data was analyzed based on yearly energy consumption and costs. Based on the utility bills provided, OLA was able to calculate a combined site EUI for the building. The building used approximately 71.1 kBtu/ft^2 site energy and had a total energy cost of $7,419 based on 2016-2018 data. Table 22 below provides a summary of the annual energy usage and costs for 2016-2018.

Table 22. 2016-2018 Annual Overall Site Energy

	Energy Usage	kBtu	Cost ($)	Cost ($) per ft^2	Site EUI (kBtu/ft^2)	CO_2 Emissions (lb/year)
Electric (kWh)	8,646	29,500	$723	$0.08	3.3	5,508
Natural Gas (therm)	6,105	610,450	$6,696	$0.74	67.8	71,476
Total		639,950	$7,419	$0.82	71.1	76,984
Gross Area (ft^2)		9,000				

Figure 28 provides the annual site EUI per energy type based on analysis of the utility bills for 2016-2018. Figure 29 provides the annual energy cost summary by energy type from the same year. Natural gas for heating is the dominant energy source for this building and is projected to account for 95% of the overall energy consumption of the building, and 90% of the total cost. The large gas usage is likely due to the heating plant constantly running to achieve the building temperature setpoint of 70°F. This is because building staff do not lower the zone thermostats during unoccupied hours. Figure 30 provides the annual CO_2 emissions breakdown by energy type.

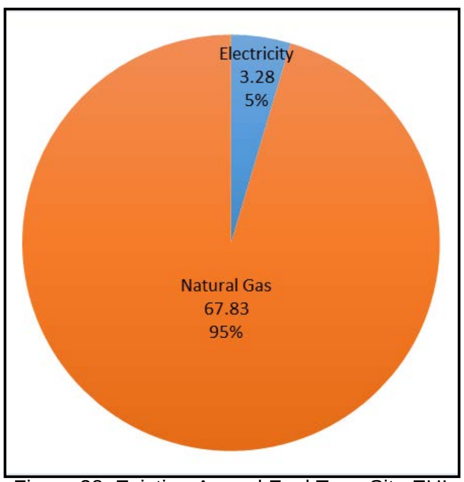

Figure 28. Existing Annual Fuel Type Site EUI Breakdown in kBtu/ft.^{2}

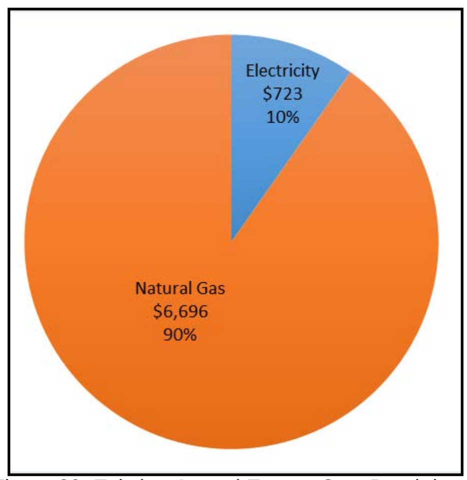

Figure 29. Existing Annual Energy Cost Breakdown

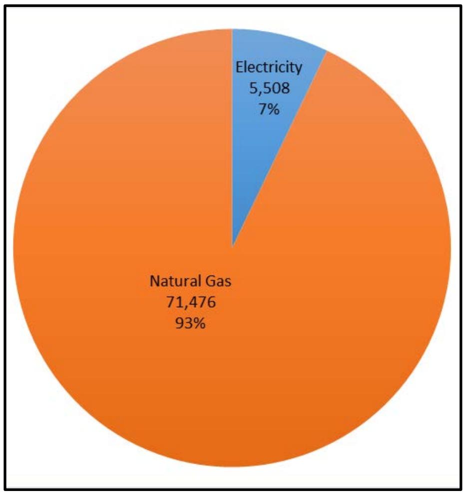

Figure 30. Existing Annual CO_2 Emissions Breakdown in lb/year

6.02.1 Electrical Usage

The historical electric usage for Hook and Ladder Fire Company is shown in Figure 31. Peak electricity usage typically occurs during the summer months (May – September), likely due to the need to run the window AC units in order to cool the building. The highest monthly usage recorded during this time was 1,320 kWh during August 2018.

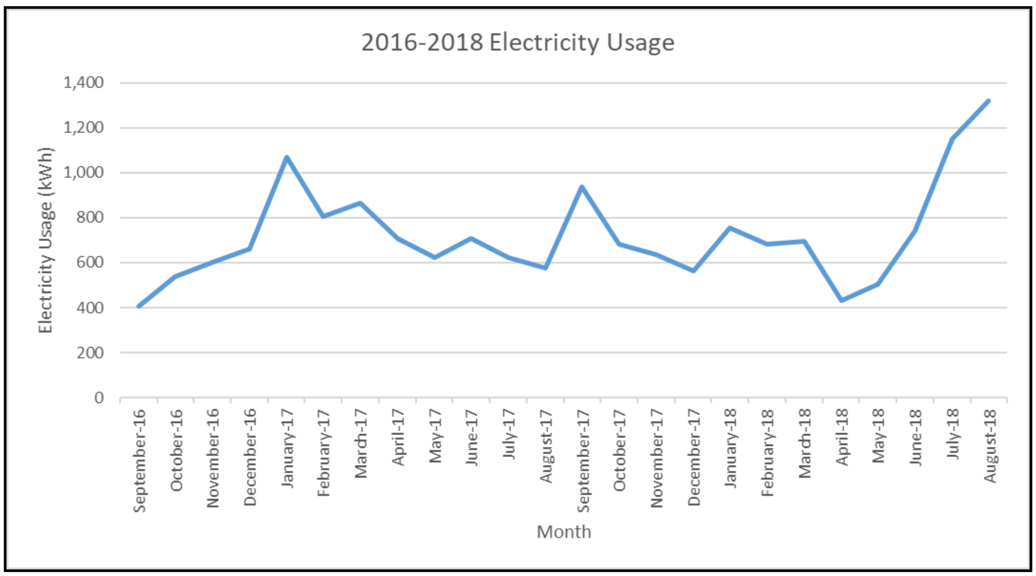

Figure 31. 2016 – 2018 Historical Electricity Use

It was noted that the building moved away from demand based electricity usage in 2017.

OLA was provided with complete electric utility bills for this analysis, and determined an electricity rate of 0.066 $/kWh based on the bills provided. For the purposes of this study, this calculated rate was used to estimate energy cost savings. Note that this rate was determined using the bills from when the building switched to a new rate structure (January 2017 – present).

6.02.2 Natural Gas Usage

Figure 32 below shows the historical 2016-2018 natural gas usage for the building. Since gas in this building is used for heating only, usage is found to be highest during the winter months. A peak usage of 1,366 therms was recorded in December 2017.

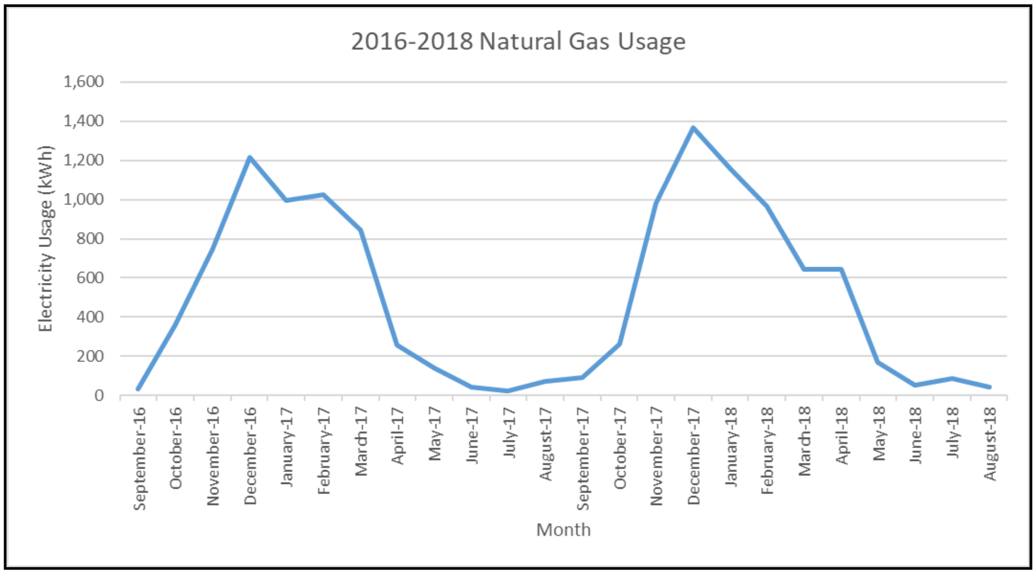

Figure 32. 2016-2018 Historical Natural Gas Usage

OLA was provided with complete utility bills for this analysis and determined a natural gas of 1.09 $/therm based on the bills provided. For the purposes of this study, this calculated rate was used to estimate energy cost savings.

6.02.3 Utility Rates and Costs

Hook and Ladder Company is served by one (1) electric meter and one (1) gas meter. Estimated blended electric and gas rates for the building were determined based on monthly usage and monthly charges. Table 23 below shows a breakdown of the utility rates for each fuel source.

Table 23. Utility Rates

Utility	Unit	2016/17	2017/18
Electric	$/kWh	$0.103	$0.066
Natural Gas	$/therm	$1.03	$1.16

6.02.4 Energy Utilization

Figure 33 below shows the breakdown of energy intensity (kBtu/ft^2) by end use type. The results confirm that fuel consumed to run the heating plant accounts for the largest portion of the site energy use and cost.

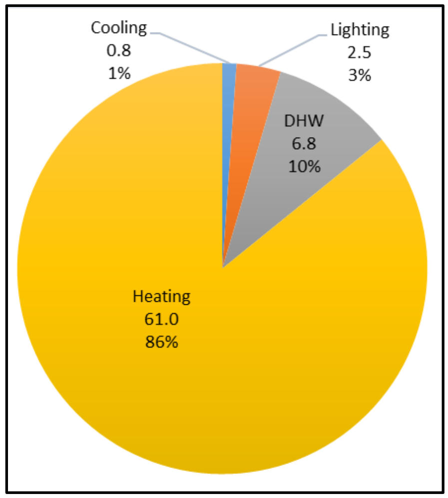

Figure 33. Energy End Use Breakdown in kBtu/ft.^{2}

6.03 Energy Efficiency Measures (EEMs)

Short Term EEM's

6.03.1 EEM 1 – LED Lighting Retrofits

This measure investigates the impact on energy consumption of reduced lighting power density utilizing high efficiency LED lighting technology and retrofit products throughout the building. The new LED lighting will result in a reduced lighting power density and potential for high savings. All of the typical 32W T8 fluorescent lighting in the building could be replaced with LED retrofit products. The existing lighting power density of the building is estimated to be 0.43 W/ft^2. The resulting lighting power density of the entire facility is estimated to be in the range of 0.31 W/ft.^{2} after a complete retrofit.

