ENERGY AUDIT REPORT

Energy Efficiency Audit: 321 Bedford Road

prepared for

Town of Bedford Hills

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1 Executive Summary

1.1 Introduction

This report details the recommendations and conclusions of an energy efficiency audit prepared for the town of Bedford Hills, New York. The town of Bedford Hills has shown tremendous initiative in promoting sustainability, spreading awareness of incented energy efficiency measures, and leading by example in terms of upgrading its municipal buildings to reach optimal efficiency. As part of this study, four of the town's municipal buildings – 74 Main Street, 425 Cherry Street, 321 Bedford Road, and 21 Park Avenue – will be audited and studied to identify capital projects to improve the facilities' energy efficiency. In addition, the town requested a feasibility study to evaluate upgrading its HVAC systems to ground and/or air source heat pumps, in an effort to electrify its facilities in response to the Westchester gas moratorium.

The following report details ERS's findings at the 321 Bedford Road.

Mr. Alain Tayoun of ERS conducted a site visit at 321 Bedford Road on November 26, 2019. He met with Mr. Frank Zipp. During the site visit, Mr. Tayoun collected information on the building's operation, schedules, envelope, mechanical systems, and maintenance. In addition, Mr. Tayoun deployed logging equipment to develop operating profiles for some the mechanical and lighting systems at the facility.

Details of our findings and recommendations for the facility are contained in this report, including a summary of recommended measures and facility details, as well as a detailed discussion on each measure. Supporting analyses and information can be found in the appendices at the end of this report.

1.2 Summary of Current Energy Use

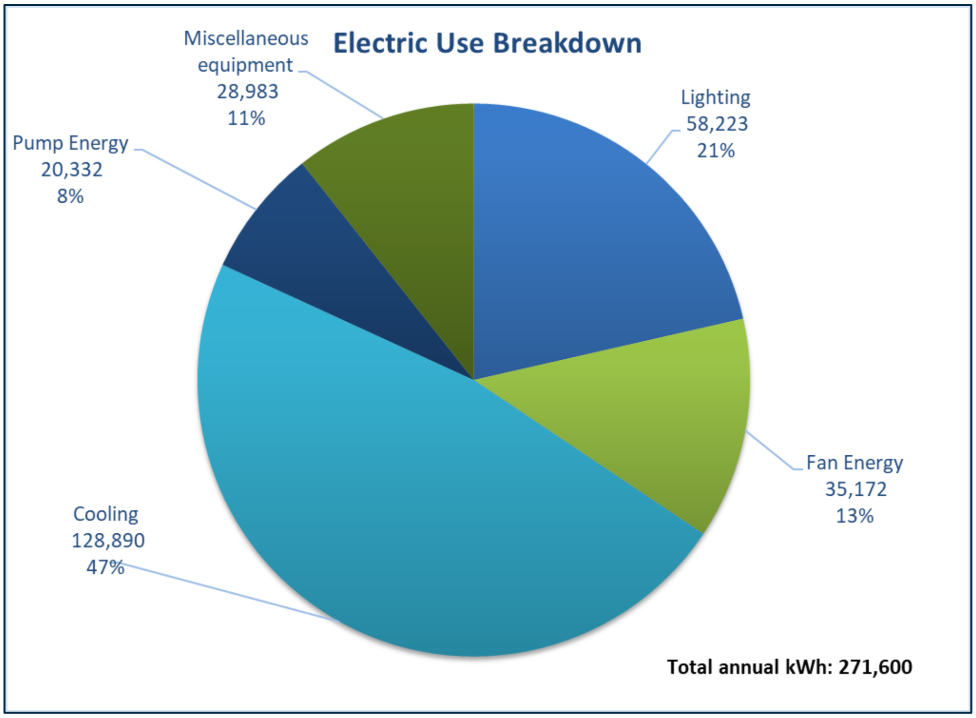
The courthouse at 321 Bedford Road was initially built in the 1920s. An extensive renovation including additions were made in the early 2000s. The building has a main floor, mezzanine and a basement with a total floor area of approximately 17,000 square feet. The courtroom along with the open and enclosed offices make up most of the square footage. Other areas include conference rooms, breakrooms, waiting rooms, and restrooms.

The utilities at this facility include electricity and natural gas. The following discussion presents electric and natural gas billing and usage information for the facility. A detailed energy profile is presented in Section 2.

1.2.1 Electric Energy Use Breakdown

In preparing this energy report, ERS studied the current (baseline) electricity use at the facility. ERS estimated the lighting energy use by doing an inventory of the facility's lighting, collecting the various fixture and lamp nameplates and using the operating profiles we developed through meter deployment. We determined the energy usage of the cooling equipment by collecting nameplate information (make, model, capacity, and efficiency) and calculating the estimated energy usage throughout the year. Since the study timeframe took place in the winter, ERS could not collect summer performance data. As a result, we developed a bin analysis to determine the baseline cooling energy usage. Pump and fan energy usage was determined by metering a sample of the equipment on site and developing an annual operating profile. The other miscellaneous end users represent the various office and kitchen equipment at the facility. Figure 1-1 presents the electric energy end-use breakdown plot.

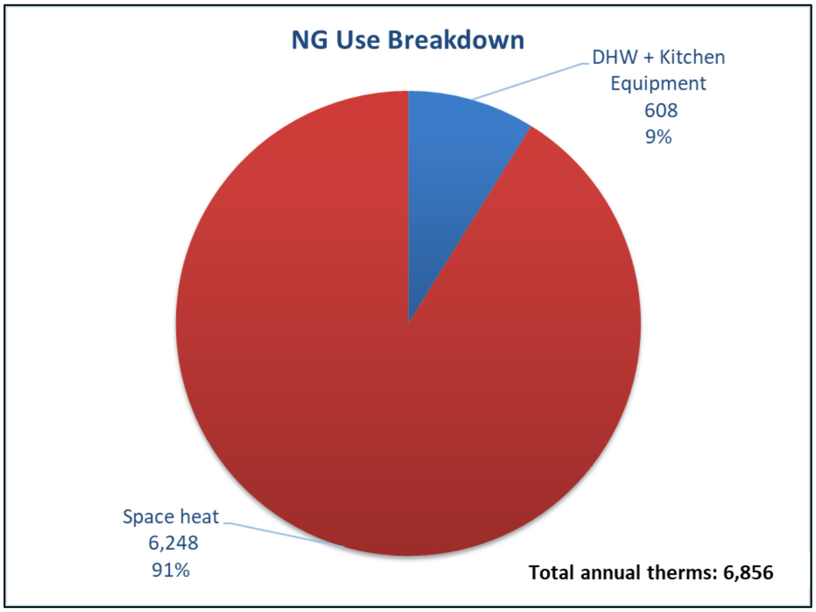
Figure 1-1. Facility Electricity End-Use Breakdown (kWh)



1.2.2 Natural Gas Energy Use Breakdown

In preparing this energy report, ERS also studied the current (baseline) natural gas use at the facility. As anticipated, space heating makes up the greater portion of gas use at 91% of the facility consumption. Figure 1-2, below, presents the natural gas energy end-use breakdown plot.

Figure 1-2. Facility Natural Gas End-Use Breakdown (Therms)



1.3 Summary of Recommended Energy Efficiency Measures

ERS recommends two energy efficiency measures (EEMs) for implementation and an additional informational measure. Details on the EEMs are shown in table 1-1, below.

Table 1-1. Summary of Recommended Energy Efficiency Measures

Measure	Peak Demand Reduction (kW)	Electrical Energy Savings (kWh/yr)	Thermal Energy Savings (therms/yr)	Cost Savings ($/yr)	CO2 Reduction (Metric Ton)	Measure Cost ($)	Simple Payback (years)	Potential Incentive ($)	Simple Payback w/Incentive (years)
EEM-1: Install Energy Efficient Lighting and Lighting Controls	9.3	42,280	n/a	$3,862	5.65	$24,118	6	$0	6.2
EEM-2-a: Improve Control on the Current HVAC System	N/A	41,971.9	0.0	$3,834.02	5.61	$15,000.00	4	N/A	N/A
EEM-2-b: Replace Current HVAC System with Air Source Heat Pumps (ASHP)	33.6	56,379.0	6,248.1	$11,921	40.72	$175,000	15	N/A	N/A
EEM-2-c: Replace Current HVAC System with Variable Refrigerant Flow (VRF) Systems	56.5	89,161.5	6,248.1	$14,916	45.10	$245,000	16	N/A	N/A
EEM-2-d: Replace Current HVAC System with Ground Source Heat Pumps (GSHP)	54.9	87,482.5	6,248.1	$14,763	44.88	$560,000	38	$105,000	31
EEM-2-e: Replace Current HVAC System with Variable Refrigerant Flow GSHPs	64.7	106,703.2	6,248.1	$16,518	47.45	$700,000	42	$105,000	36

[1]Peak demand reduction reflects kW savings during the Summer. The overall demand increases in the winter for EEM-2 due to electric heating

N/A= Not applicable

As mentioned before, the town of Bedford Hills has shown interest in clean heating and cooling technologies. Therefore, five options were studied – the first is a retrofit and retrocommissioning to the current system. The other four options are various heat pump technology alternatives. All five options are further described in section 3. We have also included an estimated NYSERDA, and utility incentive for each measure where applicable. Please note that these incentive levels are based on current utility and state offerings. For an update on the utility and state offerings available at the time of equipment purchase, we recommend contacting ERS before implementing any recommended measures.

1.3.1 EEM-1: Install Energy Efficient Lighting and Controls in Entire Facility

The lights at the facility typically operate during business hours. The interior lighting technologies in the facility include T8 fixtures with electronic ballasts and CFL biax lamps. Light-emitting diode (LED) lamps and fixtures can offer significantly improved light quality with greater system efficiency and options for better control. We recommend replacing all of the existing lights with equivalent LED designs with lighting controls in designated areas.

1.3.2 EEM-2: Replace Current HVAC System – Five Options

The town of Bedford Hills is interested in evaluating several options to serve heating and cooling loads at their facility. Currently, cooling is provided by a 60-ton air cooled reciprocating chiller. The chilled water is circulated by two alternating 3-hp chilled water pumps to the air handling units. Heating is provided by a 1,500,000 Btu/hour natural gas boiler. The hot water is circulated by two alternating 3-hp hot water pumps that are equipped with variable frequency drives (VFDs) set at 76% to the air handling units and unit vents. Air distribution in the facility is done through four air handling units that serve the courtroom and offices. Finally, multiple unit heaters are spread out in the facility that provide additional heating to vestibules, hallways, and waiting rooms.

The town is interested in both conventional and clean energy options to satisfy the building's cooling and heating loads, and as such, is considering converting its HVAC systems to either air source or ground source heat pump if the study is found to be economically viable. The electrification of the heating sytem provides multiple non-energy benefits including a reduction in greenhouse gas emmissions and an increase occupant comfort.

