Clean Energy Communities

Energy Study

Prepared for:

Town of Pound Ridge - Town House

179 Westchester Ave.

Pound Ridge, NY 10576

Audit No: CEC204647-1-M

Submitted by:

L&S Energy Services
58 Clifton Country Road, Suite 203
Clifton Park, NY 12065

Date: 6/28/2023

For questions regarding this report, please contact cec@nyserda.ny.gov.

We hope the findings of this report will assist you in making decisions about energy efficiency improvements in your facility. Thank you for your participation in this program.

State of New York

Kathy Hochul, Governor

New York State Energy Research and Development Authority

Consultant Disclaimer

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This report was prepared by:

L & S Energy

58 Clifton Country Road, Suite 203

Clifton Park, NY 12065

(518) 383-9405

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Executive Summary

This study was performed to understand how your facility is currently using energy and identify ways to reduce energy use and operating expenses.

Specific areas of concern that were identified by the owner for evaluation include lighting and envelope.

The following energy efficiency measures (EEMs) and observations to reduce energy use were identified during the site visit:

- Interior and Exterior Lighting Retrofits – Install LEDs and occupancy controls.
- Improve Temperature Controls – Install Wi-Fi Thermostats and implement deep setback schedules.
- Insulate Building Envelope – Replace and add attic, wall, and basement insulation.
- Install Double Glazing – Replace single pane windows with double pane units and reduce infiltration.
- Install Duct Insulation – The AHU ducts do not have insulation throughout the attic.
- Insulate Heating & Domestic Hot Water Pipes – There are bare pipes in the basement.
- Install Motor Controls – Add controls to turn off HVAC distribution pumps.
- Replace Condensing Units – The AC units are very old and need to be replaced.
- Install a More Efficient Boiler – Replace the existing boiler with a high efficiency condensing unit.
- Install a Tankless Water Heater – Separate the DHW system from the boiler plant.
- Air Source Heat Pumps – Replace the AC and Boiler plant with an Air Source Heat Pump system.
- Ground Source Heat Pumps - Replace the AC and Boiler plant with a Ground Source Heat Pump system.

These Energy Efficiency Measures are summarized in the Project Summary Table below and discussed in more detail in the Energy Efficiency Measures section of this report.

Present Energy Use and Cost

The energy use for your facility has been compiled to calculate the Energy Cost Index and the Energy Use Intensity.

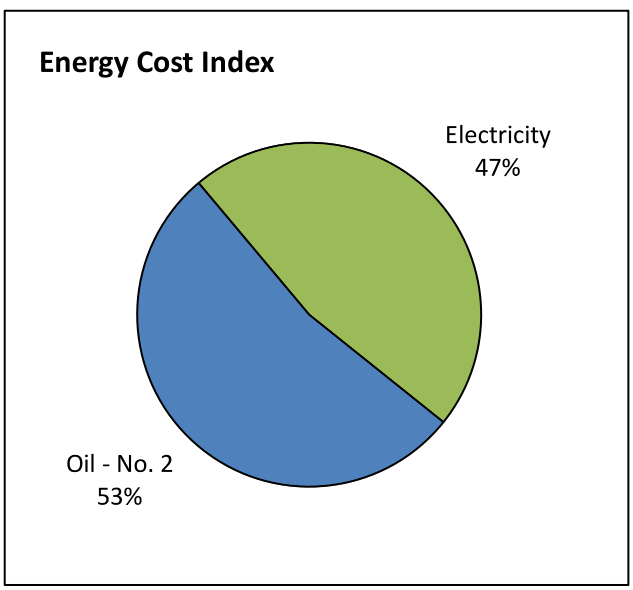
- The Energy Cost Index (ECI) is the total cost of energy divided by the conditioned floor area and is shown as dollars per square foot per year.
- The Energy Use Intensity (EUI) is the total heat content of energy divided by the conditioned floor area and is shown in units of one thousand Btus (kBtu) per square foot per year.

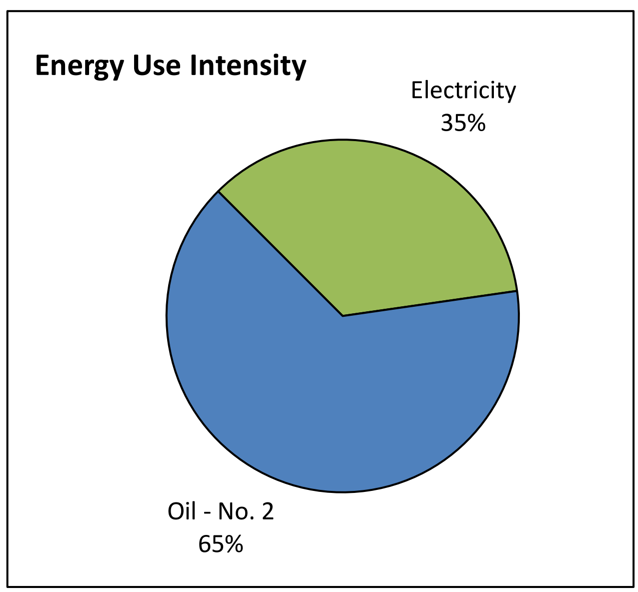
Energy Cost Index

Electricity	$ 7,882	$ 1.23	$/sq.ft./year
Oil - No. 2	$ 8,941	$ 1.39	$/sq.ft./year
Total Cost	$ 16,822	$ 2.62	$/sq.ft./year

Energy Use Intensity

Electricity	195	mmBtu	30.4	kBtu/sq.ft./year
Oil - No. 2	358	mmBtu	55.8	kBtu/sq.ft./year
Total Energy Use	553	mmBtu	86.2	kBtu/sq.ft./year





Energy Cost Index $ 2.62 /sf/yr. **Energy Use Intensity 86.2 kBTU/sf/yr.**

Benchmarking Your Building

The EPA's ENERGY STAR Portfolio Manager website allows you to upload energy use information and compare your energy use to that of other buildings of similar use. Portfolio Manager generates a benchmark score that indicates your performance. A benchmark score of 50 indicates average performance while a score of 75 or higher would earn the Energy Star designation. You can use the website to track your energy use over time and document the success of your energy conservation efforts.

You can find the Portfolio Manager at:

https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager

Project Summary Table

Energy Efficiency Measures				$ Savings & Cost		
EEM #	Measure Status	EEM Description	Reduction in Greenhouse Gas Emissions (Lbs. CO2e/Year)	Total Annual Savings	Install Costs	Simple Payback (years)
EEM-1	R	Interior Lighting Retrofit	5,655	$ 1,014	$ 5,518	5.4
EEM-2	R	Exterior Lighting Retrofit	41	$ 4	$ 42	10.6
EEM-3	R	Improve Temperature Control	9,162	$ 1,354	$ 2,700	2.0
EEM-4	RS	Insulate Building Envelope	30,690	$ 4,673	$ 52,918	11.3
EEM-5	RS	Install Double Glazing	13,979	$ 1,935	$ 36,774	19.0
EEM-6	NR	Install Duct Insulation	221	$ 22	$ 1,200	55.3
EEM-7	R	Insulate Heating And Domestic Hot Water Pipes	868	$ 133	$ 349	2.6
EEM-8	R	Install Motor Controls	1,765	$ 173	$ 300	1.7
EEM-9	NR	Replace Condensing Units	2,990	$ 463	$ 19,000	41.0
EEM-10	ME	Install A More Efficient Boiler	12,387	$ 1,897	$ 15,000	7.9
Total of Recommended Measures:			**17,491**	**$ 2,678**	**$ 8,909**	**3.3**

Measure Status Explanation:

(I) - Implemented: Measure has been installed
(R) - Recommended: Energy saved with a reasonable payback (within measure life)
(NR) - Not Recommended: When payback exceeds measure life and equipment is not at end of life
(RME) - Recommended Mutually Exclusive: Energy is saved and recommended over other options for a particular measure
(ME) - Mutually Exclusive: Non-recommended option(s) to a Recommended Mutually Exclusive (RME) measure
(RNE) - Recommended Non-Energy: Recommended based on other, non-energy factors such as comfort, water savings or equipment at end of life
(RS) - Recommended for Further Study: For measures that require analysis beyond the scope of this program.
(BE) – Building Electrification: Measures that should be considered based on greenhouse gas reductions, eliminating on-site use of fossil fuels, or other sustainability factors

Building Electrification Measures				$ Savings & Cost					
EEM #	Measure Status	Building Electrification Measure Descriptions	Reduction in Greenhouse Gas Emissions (Lbs. CO2e/Year)	Total Annual Savings	Install Costs	Simple Payback (years)	Estimated Incentives	Simple Payback after incentives
BE-1	R	Install A Tankless Water Heater	3,725	$ 590	$ 1,000	1.7	$ 2,809	1.7
BE-2	RME	Install Clean Heating System - Air Source Heat Pump	20,812	$ 4,194	$ 47,160	11.2	$ 17,760	7.0
BE-3	ME	Install Clean Heating System - Ground Source Heat Pump	28,128	$ 5,145	$ 145,730	28.3	$ 18,422	24.7
		Total of Recommended Measures:	**24,537**	**$ 4,784**	**$ 48,160**	**10.1**	**$ 20,569**	**5.8**

Simple Payback Period is the length of time it will take to recover the initial capital investment from the energy savings of the new equipment. The Simple Payback Period is calculated by dividing the initial installed cost by the annual energy cost savings. For example, an energy-saving measure that costs $5,000 and saves $2,500 per year has a Simple Payback Period of $5,000 divided by $2,500 or 2 years.

Note on Energy Project Implementation Costs

The “Project Costs” shown in this report for each Energy Efficiency Measure represent an initial estimate of the implementation cost. Unless otherwise noted in the Energy Efficiency Measure description, these costs reflect a preliminary estimate of material and labor. There may be other variables associated with your specific project that will impact the true project costs that the study may not capture. Other external factors that may impact true project costs and payback include material availability, vendor scheduling, access within the facility, general inflation, available measure incentives, and other unknown factors and conditions. For measures which significantly impact your building’s usage, it is also important to determine any potential utility rate and/or tariff changes, those of which are beyond the scope of this report. We recommend that you seek several quotes from qualified vendors prior to implementation.