6.03.2 EEM 2 – Lighting Controls Upgrades

This measure investigates the energy reduction associated with installing occupancy lighting control sensors. This building currently has no form of automatic lighting controls installed. The occupancy sensors would automatically turn lights on and off depending on whether the space is occupied. This measure will prevent lights from staying on for extended periods of time while the spaces are not being used. Note that savings for this measure is based on ECM 1 being implemented.

6.03.3 EEM 3 – Hot Water Piping Insulation

As the majority of hot water piping in the basement is uninsulated, this measure estimates the energy reduction and cost savings associated with installing standard 1" pipe insulation on all of the accessible piping.

6.03.4 EEM 4 – Heating Night Setback

This measure assesses the energy reduction and cost savings associated with implementing a night setback heating setpoint for the boiler. All of the existing dial Honeywell thermostats could be replaced with programmable thermostats that have the ability to adjust heating setpoints based on a predetermined occupied and unoccupied schedule. Lowering the heating setpoint will reduce boiler run time and reduce the overall EUI of the building.

Figure 34. Typical Honeywell programmable thermostat

Long Term EEM's

6.03.5 EEM 5 – Heating Plant Upgrades: High Efficiency Gas-Fired Hot Water Boiler

This project would eliminate the existing standard efficiency gas-fired boiler at the building and install a new high efficiency, condensing boiler for heating. We estimate that the boiler efficiency of the existing heating plant is approximately 81%. Current best achievable hot water boiler efficiency is in the range of 90% – 91%.

7.0 Ambulance Corps Garage

7.01 Existing Conditions

Hastings-on-Hudson Ambulance Corps garage is a 1-story, 3,600 square foot volunteer ambulance garage located at 47 Main Street in Hastings-on-Hudson, NY and was constructed in 1979. The first floor contains the main garage, kitchen/lounge area, bathroom, and boiler room for the garage. Photos 64 and 65 show an aerial and exterior view of the building.

Photo 64. Aerial view of Hook and Ladder Co.

Photo 65. Ambulance Garage exterior

As the ambulance garage is considered a volunteer ambulatory service, there are no permanent occupants at the building. Based on observations made during the survey, it appears the building is typically occupied by one or two volunteers during the day and unoccupied at night. Volunteers likely only occupy the building in the case of an emergency call during night hours. It was noted that no volunteers were present at the building during the site survey.

7.01.1 Existing Heating Systems

Heating for the building is provided by one (1) gas-fired hot water boiler manufactured by Bunrham (Photo 16). The size of the boiler plant was unable to be verified, as the boiler did not have any nameplate data and OLA was unable to open the front panel of the boiler. Hot water generated by the heating plant is distributed to various perimeter radiators located in the main garage (Photo 67). There appears to be no form of heating for the kitchen and lounge area. A summary of the heating plant is shown below in Table 24.

Table 24. Ambulance Garage Heating Plant Summary

Manufacturer	Type	Capacity (MBH)	Fuel Source	Quantity	Year Installed	Typical Boiler Operating Time
Burnham	Hot Water		Natural Gas	1		


Photo 66. HW boiler serving Ambulance Garage


Photo 67. Typical hot water radiator

Heating for the building is controlled by a local wall-mounted thermostat, which controls all of the perimeter radiators in the main garage (Photo 68). It was noted that the thermostat is enclosed in a plastic casing, and appears to be left at a constant temperature between 75 – 80°F.


Photo 68. Thermostat serving Ambulance Garage

7.01.2 Existing Cooling Systems

Cooling for the building is provided by three (3) Friedrich window AC units, which serve the main garage and lounge area respectively (Photos 69 and 70). Each window AC unit has an approximate capacity of 1 – 1.5 tons (12-18 MBH) of cooling, and is remotely controlled. A summary of the window AC units serving the building is shown below in Table 25.

Table 25. Ambulance Garage Cooling Plant Summary

Type	Manufacturer	Total Capacity (Tons)	Estimated Total Quantity
Window AC unit	Friedrich	1 – 1.5	3


Photo 69. Typical window AC unit serving lounge area

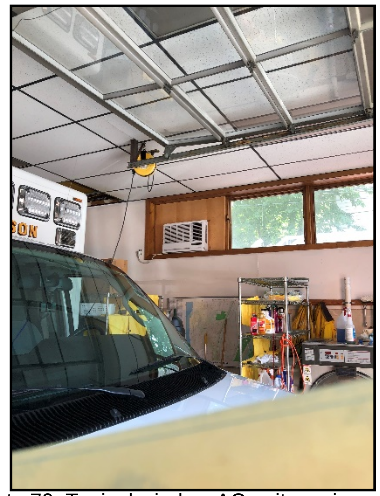
Photo 70. Typical window AC unit serving main garage

7.01.3 Existing Ventilation Systems

There is no mechanical ventilation system serving the Ambulance Garage. Ventilation is primarily provided by opening windows and the garage doors. It was noted that there is a vent located in the main garage that could provide ventilation for the space, but its purpose could not be confirmed (Photo 71).

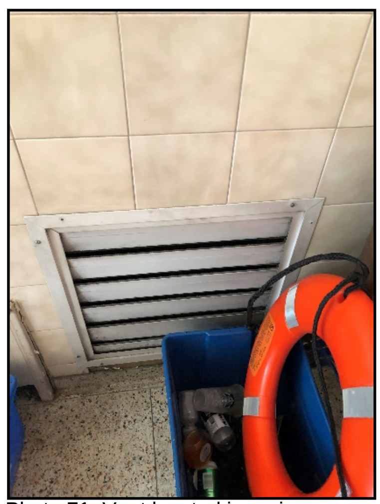
Photo 71. Vent located in main garage

7.01.4 Existing Domestic Water Systems

Domestic hot water (DHW) is generated by a combination gas-fired Bradford White DHW heater and storage tank, which is located in the boiler room (Photo 72). The DHW heater has a total capacity of 40,000 Btu/hr and storage capacity of 40 gallons. A summary of the DHW system is shown below in Table 26.

Table 26. Ambulance Garage DHW System Summary

Manufacturer	Fuel Source	Heating Capacity (MBH)	Storage Capacity (Gal)	Quantity	Year Installed
Bradford White	Natural Gas	40	40	1	2014

Photo 72. Bradford White DHW heater

7.01.5 Existing Lighting System

Interior lighting primarily consists of 2 and 3-bulb T8 fluorescent light fixtures containing Sylvania 32W T8 fluorescent lamps. These fixtures are found throughout the main garage and lounge area (Photos 73 and 74).

Photo 73. Typical T8 fluorescent lighting in main garage

Photo 74. Typical T8 fluorescent lighting in lounge area

Exterior lighting is minimal and typically features round ceiling mounted fixtures, which appear to contain fluorescent bulbs (Photo 75).


Photo 75. Typical exterior lighting

7.01.6 Existing Lighting Controls

All interior lighting is controlled manually by toggle switches (Photo 76). Exterior lighting appears to be controlled by timers, but this could not be verified (Photo 77).


Photo 76. Typical manual light switches


Photo 77. Timers appear to be for exterior lighting

7.02 Ambulance Corps Garage Analysis of Present Energy Use

A historical energy use analysis was performed for the energy sources at the Ambulance Corps garage. The following data was analyzed based on yearly energy consumption and costs. Based on the utility bills provided, OLA was able to calculate a combined site EUI for the building. Note that OLA was only provided with invoices for gas bills, and actual usage for this building was inferred based on monthly $/therm rates calculated from Hook and Ladder Co. gas bills. The building used approximately 68.3 kBtu/ft^2 site energy and had a total energy cost of $4,937 based on 2017-2018 data. OLA could not calculate an average EUI over multiple years due to the limited amount of utility bills provided. Table 27 below provides a summary of the annual energy usage and costs for 2017-2018.

Table 27. 2017-2018 Annual Overall Site Energy

	Energy Usage	kBtu	Cost ($)	Cost ($) per ft^2	Site EUI (kBtu/ft^2)	CO_2 Emissions (lb/year)
Electric (kWh)	12,121	43,713	$3,227	$1.34	17.2	7,722
Natural Gas (therm)	1,225	122,479	$1,710	$0.71	51.0	14,341
Total		163,836	$4,937	$2.06	68.3	22,062
Gross Area (ft^2)		2,400				

* Inferred based on monthly $/therm unit prices from Hook and Ladder Co.

Figure 35 provides the site EUI per energy type based on analysis of the utility bills for 2017-2018. Figure 36 provides the energy cost summary by energy type from the same year. Natural gas for heating is the dominant energy source for this building, and is projected to account for 75% of the overall energy consumption of the building, and 35% of the total cost. Figure 37 provides the annual CO_2 emissions breakdown by energy type.