Below is a brief technology description of the five different options that ERS studied as part of this project.

EEM-2-a Improve Controls on the current HVAC System

The existing HVAC system runs at a constant load whenever there's a need for heating or cooling. The hot water pumps and one of the AHUs are equipped with VFDs. However, the overall system has to operate in unison to optimize the energy usage of the entire system. For instance, the hot water pumps, though equipped with VFDs, ran continuously throughout the logging period. Even though the pumps run at a reduced speed (76%), consuming less energy, our monitoring data suggests that there is room to turn the VFDs down to 40% (recommended minimum) at times where there's no need for heating. Furthermore, the billing data suggests that excessive cooling occurs during the summer. The latter indicates that the facility's chiller operates at full capacity even though it has staging capabilities. As a result, ERS recommends that the facility retrocomissions its HVAC system and re-program the control protocols to maximize the capabilities of the current system. As part of this recommendation, the chilled water pumps, as well as three of the air handling units will require a VFD retrofit. It is important to mention that when installing VFDs on a pump, any three-way valve in the water loop system has to be replaced with a two-way valve. The later will ensure that no water flows through the bypass loops, which will starve the overall system and compromise energy savings.

EEM-2-b Air Source Heat Pump (ASHP)

An ASHP uses a refrigerant system involving a compressor and a condenser to absorb heat at one place and release it at another. Unlike water source heat pumps, ASHP refrigerants exchange heat with the ambient air. ASHPs are at most a two-speed system; therefore, the unit's compressor can only operate at one of two different levels, depending on the load it has to provide. They are a low-cost electric space heater or cooler. A high efficiency heat pump can provide up to four times as much heat as an electric resistance heater using the same amount of electricity.

EEM-2-c: Variable Refrigerant Flow Air Source Heat Pump (VRF)

A VRF is a more efficient air source heat pump with variable speed compressors and a modulating refrigerant fluid valve. Depending on the load a unit has to provide, its built-in logic controls the compressor's speed (0% to 100%) and modulates the refrigerant valve (0% to 100%) to optimize the energy usage. VRFs are a great solution for multi-zone facilities since the units adapt and optimize for the required overall load in all zones and are not restricted to one or two levels of operation.

EEM-2-d: Ground Source Heat Pump (GSHP)

Ground source heat pumps are similar in concept to ASHPs; however, the refrigerant exchanges heat with the underground soil instead of air. The advantage of having an underground system is that in most cases, the geological properties of the ground allows for optimal temperatures that favor efficient heat transfer.

EEM-2-e: Variable Refrigerant Flow Ground Source Heat Pump (VRF GSHP)

VRF GSHP is a GSHP that operates under a similar manner to a VRF. Depending on the load a unit has to provide, the compressor's speed, along with the refrigerant valve, modulate (0% to 100%) to optimize the energy usage. In addition, with small loads, a reduced volume of refrigerant has to be circulating through the underground loop, resulting in additional energy savings.

1.4 Summary of Informational Measures

1.4.1 IM-1: Replace the Existing Gas-Fired Domestic Hot Water Heater with a Heat Pump Hot Water Heater

The facility currently has a 40-gallon gas-fired domestic hot water heater with a 66% efficiency. Heat pump hot water heaters are an electric alternative to providing domestic hot water in a facility at a comparable price to gas (varies based on electric and natural gas costs). ERS is listing this upgrade as an informational measure since it has no cost savings associated with it. However, this measure is being reported since the town of Bedford Hills has shown interest in electrifying their facility in response to the Westchester gas moratorium.

2 Facility Description

This section discusses the facility and energy-consuming systems present at 321 Bedford Road in Bedford Hills, New York. Details on the annual energy consumption and end-use breakdowns are presented in the following subsections.

The courthouse at 321 Bedford Road was initially built in the 1920s but had an extensive renovation in the early 2000s where an additional section was added to the structure. The facility houses the town's courthouse and several other juridical departments. The facility also formerly housed the town of Bedford's police department before the precinct was built. The building has a main floor with a mezzanine area and a basement with a total floor area of approximately 17,000 square feet. The courtroom along with the open and enclosed offices make-up most of the square footage. Other areas include conference rooms, breakrooms, waiting rooms and restrooms.

Photo 2-1 shows the approximately 17,000-square-foot facility at 321 Bedford Road.

Photo 2-1. View of the Bedford Hills Court House

Image courtesy of Google Maps

2.1 Building Envelope, Roof, Crawl Space, and Windows

The facility's exterior walls consist of wood framing with concrete masonry and brick outer shell. The building's roof is a dark-shingled, sloped roof overlaid on a wooden frame. The windows are double-paned with aluminum frames.

The overall envelope of the building is in good condition and is well maintained. Photos 2-2 and 2-3, below, are thermal images taken by ERS on the day of the site visit.

Photo 2-2. Side Wall at 321 Bedford Road

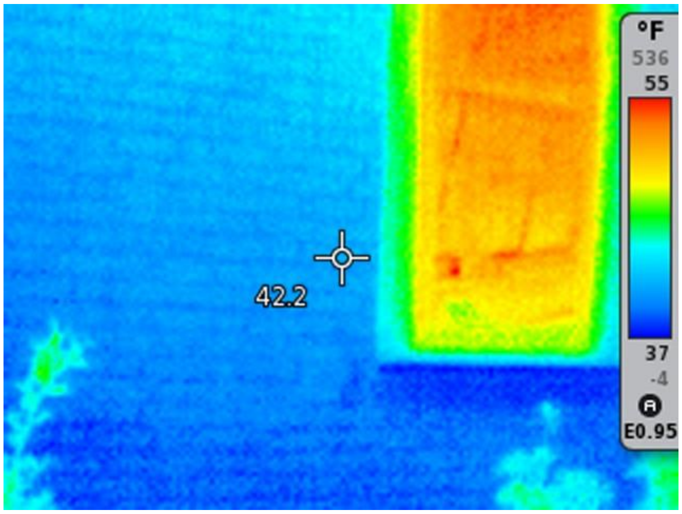
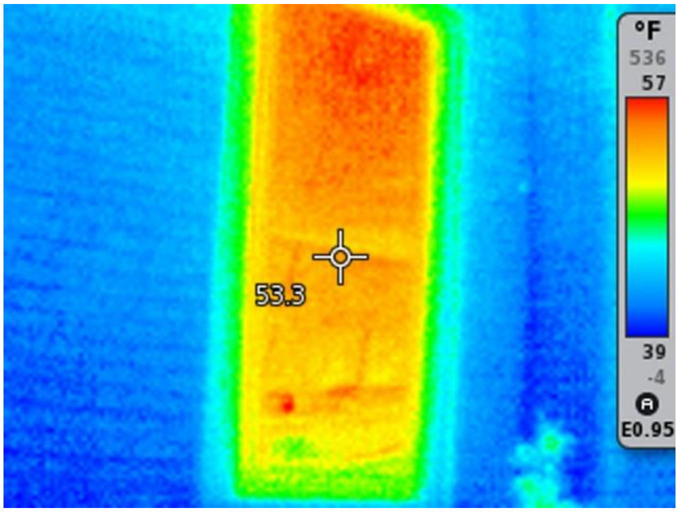


Photo 2-3. Side Window at 321 Bedford Road



The outdoor temperature was around 35°F on the day of the site visit, and heating was taking place at the facility. The thermal image in Photo 2-2, above, shows that the exterior wall is at 42.2°F. This indicates that little heat is escaping the inside of the building which is maintained at 72°F. In general, if an exterior surface (wall, window, door, roof, etc.) was poorly sealed or insulated, the temperature of the surface would be close to the building's interior temperature.

Photo 2-3, above, shows a side window at the facility that is shaded from the sun. The thermal camera shows that the surface temperature of the window is at 53.3°F, which indicates that some heat is leaking. This is to be expected since windows cannot be insulated as well as exterior walls. Even though the leakage does not warrant a window replacement, upgrading to a triple-pane windows can improve the thermal resistance of the window and contain the facility better.

2.2 Facility Lighting

Current lighting consists predominantly of 4-foot fluorescent three-lamp T8 fixtures rated at 89W per fixture, which can mostly be found in hallways, offices, and conference rooms. Some of the storage rooms, bathrooms and hallways are equipped with 60W Incandescent lamps, 26W CFL biax and U-tube T8 fixtures. All of the facility lighting is manually controlled by wall switches.

2.3 Heating and Cooling Systems

Cooling is provided by a 60-ton air cooled reciprocating chiller. The chilled water is circulated by two alternating 3-hp chilled water pumps to the air handling units. Heating is provided by a 1,500,000 Btu/hour natural gas boiler. The hot water is circulated by two alternating 3-hp hot water pumps that are equipped with VFDs set at 76% to the air handling units and unit vents. Air distribution in the facility is done through four air handling units that serve the courtroom and offices. Finally, multiple unit heaters are spread out in the facility, which provide additional heating to vestibules, hallways, and waiting rooms. Discussions with the facility staff indicates that the mechanical equipment was installed at the time the facility was renovated in the early 2000s.

Table 2-1 summarizes the HVAC equipment information. Photos 2-4 and 2-5, on the next page, show the chiller and the boiler that are installed at the facility.

Table 2-1. Current HVAC Equipment at 321 Bedford Road

Equipment	Make	Model	Quantity	Approximate age
3 HP hot water pump	Baldor	VJMM3611T	2	20 years
3 HP chilled water pump	Baldor	JMM3211T	2	20 years
3.5 HP AHU	Carrier	39THPDKAF - Q - AFC - BA	1	20 years
3.5 HP AHU	Magic Aire	48/60-BMW/BMX	1	20 years
7.5 HP AHU	Magic Aire	90/120-BMW/BMX	2	20 years
60-ton chiller	Carrier	30GTN060	1	20 years
1,500,000 Btu/hour boiler	Hydro Therm	MR-1500B	1	20 years

Photo 2-4. 60-Ton Carrier 30GTN060

Photo 2-5. 1,500,000 Btu/Hour Hydro Therm MR-1500B

2.3.1 Miscellaneous Equipment

Miscellaneous electric energy-consuming items at the facility include office equipment (computers, monitors, TVs, etc.) and kitchen appliances (Refrigerators, microwaves, toaster ovens, etc.).

The facility's domestic hot water is provided by a natural gas fired hot water heater with a 66% efficiency.

2.4 Energy Source Use Profile

The following subsections provide a detailed look at each resource, including past billing information and a breakdown of the end use.