Greenhouse Gas Reductions for the Recommended Measures

Reducing your energy use will reduce the release of greenhouse gases associated with the use of fossil fuels and the production of electricity. If the measures recommended in this report are implemented, the following reductions of greenhouse gases can be expected:

Electricity	(19,466)	kWh =	(22,580)	pounds CO2 equivalent
Oil - No. 2	2,874	gal. =	64,608	pounds CO2 equivalent
			42,028	pounds CO2 equivalent
			33.7%	reduction

Emissions factors are used to translate the energy savings data from energy efficiency and renewable generation projects into annual GHG emissions reduction values. NYSERDA uses emission factors derived from U.S. Environmental Protection Agency (EPA) emission coefficients to calculate emissions from onsite fuel. The CO2e values represent aggregate CO2, CH4, and N2O emissions.

Energy Efficiency Measure Descriptions

EEM-1 Interior Lighting Retrofit

Electric Savings:	$ 1,376	6,914 4.5	kWh per year kW demand
Fuel Savings:	($ 362)	(14.5)	MMBtu fuel per year Oil - No. 2
Total Annual Savings:	**$ 1,014**		
Project Cost:	**$ 5,518**		
Simple Payback:	**5.4**	**years**	

Introduction:

The existing lights consist primarily of fluorescent T-8 tubes and incandescent lamps in wall or ceiling sconces. Many of the spaces have lights that are left on when nobody is in the room. As such occupancy sensors should be installed.

Both the appendix and calculations show the specific locations, quantities, and fixture types for replacement.

Recommendation:

Replace the lamps with LED equivalents. The fluorescent fixtures could also be replaced, but a cheaper option exists by cutting out the ballast and direct wiring in LED self-driving T-8 tubes.

Consider calling the NYSEG direct installation program opportunity if the Town is too busy or does not have the resources to install, replace, or relamp the new lights and occupancy sensors as directed in the calculations.

EEM-2 Exterior Lighting Retrofit

Electric Savings:	$ 4		35	kWh per year
			0.0	kW demand
Fuel Savings:	$ 0		0.0	MMBtu fuel per year
Total Annual Savings:	**$ 4**			
Project Cost:	**$ 42**			
Simple Payback:	**10.6**	**years**		

Introduction:

The motion sensor fixtures on the side of the building have incandescent lamps.

Recommendation:

Replace the lamps with LED equivalents.

EEM-3 Improve Temperature Control

Electric Savings:	$ 88		773 0.0	kWh per year kW demand
Fuel Savings:	$ 1,266		50.7	MMBtu fuel per year Oil - No. 2
Total Annual Savings:	**$ 1,354**			
Project Cost:	**$ 2,700**			
Simple Payback:	**2.0**	**years**		

Introduction:

Proper temperature control is important in order to minimize energy costs. Maintaining space temperatures within a reasonable range during occupied periods and reliably reducing the amount of heating and cooling energy during unoccupied periods should be the goal for your temperature control system.

Facilities that are occupied only on weekdays can maintain a lower space temperature setpoint on weekends. Programmable thermostats are available that permit full 7-day schedules to be defined. 5-2 or 5-1-1 thermostats use the same schedule for all weekdays and provide one or two schedules for weekend days.

Recommendation:

There are multiple types of thermostats in each of the spaces. While most are programmable, staff overwrite the programs and keep the zones at a constant temperature even when they leave for the night.

This measure recommends installing (9 total) Wi-Fi enabled thermostats so that the facility manager can control each zone and maintain the space temperatures when occupied. The calculation provides an example of a 4-degree setback at night, but the mechanical contractor should provide a detailed quote and plan to deepen the setbacks a much as possible to save energy and maintain comfort during occupied times.

EEM-4 Insulate Building Envelope

Electric Savings:	$ 49		432 0.0	kWh per year kW demand
Fuel Savings:	$ 4,623		185.3	MMBtu fuel per year Oil - No. 2
Total Annual Savings:	**$ 4,673**			
Project Cost:	**$ 52,918**			
Simple Payback:	**11.3**	**years**		

Introduction:

Heat moves from areas of high temperature to areas of low temperature. As the temperature difference between a heated and an unheated space becomes greater, so does the rate of heat transfer. Insulation reduces the rate of heat transfer by filling the space with material that is less conductive than what is currently there. The effectiveness of insulation is measured by R-value, which is the resistance to heat transfer. As the R-value increases, the rate at which heat is transferred decreases.

Insulation can be installed in enclosed spaces, such as wall cavities, cathedral ceiling cavities, and floored attic cavities. It can also be installed in unfloored attics, which can accommodate greater thickness resulting in higher R-value. When insulation is combined with air sealing, convective air currents that circulate air within cavities and through insulation are reduced, which increases the effective R-value of the insulation.

Recommendation:

This measure provides an example of increasing the R-Value in the roof from an estimated R-10 to R-38, and the walls from R-3.7 to R-10. The measure is recommended for further study due to many reasons and costs should be ascertained by competent contractors who specialize in both removal and remediation of old insulation and sealing other penetrations. Costs for insulating the basement ceiling between the joists should be included as well as different scenarios for the walls, because they may not be able to be insulated adequately with blown in insulation, where an exterior insulating finishing system might be the best opportunity to maximize the R-Value.

EEM-5 Install Double Glazing

Electric Savings:	($ 206)	0	kWh per year
		0.0	kW demand
Fuel Savings:	$ 2,141	85.8	MMBtu fuel per year Oil - No. 2
Total Annual Savings:	**$ 1,935**		
Project Cost:	**$ 36,774**		
Simple Payback:	**19.0**	**years**	

Introduction:

Single pane wooden or metal frame windows can be very inefficient. Heat loss due to conduction through single pane windows can be very high. New windows utilize two panes of glass instead of one. Glass performance is measured in two ways Solar Heat Gain Co-efficient (SHGC) or Visible Transmittance (VT). SHGC is the amount of solar gain transmitted through a window into the building. VT refers to the amount of visible light that moves through the glass from exterior to interior. These two factors can be altered for a higher performing window by adding Low-E coatings and spacers with gas. The overall thermal performance of windows is generally assigned a u-value. This measurement considers all parts of a window. These parts include the frame, sash, and glass. The installation of windows with double glazing will reduce infiltration and conduction losses.

Recommendation:

Install new double-glazed windows with low-e coatings. Be sure that windows are fully caulked on the exterior and interior where they meet the existing building structure. The EPA and DOE have developed stringent standards for windows. Windows that meet these standards can earn the Energy Star Label. Replacement windows should bear the Energy Star label.

This measure provides an estimate for replacing the single pane windows with new double pane units that prevent air leakage through the frames, which was based on 10% of the overall wall area. Savings for increasing the R-Value from 0.9 to 3 and reducing the infiltration by half. Windows are prohibitively expensive, due mainly to custom sizes and labor. This measure is recommended for further study like the previous measure for the same reasons of cost creep due potential issues with an older building. Though, if the same contractor is able to replace and seal the windows, there could be a reduction in costs through scale.

EEM-6 Install Duct Insulation

Electric Savings:	$ 22	190	kWh per year
		0.0	kW demand
Fuel Savings:	$ 0	0.0	MMBtu fuel per year
Total Annual Savings:	**$ 22**		
Project Cost:	**$ 1,200**		
Simple Payback:	**55.3**	**years**	

Introduction:

Sheet metal ducts located in basement, attic or other unconditioned spaces lose energy and reduce overall system efficiency. The heating and cooling systems must operate longer to compensate for this energy loss. Adding insulation to supply and return air ducts will reduce this energy loss and improve system efficiency.

Ducts in conditioned spaces experience minimal conductive losses and gains since they are exposed to indoor spaces that must be conditioned in any event. However, these ducts may also require some insulation to prevent condensation on duct walls and to ensure that conditioned air is delivered at the desired temperature.

Recommendation:

This measure provides an example of the potential savings for insulating the attic AC ducts. Due to lower hours of use, this measure does not have a good payback relative to costs and is not recommended.

This measure is impacted by other AC and Building Electrification retrofit measures, which may require replacement of the existing distribution systems. It may also be a good idea to implement EEM-4 prior to installing new AC equipment).

Further, staff indicated that the zone controllers were not working, which should be ascertained by the mechanical contractor. The costs of fixing the existing system should be compared against the costs of replacement.

EEM-7 Insulate Heating And Domestic Hot Water Pipes

Electric Savings:	$ 0		0	kWh per year
			0.0	kW demand
Fuel Savings:	$ 133		5.3	MMBtu fuel per year Oil - No. 2
Total Annual Savings:	**$ 133**			
Project Cost:	**$ 349**			
Simple Payback:	**2.6**	**years**		

Introduction:

Heat is distributed through the building by pipes containing hot water or steam. Heating distribution system pipes lose heat to the surrounding space. If the heat is lost to an area that does not require heating, the drop in system efficiency can be significant. Un-insulated pipes in conditioned space may also overheat the space, wasting energy and causing comfort problems. All heating distribution system pipes located in unconditioned space should be insulated.

Recommendation:

The heating hot water distribution pipe from the boiler to the pumps is not insulated fully. The domestic hot water pipes from the submerged coil are not insulated at all, and they are always hot.

Install 2 in. insulation on (10 ft.) of 2 in. Dull Copper Hot Water pipe, 0.5 in. insulation on (25 ft.) of 0.5 in. Dull Copper DHW pipe and 1 in. insulation on (10 ft.) of 1 in. Dull Copper DHW pipe.

EEM-8 Install Motor Controls

Electric Savings:	$ 173	1,521	kWh per year
		0.0	kW demand
Fuel Savings:	$ 0	0.0	MMBtu fuel per year
Total Annual Savings:	**$ 173**		
Project Cost:	**$ 300**		
Simple Payback:	**1.7**	**years**	

Introduction:

The heating hot water/cold water pumps cycle monthly. However, one always operates to circulate the cold water or the hot water at all times even if the thermostats are not calling for heat from the radiators or cold air from the AHUs.