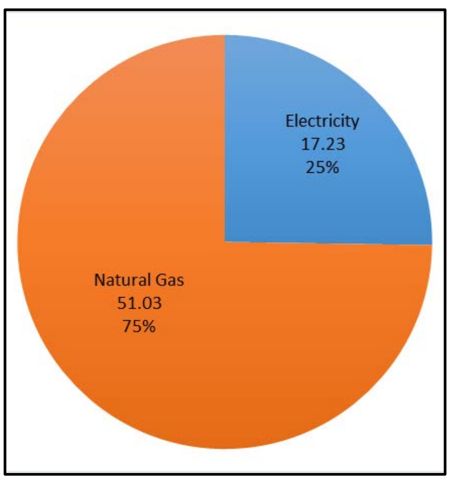

Figure 35. Existing Annual Fuel Type Site EUI Breakdown in kBtu/ft.^{2}

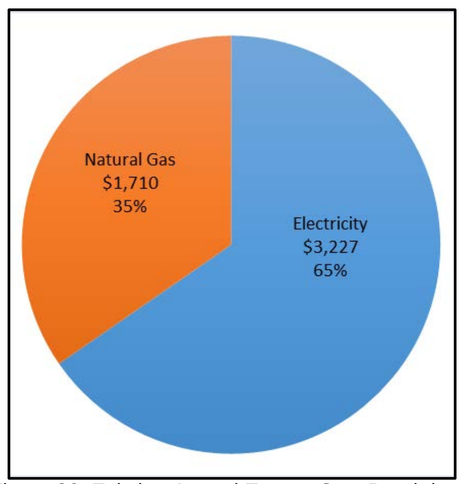

Figure 36. Existing Annual Energy Cost Breakdown

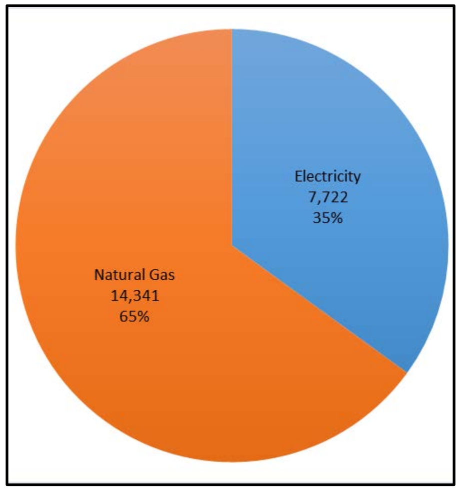

Figure 37. Existing Annual CO_2 Emissions Breakdown in lb/year

7.02.1 Electrical Usage

The historical electric usage for the Ambulance Corps garage is shown in Figure 38. Peak electricity usage typically occurs during the summer months (May – September), likely due to the need to run the window AC units in order to cool the building. The highest monthly usage recorded during this time was 2,026 kWh during July 2016.

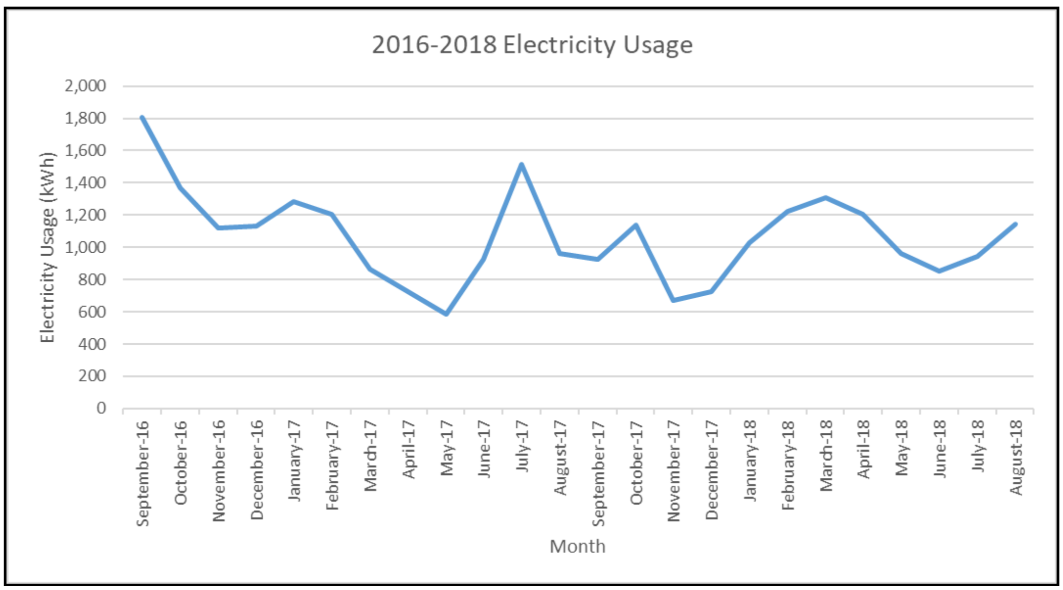

Figure 38. 2016 – 2018 Historical Electricity Use

OLA was provided with complete electric utility bills for this analysis, and determined an electricity rate of 0.266 $/kWh based on the bills provided. For the purposes of this study, this calculated rate was used to estimate energy cost savings.

7.02.2 Natural Gas Usage

Figure 39 below shows the historical 2017-2018 natural gas usage for the building. As OLA was only provided with invoices from monthly gas bills, the actual usage has been inferred based on monthly $/therm unit prices calculated from the Hook and Ladder Co. gas bills. A peak usage of 186 therms was recorded in December 2017.

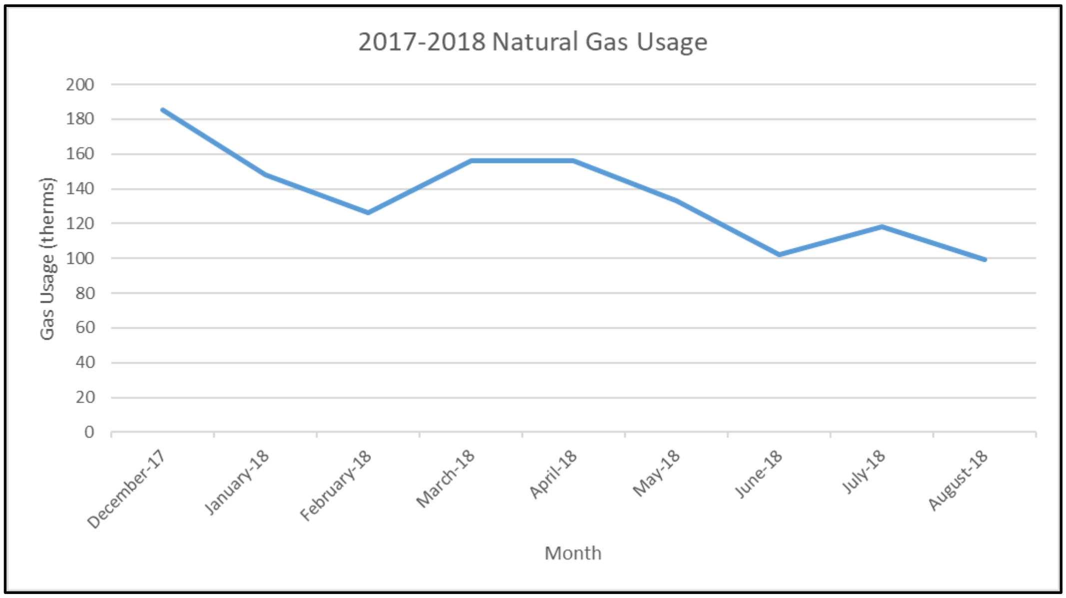

Figure 39. 2017-2018 Historical Natural Gas Usage

OLA was not provided with complete utility bills for this analysis and could not determine an actual natural gas rate. Invoices for natural gas bills were provided for the months December 2017 – August 2018. The total cost from these months was used as the annual gas utility cost for this building. For the purposes of this study, an estimated natural gas rate of $1.40/therm was calculated based on the inferred gas usage (determined by monthly $/therm rates from Hook and Ladder Co.) and the annual gas utility cost based on the invoices provided. This calculated rate was used to estimate energy cost savings.

7.02.3 Utility Rates and Costs

The Ambulance Corps garage is served by one (1) electric meter and one (1) gas meter. Estimated blended electric and gas rates for the building were determined based on monthly usage and monthly charges. Table 28 below shows a breakdown of the utility rates for each fuel source.

Table 28. Utility Rates

Utility	**Unit**	**2016/17**	**2017/18**
Electric	$/kWh	$0.249	$0.266
Natural Gas	$/therm	-	$1.40

7.02.4 Energy Utilization

Figure 40 below shows the breakdown of energy intensity (kBtu/ft^2) by end use type. The results confirm that fuel consumed to run the heating plant accounts for the largest portion of the site energy use and cost.

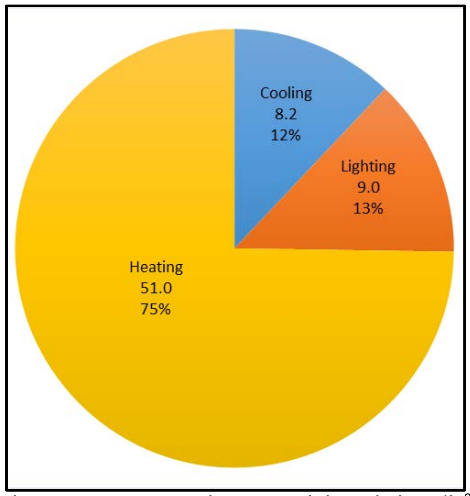

Figure 40. Energy End Use Breakdown in kBtu/ft.^{2}

7.03 Energy Efficiency Measures (EEMs)

Short Term EEM's

7.03.1 EEM 1 – LED Lighting Retrofits

This measure investigates the impact on energy consumption of reduced lighting power density utilizing high efficiency LED lighting technology and retrofit products throughout the building. The new LED lighting will result in a reduced lighting power density and potential for high savings. All of the typical 34W T8 fluorescent lighting in the building could be replaced with LED retrofit products. The existing lighting power density of the building is estimated to be 0.72 W/ft^2. The resulting lighting power density of the entire facility is estimated to be in the range of 0.49 $W/ft.^2$ after a complete retrofit.

7.03.2 EEM 2 – Night Setback Heating

This measure assesses the energy reduction and cost savings associated with implementing a night setback heating setpoint for the boiler. The existing Honeywell thermostat could be replaced with a programmable thermostat that has the ability to adjust heating setpoint based on a predetermined occupied and unoccupied schedule. Lowering the heating setpoint will reduce boiler run time and reduce the overall EUI of the building.

8.0 Chemka Pool Building

8.01 Existing Conditions

The Chemka pool building is a 1-story, 4,200 square foot pool building and locker room facility located at Hillside Avenue in Hastings-on-Hudson, NY. The building contains a lifeguard staff work and lounge area, as well as male and female locker rooms. There is also a lower level that contains mechanical and filtration equipment for the pool complex. Photos 78 and 79 show an aerial and exterior view of the building.

Photo 78. Aerial view of Chemka pool

Photo 79. Chemka pool building exterior

Hours for the pool building vary throughout the summer of 2018. The pool is typically occupied from 12:00pm – 8:00pm on weekdays 10:00am – 8:00pm on weekends during the summer. A detailed breakdown of the occupancy hours at the Chemka Pool is shown below in Table 29. The pool opened on May 23 and closed on September 9, 2018. The pool building is unoccupied during the offseason.