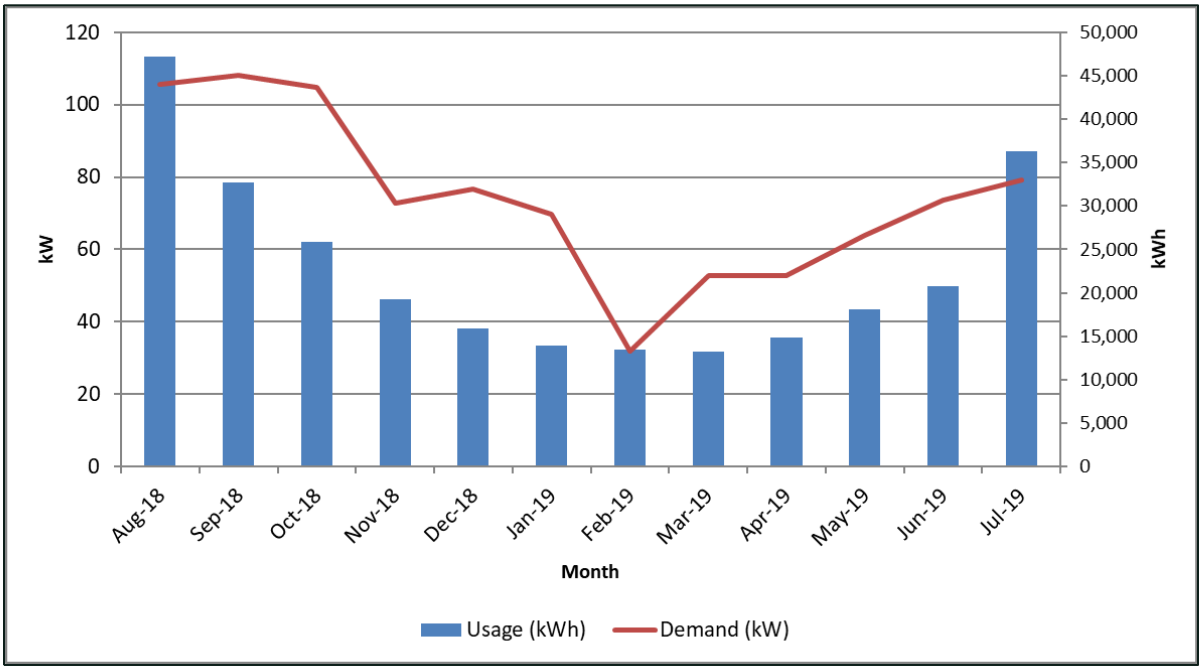
2.4.1 Electric Energy Use Profile

The facility's electricity is supplied and delivered through NYSEG. The total amount of electrical energy consumed by the facility from August 2018 to July 2019 was 271,600 kWh, and the billed on-peak demand occurrent in September 2018 at 108.0 kW. The annual cost of electricity was at $24,810 for an average cost of $0.09/kWh. Table 2-2 presents the monthly electrical energy use at the facility, and Figure 2-1, on the next page, presents this information in a plot.

Table 2-2. Electricity Billing History

Month	Billed Demand	Net kWh	Total Electric Cost
Aug-18	105.6	47,200	$4,312
Sep-18	108.0	32,720	$2,989
Oct-18	104.8	25,920	$2,368
Nov-18	72.8	19,280	$1,761
Dec-18	76.8	15,920	$1,454
Jan-19	69.6	13,920	$1,272
Feb-19	32.0	13,440	$1,228
Mar-19	52.8	13,200	$1,206
Apr-19	52.8	14,880	$1,359
May-19	64.0	18,080	$1,652
Jun-19	73.6	20,720	$1,893
Jul-19	79.2	36,320	$3,318
Total:	**N/A**	**271,600**	**$24,810**

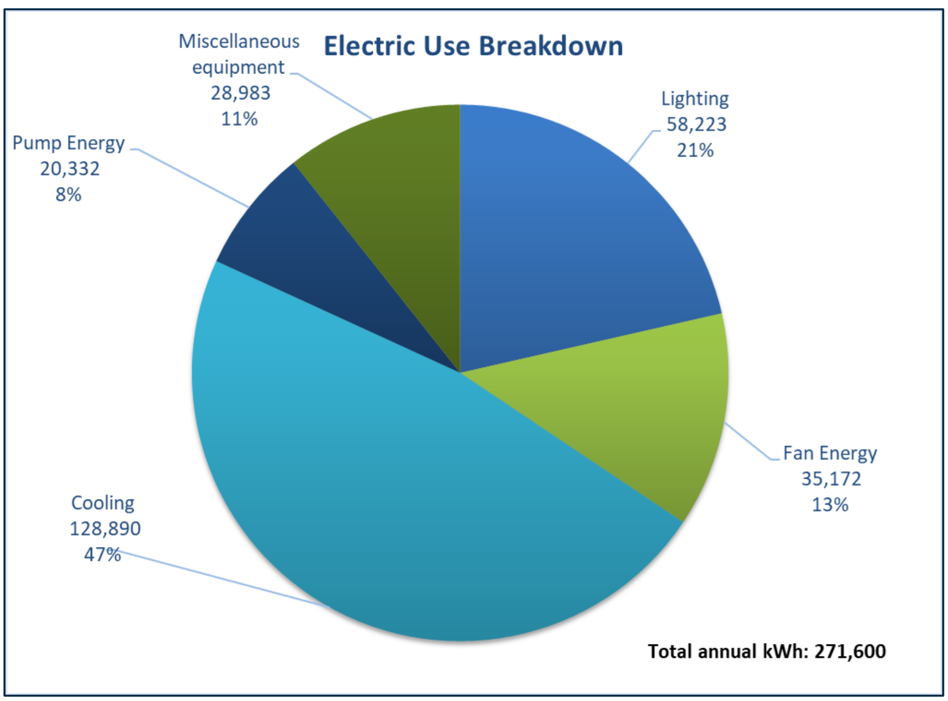
Figure 2-1. Electric Use Plot



The energy use at the facility shows a typical electric profile. The summer increase in electric usage is attributed to an increase in cooling loads.

A breakdown of the electric end use at the facility is presented in Figure 2-2.

Figure 2-2. Electric Use Breakdown (kWh)



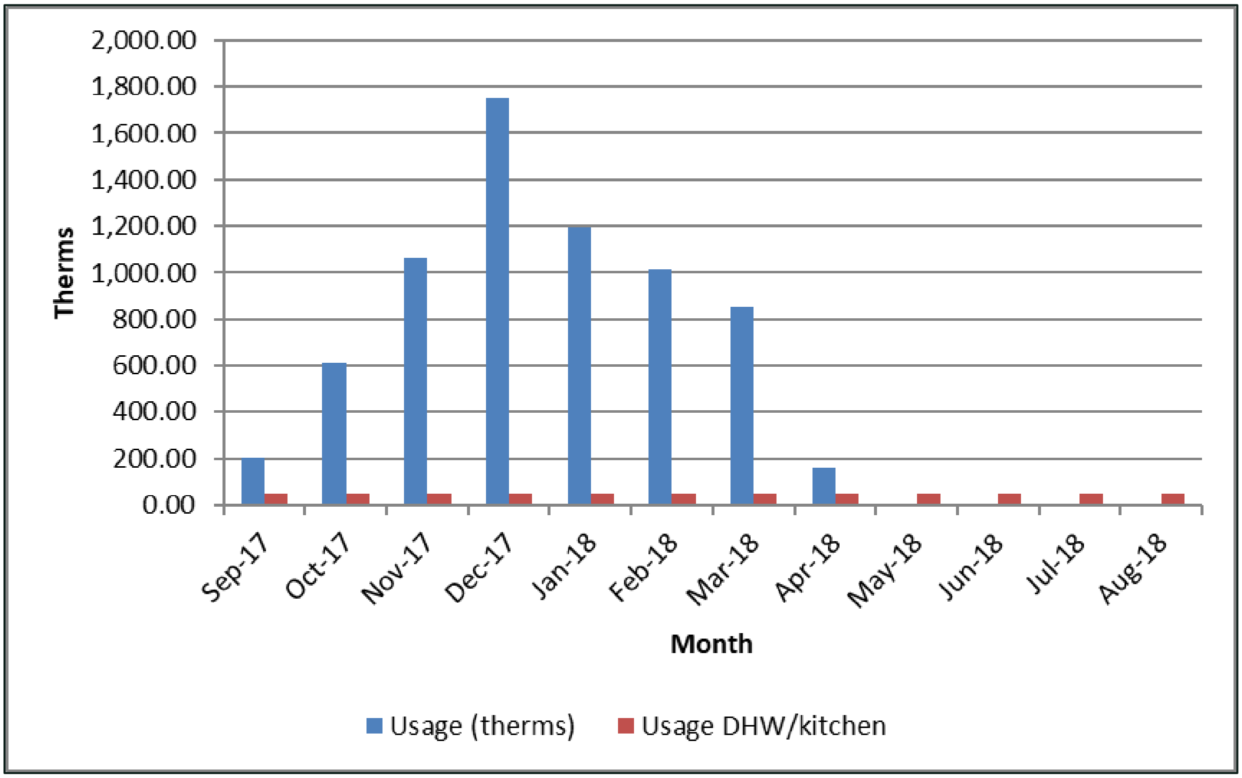
2.4.2 Natural Gas Use Profile

The facility's natural gas is supplied and delivered through Con Edison. The natural gas bills for the most recent 12 months showed no consumption. As a result, ERS used natural gas usage from the prior year to develop a thermal usage profile. The total amount of gas consumed by the facility from September 2017 to August 2018 was 6,856 therms, with a maximum consumption occurring in December 2017 at 1,751 therms. The annual cost of natural gas was at $7,430 for an average cost of $1.08/therm. Table 2-3 presents the most recent monthly natural gas use available to us, and Figure 2-3, on the next page, presents that information in a plot.