These motors will reach the end of their useful life faster. The pipes will lose temperature to the space while circulating water needlessly during unoccupied times causing the boiler or condensing units to engage more often during short cycles. This causes the units to operate inefficiently at low loads.

Recommendation:

The mechanical contractor should identify a control mechanism such as an aquastat to disengage the pump when the loop or thermostat temperatures are satisfied.

This calculation only estimates savings for reducing the running time of the motor by an estimated 50%. There are additional savings for interactive heating and cooling that can be identified for further study.

EEM-9 Replace Condensing Units

Electric Savings:	$ 463		2,578	kWh per year
			3.1	kW demand
Fuel Savings:	$ 0		0.0	MMBtu fuel per year
Total Annual Savings:	**$ 463**			
Project Cost:	**$ 19,000**			
Simple Payback:	**41.0**	**years**		

Introduction:

Air conditioning units that are over 15 years old may use reciprocating compressors and obsolete refrigerants. Current models use reliable scroll compressors and modern refrigerants to meet today's more stringent efficiency requirements. Replacement models are rated with an Energy Efficiency Ratio, commonly called EER. The higher the EER, the more efficient the unit. SEER is the Seasonal Energy Efficiency Ratio, which indicates the average EER over the course of a cooling season. The SEER will be higher than the EER for a given piece of equipment, so be sure to compare products using the same measurements.

The energy savings of a new air conditioning system is often not enough to warrant the purchase of a new unit. However, if the air conditioner requires repair or needs replacement for another reason, the highest EER rated equipment should be purchased.

Recommendation:

The original condensing units are at the end of their service life and need to be replaced. Due to the low hours of use, and the high cost of replacement, this measure does not pay back and is not recommended. They are also at the end of their useful lives, so the costs to replace should be used to compare against high efficiency building electrification measures that will be described in subsequent measures.

EEM-10 Install A More Efficient Boiler

Electric Savings:	$ 0	0	kWh per year
		0.0	kW demand
Fuel Savings:	$ 1,897	76.0	MMBtu fuel per year Oil - No. 2
Total Annual Savings:	**$ 1,897**		
Project Cost:	**$ 15,000**		
Simple Payback:	**7.9**	**years**	

Introduction:

Boiler efficiency is determined by the efficiency of the boiler burner and heat exchanger, jacket heat losses, flue losses, and boiler sizing relative to the heating load. Boilers that are oversized spend more time in standby mode, increasing the impact of high off-cycle flue losses. These types of boilers perform at overall efficiencies significantly lower than their nominal thermal efficiency (Et), which is measured at a steady state of boiler operation.

Non-condensing boilers are limited to thermal efficiencies up to ~85% Et if equipped with power burners and low-mass heat exchangers; 80% Et boilers are more common. Condensing boilers are designed to cool flue gases to the point where water vapor produced in the combustion process condenses. The thermal efficiency of a condensing boiler depends on the entering water temperature, with lower temperatures yielding higher efficiency. Condensing boilers can achieve thermal efficiencies between 88% and 98%.

Recommendation:

This measure simply provides an analysis for installing a new oil fired condensing boiler. Though, it may be difficult to procure one since most condensing units have gas/propane fired burners. In addition, the boiler will not have a domestic hot water coil, so a new domestic hot water maker will need to be purchased (note that there are many options for high efficiency combi-boilers, but they also require gas/propane). Hot water heating via perimeter radiators is not the most effective way to heat this facility since the walls are not insulated. Most facilities cannot overcome this deficiency, but ducts provide cold air via water coils in the AHUs. There could be a way to retrofit the air distribution system to provide hot air via a gas fired condensing furnace.

NYS has goals to remove fossil fuel heating from buildings, and the boiler is reaching the end of its useful life in a few years. Now is the time to have a comprehensive plan to upgrade the building infrastructure before a failure necessitates an emergency boiler replacement that will last another 15 years. The mechanical contractor should provide quotes for both the replace-in-kind as well as consideration of a gas furnace, but both should be used to compare against the subsequent building electrification measures. As such, this measure is considered mutually exclusive despite a potential good payback.

Building Electrification Measures

The following measures evaluate the impact of replacing your existing fossil-fuel heating systems with clean heating and cooling systems powered by electricity. For space heating, air source heat pumps and ground source heat pumps are available in various system types to provide both heating and cooling to your building.

Fossil fuel-fired water heaters may also be replaced with heat pump water heaters to further reduce your use of fossil fuels.

When combined with renewable electricity, heat pump systems can eliminate the use of fossil fuels in your building.

See Appendix E - Benefits Of Clean Heating and Cooling (CHC) Technologies for more information on these system types.

BE-1 Install A Tankless Water Heater

Electric Savings:	($ 567)	(3,301) (1.5)	kWh per year kW demand
Fuel Savings:	$ 1,157	46.4	MMBtu fuel per year Oil - No. 2
Total Annual Savings:	**$ 590**		
Project Cost:	**$ 1,000**		
Simple Payback:	**1.7**	**years**	

Introduction:

There is a submerged coil in the boiler that provides hot water on demand. During the summer, the demand on the boiler is so low that the unit operates inefficiently to make domestic hot water.

This calculation estimates that the current oil usage is 14% for domestic hot water using utility bill extrapolation. This is quite high for simply hand and dishwashing.

Recommendation:

Install a tankless on demand unit that is electric that is size to serve the hot water loads in the facility.

BE-2 Install Clean Heating System - Air Source Heat Pump

Electric Savings:	($ 3,508)		(25,408)	kWh per year
			2.2	kW demand
Fuel Savings:	$ 7,702		308.7	MMBtu fuel per year Oil - No. 2
Total Annual Savings:	**$ 4,194**			
Project Cost:	**$ 47,160**			
Simple Payback:	**11.2**	**years,**	**7.0**	**years after incentives**

Introduction:

Air source heat pumps (ASHP) provide both heating and cooling using electricity to exchange energy with the outdoor air. Existing buildings may be retrofitted with various heat pump technologies to reduce or eliminate their dependence on fossil fuels for space heating. System options range from centrally-ducted cold climate air source heat pumps and mini-split heat pumps to large variable refrigerant flow systems having multiple indoor units supported by each outdoor unit.

At very cold outdoor air conditions, air source heat pumps may require supplemental heat to meet your building's heating load. Supplemental heat may be in the form of electric resistance heat or your existing fossil-fueled heating system, if it remains in service. The extent to which an ASHP system reduces your fossil fuel use will depend on the exact design and control of your new system.

Recommendation:

Replace your oil - no. 2 heating system with a central ducted air source heat pump system serving the entire building. The system type is: Central Ducted ASHP with Integrated/ Modulating controls sized to 100% of the building heating load.

The heat pumps are assumed to be rated at 13.05 EER full load cooling, 15 SEER. The heat pumps are assumed to be rated at 10 HSPF for heating, which may be adjusted to 2.52 COP. Be sure to specify heat pumps that meet NEEP requirements (Northeast Energy Efficiency Partnerships). See https://ashp.neep.org/#!/product_list/ for current models that meet these requirements.

They should be rated for cold climates (needing a larger size to accommodate the reduction in capacity during cold temperatures) so that the boiler plant can be removed. This measure has the best payback for heating and cooling the facility with heat pumps and is considered recommended, mutually exclusive. However, this is based on probable costs without incentives. The subsequent ground source heat pump has better utility incentives at this time and should be also evaluated.

BE-3 Install Clean Heating System - Ground Source Heat Pump

Electric Savings:	($ 1,922)		(15,531)	kWh per year
			3.4	kW demand
Fuel Savings:	$ 7,067		283.3	MMBtu fuel per year Oil - No. 2
Total Annual Savings:	**$ 5,145**			
Project Cost:	**$ 145,730**			
Simple Payback:	**28.3**	**years,**	**24.7**	**years after incentives**

Introduction:

Smaller buildings can take advantage of water-to-air ground source heat pump technology by replacing furnaces and other ducted systems with heat pumps having either open or closed loop ground heat exchangers. Closed loop ground heat exchangers that are properly sized provide water between 32° and 77° for heat pumps to draw heat from or reject heat to. Open loop systems see water temperatures of ~50° throughout the year. This allows heat pumps to operate at higher efficiency than air-source heat pumps that must draw from more extreme outdoor air temperatures.

The heat pumps in this type of system each have a loop pump. The building may have multiple heat pumps, but every heat pump must have a dedicated ground source heat exchanger. The heat pumps should have two-stage or variable capacity compressors for the highest efficiency. The loop pump may be constant speed, but two-speed or variable speed pumps offer higher efficiency and are preferred.

Recommendation:

Consider replacing your present heating system with a clean heating and cooling system using ground source heat pumps.

Install a closed loop heat pump system with variable-speed compressors and variable pumping. The heat pumps are assumed to be rated at 17 EER full load cooling, 22 EER part load. The heat pumps are assumed to be rated at 3.6 COP full load heating, 4.1 COP part load.

This is the most efficient option; however, it has the highest cost component without incentives. NYSEG has a very good incentive opportunity for GSHPs relative to ASHP and the Federal Inflation Recovery Act has likely a 40% tax credit (that can be directly paid to the municipality) available, making this option likely on par with the previous measure. Consult a competent contractor to identify the possibility of this option in addition to the ASHP that are recommended based on this study.

Existing Conditions

This site is a Town Hall with multiple departments. Originally, this building was constructed in 1850 as a private residence. There was an addition in 1988 that built out the rear and expanded the second story. Overall, the facility is 6,420 ft^2 with 3,658 ft^2 on the first floor and 2,762 ft^2 on the second floor. There are at least 20 staff in the office daily with many more people coming in person to meet with the staff about their buildings, taxes, or have meetings at the court, or for their committees and non-profits as this building is one of the only places in town to gather in a public forum. The typical office hours are 9-5 M-F, but oftentimes meeting spaces are open as late as midnight.