Table 29. Chemka Pool Building Operating Hours

Date	Time	Monday	Tuesday	Wednesday	Thursday	Friday	Weekend
5/23 – 6/23 & 8/20 – 9/2	12:00pm	Building opens	Building opens	Building opens	Building opens	Building opens	Building open 10:00am – 8:00pm
	8:00pm	Building closes	Building closes	Building closes	Building closes	Building closes	
6/24 – 8/19	12:30pm	Building opens	Building opens	Building opens	Building opens	Building opens	Building open 10:00am – 8:00pm
	8:00pm	Building closes	Building closes	Building closes	Building closes	Building closes	
9/3 – 9/9	3:00pm	Building opens	Building opens	Building opens	Building opens	Building opens	Building open 11:00am – 7:00pm
	7:00pm	Building closes	Building closes	Building closes	Building closes	Building closes	

8.01.1 Existing Pool Filtration Systems

The Chemka Pool complex features three (3) different pools: the main pool, training pool, and wading pool. Each pool contains its own dedicated feature pump and chemical monitoring system (Photos 80 and 81). The main and training pools also have their own dedicated filtration tanks, which collect and filter the pool water before it is pumped to its respective pool.

Photo 80. Main pool feature pump

Photo 81. Typical pool chemical monitoring system

8.01.2 Existing Heating Systems

As the pool building is used seasonally, there is no heating plant serving the locker rooms and staff area. The locker room and staff areas are winterized during the off season. The pool equipment room is heated by a wall-mounted electric resistance heater to protect that equipment.

8.01.3 Existing Cooling Systems

There is no form of mechanical cooling at the pool building. The only conditioning for the locker rooms and staff office is provided by natural airflow through doorways.

8.01.4 Existing Ventilation Systems

There is no mechanical ventilation system serving the pool building. Ventilation is provided only by natural airflow through the locker rooms and staff office as noted above.

8.01.5 Existing Domestic Water Systems

Domestic hot water (DHW) is generated by two (2) combination electric Rheem DHW heaters and storage tanks located in the building (Photo 82). Each DHW heater has a total input capacity of 9 kW and storage capacity of 120 gallons. A summary of the DHW system is shown below in Table 30.

Table 30. Chemka Pool Building DHW System Summary

Manufacturer	**Fuel Source**	**Heating Capacity**	**Storage Capacity (Gal)**	**Quantity**	**Year Installed**
Rheem	Electric	9 kW (each) 30.7 MBH (each)	120 (each)	2	2004


Photo 82. Rheem electric DHW heater

8.01.6 Existing Lighting System

Interior lighting for the locker rooms and staff office primarily consists of round ceiling mounted fixtures, which contain a mixture of LED and fluorescent bulbs (Photos 83 and 84).


Photo 83. Typical locker room lighting


Photo 84. Typical staff office lighting

Exterior lighting primarily consists of wall and ceiling mounted fixtures containing fluorescent lamps (Photo 85). There are two (2) exterior light towers that provide light for the entire pool complex. Each tower contains approximately sixteen (16) bulbs (Photo 86). The wattage of these bulbs could not be verified during the site visit.


Photo 85. Typical exterior lighting


Photo 86. Typical exterior lighting tower

8.01.7 Existing Lighting Controls

All interior lighting is controlled manually by toggle switches. The exterior light towers are controlled by timers; the control panels for which are located in the pool equipment room.

8.02 Chemka Pool Building Analysis of Present Energy Use

A historical energy use analysis was performed for the energy sources at the Chemka Pool building. The following data was analyzed based on yearly energy consumption and costs. Based on the utility bills provided, OLA was able to calculate a combined site EUI for the building. The building used approximately 89.1 kBtu/ft^2 site energy and had a total energy cost of $26,347 based on 2016-2018 data. Table 31 below provides a summary of the annual energy usage and costs for 2016-2018.

Table 31. 2016-2018 Annual Overall Site Energy

	Energy Usage	kBtu	Cost ($)	Cost ($) per ft^2	Site EUI (kBtu/ft^2)	CO_2 Emissions (lb/year)
Electric (kWh)	109,680	374,228	$26,347	$6.57	89.1	69,872
Total		374,228	$26,347	$6.57	89.1	69,872
Gross Area (ft^2)		4,200				

8.02.1 Electrical Usage

The historical electric usage for the Chemka Pool building is shown in Figure 41. Peak electricity usage occurs during the summer months (May – September), due to the continuous operation of the pool equipment. The highest monthly usage recorded during this time was 20,240 kWh during June 2017.

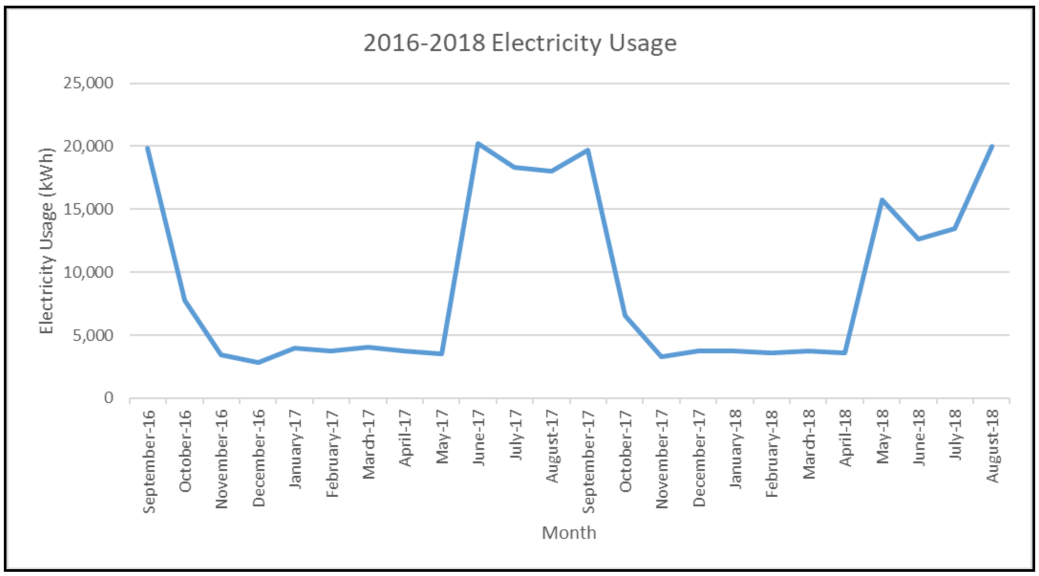

Figure 41. 2016 – 2018 Historical Electricity Use

The historical electric demand is shown in Figure 42. Similar to the historical electricity usage above, the building's peak demand occurs between May and September. The highest recorded demand of 107.2 kW occurred in August 2018.

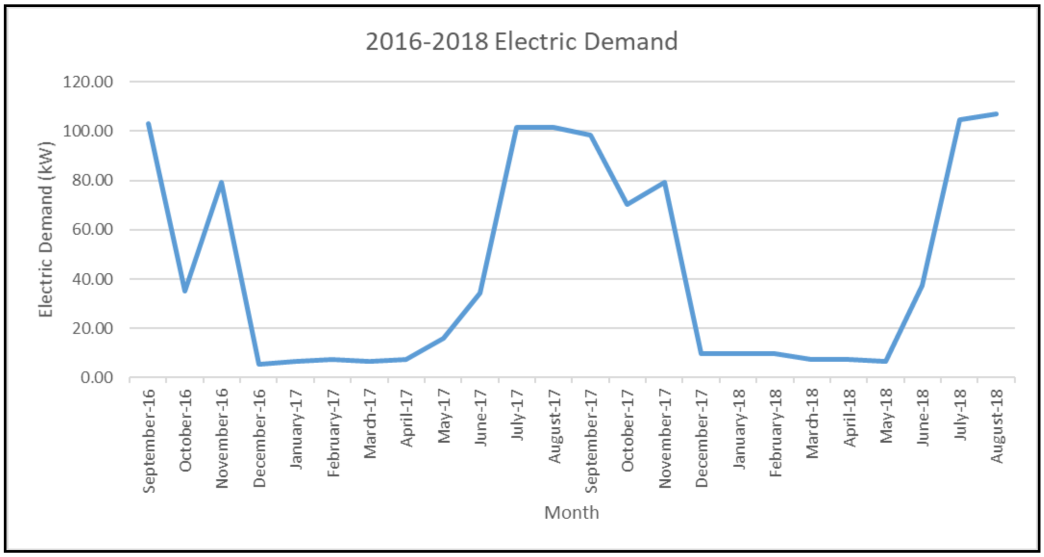

Figure 42. 2016 – 2018 Historical Electric Demand

OLA was provided with complete electric utility bills for this analysis, and determined an electricity rate of 0.240 $/kWh based on the bills provided. For the purposes of this study, this calculated rate was used to estimate energy cost savings.

8.02.2 Utility Rates and Costs

The Ambulance Corps garage is served by one (1) electric meter and one (1) gas meter. Estimated blended electric and gas rates for the building were determined based on monthly usage and monthly charges. Table 32 below shows a breakdown of the utility rates for each fuel source.

Table 32. Utility Rates

Utility	Unit	2016/17	2017/18
Electric	$/kWh	$0.229	$0.251

8.02.3 Energy Utilization

Figure 43 below shows the breakdown of energy intensity (kBtu/ft^2) by end use type. The pumping energy for the pool filtration system accounts for 64% of the total electricity usage.

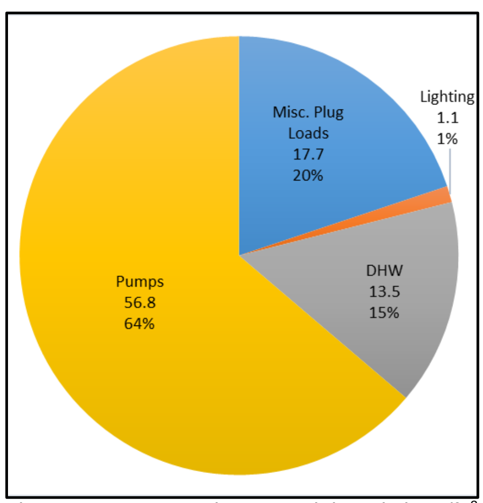

Figure 43. Energy End Use Breakdown in kBtu/ft.^{2}

8.03 Energy Efficiency Measures (EEMs)

Short Term EEM's

8.03.1 EEM 1 – Complete LED Lighting Retrofit

Although much of the space has already been converted to LED lighting, this measure investigates the impact of a complete LED retrofit and energy consumption of reduced lighting power density. The new LED lighting will result in a reduced lighting power density and potential for high savings. All of the typical 23W fluorescent and 32W T8 fluorescent lighting in the building could be replaced with LED retrofit products. The existing lighting power density of the building is estimated to be 0.33 W/ft^2. The resulting lighting power density of the entire facility is estimated to be in the range of 0.19 W/ft.^{2} after a complete retrofit.