Table 2-3. Natural Gas Billing History

Month/Year	Natural Gas Usage (Therms)	Cost
Sep-17	204	$263
Oct-17	615	$629
Nov-17	1,063	$1,036
Dec-17	1,751	$1,566
Jan-18	1,193	$1,404
Feb-18	1,016	$1,209
Mar-18	853	$952
Apr-18	161	$241
May-18	0	$34
Jun-18	0	$32
Jul-18	0	$31
Aug-18	0	$34
Total	**6,856.0**	**$7,430**

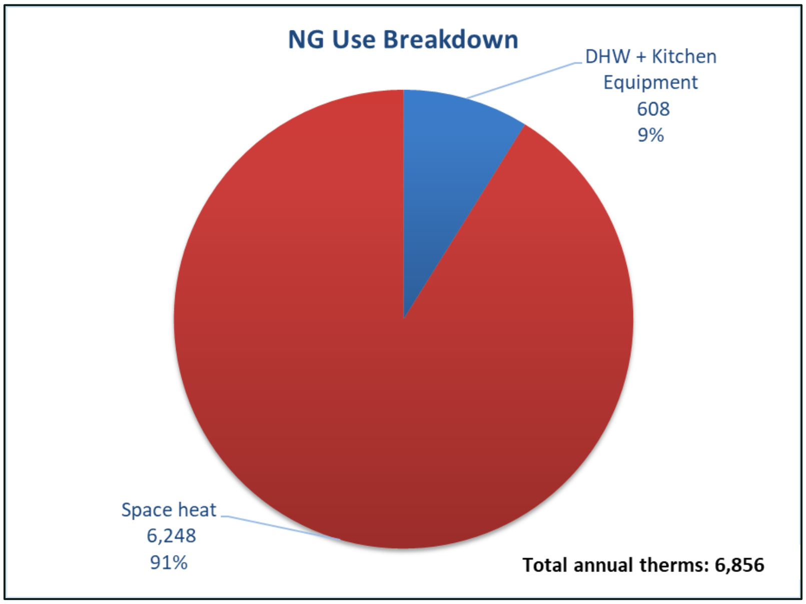
Figure 2-3. Natural Gas Use Plot



The natural gas data indicated a strong correlation with weather. Natural gas usage increases during winter months to provide space heating. The energy usage during non-heating seasons can be attributed to domestic hot water production.

A breakdown of the natural gas end uses at the facility is presented in Figure 2-4.

Figure 2-4. Natural Gas Use Breakdown (Therms)



3 Energy Efficiency Measures

This section provides details of the recommended EEMs for the facility at 425 Cherry Street, Bedford Hills, New York. Two EEMs have been studied and are recommended for implementation, as listed below:

- EEM-1: Install energy efficient LED lighting and controls in the entire facility
- EEM-2: Replace current HVAC system with one of the following:
  - 2-a – Improve controls on current HVAC system
  - 2-b – A multi-zone ASHP
  - 2-c – A multi-zone VRF
  - 2-d – A multi-zone GSHP
  - 2-e – A multi-zone VRF GSHP

The following subsections indicate the estimated implementation costs and available incentives as well as the energy, demand, and cost savings for each measure.

All of the costs, incentives, and savings are estimates and may vary upon implementation.

3.1 EEM-1: Install Energy Efficient LED Lighting and Controls in the Entire Facility

Energy Impacts				
Electric Demand Savings (kW)	Electric Energy Savings (kWh/yr)	Total Annual Savings ($/yr)	Tons CO_2 Reduction	Installed Cost
9.3	42,280	$3,862	5.65	$24,118
			Simple payback w/o incentives (years):	6.0

3.1.1 Discussion

The lights at the facility typically operate during business hours. The interior lighting technologies observed in the facility include linear and U-tube T8 fixtures with electronic ballasts and CFL biax lamps. LED lamps and fixtures can offer significantly improved light quality with greater system efficiency and options for better control. We recommend replacing all of the existing lights with equivalent LED designs with lighting controls in designated areas.

3.1.2 Measure Savings and Implementation Cost

While on-site, ERS developed an inventory of the existing lights throughout the facility. ERS deployed light loggers in a sample of space types to develop a lighting operating profile. The loggers were deployed on November 26, 2019 and retrieved on December 19, 2019. ERS developed the average hourly operating profiles in the space types metered for each day of the week and then extrapolated to obtain a representative annual profile. Table 3-1, below, shows the different space types identified and their operating hours.

The facility's lighting inventory is shown in Appendix A. The recommended retrofits/replacements are as follows:

- Retrofit all 4-foot T8 fixtures with 12 W 4-foot LED tubes.
- Replace all compact fluorescent and incandescent lamps with 8 W A-lamp LEDs.
- Install occupancy sensors in all offices, conference rooms, board rooms, restrooms, and storage spaces. Table 3-1 also shows the proposed operating hours, should the occupancy sensors be installed.

Table 3-1. Facility Space Types and Operating Hours

Usage Groups	Baseline Lighting Annual Hours	Proposed Lighting Annual Hours
Open Office*	3,000	1,416
Enclosed Office	2,464	1,725
Staff Room	1,354	948
Hallway*	8,760	2,213
Storage	1,825	1,277
Kitchen	1,776	1,243
Conference Room	1,296	907
Basement Hallway*	8,760	8,760

*No occupancy sensors recommended for this space-type.

ERS's list of recommended fixtures can be found in Appendix A. Using the operating hours and fixture information collected on-site, ERS determined the savings to expect from implementing the measure. The measure cost is based on an internal cost database developed using information obtained from several projects over the years. ERS estimates a material and installation cost of $24,118. The provided price includes the replacement lamp cost and the labor cost only. If further rewiring or electrical upgrades are required, an additional cost would incur. Table 3-2, below, shows the energy savings and economics of replacing the lights and installing controls.

Table 3-2. Energy Savings

Demand savings (kW-month)	9.3
Energy savings (kWh/yr)	42,280
Natural gas savings (Therms/yr)	0
Annual cost savings ($/yr)	$3,862
Implementation cost	$24,118
Simple payback (years)	6.0

3.2 EEM-2: Replace Current HVAC System – Five Options

Energy Impacts							
Option	Electric Peak Demand Reduction (kW)	Electric Energy Savings (kWh/yr)	Natural Gas Savings (Therms)	Total Annual Savings ($/yr)	Tons CO2 Reduction	Installed Cost ($)	Simple Payback w/o Incentive (Years)
a: Improve Controls	0	41,972	0	$3,834	5.6	$15,000	4
b: ASHP	33.6	56,379	6,248	$11,921	40.7	$175,000	15
c: VRF	56.5	89,162	6,248	$14,916	45.1	$245,000	16
d: GSHP	54.9	87,483	6,248	$14,763	44.9	$560,000	38
e: VRF GSHP	64.7	106,703	6,248	$16,518	47.5	$700,000	42

3.2.1 Discussion

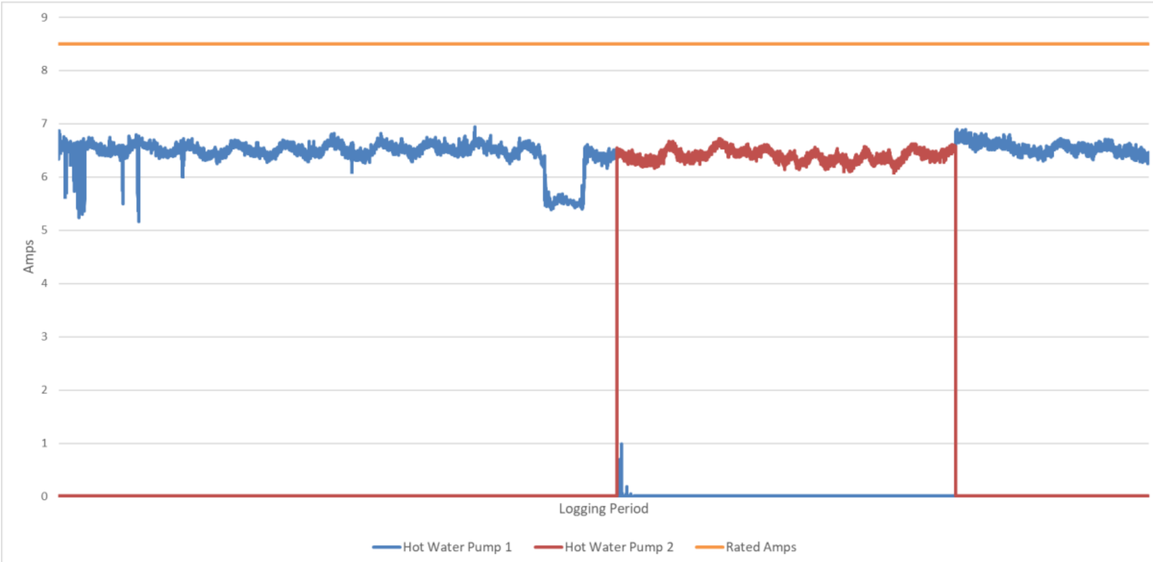
Cooling is provided by a 60-ton air cooled reciprocating chiller. The chilled water is circulated by two alternating 3-hp chilled water pumps to the air handling units. Heating is provided by a 1,500,000 Btu/hour natural gas boiler. The hot water is circulated by two alternating 3-hp hot water pumps that are equipped with VFDs set at 76% to the air handling units and unit vents. Air distribution in the facility is done through four air handling units that serve the courtroom and offices. Finally, multiple unit heaters are spread out in the facility, which provide additional heating to vestibules, hallways, and waiting rooms. Discussions with the facility staff indicates that the mechanical equipment was installed at the time the facility was renovated in the early 2000s.

3.2.2 Measure Savings and Implementation Cost

While on-site, ERS developed an inventory of the existing HVAC equipment at the facility. ERS also deployed current transformers on both hot water pumps to measure their amperage as they operate. The pumps supply hot water to the air-handling units and to unit heaters throughout the facility. In addition, ERS current transformers were installed on one of the facility’s air-handling units as well as temperature loggers in the supply and return air ducts of that same unit. The logging equipment installed gives insight on the equipment’s energy usage profile and its behavior with respect to outside, supply, and return-air temperature.

Our data suggests that the pumps alternate in operation; however, they run continuously. ERS also identified that the pumps are retrofitted with VFDs. The data also showed that the pumps run at a reduced speed. Figure 3-1 shows the hot water pumps operation.

Figure 3-1. HWP 1 and 2 Measured Amps Over Logging Period



ERS also developed an operating profile for the AHU's load for a typical week. The profile shows that the unit runs on Monday through Friday from 6 a.m.–5 p.m. and cycles on and off throughout the day. Figure 3-2 shows AHU1's operating profile.

Figure 3-2. AHU 1 Operating Profile

% Load		Hour																							
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Weekday	0	21%	19%	7%	12%	10%	6%	43%	37%	38%	41%	34%	27%	22%	23%	22%	23%	25%	21%	8%	14%	16%	21%	19%	10%
	1	0%	0%	0%	5%	5%	5%	31%	29%	38%	37%	36%	22%	19%	17%	18%	18%	19%	13%	11%	23%	22%	12%	21%	16%
	2	0%	0%	0%	7%	2%	5%	44%	27%	32%	40%	36%	26%	23%	22%	22%	22%	25%	16%	9%	8%	7%	7%	9%	10%
	3	0%	0%	0%	6%	12%	0%	38%	26%	40%	41%	26%	22%	23%	25%	23%	23%	24%	20%	18%	19%	25%	17%	26%	19%
	4	0%	0%	5%	2%	14%	0%	37%	38%	41%	32%	24%	23%	22%	21%	21%	21%	23%	21%	2%	0%	0%	0%	0%	0%
	5	5%	22%	17%	5%	24%	24%	0%	14%	1%	0%	43%	41%	26%	26%	27%	2%	0%	0%	0%	2%	10%	10%	6%	13%
	6	13%	13%	11%	13%	19%	28%	1%	11%	3%	12%	40%	33%	27%	30%	24%	3%	0%	4%	12%	13%	12%	8%	16%	13%

Energy monitoring, specifically for cooling equipment, typically takes place during the summer over a minimum of two weeks to collect ample data to appropriately establish a cooling profile. Since the project moved forward in early October, the outdoor air temperature was mild and would not have been representative of a typical summer operation. As a result, ERS estimated the baseline cooling energy usage by developing a bin analysis. The chiller was estimated to operate at stage 2, and the AHU fans' speed were estimated to be at 80% during the cooling season (OAT greater than 60°F); however ERS calculated a load factor that was applied to off-peak cooling bins (OAT is between 60°F and 80°F). The load factor was calculated to be the AHU's average load factor during the metering period. Appendix B includes the bin analysis and load factor calculation. Table 3-3 summarizes the annual energy usage by equipment.