There is a small basement and crawlspace under the original part of the building. The basement has a slab floor and stone walls, while the crawlspace has a dirt floor. The building is wood frame, with 2"x4" boards in the original building and 2"x6" boards in the addition. There is no insulation between the wall frames in the original building, but there is some insulation in the addition. The exterior siding is wood cladding, and the interior is drywall. The main hipped roof has minimal, aged insulation, boarded up on the underside of the roof deck above the attic. A smaller hipped roof has an attic crawlspace, which has vermiculite, or similar older insulation on the attic floor between the joists.

The original building has exclusively single pane windows. About half the windows are double hung, while the others are fixed or can open by handle. The addition has double pane glass and double hung windows. All have wood frames. There are also several doors to the facility, and they are all solid wood with good weather stripping and/or seals.

Lighting Systems

Lighting is primarily 4' T-8 fluorescent surface mount fixtures. There are also a mixture of candelabra type chandelier or wall sconce incandescent fixtures as well as incandescent ceiling surface mount lamps. The recessed lamps are either incandescent, or LED. Some desk lamps are CFL. All lights are controlled via switches, and many are left operating all day (and evening) when the space is unoccupied until the last person (or security) in the office turns them off at night.

Exterior fixtures consist of LED wall packs that operate at night with photocells, and two CFL wall sconces on a switch at night. The side doors have 100W incandescent lights on motion sensors.

Heating Ventilating and Air Conditioning Systems

Heating is provided by a hot water cast iron boiler, fired by oil. The boiler is a Peerless, model EC-04-WPCL, manufactured in 2013. It has a firing rate of 1.75 gallons per hour, and 245 Mbh, with an output of 215 Mbh, per specifications found online. The DOE energy rating sticker is 84.5% while the specifications suggest an AFUE of 86.8%. The boiler uses two, 1/2 hp pumps (that cycle monthly) to circulate hot water to radiator/console units along the perimeter of the facility. Most of the pipes in the boiler room are insulated.

Cooling is provided by two condensing units that cool water pipes instead of refrigerant lines. The condensing units are Trane, model TTD760B1000A2 units from 1990. The outdoor fan motor has a 1/4 capacity. The water loop ties into the (same heating) pumps in the basement which circulate the cold water to two air handling units (AHUs) in the attic space that distribute cold air to ducts in the wall. The AHUs are Magic Aire 36-BHW-4 units with 1/3 hp units with a 3-ton capacity. The air handlers serve ducted distribution in the walls along the first and second floors. The ducts in the attic are not insulated.

The addition has a separate heating and cooling distribution system located in the attic that was not accessed during the walkthrough. The AHU has a hot water coil that uses the existing boiler, and a refrigerant coil that is served by a Lennox condensing unit, model HS18-461-4P, manufactured in 1997.

There are various controls serving the zones. The addition has old Robert Shaw analog units, and Town Supervisor has a new Honeywell touchscreen home unit. The rest of the units are Honeywell digital 5-1-1 thermostats. The controls, however, are not used for the most part. Staff overwrite the controls and hold the temperature. They claim that heating and cooling do not work well in parts of the building, and therefore the control setpoints are held around 70-74 °F in heating and cooling modes.

Staff also claim that the zone dampers for the cooling system do not work. There is also likely an imbalance in the building. Another issue is that the size of the systems is unable to serve the spaces in peak temperatures due to leaky windows and uninsulated or poorly insulated walls/windows.

The heating system is valved off from the main distribution during cooling season and vice versa. The circulator pump never turns off despite the controls not calling for heating or cooling.

The server room has a small window AC unit. It is a Perfect Aire unit with a 5,000 Btu/h capacity and an 11 CEER. The basement has an Electrolux dehumidifier with a 50 pint/day capacity that was manufactured in 2010.

Water Heating System

The boiler has a submerged coil in it for hot water needs and stays hot all year round. There is no storage tank and the ½" copper pipes are not insulated. The temperature was measured at 123 °F and the water is used for handwashing and dishwashing.

Other Energy-using Systems

This building has typical office equipment. Each space has multiple computers and printers. There is a security system, and two server cabinets. There is a small kitchen with a refrigerator, microwave, toaster, oven set, and a dishwasher.

See Appendix D for further details regarding the energy calculations performed for this study.

Appendix A

Equipment Inventory

Heating and Air Conditioning Equipment									
Unit Type	Qty	Make/Model	Heating kBtuh	Heating Eff.	Cooling Capacity	Units	EER	Serves/Location	Year
Cast Iron Boiler	1	Peerless EC-04-WPCL	245	84.50%				All Building/Basement	2013
Condensing Units	2	Trane TTD760B1000A2			3	tons	9.0	All Building/Ext. Rear	1990
Window AC	1	Perfect Aire 5PMC			0.42	tons	11.0	Server Room	2018
Split System AC	1	Lennox HS18-461-4P			3 1/2	tons	9.0	Addition/Ext. Rear	1997

Domestic Hot Water									
Unit Type	Qty	Make/Model	Capacity	Units	Fuel Type	Storage Capacity (gal.)	Eff.	Serves/Location	Year
Tankless	1	Peerless EC-04-WPCL	245	kBtu/h	Oil - No. 2	None	84.5%	Faucets/Basement	2013

Motors									
Unit Type	Qty	Make/Model	HP	Loading	Type	Hours/year	Eff.	Serves/Location	Year
Filtration Pump	1	Baldor Reliance	1/2					Domestic Water Tanks/Basement	
HHW/CHW Pump	1	Baldor Reliance	1/2					Radiators & AHUs/Basement	
HHW/CHW Pump	1	Magnetek	1/3					Radiators & AHUs/Basement	
Condenser Fan	2	Trane	1/4					Cooling/Exterior Rear	
AHU Fan	2	Magic Aire	1/3					Cooling/Attic	

Interior Lighting Fixtures											
Existing Fixtures						Recommended	Recommended Interior Lighting Efficiency Improvements				
Line #	Area	Qty	Present Lighting Type	Lamps /fixt	Watts /Fixt	Control Type	Measure Type	Qty	Proposed Lighting Type	Lamps /fixt	Watts /Fixt
1	Basement	6	4' 32w T8 Elec. bal.	2	59	No Change	Linear LED Bypass	6	4' LED T8 2000 lu. 14W	2	28
2	Basement	1	100 watt Incandescent	1	100	No Change	LED Relamp	1	A19 LED, 14W	1	14
3	Basement	1	A19 LED, 9W	1	9	No Change	No change	1	A19 LED, 9W	1	9
4	Bldg. Dept.	5	4' 32w T8 Elec. bal.	2	59	No Change	Linear LED Bypass	5	4' LED T8 2000 lu. 14W	2	28
5	Bldg. Dept. Vault	5	4' 32w T8 Elec. bal.	2	59	Remote Occ Sensor	Linear LED Bypass	5	4' LED T8 2000 lu. 14W	2	28
6	Records Room	2	4' 32w T8 Elec. bal.	2	59	Remote Occ Sensor	Linear LED Bypass	2	4' LED T8 2000 lu. 14W	2	28
7	Tax Office	4	4' 32w T8 Elec. bal.	2	59	No Change	Linear LED Bypass	4	4' LED T8 2000 lu. 14W	2	28
8	Rear Hallway	4	4' 32w T8 Elec. bal.	2	59	No Change	Linear LED Bypass	4	4' LED T8 2000 lu. 14W	2	28
9	Hallway	2	60 watt Incandescent	1	60	No Change	No change	2	A19 LED, 9W	1	9
10	Hallway	1	4' 32w T8 Elec. bal.	2	59	No Change	Linear LED Bypass	1	4' LED T8 2000 lu. 14W	2	28
11	Court Office	3	4' 32w T8 Elec. bal.	2	59	Remote Occ Sensor	Linear LED Bypass	3	4' LED T8 2000 lu. 14W	2	28
12	Kitchen	2	4' 32w T8 Elec. bal.	2	59	Remote Occ Sensor	Linear LED Bypass	2	4' LED T8 2000 lu. 14W	2	28
13	Side Hallway	3	75 watt Incandescent	1	75	No Change	LED Relamp	3	A19 LED, 9W	1	9
14	Dining Room	1	25 watt Incandescent	8	200	No Change	LED Relamp	1	A15 LED, 5W	8	40
15	Dining Room	8	PAR30 LED, 12W	1	12	No Change	No change	8	PAR30 LED, 12W	1	12
16	Dining Room	6	40 watt Incandescent	1	40	No Change	LED Relamp	6	A15 LED, 6W	1	6
17	Town Clerk	6	4' 32w T8 Elec. bal.	2	59	Remote Occ Sensor	Linear LED Bypass	6	4' LED T8 2000 lu. 14W	2	28
18	Clerk Office	3	4' 32w T8 Elec. bal.	2	59	No Change	Linear LED Bypass	3	4' LED T8 2000 lu. 14W	2	28
19	Reception	1	25 watt Incandescent	3	75	No Change	LED Relamp	1	A15 LED, 5W	3	15
20	Reception	2	40 watt Incandescent	1	40	No Change	LED Relamp	2	A15 LED, 6W	1	6
21	Courtroom	11	PAR30 LED, 12W	1	12	No Change	No change	11	PAR30 LED, 12W	1	12
22	Supervisor Office	3	100 watt Incandescent	1	100	No Change	LED Relamp	3	A19 LED, 14W	1	14
23	Supervisor Office	4	40 watt Incandescent	1	40	No Change	LED Relamp	4	A15 LED, 6W	1	6
24	Supervisor Office	3	PAR30 LED, 12W	1	12	No Change	No change	3	PAR30 LED, 12W	1	12
25	Assistant Office	1	4' 32w T8 Elec. bal.	2	59	No Change	Linear LED Bypass	1	4' LED T8 2000 lu. 14W	2	28
26	Assistant Office	2	60 watt Incandescent	1	60	No Change	LED Relamp	2	A19 LED, 9W	1	9
36	Bathroom	1	11w CFL Spiral Elec. bal.	1	11	No Change	No change	1	11w CFL Spiral Elec. bal.	1	11
37	Server Room	1	4' 32w T8 Elec. bal.	2	59	No Change	Linear LED Bypass	1	4' LED T8 2000 lu. 14W	2	28
38	Meeting Room	1	4' 32w T8 Elec. bal.	2	59	No Change	Linear LED Bypass	1	4' LED T8 2000 lu. 14W	2	28