8.03.1 EEM 2 – Variable Speed Pumps and High Efficiency Motors

This measure assesses the impact of installing variable frequency drives (VFD's) and high efficiency motors on the pumps serving the three (3) different pools on site. Allowing the pool pumps to modulate to lower speeds during unoccupied hours would result in a significant energy and cost reduction.

8.03.2 EEM 3 – Air Source VRF Heat Pump for Pool Equipment Room

This measure assesses the energy reduction associated with installing a single-zone air source heat pump to heat and cool the pool equipment room. Air source heat pumps typically offer high heating and cooling efficiencies, which could result in an overall EUI reduction and cost savings. Indoor units would be installed where appropriate, providing heating and cooling to the spaces they serve.

Figure 44. Single-zone Mitsubishi air-source heat pump

8.03.3 EEM 4 – Domestic Hot Water Heat Pumps

Replacing the existing electric resistance domestic hot water heaters with a commercial grade electric heat pump system should be considered in the future. It is possible to utilize the existing storage tanks. Providing the building with a new high efficient electric heat pump water heater would reduce the source EUI of the building.

Figure 45. Colmac DHW heat pump

Long Term EEM's

8.03.4 EEM 5 – Solar Tube Skylight

This measure assess the impact of installing skylights on the roof of the building that utilize natural daylight for lighting in the pool building locker rooms. Solar tube technology harnesses and transfers natural sunlight into the space with reflective material within the tubing. This would offset a portion of the energy usage and costs associated with lighting, thereby reducing greenhouse gas emissions.

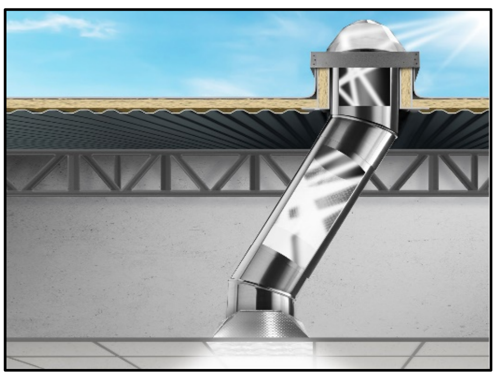

Figure 46. Typical skylight diagram

Figure 47. "Solatube" skylight installed in locker room

9.0 Department of Public Works (DPW) Garage

9.01 Existing Conditions

The Department of Public Works (DPW) garage is a 1-story, 12,000 square foot garage located at 69 Southside Avenue in Hastings-on-Hudson, NY and was constructed in approximately 1985. The building acts as a storage and maintenance facility for the vehicles and associated equipment used for public service in the town. One half of the garage is used as a repair shop, and contains offices, restrooms, and a lounge for the mechanics. The other half is used as storage for the vehicles. Photos 87 and 88 show an aerial and exterior view of the building.

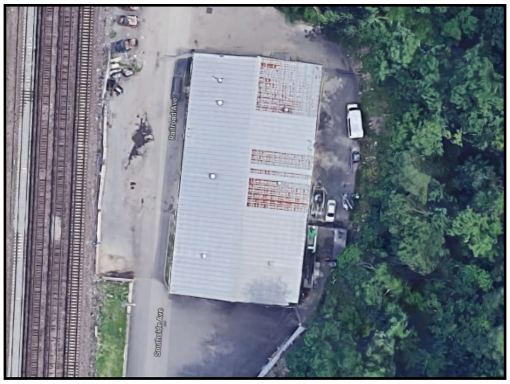

Photo 87. Aerial view of DPW garage

Photo 88. DPW Garage exterior

Typical building hours for the garage range from 7:00am – 3:30pm Monday through Friday, and 8:00am – 12:00pm on Saturdays. The garage is closed on Sundays. A breakdown of the building operating hours is shown below in Table 33.

Table 33. DPW Garage Operating Hours

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Weekend
7:00am	Building opens	Building opens	Building opens	Building opens	Building opens	Saturday: 8:00am – 12:00pm Sunday: Building closed
3:30pm	Building closes	Building closes	Building closes	Building closes	Building closes	

9.01.1 Existing Heating Systems

Heating for the garage is provided by a combination of an American Standard condensing gas-fired furnace serving the repair shop (Photo 89), and Reznor gas-fired unit heaters serving the remainder of the garage (Photo 90). A summary table of the heating systems at the DPW garage is located in Table 34 below.

Table 34. DPW Garage Heating Plant Summary

Manufacturer	Type	Capacity (MBH)	Fuel Source	Quantity	Year Installed	Typical Operating Time
American Standard	Furnace	-	Natural Gas	1		7:00am – 3:30pm
Reznor	Unit Heater	75* (each)	Natural Gas	2		7:00am – 3:30pm

*Based on existing drawings

Photo 89. Gas-fired furnace serving repair shop

Photo 90. Typical gas-fired unit heater serving garage

The gas-fired furnace is located on an elevated platform and serves the open areas of the repair shop only. The offices, restrooms, and lounge area are all considered enclosed spaces and are not adequately heated by the furnace. Heating for these spaces is provided only by plug-in heaters and radiators (Photo 91). There is an additional office that is served by electric baseboard and controlled be a wall-mounted Lux thermostat (Photo 92). It was noted that only two (2) of the unit heaters serving the garage have been replaced and are currently functioning (Photo 93). The remaining unit heaters have been dysfunctional for several years according to staff and are abandoned in place.

Photo 90. Typical plug-in space heater

Photo 92. Thermostat controlling electric baseboard

Photo 93. Typical gas-fired unit heater abandoned in place

Heating for the repair shop is controlled by a wall-mounted programmable Honeywell thermostat located outside one of the offices (Photo 94). It was noted that staff typically set the thermostat for approximately 68°F during occupied hours, and will automatically reduce the temperature setpoint to approximately 62°F during unoccupied hours. Heating for the garage is also controlled by similar wall-mounted Honeywell thermostats (Photo 95). Each thermostat typically controls one of the Reznor unit heaters.

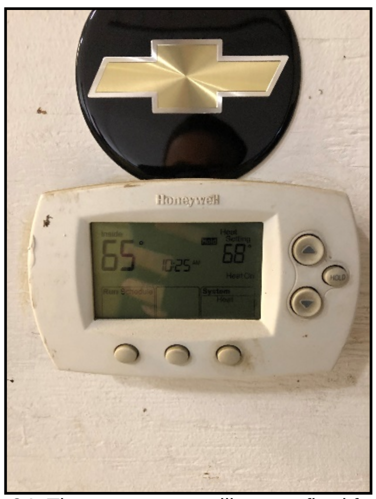

Photo 94. Thermostat controlling gas-fired furnace

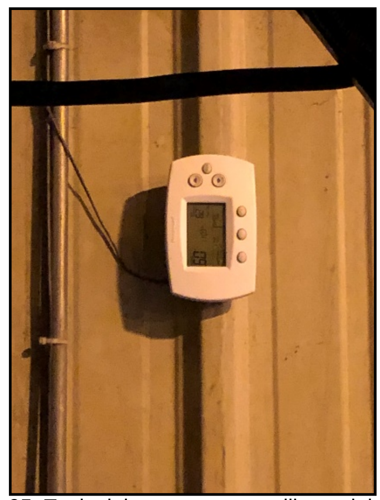

Photo 95. Typical thermostat controlling unit heater

9.01.2 Existing Cooling Systems

Cooling is provided by a combination of window AC units serving the offices and lounge within the repair shop, and ceiling fans in the garage. There are four (4) Friedrich window AC units that serve the offices and lounge. Each window AC unit has an approximate capacity of 1 – 1.5 tons (12-18 MBH) of cooling, and is controlled manually A summary of the window AC units serving the building is shown below in Table 35.

Table 35. DPW Garage Cooling Plant Summary

Type	Manufacturer	Total Capacity (Tons)	Estimated Total Quantity
Window AC unit	Friedrich	1 – 1.5	4

9.01.3 Existing Ventilation Systems

There is no mechanical ventilation system serving the garage. Ventilation is provided only by opening the garage doors.

9.01.4 Existing Domestic Water Systems

Domestic hot water (DHW) is generated by one (1) combination gas-fired Rheem DHW heater and storage tank located in the repair shop (Photo 96). The DHW heater has a total input capacity of 38 MBH and storage capacity of 40 gallons. A summary of the DHW system is shown below in Table 36.

Table 36. DPW Garage DHW System Summary

Manufacturer	Fuel Source	Heating Capacity (MBH)	Storage Capacity (Gal)	Quantity	Year Installed
Rheem	Natural Gas	30	40	1	2003

Photo 82. Rheem DHW heater

9.01.5 Existing Lighting System

Interior lighting primarily consists of T8 fluorescent light fixtures in offices, restrooms, and the lounge area, ceiling hung metal halide fixtures in the repair shop, and ceiling hung high pressure sodium (HPS) fixtures in the remainder of the garage (Photos 97 – 99).