Table 3-3. Summary of Baseline Energy Usage

Equipment	Baseline Energy Usage kWh	Baseline Peak kW
Chiller	128,890	79.9
AHU fans	35,172	13.2
HW and CHW pumps	20,332	2.3
Total	**184,394**	**95.4**

EEM-2-a: Improve Controls on the current HVAC System

The existing HVAC system runs at a constant load whenever there's a need for heating or cooling. The hot water pumps and one of the AHUs are equipped with VFDs. However, the overall system has to operate in unison to optimize the energy usage of the entire system. For instance, the hot water pumps, though equipped with VFDs, ran continuously throughout the logging period. Even though the pumps run at a reduced speed (76%), consuming less energy, our monitoring data suggests that there is room to turn the VFDs down to 40% (recommended minimum) at times where there's no need for heating. Furthermore, the billing data suggests that excessive cooling occurs during the summer. The latter indicates that the facility's chiller, operates at full capacity even though it has staging capabilities. As a result, ERS recommends that the facility retrocomissions its HVAC system and re-program the control protocols to maximize the capabilities of the current system. As part of this recommendation, the chilled water pumps, as well as three of the air handling units will require a VFD retrofit. It is important to mention that when installing VFDs on a pump, any three-way valve in the water loop system has to be replaced with a two-way valve. The later will ensure that no water flows through the bypass loops, which will starve the overall system and compromise energy savings.

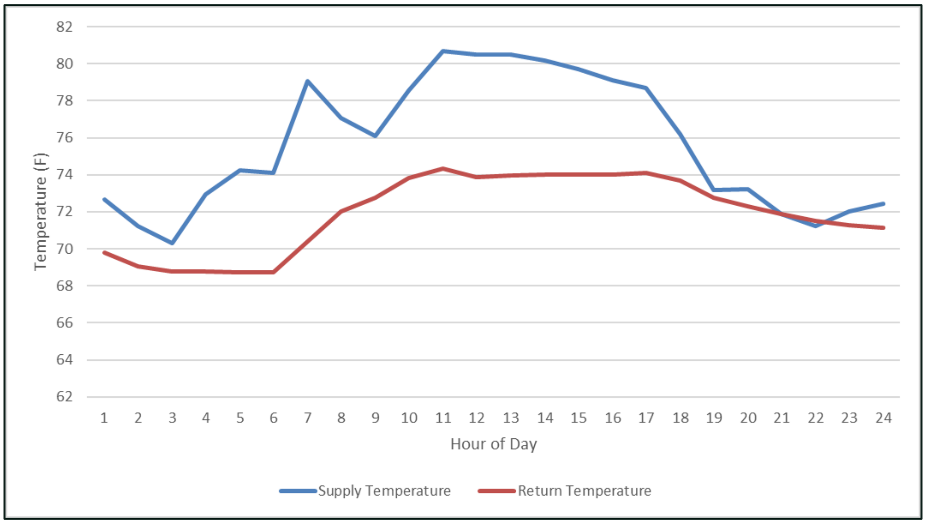
ERS developed a bin analysis that would represent the adequate usage of the chiller and AHU fan loads for each bin temperature inside the operating hours (Monday through Friday from 6:00 a.m.–5:00 p.m.). This included percent load during the occupied and unoccupied periods and the overnight set-back temperature. Table 3-4, below, shows the developed bin analysis.

Table 3-4. Summary of Operation

Bin Information		Cooling Tower				AHUs		
Temp Bin	Hours (6-5)	Stage	%load	Kw	kWh	%load	Kw	kWh
95	14	2	80%	79.9	1,118	80%	13.2	184
90	21	2	80%	79.9	1,677	80%	13.2	277
85	67	2	80%	79.9	5,351	80%	13.2	882
80	169	2	72%	71.9	12,148	70%	11.5	1,947
75	248	2	68%	67.9	16,836	65%	10.7	2,653
70	332	2	64%	63.9	21,213	60%	9.9	3,279
65	382	2	60%	59.9	22,882	55%	9.1	3,458
60	366	1	31%	31.0	11,358	27%	4.4	1,627
55	320	1	24%	24.4	7,802	27%	4.4	1,422
50	365	0	0%	0.0	-	27%	4.4	1,622
45	203	0	0%	0.0	-	27%	4.4	902
40	234	0	0%	0.0	-	27%	4.4	1,040
35	258	0	0%	0.0	-	55%	9.1	2,336
30	252	0	0%	0.0	-	60%	9.9	2,489
25	180	0	0%	0.0	-	65%	10.7	1,926
20	125	0	0%	0.0	-	70%	11.5	1,440
15	79	0	0%	0.0	-	80%	13.2	1,040
10	24	0	0%	0.0	-	80%	13.2	316
5	9	0	0%	0.0	-	80%	13.2	119
0	2	0	0%	0.0	-	80%	13.2	26
Total					**100,387**			**28,986**

In addition, ERS reviewed the supply and return temperature of the AHU. On average, the supply temperature is greater than the return air temperature, which is to be expected, as shown in figure 3-3, below.

Figure 3-3. Average Daily Supply and Return Temperature



ERS developed a supply and return temperature profile and determined that there are instances where the temperature difference between those two streams is very minimal. The latter indicates that there is no need for heating. This signal should prompt the hot water pumps to ramp down. Figures 3-4 shows the profile of the temperature difference. Appendix C includes the supply and return temperature profiles as well as the existing and proposed hot water pump profile.

Figure 3-4. Supply-Return Temperature Profile

Temp (F)		Hour																							
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Weekday	0	9.3	10.7	11.0	9.4	9.4	9.6	10.1	6.3	4.0	5.1	6.7	8.6	10.4	11.3	10.8	10.1	9.1	5.7	0.0	0.5	0.1	1.0	1.6	2.1
	1	1.3	0.0	0.0	2.0	3.0	3.0	8.1	4.0	2.1	3.6	3.6	3.3	2.0	1.5	1.5	1.1	1.1	0.2	0.3	1.4	1.3	0.0	1.3	1.1
	2	0.8	0.0	0.0	2.7	1.8	3.8	8.1	4.8	2.0	3.1	3.9	4.6	4.8	4.6	4.0	3.4	3.1	0.9	0.0	0.0	0.0	0.0	0.0	0.9
	3	0.5	0.0	0.0	1.3	5.2	2.6	5.0	1.9	1.7	1.9	3.8	4.7	4.7	4.2	4.3	4.5	4.2	2.2	1.9	2.6	0.2	2.7	4.2	3.7
	4	3.8	3.0	1.8	6.4	6.4	7.7	9.2	6.0	6.4	9.5	13.6	13.3	12.9	11.7	10.4	9.5	8.5	3.4	2.3	1.7	0.5	0.0	0.0	0.0
	5	0.0	3.1	6.7	5.7	5.4	8.8	8.4	6.2	9.0	3.2	8.4	6.7	4.8	2.2	3.3	4.5	2.8	1.3	0.4	0.5	1.9	2.8	2.5	3.4
	6	5.7	5.9	6.6	6.0	7.2	10.6	9.2	8.1	5.0	10.0	11.0	7.2	5.4	4.2	3.8	3.4	1.4	0.9	3.5	6.9	6.4	6.7	6.6	8.2

Energy savings can be achieved by ramping down the hot water pumps to 40% speed (recommended minimum) when the difference between the supply and return temperature is less than 5°F.

Table 3-5, below, outlines option 2-a's summary.

Table 3-5. Option 2-a Summary

Peak Demand savings (kW-month)	0.0
Energy savings (kWh/yr)	41,972
Natural gas savings (Therms/yr)	0
Annual cost savings ($/yr)	$3,834
Implementation cost	$12,000
Simple payback (years)	4.0

The section below discusses the four heat pump options available.

ERS sized the proposed heat pumps based on the current load supplied by the HVAC system. Subsequently, we collected performance information on all four options studied and evaluated their energy usage under the baseline operating conditions with controls (EEM2-a).

The following section outlines electric and natural gas savings, cost savings, implementation costs, and available incentives for all four options proposed above. Appendix D presents a more detailed analysis for each of these options.

EEM-2-b: Air Source Heat Pump (ASHP)

An ASHP uses a refrigerant system involving a compressor and a condenser to absorb heat at one place and release it at another. Unlike water source heat pumps, the refrigerant of air source heat pumps exchanges heat with the ambient air. Air source heat pumps are at most a two-speed system; therefore, the unit's compressor can only operate at one of two different levels depending on the load it has to provide. They are a low-cost electric space heater or cooler. A high efficiency heat pump can provide up to four times as much heat as an electric resistance heater using the same amount of electricity.

For the purpose of this study, we selected a 5-ton heat pump that has a SEER of 15 and a COP of 3.5.

ERS contacted several vendors to get implementation cost estimates. On average, an ASHP installation will cost around $1,000/ton. This amount includes material and labor costs but excludes ducting costs. We recommend soliciting design and installation quotes from qualified NYSERDA vendors for more accurate costs.

Table 3-6 outlines option 2-b's summary

Table 3-6. Option 2-b Summary

Peak Demand savings (kW-month)	33.6
Energy savings (kWh/yr)	56,379
Natural gas savings (Therms/yr)	6,248
Annual cost savings ($/yr)	$11,921
Implementation cost	$175,000
Simple payback (years)	15

EEM-2-c: Variable Refrigerant Flow Air Source Heat Pump (VRF)

A VRF is a more efficient air source heat pump with variable speed compressors and a modulating refrigerant fluid valve. Depending on the load that a unit has to provide, its built-in logic controls the compressor's speed (0% to 100%) and modulates the refrigerant valve (0% to 100%) to optimize the energy usage. VRFs are a great solution for multi-zone facilities since the units adapt and optimize for the required overall load in all zones and are not restricted to one or two levels of operation.