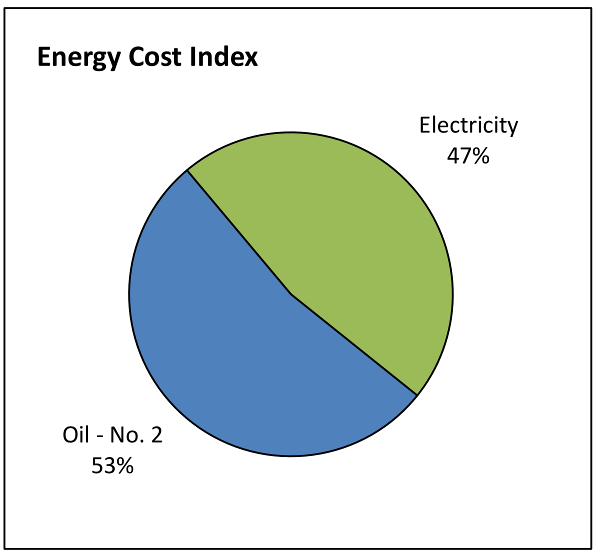
Exterior Lighting Fixtures											
Existing Fixtures						Recommended	Lighting Efficiency Improvements				
Line #	Area	Qty	Present Lighting Type	Lamps /fixt	Watts /Fixt	Control Type	Measure Type	Qty	Proposed Lighting Type	Lamps /fixt	Watts /Fixt
1	Front	3	LED area light, 28W	1	28	No Change	No change	3	LED area light, 28W	1	28
2	Side	2	100 watt Incandescent	2	200	No Change	LED Relamp	2	PAR30 LED, 12W	2	24
3	Front	2	15w CFL Spiral Elec. bal.	1	15	No Change	No change	2	15w CFL Spiral Elec. bal.	1	15

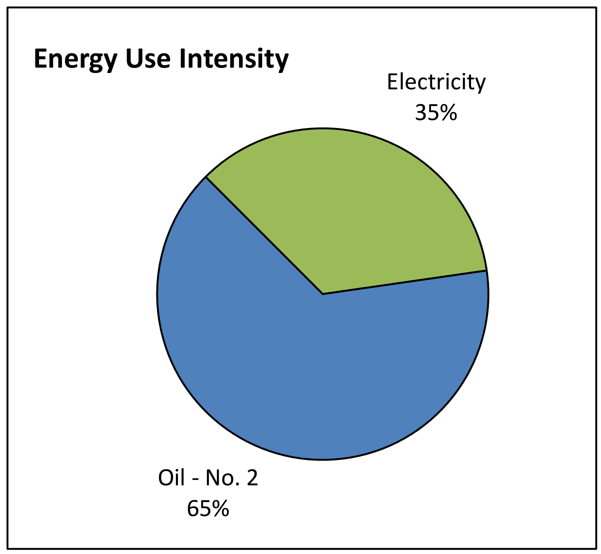
Appendix B

Energy Use and Cost Summary

Energy		Units Used		BTU/unit	mmBTU	% of total	kBtu/sq.ft./year
	Electricity	57,120	kwh	3,412	195	35%	30.4
	Oil - No. 2	2,597	gal.	138,000	358	65%	55.8
	Total				553		86.2

Cost	Energy Cost	Unit Costs		% of total	$/sq.ft./year
Electricity	$ 7,882	$ 0.114	kwh	47%	$ 1.23
Oil - No. 2	$ 8,941	$ 3.443	gal.	53%	$ 1.39
Total	$ 16,822				$ 2.62





Energy Cost Index $ 2.62 /sf/yr. **Energy Use Intensity 86.2 kBTU/sf/yr.**

Utility Bill Data

The following pages present the energy use and cost data for your facility and establish the value of each type of energy. Electricity is measured and billed in units of kilowatt-hours (kWh) that represent the total amount of electricity used in the billing period. Electricity may also be billed based on the highest rate of use, or peak demand, that occurred during the billing period. Electric demand is billed in units of kilowatts (kW).

Other fuels may be billed in volume units (gallons, hundred cubic feet or ccf, etc.) or based on their heat content (therms, equal to 100,000 British Thermal Units). All energy types may be converted into a common unit, such as BTUs, to facilitate analysis and comparison with other facilities. One million BTUs is abbreviated as mmBtu in this report.

ELECTRICITY CONSUMPTION AND COST ANALYSIS

Town of Pound Ridge - Town House

Gross Area:	6,420	s.f.
	30,357	Btu/s.f./Yr
	$ 1.23	/s.f.
	3.3	watts/s.f.

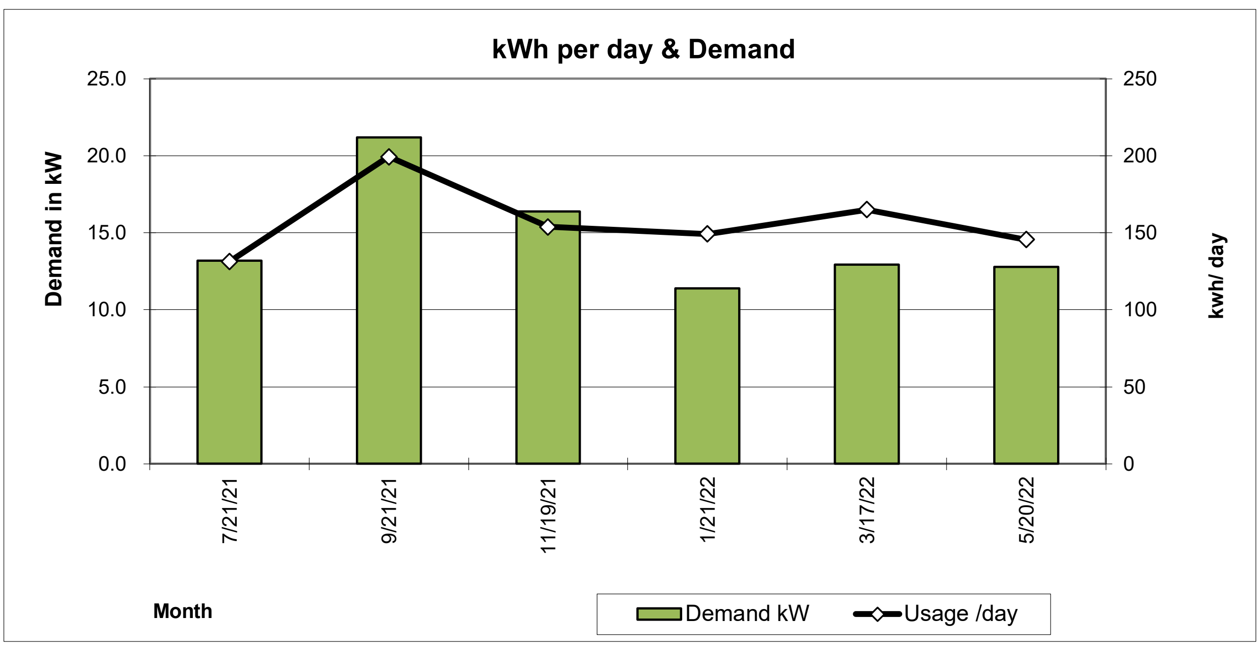
Utility:	NYSEG	
Account #	ends w/ -162	
Rate:	SC	
Meter Charge:	$ 33.00	/ month
Demand Charge:	$ 10.85	/ kW
Supplier:		

Month Ending	Days	Usage Energy kWh	Usage Demand kW	Electricity Charges Utility Cost	Electricity Charges Supply Costs	Total Electricity Cost	Demand Cost	Energy $/kWh	Load Factor	Usage /day
7/21/21	60	7,880	13.2	$ 393	$ 722	$ 1,115	$ 143	$ 0.115	0.41	131
9/21/21	62	12,360	21.2	$ 616	$ 1,132	$ 1,748	$ 230	$ 0.117	0.39	199
11/19/21	59	9,080	16.4	$ 477	$ 831	$ 1,309	$ 178	$ 0.117	0.39	154
1/21/22	63	9,400	11.4	$ 373	$ 841	$ 1,214	$ 124	$ 0.109	0.55	149
3/17/22	55	9,080	12.9	$ 388	$ 813	$ 1,201	$ 140	$ 0.110	0.53	165
5/20/22	64	9,320	12.8	$ 403	$ 892	$ 1,295	$ 139	$ 0.117	0.47	146
	363	**57,120**	**87.9**	**$ 2,651**	**$ 5,231**	**$ 7,882**	**$ 954**	**$ 0.114**	**0.45**	**157**

Annual Energy:	**57,120**	**kWh / year**	**$ 7,882**	**/year**
Peak Demand:	**21**	**kW Peak**		
Average Demand:	**15**	**kW**		

Unit Costs

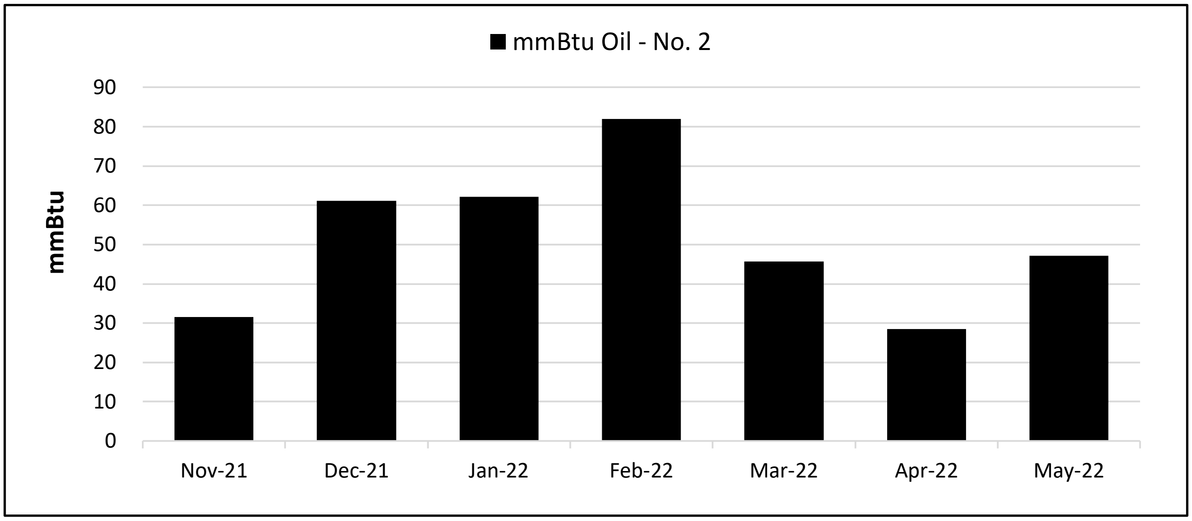
Demand	**$ 10.85**	**$/kW**
Energy	**$ 0.114**	**$/kWh Incremental**
Blended	**$ 0.138**	**$/kWh Blended**