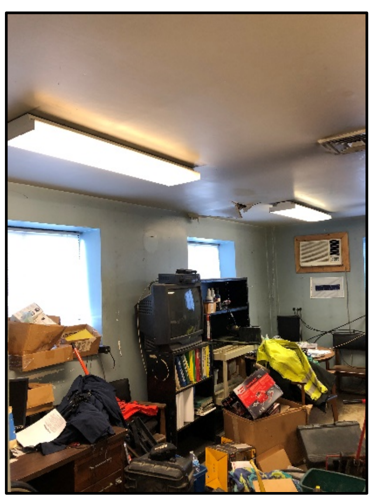

Photo 97. Typical T8 fluorescent light fixtures

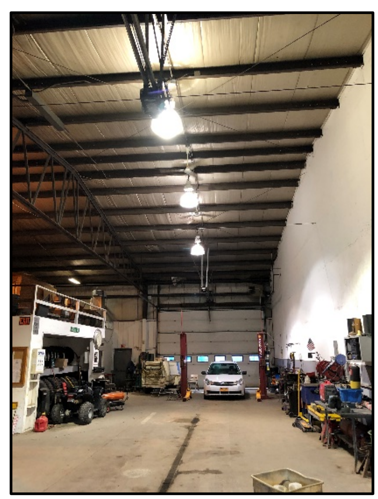

Photo 98. Typical metal halide light fixtures

Photo 99. Typical HPS light fixtures

9.01.6 Existing Lighting Controls

All interior lighting is manually controlled by toggle switches.

9.02 DPW Garage Analysis of Present Energy Use

A historical energy use analysis was performed for the energy sources at the DPW Garage. The following data was analyzed based on yearly energy consumption and costs. Based on the utility bills provided, OLA was able to calculate a combined site EUI for the building. The building used approximately 66.3 kBtu/ft^2 site energy and had a total energy cost of $13,053 based on 2016-2018 data. Table 37 below provides a summary of the annual energy usage and costs for 2016-2018.

Table 37. 2016-2018 Annual Overall Site Energy

	Energy Usage	kBtu	Cost ($)	Cost ($) per ft^2	Site EUI (kBtu/ft^2)	CO_2 Emissions (lb/year)
Electric (kWh)	35,091	122,494	$5,792	$0.48	10.2	22,871
Natural Gas (therm)	6,728	672,800	$7,262	$0.61	56.1	78,776
Total		795,294	$13,053	$1.09	66.3	101,647
Gross Area (ft^2)		12,000				

Figure 48 provides the annual site EUI per energy type based on analysis of the utility bills for 2016-2018. Figure 49 provides the annual energy cost summary by energy type from the same year. Natural gas for heating is the dominant energy source for this building, and accounts for 85% of the overall energy consumption of the building. However, natural gas only accounts for 56% of the cost, due to the higher cost of electricity. Figure 50 provides the annual CO_2 emissions breakdown by energy type.

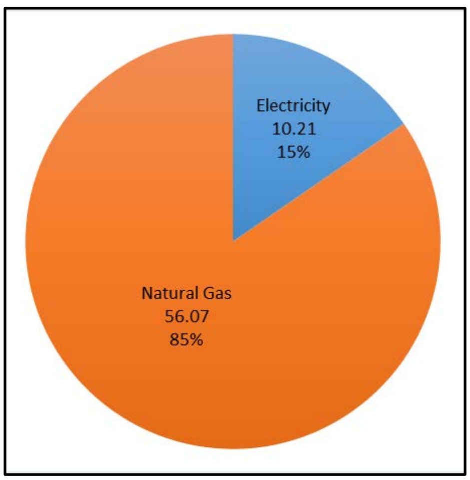

Figure 48. Existing Annual Fuel Type Site EUI Breakdown in kBtu/ft.^{2}

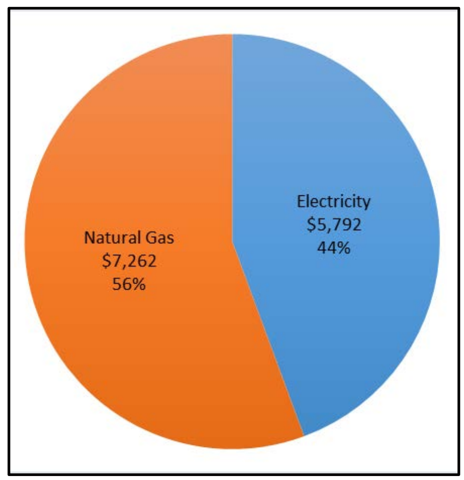

Figure 49. Existing Annual Energy Cost Breakdown

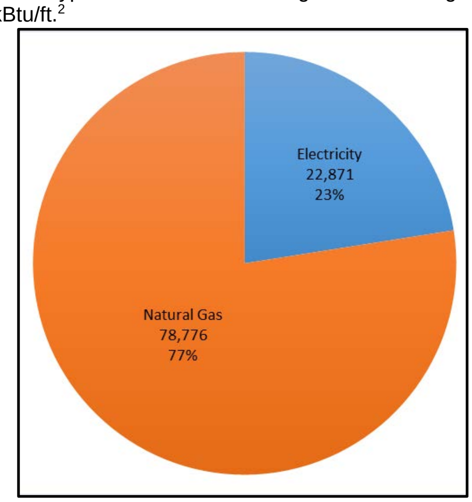

Figure 50. Existing Annual CO_2 Emissions Breakdown in lb/year

9.02.1 Electrical Usage

The historical electric usage for the DPW Garage is shown in Figure 51. Peak electricity usage typically occurs during the winter months for this building, likely due to electric heaters, and because there is no form of cooling at the facility. The highest monthly usage recorded during this time was 5,310 kWh during January 2018.

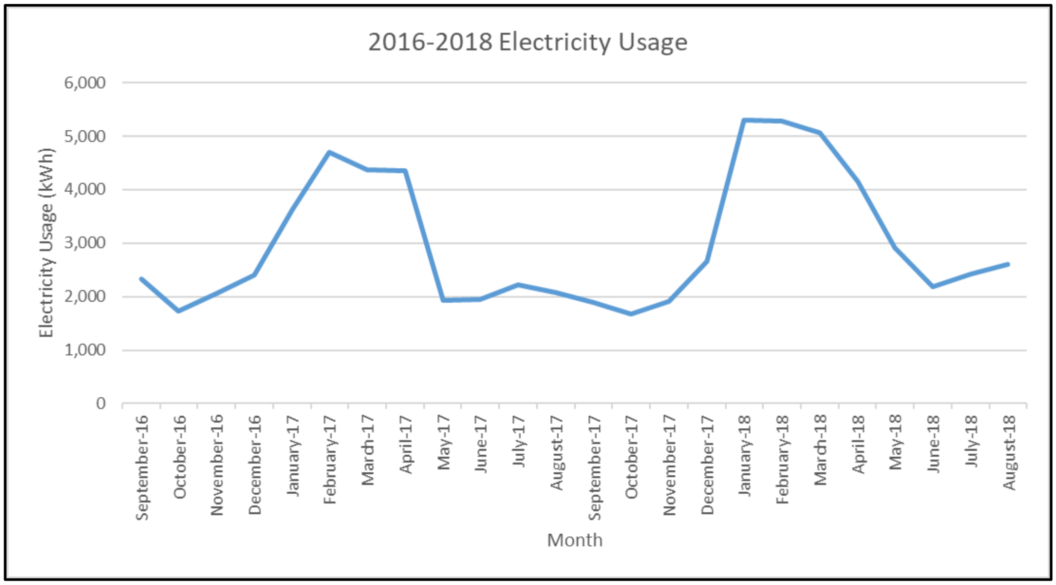

Figure 51. 2016 – 2018 Historical Electricity Use

The historical electric demand is shown in Figure 52. Similar to the historical electricity usage above, the building's peak demand typically occurs during the winter months. The highest recorded demand of 14.6 kW occurred in February 2018.

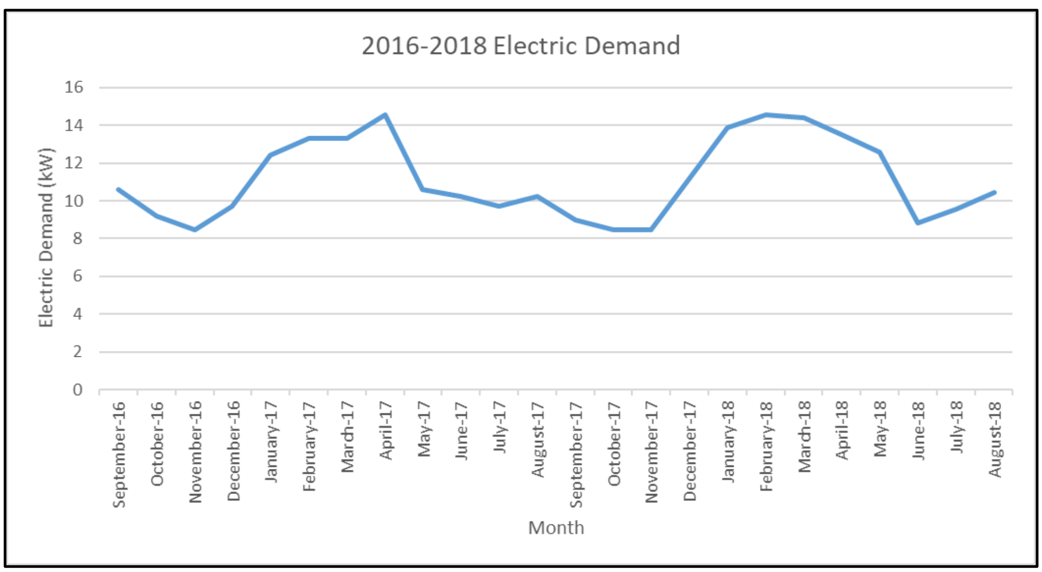

Figure 52. 2016 – 2018 Historical Electric Demand

OLA was provided with complete electric utility bills for this analysis, and determined an electricity rate of 0.161 $/kWh based on the bills provided. For the purposes of this study, this calculated rate was used to estimate energy cost savings.

9.02.2 Natural Gas Usage

Figure 53 below shows the historical 2016-2018 natural gas usage for the building. Since gas in this building is used for heating only, usage is found to be highest during the winter months. A peak usage of 2,374 therms was recorded in February 2017.