For the purpose of this study, we selected a 10-ton heat pump that has an IEER of 25 and a COP of 3.71.

On average, a VRF installation will cost approximately $2,500/ton. This amount includes material and labor costs but excludes ducting costs. We recommend soliciting design and installation quotes from qualified NYSERDA vendors for more accurate costs.

Table 3-7 outlines option 2-c's summary.

Table 3-7. Option 2-c Summary

Peak Demand savings (kW-month)	56.5
Energy savings (kWh/yr)	89,162
Natural gas savings (Therms/yr)	6,248
Annual cost savings ($/yr)	$14,916
Implementation cost	$245,000
Simple payback (years)	16

EEM-2-d: Ground Source Heat Pump (GSHP)

Ground source heat pumps are similar in concept to ASHPs; however, with ground source, the refrigerant exchanges heat with the underground soil instead of air, hence the name ground source. The advantage of having an underground system is that in most cases, the geological properties of the ground allows for optimal temperatures that favor efficient heat transfer.

For the purpose of this study, we selected a 6-ton water source heat pump that has a SEER of 23.9 and a COP of 4.2.

On average, a GSHP installation will cost approximately $8,000/ton. This amount includes material and labor costs as well as all piping, ducting, and drilling necessary. We recommend soliciting design and installation quotes from qualified NYSERDA vendors for more accurate costs.

The project also qualifies for a NYSERDA incentive, which offers $1,500/ton.

Geothermal heat pumps are recognized by the federal government as a qualified technology for the Investment Tax Credit (ITC). The ITC for geothermal systems is a credit equal to 10% of the cost of the system, net of any incentives. While the town of Bedford Hills does not pay federal taxes, this credit can still bring down system costs through an ownership agreement with a vendor. Under this model, the vendor who supplies the system would actually own and service the equipment and the town of Bedford Hills would pay the vendor a monthly amount agreed on between the two parties. Under this model, the vendor would be able to use the ITC, which would lower the overall cost to the town of Bedford Hills. We would encourage Bedford Hills to engage vendors to learn more about this model.

Table 3-8 outlines option 2-d's summary

Table 3-8. Option 2-d Summary

Peak Demand savings (kW-month)	54.9
Energy savings (kWh/yr)	87,482.5
Natural gas savings (Therms/yr)	6,248
Annual cost savings ($/yr)	$14,763
Implementation cost	$560,000
Simple payback (years)	38
NYSERDA incentive*	**$105,000**
Simple payback (years) after incentive	**30.8**

*At current incentive availbility and level

EEM-2-e: Variable Refrigerant Flow Ground Source Heat Pump (VRF GSHP)

VRF GSHP is a GSHP that operates under a similar manner to a VRF, and as a result operates more efficiently than a standard GSHP.

For the purpose of this study, we selected a 5-ton water source heat pump that has a SEER of 32.9 and a COP of 5.3.

On average, a GSHP installation will cost around $10,000/ton. This amount includes material and labor costs as well as all piping, ducting, and drilling necessary. We recommend soliciting design and installation quotes from qualified NYSERDA vendors for more accurate costs.

The project also qualifies for a NYSERDA incentive, which offers $1,500/ton.

As stated above, geothermal heat pumps are recognized by the federal government as a qualified technology for the ITC. The ITC for geothermal systems is a credit equal to 10% of the cost of the system, net of any incentives, and functions in the same manner as outlined above regarding the GSHP.

Table 3-9 outlines option 2-e's summary

Table 3-9. Option 2-e Summary

Peak Demand savings (kW-month)	64.7
Energy savings (kWh/yr)	106,703
Natural gas savings (Therms/yr)	6,248
Annual cost savings ($/yr)	$16,518
Implementation cost	$700,000
Simple payback (years)	42
NYSERDA incentive*	**$105,000**
Simple payback (years) after incentive	**36.0**

*At current incentive availbility and level

4 Informational Measures

This section presents additional information for a measure that requires more detailed investigation and is beyond the scope of this assessment:

- IM-1: Replace the existing gas-fired domestic hot water heater with a heat pump hot water heater

4.1 IM-1: Replace the Existing Gas-Fired Domestic Hot Water Heater with a Heat Pump Hot Water Heater

4.1.1 Discussion

The facility currently has a 40-gallon gas-fired domestic hot water heater with a 66% efficiency. Heat pump hot water heaters are an electric alternative to providing domestic hot water in a facility at a comparable price to gas (varies based on electric and natural gas costs). ERS is listing this upgrade as an informational measure since it has no cost savings associated with it. However, this measure is being reported since the town of Bedford Hills has shown interest in electrifying their facility in response to the Westchester gas moratorium.

For the purpose of this study, we selected a 10-ton heat pump that has an IEER of 25 and a COP of 3.71.

On average, a VRF installation will cost approximately $2,500/ton. This amount includes material and labor costs but excludes ducting costs. We recommend soliciting design and installation quotes from qualified NYSERDA vendors for more accurate costs.

Table 3-9 outlines option 2-c's summary.

Table 3-9. Option 2-c Summary

Peak Demand savings (kW-month)	29.9
Energy savings (kWh/yr)	28,167
Natural gas savings (Therms/yr)	2,954
Annual cost savings ($/yr)	$5,214
Implementation cost	$122,500
Simple payback (years)	23.0

EEM-2-d: Ground Source Heat Pump (GSHP)

GSHPs are similar in concept to ASHPs; however, with ground source, the refrigerant exchanges heat with the underground soil instead of air, hence the name ground source. The advantage of having an underground system is that in most cases, the geological properties of the ground allows for optimal temperatures that favor efficient heat transfer.

For the purpose of this study, we selected a 6-ton water source heat pump that has a SEER of 23.9 and a COP of 4.2.

On average, a GSHP installation will cost approximately $8,000/ton. This amount includes material and labor costs as well as all piping, ducting, and drilling necessary. We recommend soliciting design and installation quotes from qualified NYSERDA vendors for more accurate costs.

The project also qualifies for a NYSERDA incentive, which offers $1,500/ton.

Geothermal heat pumps are recognized by the federal government as a qualified technology for the Investment Tax Credit (ITC). The ITC for geothermal systems is a credit equal to 10% of the cost of the system, net of any incentives. While the town of Bedford Hills does not pay federal taxes, this credit can still bring down system costs through an ownership agreement with a vendor. Under this model, the vendor who supplies the system would actually own and service the equipment and the town of Bedford Hills would pay the vendor a monthly amount agreed on between the two parties. Under this model, the vendor would be able to use the ITC, which would lower the overall cost to the town of Bedford Hills. We would encourage Bedford Hills to engage vendors to learn more about this model.

Table 3-10 outlines option 2-d's summary.

Table 3-10. Option 2-d Summary

Peak Demand savings (kW-month)	29.0
Energy savings (kWh/yr)	29,643
Natural gas savings (Therms/yr)	2,954
Annual cost savings ($/yr)	$5,371
Implementation cost	$280,000
Simple payback (years)	52.0
NYSERDA incentive*	**$52,500**
Simple payback (years) after incentive	**42.4**

*At current incentive availbility and level

EEM-2-e: Variable Refrigerant Flow Ground Source Heat Pump (VRF GSHP)

VRF GSHP is a GSHP that operates under a similar manner to a VRF, and as a result operates more efficiently than a standard GSHP.

For the purpose of this study, we selected a 5-ton water source heat pump that has a SEER of 32.9 and a COP of 5.3.

On average, a GSHP installation will cost around $10,000/ton. This amount includes material and labor costs as well as all piping, ducting, and drilling necessary. We recommend soliciting design and installation quotes from qualified NYSERDA vendors for more accurate costs.

The project also qualifies for a NYSERDA incentive which offers $1,500/ton.

Geothermal heat pumps are recognized by the federal government as a qualified technology for the ITC. The ITC for geothermal systems is a credit equal to 10% of the cost of the system, net of any incentives, and functions in the same manner as outlined above regarding the GSHP.

Table 3-11, below, outlines option 2-e's summary.

Table 3-11. Option 2-e Summary

Peak Demand savings (kW-month)	34.7
Energy savings (kWh/yr)	36,742
Natural gas savings (Therms/yr)	2,954
Annual cost savings ($/yr)	$6,124
Implementation cost	$350,000
Simple payback (years)	57.0
NYSERDA incentive*	**$52,500**
Simple payback (years) after incentive	**48.6**

*At current incentive availbility and level

4 INFORMATIONAL MEASURES

This section presents additional information for a measure that requires more detailed investigation and is beyond the scope of this assessment:

- IM-1: Replace the existing gas-fired domestic hot water heater with a heat pump hot water heater

4.1 Discussion

The facility currently has a 40-gallon, gas-fired domestic hot water heater with a 66% efficiency. Heat pump hot water heaters are an electric alternative to providing domestic hot water in a facility at a comparable price to gas (varies based on electric and natural gas costs). ERS is listing this upgrade as an informational measure since it has no cost savings associated with it. However, this measure is being reported since the town of Bedford Hills has shown interest in electrifying their facility in response to the Westchester gas moratorium.