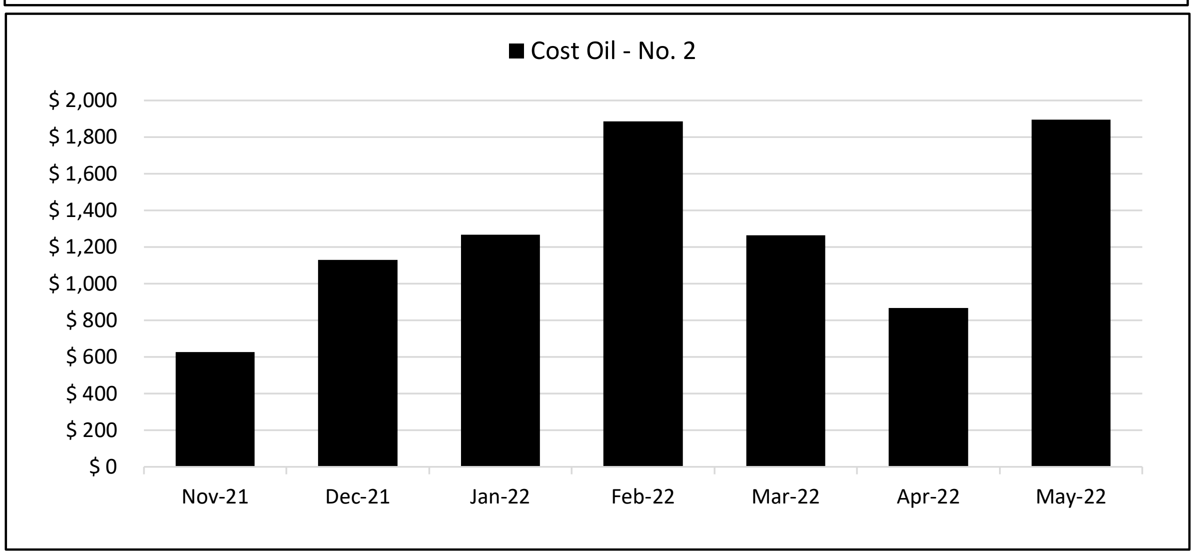


Note:
The electric supply costs for July, September, and November were extrapolated based on data provided for January, March, and May. The rate class, meter charge, and demand charges were each estimated based on NYSEG's current tariffs.

ALL FUELS CONSUMPTION AND COST ANALYSIS **Town of Pound Ridge - Town House**

Month	mmBtu Oil - No. 2	Cost Oil - No. 2
Nov-21	32	$ 628
Dec-21	61	$ 1,130
Jan-22	62	$ 1,267
Feb-22	82	$ 1,886
Mar-22	46	$ 1,266
Apr-22	29	$ 869
May-22	47	$ 1,895
Total	358	$ 8,941
$/mmBtu	$ 24.95	
BTU/unit	138,000	1 mmBtu = 1,000,000 Btus
kBtu/SF/Yr.	55.8	1 kBtu = 1,000 Btus





Appendix C

EEM Calculations

Interactions

The Energy Efficiency Measure calculations in this section are stand-alone measures that are not interacted with the other calculations. Each measure shows the energy savings that may be expected if it is the only measure to be implemented. If multiple measures will be implemented, energy savings will likely be lower than the calculations represent.

As an example, replacing an 80% efficient boiler with a 92% efficient boiler will reduce the amount of fuel required to heat the building. If the walls and roof are insulated such that the required heating energy is reduced by 30%, the new boiler will serve a smaller heating load, and the energy savings gained from the boiler replacement will be reduced by 30%.

CALCULATIONS FOR INTERIOR LIGHTING RETROFIT

EEM-1 **Town of Pound Ridge - Town House**

Type:	Units:	Unit cost:	BTU/unit	
Oil - No. 2	gal.	$ 3.443	138,000	
Electricity	kwh	$ 0.114	3,412	
Demand	kW	$ 10.85	12	Months of demand savings/year

100% of building is air conditioned

HVAC Adjustment Factors		
Cooling	Demand	Fuel
HVACc	HVACd	HVACg
16.00%	20.00%	-2.10%