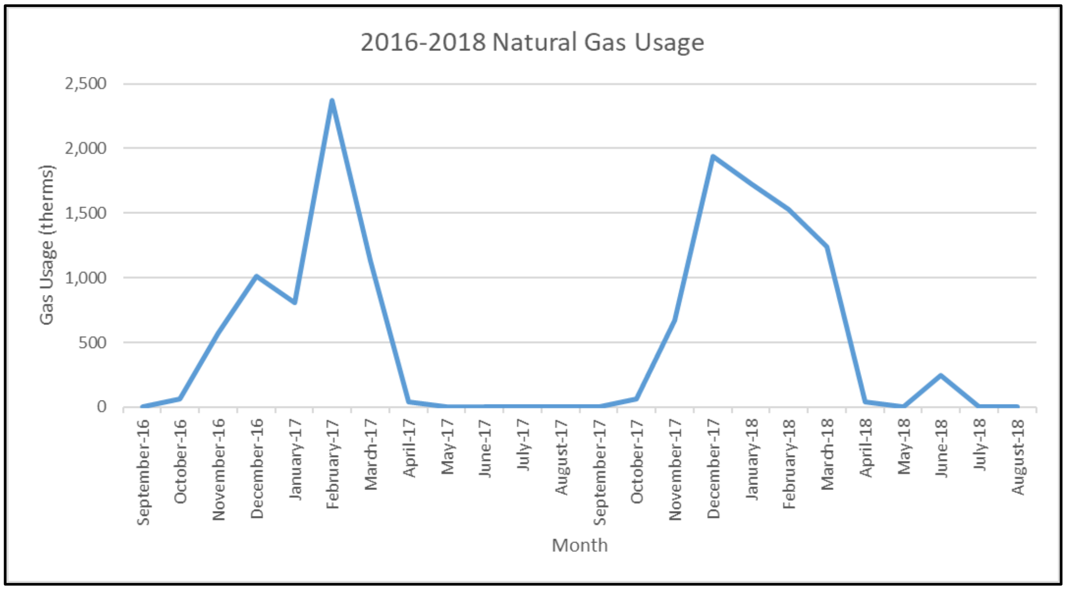

Figure 53. 2016-2018 Historical Natural Gas Usage

OLA was provided with complete utility bills for this analysis and determined a natural gas of 1.08 $/therm based on the bills provided. For the purposes of this study, this calculated rate was used to estimate energy cost savings.

9.02.3 Utility Rates and Costs

The DPW garage is served by one (1) electric meter and one (1) gas meter. Estimated blended electric and gas rates for the building were determined based on monthly usage and monthly charges. Table 38 below shows a breakdown of the utility rates for each fuel source.

Table 32. Utility Rates

Utility	Unit	2016/17	2017/18
Electric	$/kWh	$0.160	$0.162
Natural Gas	$/therm	$1.06	$1.10

9.02.4 Energy Utilization

Figure 54 below shows the breakdown of energy intensity (kBtu/ft^2) by end use type. The results confirm that fuel consumed to run the heating plant accounts for the largest portion of the site energy use and cost.

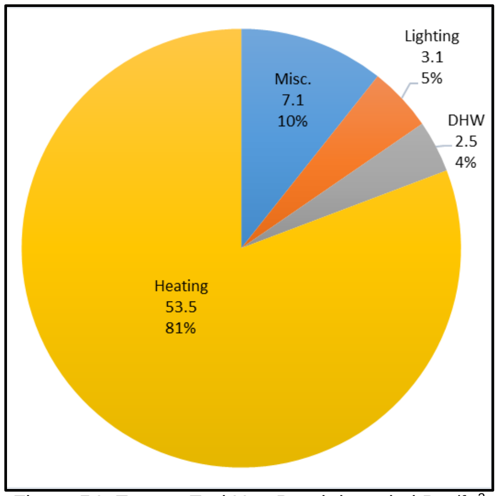

Figure 54. Energy End Use Breakdown in kBtu/ft.^{2}

9.03 Energy Efficiency Measures (EEMs)

Short Term EEM's

9.03.1 EEM 1 – LED Lighting Retrofits

This measure investigates the impact on energy consumption of reduced lighting power density utilizing high efficiency LED lighting technology and retrofit products throughout the building. The new LED lighting will result in a reduced lighting power density and potential for high savings. All of the typical 32W T8 fluorescent lighting and HPS / metal halide flood lighting in the building could be replaced with LED retrofit products. The existing lighting power density of the building is estimated to be 0.33 W/ft^2. The resulting lighting power density of the entire facility is estimated to be in the range of 0.16 W/ft.^{2} after a complete retrofit.

Long Term EEM's

9.03.2 EEM 2 – Air Source VRF Heat Pump for Repair Shop

This measure assesses the energy reduction associated with installing a multi-zone air source heat pump with variable refrigerant flow (VRF) to heat the repair shop and adjacent office spaces. Air source heat pumps typically offer high heating and cooling efficiencies, which could result in an overall EUI reduction and cost savings. Indoor units would be installed where appropriate, providing heating and cooling to the spaces they serve.

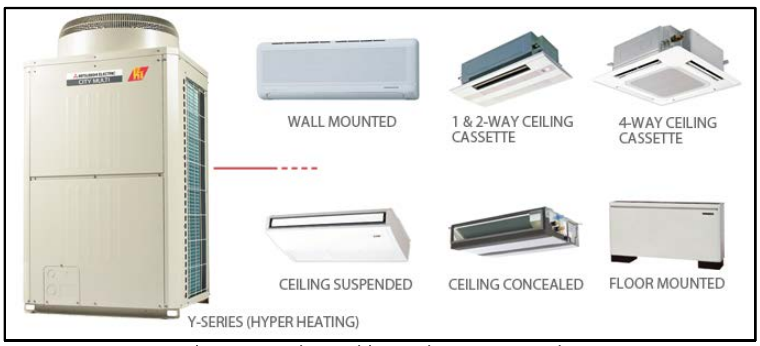

Figure 55. City-Multi VRF heat pump units

10.0 Energy Efficiency Measure (EEM) Summary

Table 33 summarizes the results of the energy analysis for the EEMs investigated.

Participant's Name and Address:
Village of Hastings-on-Hudson
7 Maple Avenue
Hastings-on-Hudson, NY

ENERGY EFFICIENCY MEASURE SUMMARY

	Measure Description	Measure Status (See Notes)	Building Electricity Usage (kWh)	Building Oil Usage (gallons)	Building Gas Usage (therms)	Building Energy Use (kBtu/ft^2)	Electricity Saved (kWh)	Oil Fuel Saved (gallons)	Natural Gas Saved (therms)	Site Energy Saved (kBtu/ft^2)	Demand Saved (kW)	CO_2 Emissions Saved (lb/year)	Annual Utility Cost ($/year)	Annual Energy Cost Saved ($/yr)	Estimated Cost for Implementation ($)	Simple Payback (Total Cost Basis)
Village Hall and Library																
Existing Building (Combined 2017-2018 Usage)			252,360	2,621	12,107	102.4	-	-	-	-	-	-	$58,494	-	-	-
Existing Building (Adjusted Baseline Usage - Gas Only)			252,360	0	15,926	103.0	-	-	-	-	-	-	$56,490	-	-	-
EEM 1	Village Hall LED Lighting Retrofit and Lighting Controls Upgrade	R	244,039	0	15,926	101.8	8,321	0	0	1.2	2.7	5,301	$55,409	$1,080	$16,000	14.8
EEM 2	Library Lighting Controls and Daylighting Upgrade	R	241,260	0	15,926	101.4	2,780	0	0	0.4	0.0	1,771	$54,961	$448	$10,000	22.3
EEM 3	Building Envelope Upgrades - New Windows	R	241,260	0	14,843	96.9	0	0	1,083	4.5	0	12,685	$53,752	$1,209	$362,000	299.3
EEM 4	Building Envelope Upgrades - Wall Insulation and Air Barrier	R	241,260	0	13,653	91.9	0	0	1,190	5.0	0	13,937	$52,423	$1,329	$160,000	120.4
EEM 5A	Condensing Gas-Fired Hot Water Boilers	R	241,260	0	12,154	85.6	0	0	1,499	6.3	0	17,551	$50,750	$1,673	$593,000	354.4
EEM 5B	Geothermal Heat Pumps for VH	RS	273,494	0	7,842	72.1	-32,235	0	5,811	19.8	14.7	47,506	$49,533	$2,890	$1,159,250	401.1
EEM 5C	Air Source VRF Heat Pumps for VH	R	280,701	0	7,842	73.1	-39,441	0	5,811	18.7	8.6	42,915	$51,412	$1,011	$256,000	253.1
EEM 6	Library Roof-Mounted Solar PV System	RS	199,289	0	13,653	85.9	41,971	0	0	6.0	0	26,738	$50,418	$2,005	$145,000	72.3
EEM 7	Library AHU Replacement	R	225,321	0	13,653	89.6	15,939	0	0	2.3	0.0	10,154	$49,854	$2,569	$324,000	126.1
James Harmon Community Center																
Existing Building (Adjusted Baseline Usage)			209,400	0	11,691	110.8	-	-	-	-	-		$43,027	-	-	-
EEM 1	LED Lighting Retrofits	R	203,315	0	11,691	109.6	6,085	0	0	1.2	2.4	3,877	$42,135	$892	$16,000	17.9
EEM 2	Rescheduling of RTU's	R	196,770	0	11,691	108.3	6,545	0	0	1.3	0	4,169	$41,176	$959	$1,200	1.3
EEM 3	Variable Frequency Drives (VFD's) on RT-3 and RT-4	R	182,057	0	11,691	105.3	14,713	0	0	3.0	0	9,373	$39,021	$2,156	$36,000	16.7
EEM 4	Condensing Gas-Fired Hot Water Boiler	RS	182,057	0	10,311	97.2	0	0	1,380	8.1	0	16,164	$37,503	$1,518	$191,000	125.9
EEM 5	Supplemental Domestic Hot Water Heat Pump	RS	183,212	0	10,154	96.5	-1,154	0	157	0.7	0	1,098	$37,500	$3	$20,000	6591