Appendix A

Lighting Inventory & Proposed Fixtures

for

321 Bedford Road

Town of Bedford Hills

Description			Baseline						Proposed						Savings	
FL	Location	Operating Group	Fixture Type	Wattage	Quantity	Hours	Total Connected kW	kWh	Fixture Type	Wattage	Quantity	Hours	Total Connected kW	kWh	kW	kWh
1	Main Open Office Area	Open Office	(3) 4' T8	89	20	3,000	1.8	5,340	(3) 4' T8 LED	36	20	3,000	0.7	2,160	1.1	3,180
1	Office 1	Enclosed Office	(2) U-T8	59	4	2,464	0.2	581	(2) U-LED	24	4	1,725	0.1	166	0.1	416
1	Office 2	Enclosed Office	(2) U-T8	59	4	2,464	0.2	581	(2) U-LED	24	4	1,725	0.1	166	0.1	416
1	Office 3	Enclosed Office	(3) 4' T8	89	2	2,464	0.2	439	(3) 4' T8 LED	36	2	1,725	0.1	124	0.1	314
1	Office 4	Enclosed Office	(3) 4' T8	89	2	2,464	0.2	439	(3) 4' T8 LED	36	2	1,725	0.1	124	0.1	314
1	Break Room	Kitchen	(2) U-T8	59	1	1,776	0.1	105	(2) U-LED	24	1	1,243	0.0	30	0.0	75
1	Storage	Storage	(2) U-T8	59	1	1,825	0.1	108	(2) U-LED	24	1	1,277	0.0	31	0.0	77
1	Hallway	Hallway	(2) CFL biax	72	17	8,760	1.2	10,722	LED Flood Lamps	10	17	8,760	0.2	1,489	1.1	9,233
1	Court Room (cove lights)	Open Office	(1) 4' T8	32	44	3,000	1.4	4,224	(1) 4' T8 LED	12	44	3,000	0.5	1,584	0.9	2,640
1	Conference Room	Conference Room	(2) U-T8	59	4	1,296	0.2	306	(2) U-LED	24	4	907	0.1	87	0.1	219
1	Clrek Office	Enclosed Office	(3) 4' T8	89	4	2,464	0.4	877	(3) 4' T8 LED	36	4	1,725	0.1	248	0.2	629
1	Office 1	Enclosed Office	(3) 4' T8	89	2	2,464	0.2	439	(3) 4' T8 LED	36	2	1,725	0.1	124	0.1	314
1	Copy Room	Storage	(2) U-T8	59	2	1,825	0.1	215	(2) U-LED	24	2	1,277	0.0	61	0.1	154
1	Office	Enclosed Office	(2) CFL biax	72	11	2,464	0.8	1,951	LED Flood Lamps	10	11	1,725	0.1	190	0.7	1,762
1	Office 2	Enclosed Office	(3) 4' T8	89	6	2,464	0.5	1,316	(3) 4' T8 LED	36	6	1,725	0.2	373	0.3	943
1	Supervisor Burdick's Office	Enclosed Office	(2) U-T8	59	9	2,464	0.5	1,308	(2) U-LED	24	9	1,725	0.2	373	0.3	936
1	Receiver Taxes	Enclosed Office	(3) 4' T8	89	6	2,464	0.5	1,316	(3) 4' T8 LED	36	6	1,725	0.2	373	0.3	943
1	Lobby Chandelier	Hallway	60W Incandescent	60	18	8,760	1.1	9,461	8W LED A-lamp	8	18	8,760	0.1	1,261	0.9	8,199
1	Assessor's Office	Enclosed Office	(3) 4' T8	89	8	2,464	0.7	1,754	(3) 4' T8 LED	36	8	1,725	0.3	497	0.4	1,258
1	Copy Room	Storage	(3) 4' T8	89	3	1,825	0.3	487	(3) 4' T8 LED	36	3	1,277	0.1	138	0.2	349
1	Office	Enclosed Office	(3) 4' T8	89	6	2,464	0.5	1,316	(3) 4' T8 LED	36	6	1,725	0.2	373	0.3	943
Bsmnt	Hallway	Basement Hallway	(2) 4' T8	59	8	8,760	0.5	4,135	(2) 4' T8 LED	24	8	8,760	0.2	1,682	0.3	2,453
Bsmnt	Hallway	Basement Hallway	(4) 4' T8	112	3	8,760	0.3	2,943	(4) 4' T8 LED	48	3	8,760	0.1	1,261	0.2	1,682
Bsmnt	Hallway	Basement Hallway	Circline Fluorescent	40	5	8,760	0.2	1,752	Circline LED	13	5	8,760	0.1	569	0.1	1,183
Bsmnt	Open Office	Open Office	(2) 2' T8	28	9	3,000	0.3	756	(2) 2' T8 LED	18	9	3,000	0.2	486	0.1	270
Bsmnt	Boiler Room	Storage	(2) 2' T8	28	4	1,825	0.1	204	(2) 2' T8 LED	18	4	1,277	0.1	92	0.0	112
Bsmnt	Storage	Storage	(2) 4' T8	59	3	1,825	0.2	323	(2) 4' T8 LED	24	3	1,277	0.1	92	0.1	231
Bsmnt	Office 1	Enclosed Office	(2) 4' T8	59	2	2,464	0.1	291	(2) 4' T8 LED	24	2	1,725	0.0	83	0.1	208
Bsmnt	Locker Room	Storage	(3) 4' T8	89	2	1,825	0.2	325	(3) 4' T8 LED	36	2	1,277	0.1	92	0.1	233
Bsmnt	Open Office 2	Open Office	(2) 4' T8	59	12	3,000	0.7	2,124	(2) 4' T8 LED	24	12	3,000	0.3	864	0.4	1,260
2	Historian Office	Enclosed Office	(4) 4' T8	112	4	2,464	0.4	1,104	(4) 4' T8 LED	48	4	1,725	0.2	331	0.3	773
2	Hallway	Hallway	(4) 4' T8	112	1	8,760	0.1	981	(4) 4' T8 LED	48	1	8,760	0.0	420	0.1	561
Total							**14.3**	**58,223**					**5.0**	**15,943**	**9.3**	**42,280**

Appendix B

Mechanical Equipment Baseline Profiles

for

321 Bedford Road

Town of Bedford Hills

Cooling Tower and AHU Profile

Bin Information		Cooling Tower				AHUs		
Temp Bin	Hours (6-5)	Stage	%load	Kw	kWh	%load	Kw	kWh
95	14	2	80%	79.9	1,118	80%	13.2	184
90	21	2	80%	79.9	1,677	80%	13.2	277
85	67	2	80%	79.9	5,351	80%	13.2	882
80	169	2	80%	79.9	13,498	80%	13.2	2,225
75	248	2	80%	79.9	19,807	80%	13.2	3,266
70	332	2	80%	79.9	26,516	80%	13.2	4,372
65	382	2	80%	79.9	30,510	80%	13.2	5,030
60	366	1	44%	44.3	16,226	27%	4.5	1,648
55	320	1	44%	44.3	14,186	27%	4.5	1,441
50	365	0	0%	0.0	-	27%	4.5	1,644
45	203	0	0%	0.0	-	27%	4.5	914
40	234	0	0%	0.0	-	27%	4.5	1,054
35	258	0	0%	0.0	-	80%	13.2	3,397
30	252	0	0%	0.0	-	80%	13.2	3,318
25	180	0	0%	0.0	-	80%	13.2	2,370
20	125	0	0%	0.0	-	80%	13.2	1,646
15	79	0	0%	0.0	-	80%	13.2	1,040
10	24	0	0%	0.0	-	80%	13.2	316
5	9	0	0%	0.0	-	80%	13.2	119
0	2	0	0%	0.0	-	80%	13.2	26
Total					**128,890**			**35,172**

Pump Profile

Bin Information		Hot Water Pumps			Chilled Water Pumps		
Temp Bin	All hours	%Load	kW	kWh	%Load	kW	kWh
95	14	0%	0.0	-	76%	2.3	32
90	23	0%	0.0	-	76%	2.3	53
85	76	0%	0.0	-	76%	2.3	176
80	210	0%	0.0	-	76%	2.3	487
75	346	0%	0.0	-	76%	2.3	803
70	564	0%	0.0	-	76%	2.3	1,309
65	875	0%	0.0	-	76%	2.3	2,031
60	1037	0%	0.0	-	76%	2.3	2,407
55	814	0%	0.0	-	76%	2.3	1,889
50	854	76%	2.3	1,982	0%	0.0	-
45	596	76%	2.3	1,383	0%	0.0	-
40	744	76%	2.3	1,727	0%	0.0	-
35	708	76%	2.3	1,643	0%	0.0	-
30	624	76%	2.3	1,448	0%	0.0	-
25	438	76%	2.3	1,017	0%	0.0	-
20	474	76%	2.3	1,100	0%	0.0	-
15	213	76%	2.3	494	0%	0.0	-
10	90	76%	2.3	209	0%	0.0	-
5	49	76%	2.3	114	0%	0.0	-
0	11	76%	2.3	26	0%	0.0	-
Total				11,143			9,189

Thermal Load

Temp Bin	Hours (8-5)	% Load	Btu/hr - in	Therms	Btu/hr - Out
95	14		-	-	-
90	21		-	-	-
85	64		-	-	-
80	156		-	-	-
75	211		-	-	-
70	287		-	-	-
65	301		-	-	-
60	281		-	-	-
55	257		-	-	-
50	295	10%	150,000	443	120,000
45	163	24%	360,000	587	288,000
40	164	24%	360,000	590	288,000
35	204	25%	375,000	765	300,000
30	213	30%	453,543	966	362,835
25	136	45%	675,000	918	540,000
20	84	75%	1,124,213	944	899,370
15	51	100%	1,500,000	765	1,200,000
10	16	100%	1,500,000	240	1,200,000
5	2	100%	1,500,000	30	1,200,000
0	0	100%	1,500,000	-	1,200,000
Total				**6,248**	

Load Factor Calculation

Weekday	AHU Hourly Average Amp Profile - From Metered Data																						
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	1.61	1.42	0.56	0.90	0.78	0.46	3.31	2.84	2.87	3.09	2.59	2.02	1.69	1.73	1.68	1.78	1.94	1.58	0.64	1.07	1.19	1.57	1.47	0.74
1	0.01	0.01	0.01	0.41	0.40	0.40	2.38	2.21	2.92	2.85	2.72	1.71	1.44	1.27	1.34	1.37	1.42	0.95	0.85	1.76	1.67	0.94	1.60	1.20
2	0.01	0.01	0.01	0.55	0.15	0.38	3.37	2.09	2.46	3.01	2.72	1.99	1.76	1.66	1.67	1.70	1.92	1.24	0.67	0.57	0.57	0.55	0.71	0.75
3	0.01	0.01	0.01	0.44	0.90	0.01	2.89	1.99	3.05	3.09	2.02	1.66	1.72	1.91	1.72	1.75	1.86	1.54	1.37	1.48	1.89	1.28	1.96	1.47
4	0.01	0.01	0.39	0.18	1.03	0.01	2.79	2.89	3.11	2.41	1.80	1.72	1.68	1.59	1.57	1.58	1.78	1.62	0.16	0.01	0.01	0.01	0.01	0.01
5	0.37	1.69	1.33	0.38	1.79	1.83	0.01	1.09	0.04	0.01	3.28	3.15	2.00	1.96	2.06	0.16	0.01	0.01	0.02	0.18	0.76	0.78	0.43	1.00
6	0.98	0.99	0.83	1.00	1.44	2.11	0.05	0.86	0.20	0.92	3.01	2.48	2.09	2.26	1.81	0.26	0.01	0.31	0.89	1.01	0.92	0.65	1.24	0.98

Average Amps	2.1
Full Load Amps	7.6
Load Factor	27%

Average amps during operation (M-F 6am - 5pm)