Existing Interior Lighting Systems					Recommended Lighting Controls					Recommended Interior Lighting Efficiency Improvements										Energy & Demand Calculations: Demand			Total Use		Energy Savings	
Area	Qty	Present Lighting Type	Lamps /fixt	Watts /Fixt	Control Type	% Reduction	Present Hrs./yr.	Proposed Hrs./yr.	# Controls required	Measure Type	Qty	Proposed Lighting Type	Lamps /fixt	Reflect or ?	Watts /Fixt	Project Cost	Annual Savings	kWh/yr. Savings	Payback (Years)	Present kW	Proposed kW	kW Saved	Present kwh/year	Proposed kwh/year	Controls kwh/year	Efficiency kwh/year
Basement	6	4' 32w T8 Elec. bal.	2	59	No Change	0%	50	50	0	Linear LED Bypass	6	4' LED T8 2000 lu. 14W	2		28	$ 338	$ 25	9	13.4	0.4	0.2	0.2	18	8	0	9
Basement	1	100 watt Incandescent	1	100	No Change	0%	50	50	0	LED Relamp	1	A19 LED, 14W	1		14	$ 12	$ 12	4	1.0	0.1	0.0	0.1	5	1	0	4
Basement	1	A19 LED, 9W	1	9	No Change	0%	50	50	0	No change	1	A19 LED, 9W	1		9	$ 0	$ 0	0		0.0	0.0	0.0	0	0	0	0
Bldg. Dept.	5	4' 32w T8 Elec. bal.	2	59	No Change	0%	2,000	2,000	0	Linear LED Bypass	5	4' LED T8 2000 lu. 14W	2		28	$ 282	$ 56	310	5.1	0.3	0.1	0.2	590	280	0	310
Bldg. Dept. Vault	5	4' 32w T8 Elec. bal.	2	59	Remote Occ Sensor	75%	2,000	500	2	Linear LED Bypass	5	4' LED T8 2000 lu. 14W	2		28	$ 762	$ 79	520	9.6	0.3	0.1	0.2	590	70	443	78
Records Room	2	4' 32w T8 Elec. bal.	2	59	Remote Occ Sensor	50%	2,000	1,000	1	Linear LED Bypass	2	4' LED T8 2000 lu. 14W	2		28	$ 353	$ 29	180	12.3	0.1	0.1	0.1	236	56	118	62
Tax Office	4	4' 32w T8 Elec. bal.	2	59	No Change	0%	500	500	0	Linear LED Bypass	4	4' LED T8 2000 lu. 14W	2		28	$ 226	$ 23	62	9.7	0.2	0.1	0.1	118	56	0	62
Rear Hallway	4	4' 32w T8 Elec. bal.	2	59	No Change	0%	2,000	2,000	0	Linear LED Bypass	4	4' LED T8 2000 lu. 14W	2		28	$ 226	$ 44	248	5.1	0.2	0.1	0.1	472	224	0	248
Hallway	2	60 watt Incandescent	1	60	No Change	0%	2,000	2,000	0	No change	2	A19 LED, 9W	1		9	$ 7	$ 37	204	0.2	0.1	0.0	0.1	240	36	0	204
Hallway	1	4' 32w T8 Elec. bal.	2	59	No Change	0%	2,000	2,000	0	Linear LED Bypass	1	4' LED T8 2000 lu. 14W	2		28	$ 56	$ 11	62	5.1	0.1	0.0	0.0	118	56	0	62
Court Office	3	4' 32w T8 Elec. bal.	2	59	Remote Occ Sensor	25%	2,000	1,500	1	Linear LED Bypass	3	4' LED T8 2000 lu. 14W	2		28	$ 409	$ 38	228	10.7	0.2	0.1	0.1	354	126	89	140
Kitchen	2	4' 32w T8 Elec. bal.	2	59	Remote Occ Sensor	75%	2,000	500	1	Linear LED Bypass	2	4' LED T8 2000 lu. 14W	2		28	$ 353	$ 32	208	11.1	0.1	0.1	0.1	236	28	177	31
Side Hallway	3	75 watt Incandescent	1	75	No Change	0%	2,000	2,000	1	LED Relamp	3	A19 LED, 9W	1		9	$ 11	$ 71	396	0.2	0.2	0.0	0.2	450	54	0	396
Dining Room	1	25 watt Incandescent	8	200	No Change	0%	500	500	0	LED Relamp	1	A15 LED, 5W	8		40	$ 58	$ 30	80	1.9	0.2	0.0	0.2	100	20	0	80
Dining Room	8	PAR30 LED, 12W	1	12	No Change	0%	500	500	0	No change	8	PAR30 LED, 12W	1		12	$ 0	$ 0	0		0.1	0.1	0.0	48	48	0	0
Dining Room	6	40 watt Incandescent	1	40	No Change	0%	10	10	0	LED Relamp	6	A15 LED, 6W	1		6	$ 14	$ 27	2	0.5	0.2	0.0	0.2	2	0	0	2
Town Clerk	6	4' 32w T8 Elec. bal.	2	59	Remote Occ Sensor	25%	2,000	1,500	1	Linear LED Bypass	6	4' LED T8 2000 lu. 14W	2		28	$ 578	$ 76	456	7.6	0.4	0.2	0.2	708	252	177	279
Clerk Office	3	4' 32w T8 Elec. bal.	2	59	No Change	0%	500	500	0	Linear LED Bypass	3	4' LED T8 2000 lu. 14W	2		28	$ 169	$ 17	47	9.7	0.2	0.1	0.1	89	42	0	47
Reception	1	25 watt Incandescent	3	75	No Change	0%	2,000	2,000	0	LED Relamp	1	A15 LED, 5W	3		15	$ 22	$ 21	120	1.0	0.1	0.0	0.1	150	30	0	120
Reception	2	40 watt Incandescent	1	40	No Change	0%	2,000	2,000	0	LED Relamp	2	A15 LED, 6W	1		6	$ 5	$ 24	136	0.2	0.1	0.0	0.1	160	24	0	136
Courtroom	11	PAR30 LED, 12W	1	12	No Change	0%	500	500	0	No change	11	PAR30 LED, 12W	1		12	$ 0	$ 0	0		0.1	0.1	0.0	66	66	0	0
Supervisor Office	3	100 watt Incandescent	1	100	No Change	0%	1,000	1,000	0	LED Relamp	3	A19 LED, 14W	1		14	$ 36	$ 63	258	0.6	0.3	0.0	0.3	300	42	0	258
Supervisor Office	4	40 watt Incandescent	1	40	No Change	0%	1,000	1,000	0	LED Relamp	4	A15 LED, 6W	1		6	$ 10	$ 33	136	0.3	0.2	0.0	0.1	160	24	0	136
Supervisor Office	3	PAR30 LED, 12W	1	12	No Change	0%	1,000	1,000	0	No change	3	PAR30 LED, 12W	1		12	$ 0	$ 0	0		0.0	0.0	0.0	36	36	0	0
Assistant Office	1	4' 32w T8 Elec. bal.	2	59	No Change	0%	2,000	2,000	0	Linear LED Bypass	1	4' LED T8 2000 lu. 14W	2		28	$ 56	$ 11	62	5.1	0.1	0.0	0.0	118	56	0	62
Assistant Office	2	60 watt Incandescent	1	60	No Change	0%	2,000	2,000	0	LED Relamp	2	A19 LED, 9W	1		9	$ 7	$ 37	204	0.2	0.1	0.0	0.1	240	36	0	204
2nd Floor Hallway	3	60 watt Incandescent	2	120	No Change	0%	2,000	2,000	0	LED Relamp	3	A19 LED, 9W	2		18	$ 22	$ 110	612	0.2	0.4	0.1	0.3	720	108	0	612
Printer Room	2	60 watt Incandescent	1	60	No Change	0%	50	50	0	LED Relamp	2	A19 LED, 9W	1		9	$ 7	$ 14	5	0.5	0.1	0.0	0.1	6	1	0	5
Grants Office	1	4' 32w T8 Elec. bal.	2	59	No Change	0%	2,000	2,000	0	Linear LED Bypass	1	4' LED T8 2000 lu. 14W	2		28	$ 56	$ 11	62	5.1	0.1	0.0	0.0	118	56	0	62
Grants Office	2	60 watt Incandescent	1	60	No Change	0%	2,000	2,000	0	LED Relamp	2	A19 LED, 9W	1		9	$ 7	$ 37	204	0.2	0.1	0.0	0.1	240	36	0	204
Rec. Dept.	5	4' 32w T8 Elec. bal.	2	59	No Change	0%	2,000	2,000	0	Linear LED Bypass	5	4' LED T8 2000 lu. 14W	2		28	$ 282	$ 56	310	5.1	0.3	0.1	0.2	590	280	0	310
Finance Dept.	2	4' 32w T8 Elec. bal.	4	112	No Change	0%	2,000	2,000	0	Linear LED Bypass	2	4' LED T8 2000 lu. 14W	4		56	$ 166	$ 40	224	4.1	0.2	0.1	0.1	448	224	0	224
Assessor's Office	3	4' 32w T8 Elec. bal.	2	59	No Change	0%	2,000	2,000	0	Linear LED Bypass	3	4' LED T8 2000 lu. 14W	2		28	$ 169	$ 33	186	5.1	0.2	0.1	0.1	354	168	0	186
Assessor's Vault	3	4' 32w T8 Elec. bal.	2	59	Remote Occ Sensor	75%	2,000	500	1	Linear LED Bypass	3	4' LED T8 2000 lu. 14W	2		28	$ 409	$ 48	312	8.6	0.2	0.1	0.1	354	42	266	47
2nd Floor Hallway	1	4' 32w T8 Elec. bal.	2	59	Remote Occ Sensor	75%	2,000	500	1	Linear LED Bypass	1	4' LED T8 2000 lu. 14W	2		28	$ 296	$ 16	104	18.7	0.1	0.0	0.0	118	14	89	16
Bathroom	1	11w CFL Spiral Elec. bal	1	11	No Change	0%	250	250	0	No change	1	11w CFL Spiral Elec. bal	1		11	$ 0	$ 0	0		0.0	0.0	0.0	3	3	0	0
Server Room	1	4' 32w T8 Elec. bal.	2	59	No Change	0%	50	50	0	Linear LED Bypass	1	4' LED T8 2000 lu. 14W	2		28	$ 56	$ 4	2	13.4	0.1	0.0	0.0	3	1	0	2
Meeting Room	1	4' 32w T8 Elec. bal.	2	59	No Change	0%	250	250	0	Linear LED Bypass	1	4' LED T8 2000 lu. 14W	2		28	$ 56	$ 5	8	11.5	0.1	0.0	0.0	15	7	0	8
	115		6.1	kW existing					9		115			2.3	kW proposed					6.1	2.3	3.8	8,573	2,612	1,357	4,604
																									5,961	kwh

Note: bal. = ballast, EE = energy efficient, STD = standard efficiency, mag. = magnetic, Elec. = electronic, CFL = compact fluorescent lamp

SUMMARY OF SAVINGS BY MEASURE TYPE:

	Measure Type	Fixture Qty.	Energy Savings: Controls kwh/year	Energy Savings: Efficiency kwh/year	Demand: kW Savings	Project Cost	Electric Savings	Payback (Years)	Measure Description
EEM-1B	Linear LED Bypass	59		2,242	1.9	$ 3,380	$ 500	6.8	Replace fluorescent lamps with LED lamps; disconnect ballast
EEM-1C	LED Relamp	30		2,157	1.8	$ 210	$ 478	0.4	Screw-in or Socket based LED lamps
EEM-1L	No change	26		204	0.1	$ 7	$ 37	0.2	
EEM-1O	Remote Occ Sensor	8	1,357			$ 1,920	$ 155	12.4	Remote Mounted Occupancy Sensor
		115	1,357	4,604	3.8	$ 5,518	$ 1,169		
	Gross Energy Savings		5,961	kwh					
	Net Energy Savings		**6,914**	**kwh**	**4.5**	**-105**	**gal.**	**$ 1,014**	**net**

PAYBACK PERIOD:

Estimated Cost Interior Lighting:	$ 5,518 = 5.4 year payback
Annual Energy Savings (kWh + kW):	$ 1,014

CALCULATIONS FOR EXTERIOR LIGHTING RETROFIT

EEM-2 Town of Pound Ridge - Town House

	Electricity	
Unit cost:	$ 0.114	/kwh
kW demand	$ 10.85	
Months of demand savings:	0	months/year

Existing Exterior Lighting Systems / **Recommended Lighting Controls**

Line #	Area	Qty	Present Lighting Type	Lamps /fixt	Watts /Fixt	Control Type	% Reduction	Present Hrs./yr.	Proposed Hrs./yr.	# Controls required
1	Front	3	LED area light, 28W	1	28	No Change	0%	4,380	4,380	0
2	Side	2	100 watt Incandescent	2	200	No Change	0%	100	100	0
3	Front	2	15w CFL Spiral Elec. ba	1	15	No Change	0%	1,000	1,000	0
		7			0.5	kW				0

Recommended Exterior Lighting Efficiency Improvements

Line #	Measure Type	Qty	Proposed Lighting Type	Lamps /fixt	Reflect or ?	Watts /Fixt	Project Cost	Annual Savings	kWh/yr. Savings	Payback (Years)
1	No change	3	LED area light, 28W	1		28	$ 0	$ 0	0	
2	LED Relamp	2	PAR30 LED, 12W	2		24	$ 42	$ 4	35	10.6
3	No change	2	15w CFL Spiral Elec.	1		15	$ 0	$ 0	0	
		7				0.2	kW			

Energy & Demand Calculations

Line #	Demand: Present kW	Demand: Proposed kW	Demand: kW Saved	Total Use: Present kwh/year	Total Use: Proposed kwh/year	Energy Savings: Controls kwh/year	Energy Savings: Efficiency kwh/year
1	0.1	0.1	0.0	368	368	0	0
2	0.4	0.0	0.4	40	5	0	35
3	0.0	0.0	0.0	30	30	0	0
	0.5	0.2	0.4	438	403	0	35
						35	kwh

SUMMARY OF SAVINGS BY MEASURE TYPE:

Measure Type	Fixture Qty.	Energy Savings: Controls kwh/year	Energy Savings: Efficiency kwh/year	kW Reduction	Project Cost	Annual Savings	Payback (Years)	Measure Description
LED Relamp	2		35	0.4	$ 42	$ 4	10.6	
	2	0	35	0.4	$ 42	$ 4	10.6	
		35	kwh					

PAYBACK PERIOD:

Estimated Cost Exterior Lighting:	$ 42	= 10.6 year payback
Annual Energy Savings (kWh + kW):	$ 4	

CALCULATIONS TO IMPROVE TEMPERATURE CONTROL

EEM-3 **Town of Pound Ridge - Town House**

INPUT DATA: 100% of Building to be Setback

		Current	Proposed	
Heating T Setpoint:	Occupied	70	70	deg. F.
	Unoccupied	70	66	deg. F.
Cooling T Setpoint:	Occupied	74	74	deg. F.
	Unoccupied	74	78	deg. F.
HVAC Schedule	Occupied	40.0	40.0	Hours per week
	Unoccupied	128.0	128.0	Hours per week
Q internal gains:	Occupied	44,988	44,988	Btuh
	Unoccupied	16,075	16,075	Btuh
Q internal gains:	Schedule	40	40	Hours per week
BLC:	Occupied	1,840	1,840	Btuh/deg. F.
(excludes DOAS)	Unoccupied	2,165	2,165	Btuh/deg. F.