Hook and Ladder Company																
Existing Building (Adjusted Baseline Usage)			8,646	0	6,362	74.0	-	-	-	-	-		$7,419	-	-	-
EEM 1	LED Lighting Retrofit	R	6,828	0	6,362	73.3	1,818	0	0	0.7	1.1	1,158	$7,298	$121	$6,000	49.7
EEM 2	Lighting Controls Upgrade	R	6,354	0	6,362	73.1	474	0	0	0.2	0.0	302	$7,267	$31	$6,000	190.7
EEM 3	Hot Water Piping Insulation	R	6,354	0	5,997	69.0	0	0	365	4.1	0.0	4,274	$6,867	$400	$3,300	8.2
EEM 4	Heating Night Setback	R	6,354	0	4,668	54.3	0	0	1,329	14.8	0.0	15,562	$5,409	$1,458	$7,000	4.8
EEM 5	Condensing Gas-Fired Hot Water Boiler	RS	6,354	0	4,195	49.0	0	0	473	5.3	0	5,542	$4,890	$519	$80,000	154.1
Ambulance Corps Garage																
Existing Building (Adjusted Baseline Usage)			12,121	0	1,978	99.7	-	-	-	-	-		$4,937	-	-	-
EEM 1	LED Lighting Retrofit	R	10,069	0	1,978	96.7	2,052	0	0	2.9	0.8	1,307	$4,391	$546	$7,000	12.8
EEM 2	Heating Night Setback	R	10,069	0	1,479	75.9	0	0	499	20.8	0.0	5,847	$3,694	$697	$2,000	2.9
Chemka Pool Building																
Existing Building			109,680	0	0	89.1	-	-	-	-	-		$26,347	-	-	-
EEM 1	Complete LED Lighting Retrofit	R	109,138	0	0	88.7	542	0	0	0.4	0.6	346	$26,217	$130	$3,000	23.0
EEM 2	Variable Speed Pumps and High Efficiency Motors	R	68,797	0	0	55.9	40,340	0	0	32.8	0	25,699	$16,526	$9,690	$83,000	8.6
EEM 3	Air Source VRF Heat Pump for Pool Equipment Room	R	67,148	0	0	54.6	1,649	0	0	1.3	6.7	1,050	$16,042	$484	$12,000	24.8
EEM 4	Domestic Hot Water Heat Pumps	RS	63,044	0	0	51.2	4,104	0	0	3.3	0.0	2,614	$15,056	$986	$56,000	56.8
EEM 5	Solar Tube Skylight	R	62,510	0	0	50.8	534	0	0	0.4	0.0	340	$14,928	$128	$44,000	342.8
DPW Garage																
Existing Building (Adjusted Baseline Usage)			35,901	0	8,077	77.5	-	-	-	-	-		$13,053	-	-	-
EEM 1	LED Lighting Retrofit	R	30,589	0	8,077	76.0	5,312	0	0	1.5	2.1	3,384	$12,197	$857	$11,000	12.8
EEM 2	Air Source VRF Heat Pumps for Repair Shop	RS	54,640	0	4,894	56.3	-24,051	0	3,183	19.7	-17.0	37,272	$12,810	-$613	$130,000	

Measure Status: Recommended (R); Further Study Recommended (RS)

Notes:

1.) Energy and cost savings for all EEM's are considered incremental. Savings for a particular measure is calculated assuming the preceding measure has been implemented.

2.) Village Hall - Library EEM's 5 - 7 are designated as long term. Savings for long term EEM's are based on EEM 4, and are not incremental (i.e. EEM 7 is not incremental to EEM 6).

11.0 Recommendations for Strategic Implementation

This section is provided to clarify the sequence and scope of our recommendations and implementation and provide commentary on the recommended measures. This section will be update after a review discussion with the Village of Hastings to develop a prioritization of EEMs. Please note that costs are preliminary and should be further explored, designed and bid to establish reliable costs for implementation. These costs are for “order of magnitude” only and should be understood to be preliminary and not for budgeting purposes.

Table 34. Recommended Sequence for Implementation

Time Period (Implementation)	Building Key	EEM		CO_2 Emissions Saved (lb/year)	Implementation Costs	Simple Payback (years)
Short Term Low Cost EEM's	HL	EEM 4	Hook and Ladder - Heating Night Setback	15,562	$7,000	5
	AC	EEM 2	Ambulance Corps - Heating Night Setback	5,847	$2,000	3
	HL	EEM 3	Hook and Ladder - Hot Water Piping Insulation	4,274	$3,300	8
	CC	EEM 2	Community Center - Rescheduling of RTU's	4,169	$1,200	1
	AC	EEM 1	Ambulance Corps - LED Lighting Retrofit	1,307	$7,000	13
	CP	EEM 1	Chemka Pool Building - Complete LED Lighting Retrofit	346	$3,000	23
Remaining Short Term EEM's	HL	EEM 1	Hook and Ladder - LED Lighting Retrofit	1,158	$6,000	50
	HL	EEM 2	Hook and Ladder - Lighting Controls Upgrade	302	$6,000	191
	DPW	EEM 1	DPW Garage - LED Lighting Retrofit	3,384	$11,000	13
	LI	EEM 2	Library - Lighting Controls and Daylighting Upgrade	1,771	$10,000	22
	VH	EEM 1	Village Hall - LED Lighting Retrofit and Lighting Controls Upgrade	5,301	$16,000	15
	CC	EEM 1	Community Center - LED Lighting Retrofits	3,877	$16,000	18
	CP	EEM 2	Chemka Pool Building - Variable Speed Pumps and High Efficiency Motors	25,699	$83,000	9
	CC	EEM 3	Community Center - Variable Frequency Drives (VFD's) on RT-3 and RT-4	9,373	$36,000	17
	CP	EEM 4	Chemka Pool Building - Domestic Hot Water Heat Pumps	2,614	$56,000	57
	CP	EEM 3	Chemka Pool Building - Air Source VRF Heat Pump for Pool Equipment Room	1,050	$12,000	25
Long Term EEM's	DPW	EEM 2	DPW Garage - Air Source VRF Heat Pumps for Repair Shop	37,272	$130,000	-
	VH	EEM 4	Village Hall - Building Envelope Upgrades: Wall Insulation and Air Barrier	13,937	$160,000	120
	VH	EEM 3	Village Hall - Building Envelope Upgrades: New Windows	12,685	$362,000	299
	VH / LI	EEM 5A, 5B, 5C	Village Hall / Library - Condensing Gas-Fired Hot Water Boilers	17,551	$593,000	354
			Village Hall - Geothermal Heat Pumps	47,506	$1,159,250	401
			Village Hall - Air Source VRF Heat Pumps	42,915	$256,000	253
	LI	EEM 6	Library - Roof-Mounted Solar PV System	26,738	$145,000	72
	LI	EEM 7	Library - AHU Replacement	10,154	$324,000	126
	CP	EEM 5	Chemka Pool Building - Solar Tube Skylight	340	$44,000	343
	CC	EEM 4	Community Center - Condensing Gas-Fired Hot Water Boiler	16,164	$191,000	126
	HL	EEM 5	Hook and Ladder - Condensing Gas-Fired Hot Water Boiler	5,542	$80,000	154
	CC	EEM 5	Community Center - Supplemental Domestic Hot Water Heat Pump	1,098	$20,000	6,591

Building Key
AC - Ambulance Corps Garage
CC - James Harmon Community Center
CP - Chemka Pool Building
DPW - DPW Garage
HL - Hook and Ladder Company
LI - Library
VH - Village Hall

1. Low-cost measures

Several buildings can benefit from simple low-cost measures like programmable set-back thermostats, pipe insulation, proper scheduling of equipment, and simple LED retrofits. Regarding scheduling and thermostats, occupants of the buildings should be educated that the goal is operate at a high efficiency without energy waste, and on how to mitigate unnecessary energy use by using the night setback.

Simple screw-in and swap-in retrofits for LED lights in the Pool building and Ambulance corps can also be prioritized.

2. LED Lighting and Lighting Controls

Additional LED lighting retrofits and lighting controls are cost effective measures that should also be prioritized. Some buildings may require more elaborate retrofit kits or fixture replacements such as in the Community Center, but many can use T8 retrofit products. The lighting controls recommended for various buildings include occupancy sensors and daylight sensing in various locations. These are fairly easy to implement and can be preferably all be done as part of a larger lighting upgrade project Village wide.

Continuing to trend energy costs and consumption to try to approach high performance operation will emphasize the importance of optimizing the building operation. .

3. Variable Speed Drives for RTUs and Pool pumps

Some HVAC can benefit from the use of variable speed drives to save energy. These measures have the potential to save considerable energy and associated GHG emissions for the Community Center RTU's and the Pool pump motors. The measures have a reasonable payback and make sense to prioritize after the lower cost measures.

4. Air-source heat pumps (Space Heat)

Several measures look at using cold-climate air-source heat pumps in lieu of electric resistance heat or in the case of the DPW garage, gas fired heat. In the case of the Pool building, a small heat pump to heat the mechanical room is preferable to electric resistance heat and can cut GHGs. For the DPW Garage, it appeared that an air-source heat pump system could provide additional benefits of providing cooling as well as heat to the office spaces, some of which only have space heaters that provide poor or no temperature control, and only have window units for cooling. Heat pump systems have the ability to reduce GHGs significantly.

5. Village Hall Envelope Improvements

Several measures looked at improving the envelope (windows and walls) of the Village Hall. Given the age of the building, these measures would obviously be capital intensive, but do have the benefit of reducing building loads, reducing GHGs significantly, and likely improving occupant comfort. These may be considered longer term measures. We would recommend considering these measures before investing in the heating system however, in order to optimize any future heating plant, and reduce equipment sizing requirements.

6. Village Hall / Library Heating System

The Village Hall and Library heating system is currently shared. This study looked at several options to improve the energy performance and reduce GHGs for both buildings. Both geothermal and air-source heat pump systems were considered as a replacement heating system for the Village Hall. The geothermal option does have the potential to save more energy than an air-source heat pump, however it comes with significantly higher capital cost. We also determined that a geothermal system likely cannot serve both Village Hall and Library due to lack of available land area.

Recent improvements in cold-climate air-source heat pumps would make it possible to heat the Village Hall building and avoid using the boiler. The boiler could be retained to heat just the Library, and eventually replaced in the future with a condensing gas boiler to heat the Library. This is a cost effective approach since the Library already has a hydronic heating system.

7. Library AHU Replacement

The library main air handling unit (HV-1) is original to the building, past its expected useful life and should be planned for eventual replacement. The existing system use constant speed fans, but a future modern system would use variable speed fans for energy savings. This is capital intensive project, but should be considered for the future.

8. Community Center and Hook & Ladder Condensing Boilers

These buildings all have existing hydronic heating systems with boilers that are not too old. Eventually the equipment may need to be replaced, and the current best available boiler technology would be condensing boilers to improve efficiency and reduce emission.

9. Heat Pump Domestic hot water heaters

Several buildings can benefit from using heat-pump water heaters, particularly the Pool building which likely has more of a hot water load and uses electric resistance heaters. The Community Center water heater is not at the end of its useful life yet, but eventually could be replaced with a heat-pump water heater.

12.0 Appendices