Appendix C

Supply and Return Temperature Profiles & Hot Water Pump Baseline and Proposed Profiles

for

321 Bedford Road

Town of Bedford Hills

Weekday	AHU Hourly Average Supply Temperature Profile - From Metered Data																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	77.0	78.4	79.5	77.8	77.8	78.3	80.7	78.4	76.8	79.0	81.1	83.4	85.0	85.7	85.2	84.6	83.8	80.1	71.9	72.6	71.7	72.5	73.0	73.4
1	71.4	69.2	67.5	70.8	71.7	71.6	78.0	75.4	74.6	77.2	77.8	75.7	75.3	75.2	75.1	74.6	74.6	73.0	72.4	73.5	73.5	71.5	73.0	72.8
2	71.2	69.4	67.9	71.7	70.5	72.6	78.8	77.0	74.4	76.5	78.0	78.6	78.6	78.4	77.8	77.2	77.1	74.6	71.8	71.2	71.0	70.8	71.6	72.5
3	71.2	69.5	68.1	70.3	74.5	71.6	74.9	72.8	73.1	74.0	76.1	76.9	76.8	76.4	76.5	76.7	76.5	74.3	73.6	74.0	70.7	73.0	74.5	74.1
4	73.1	71.7	69.8	75.1	74.8	76.5	79.3	78.1	79.7	83.8	88.8	88.5	88.1	86.8	85.4	84.4	83.4	77.5	74.5	72.4	70.3	68.7	67.6	66.7
5	66.8	70.8	74.6	73.3	73.0	76.7	76.7	73.9	77.8	70.9	78.2	79.1	77.2	73.6	75.2	75.5	72.4	70.3	68.8	68.6	69.9	70.7	70.1	71.0
6	73.4	73.4	74.0	73.3	74.5	78.2	77.7	76.3	72.8	78.6	81.5	79.1	77.5	75.8	76.0	74.4	71.0	69.8	72.1	75.5	74.7	75.0	74.8	76.2

Weekday	AHU Hourly Average Return Temperature Profile - From Metered Data																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	67.7	67.6	68.6	68.4	68.4	68.7	70.7	72.0	72.9	73.9	74.5	74.9	74.6	74.4	74.4	74.5	74.7	74.5	72.9	72.1	71.7	71.5	71.4	71.3
1	70.1	69.3	68.7	68.8	68.7	68.6	69.9	71.5	72.4	73.6	74.1	72.4	73.4	73.7	73.6	73.6	73.5	72.8	72.1	72.1	72.2	71.6	71.6	71.6
2	70.4	69.6	69.0	69.0	68.7	68.8	70.7	72.2	72.4	73.4	74.0	74.0	73.8	73.8	73.8	73.9	74.0	73.7	73.1	72.9	72.7	72.5	71.9	71.6
3	70.6	69.8	69.2	69.1	69.4	69.0	69.9	70.9	71.4	72.2	72.3	72.2	72.1	72.2	72.2	72.2	72.3	72.1	71.6	71.3	70.5	70.3	70.3	70.4
4	69.3	68.7	68.1	68.8	68.4	68.7	70.1	72.1	73.3	74.3	75.1	75.2	75.2	75.1	75.1	75.0	74.9	74.0	72.2	70.7	69.8	69.1	68.6	68.1
5	67.7	67.7	67.9	67.6	67.5	67.9	68.2	67.8	68.8	67.7	69.7	72.4	72.3	71.4	71.8	71.1	69.7	69.0	68.4	68.1	67.9	67.9	67.6	67.6
6	67.6	67.5	67.5	67.4	67.3	67.6	68.4	68.2	67.8	68.6	70.5	71.9	72.1	71.6	72.2	71.0	69.6	68.9	68.6	68.6	68.3	68.3	68.2	68.0

Weekday	Hot Water Pump Hourly Average Profile - From Metered Data																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.5	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.5	6.5	6.5
1	6.6	6.6	6.6	6.7	6.6	6.6	6.6	6.5	6.6	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.4	6.5	6.3	6.4	6.4	6.5
2	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.5	6.5	6.4	6.5	6.5	6.5	6.5	6.4	6.4	6.3	6.4	6.4	6.4	6.4	6.5
3	6.5	6.6	6.4	6.6	6.6	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.4	6.5	6.4	6.4	6.4	6.4	6.4	6.3	6.4	6.4	6.4	6.5
4	6.4	6.5	6.5	6.5	6.6	6.5	6.5	6.4	6.4	6.4	6.4	6.3	6.2	6.1	6.1	6.1	6.1	6.0	6.1	6.1	6.1	6.1	6.2	6.1
5	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.5	6.5	6.5	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.5	6.5
6	6.6	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.4	6.5	6.4	6.5	6.5	6.5	6.5	6.4	6.5	6.5	6.5	6.5

Weekday	Hot Water Pump Hourly Average Proposed Profile - Calculated																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.5	0.9	6.4	6.4	6.5	6.4	6.4	6.4	6.4	6.4	6.4	6.4	0.9	0.9	0.9	0.9	0.9
1	0.9	6.6	6.6	0.9	0.9	0.9	6.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	6.4	0.9	0.9
2	0.9	6.6	6.6	0.9	0.9	0.9	6.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	6.3	6.4	6.4	6.4	6.4	0.9
3	0.9	6.6	6.4	0.9	6.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
4	0.9	0.9	0.9	6.5	6.6	6.5	6.5	6.4	6.4	6.4	6.4	6.3	6.2	6.1	6.1	6.1	6.1	0.9	0.9	0.9	0.9	6.1	6.2	6.1
5	6.2	0.9	6.2	6.2	6.2	6.2	6.2	6.2	6.5	0.9	6.5	6.4	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
6	6.6	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.4	0.9	0.9	0.9	0.9	0.9	0.9	6.4	6.5	6.5	6.5	6.5

Appendix D

Heat Pump Calculations

for

321 Bedford Road

Town of Bedford Hills

Electric Energy Profiles

Bin Information		Advanced Controls			ASHP		VRF		GSHP		GSHP VRF	
Temp Bin	**Hours (6-5)**	**kW**	**kWh**	**Load - Btu/hr**	**kW**	**kWh**	**kW**	**kWh**	**kW**	**kWh**	**kW**	**kWh**
95	14	79.9	1,118	858,951	57.3	802	34.4	481	35.9	503	26.1	366
90	21	79.9	1,677	858,951	57.3	1,203	34.4	722	35.9	755	26.1	548
85	64	79.9	5,351	858,951	57.3	3,665	34.4	2,199	35.9	2,300	26.1	1,671
80	156	71.9	12,148	773,056	51.5	8,040	30.9	4,824	32.3	5,046	23.5	3,666
75	211	67.9	16,836	730,108	48.7	10,270	29.2	6,162	30.5	6,446	22.2	4,682
70	287	63.9	21,213	687,161	45.8	13,148	27.5	7,889	28.8	8,252	20.9	5,994
65	301	59.9	22,882	644,213	42.9	12,927	25.8	7,756	27.0	8,113	19.6	5,894
60	281	31.0	11,358	333,742	22.2	6,252	13.3	3,751	14.0	3,924	10.1	2,851
55	257	24.4	7,802	262,226	17.5	4,493	10.5	2,696	11.0	2,820	8.0	2,048
50	295	0.0	-	-	0.0	-	0.0	-	0.0	-	0.0	-
45	163	0.0	-	-	0.0	-	0.0	-	0.0	-	0.0	-
40	164	0.0	-	-	0.0	-	0.0	-	0.0	-	0.0	-
35	204	0.0	-	-	0.0	-	0.0	-	0.0	-	0.0	-
30	213	0.0	-	-	0.0	-	0.0	-	0.0	-	0.0	-
25	136	0.0	-	-	0.0	-	0.0	-	0.0	-	0.0	-
20	84	0.0	-	-	0.0	-	0.0	-	0.0	-	0.0	-
15	51	0.0	-	-	0.0	-	0.0	-	0.0	-	0.0	-
10	16	0.0	-	-	0.0	-	0.0	-	0.0	-	0.0	-
5	2	0.0	-	-	0.0	-	0.0	-	0.0	-	0.0	-
0	0	0.0	-	-	0.0	-	0.0	-	0.0	-	0.0	-
Total			**100,387**			**60,799**		**36,479**		**38,158**		**27,720**

Bin Information		Controls	ASHP		VRF		GSHP		GSHP VRF	
Temp Bin	Hours (6-5)	Btu/hr - Out	kW	kWh	kW	kWh	kW	kWh	kW	kWh
95	14	-	0.0	-	0.0	-	0.0	-	0.0	-
90	21	-	0.0	-	0.0	-	0.0	-	0.0	-
85	64	-	0.0	-	0.0	-	0.0	-	0.0	-
80	156	-	0.0	-	0.0	-	0.0	-	0.0	-
75	211	-	0.0	-	0.0	-	0.0	-	0.0	-
70	287	-	0.0	-	0.0	-	0.0	-	0.0	-
65	301	-	0.0	-	0.0	-	0.0	-	0.0	-
60	281	-	0.0	-	0.0	-	0.0	-	0.0	-
55	257	-	0.0	-	0.0	-	0.0	-	0.0	-
50	295	164,545	13.8	4,064	11.5	3,386	11.5	3,386	9.1	2,683
45	163	358,625	30.0	4,894	25.0	4,078	25.0	4,078	19.8	3,232
40	164	365,568	30.6	5,019	25.5	4,182	25.5	4,182	20.2	3,314
35	204	380,949	31.9	6,506	26.6	5,421	26.6	5,421	21.1	4,296
30	213	440,583	36.9	7,856	30.7	6,547	30.7	6,547	24.4	5,188
25	136	687,605	57.6	7,828	48.0	6,524	48.0	6,524	38.0	5,170
20	84	1,092,087	91.4	7,680	76.2	6,400	76.2	6,400	60.4	5,071
15	51	1,200,000	100.5	5,123	83.7	4,269	83.7	4,269	66.3	3,383
10	16	1,200,000	100.5	1,607	83.7	1,339	83.7	1,339	66.3	1,061
5	2	1,200,000	100.5	201	83.7	167	83.7	167	66.3	133
0	0	1,200,000	100.5	-	83.7	-	83.7	-	66.3	-
Total				**50,778**		**42,315**		**42,315**		**33,532**

Technology	Fan Energy		Pump energy		Cooling		Heating			Total	
	kWh Usage	kWh Savings	kWh Usage	kWh Savings	kWh Usage	kWh Savings	Therm Used	Therms Savings	Added Electric (kWh)	Cost	Cost Savings
Baseline	35,172	-	20,332	-	128,890	-	6,248	-	-	$23,615	$0
Controls	28,986	6,185	13,049	7,283	100,387	28,503	6,248	-	-	$19,781	$3,834
ASHP*	16,438	18,733	-	20,332	60,799	68,091	-	6,248	50,778	$11,694	$11,921
VRF*	16,438	18,733	-	20,332	36,479	92,411	-	6,248	42,315	$8,699	$14,916
GSHP*	16,438	18,733	-	20,332	38,158	90,732	-	6,248	42,315	$8,853	$14,763
GSHP VRF*	16,438	18,733	-	20,332	27,720	101,170	-	6,248	33,532	$7,097	$16,518

* The existing AHU system can be repurposed to ventilate the space when there is no need for cooling or heating and the Heat Pump Fans are off