	Heating	Cooling		
Fuel Data				
Type:	Oil - No. 2	Electricity	Economizer?	
Units:	gal.	kwh	0.0	
Unit cost:	$ 3.443	$ 0.114		
BTU/unit	138,000	3,412		
Efficiency/ COP:	78.0%	2.64	Avg. COP. EER:	9.0
		100.0%	of bldg. is cooled	

CALCULATIONS:

Current — White Plains, 40 hrs./week

Bin Mid Pt.	Occupied Hours	Unoccupied Hours	Occ Net Heat Loss BTUH	Unocc Net Heat Loss BTUH	Heating Fuel Use gal.	Cooling Energy kwh
2.5	0	17	79,245	130,081	21	0
7.5	2	41	70,043	119,255	47	0
12.5	6	84	60,840	108,429	88	0
17.5	39	179	51,638	97,602	181	0
22.5	52	421	42,436	86,776	360	0
27.5	97	332	33,233	75,949	264	0
32.5	142	509	24,031	65,123	340	0
37.5	148	553	14,828	54,297	299	0
42.5	117	661	5,626	43,470	273	0
47.5	179	685	0	32,644	208	0
52.5	136	457	(5,417)	21,817	93	82
57.5	196	615	(14,620)	10,991	63	318
62.5	214	834	(23,822)	165	1	567
67.5	220	626	(33,025)	(2,001)	0	947
72.5	225	326	(42,227)	(12,827)	0	1,521
77.5	152	182	(51,429)	(23,654)	0	1,347
82.5	100	113	(60,632)	(34,480)	0	1,107
87.5	42	29	(69,834)	(45,306)	0	472
92.5	18	6	(79,037)	(56,133)	0	196
97.5	3	2	(88,239)	(66,959)	0	44
102.5	0	0	(97,442)	(77,786)	0	0
107.5	0	0	(106,644)	(88,612)	0	0
112.5	0	0	(115,847)	(99,438)	0	0
117.5	0	0	(125,049)	(110,265)	0	0
	8,760	hours			2,237	6,601

Proposed — White Plains, 40 hrs./week

Bin Mid Pt.	Occupied Hours	Unoccupied Hours	Occ Net Heat Loss BTUH	Unocc Net Heat Loss BTUH	Heating Fuel Use gal.	Cooling Energy kwh
2.5	0	17	79,245	121,420	19	0
7.5	2	41	70,043	110,594	43	0
12.5	6	84	60,840	99,768	81	0
17.5	39	179	51,638	88,941	167	0
22.5	52	421	42,436	78,115	326	0
27.5	97	332	33,233	67,288	237	0
32.5	142	509	24,031	56,462	299	0
37.5	148	553	14,828	45,635	255	0
42.5	117	661	5,626	34,809	220	0
47.5	179	685	0	23,983	153	0
52.5	136	457	(5,417)	13,156	56	82
57.5	196	615	(14,620)	2,330	13	318
62.5	214	834	(23,822)	0	0	567
67.5	220	626	(33,025)	0	0	808
72.5	225	326	(42,227)	(4,166)	0	1,207
77.5	152	182	(51,429)	(14,992)	0	1,172
82.5	100	113	(60,632)	(25,819)	0	998
87.5	42	29	(69,834)	(36,645)	0	444
92.5	18	6	(79,037)	(47,472)	0	190
97.5	3	2	(88,239)	(58,298)	0	42
102.5	0	0	(97,442)	(69,125)	0	0
107.5	0	0	(106,644)	(79,951)	0	0
112.5	0	0	(115,847)	(90,777)	0	0
117.5	0	0	(125,049)	(101,604)	0	0
	8,760	hours			1,869	5,828

	Present	Proposed	Savings	
Heating	2,237	1,869	368	gal.
Cooling	6,601	5,828	773	kwh
Annual Energy $			$ 1,354	

IMPLEMENTATION COST & PAYBACK PERIOD:

Item	Material $/unit	Labor $/unit	Quantity	Total
Wi-fi thermostat	$ 200	$ 100	9	$ 2,700
				$ 0
				$ 2,700

Implementation Cost:	$ 2,700	= 2 year payback
Annual Energy Savings:	$1,354	

CALCULATIONS TO INSULATE BUILDING ENVELOPE

EEM-4 **Town of Pound Ridge - Town House**

INPUT DATA:

	Roof	Walls		
Surface to be insulated:	Roof	Walls		
Area:	3,589	3,497	sq ft	
Present R value:	10.0	3.7		
Revised R value	38.0	10.0		
Present U factor::	0.100	0.272	Btuh/sq ft-deg F	
Revised U factor:	0.026	0.100	Btuh/sq ft-deg F	
Present U x Area	359	950	1,309	UA Total present
Proposed U x Area	94	350	444	UA Total proposed

CALCULATIONS:	Occupied	Unoccupied	**Fuel Data**	Heating	Cooling
Heating Setpoint:	70	70	Type:	Oil - No. 2	Electricity
Cooling Setpoint:	74	74	Units:	gal.	kwh
Q internal gains (Btuh):	44,988	16,075	Unit cost:	$ 3.443	$ 0.114
BLC (Btuh/degree F):	1,840	2,165	BTU/unit	138,000	3,412
T Balance (°F.):	45.6	62.6	Efficiency/ COP:	78.0%	263.8%
T Balance = T Setpoint - (Q internal gains / BLC)			EER:		9.0

Bin Mid-Pt.	Occupied Hours	Unoccupied Hours	Change in Occupied Heat Loss	Change in Unoccupied Heat Loss	Heating Savings gal.	Cooling Savings kwh
2.5	0	17	58,393	58,393	9	0
7.5	2	41	54,068	54,068	22	0
12.5	6	84	49,742	49,742	42	0
17.5	39	179	45,417	45,417	92	0
22.5	52	421	41,092	41,092	181	0
27.5	97	332	36,766	36,766	147	0
32.5	142	509	32,441	32,441	196	0
37.5	148	553	28,115	28,115	183	0
42.5	117	661	23,790	23,790	172	0
47.5	179	685	0	19,464	124	0
52.5	136	457	0	15,139	64	0
57.5	196	615	0	10,814	62	0
62.5	214	834	0	6,488	50	0
67.5	220	626	0	0	0	0
72.5	225	326	0	0	0	0
77.5	152	182	(3,028)	(3,028)	0	112
82.5	100	113	(7,353)	(7,353)	0	174
87.5	42	29	(11,679)	(11,679)	0	92
92.5	18	6	(16,004)	(16,004)	0	43
97.5	3	2	(20,329)	(20,329)	0	11
102.5	0	0	(24,655)	(24,655)	0	0
107.5	0	0	(28,980)	(28,980)	0	0
112.5	0	0	(33,306)	(33,306)	0	0
117.5	0	0	(37,631)	(37,631)	0	0
	8,760	hours		Energy Savings:	1,343	432
					$ 4,623	$ 49

IMPLEMENTATION COST & PAYBACK PERIOD:

Item	Material & Labor ($ / sq ft)	Quantity	Total
Roof	$ 5.00	3,589	$ 17,944
Walls	$ 10.00	3,497	$ 34,974
	$ 0.00	7,086	$ 0

Implementation Cost:	$ 52,918	= 11.3 year payback
Annual Energy Savings:	$ 4,673	

CALCULATIONS TO INSTALL DOUBLE GLAZING

EEM-5 Town of Pound Ridge - Town House

Type:	Oil - No. 2
Units:	**gal.**
Unit cost:	**$ 3.443** /gal.
Heat Content of Fuel	**138,000** Btu/gal.
Combustion Efficiency:	78%

DATA:

	Occupied	Unoccupied	
T Setpoint:	**70**	**70**	degrees F
Q internal gains:	**44,988**	**16,075**	Btuh
BLC:	**1,840**	**2,165**	Btuh/degree F
T Balance:	45.6	62.6	degrees F

T Balance = T Setpoint - (Q internal gains / BLC)

Glazing Information

	Glazing 1		Glazing 2	
Present Conditions	Double glazed windows		Single glazed windows	
Present Area:	**96**	sq ft	**409**	sq ft
U factor:	**0.50**	Btuh/sq ft-deg F	**1.11**	Btuh/sq ft-deg F
Crack Length:	112	feet	477	feet
Present Infiltration:	10	cfh	20	cfh
Proposed Condition	Double glazed casement windows		Double glazed casement windows	
Proposed Area:	**96**	sq ft	**409**	sq ft
New U factor:	0.50	Btuh/sq ft-deg F	0.33	Btuh/sq ft-deg F
New Crack Length:	112	feet	477	feet
Proposed Infiltration:	10	cfh	10	cfh

Bin Data for White Plains, 40 hrs./week

	T Setpoint	T Balance	Accum Hours	Average O.A. Temp below T Balance	Temp Difference (T Set- Avg OAT)
Occupied	70	45.6	**603**	**32.7**	37.3
Unoccupied	70	62.6	**5,388**	**43.2**	26.8

CALCULATIONS:

Conduction Savings = (AreaPr x Upr) - (AreaRev x Urev + AreaInfill x Uinfill) x Accum Hours x Temp Diffe

Infiltration Savings = 1/2 x 0.018 x {(LengthPr x Ipr) - (Length Rev x Irev)} x Accum Hours x Temp Differen

Energy Cost Savings = (Energy Savings / Conversion Factor) x (Unit cost / Efficiency)

Winter	Conduction Savings (Btu/year)	Infiltration Savings (Btu/year)	Total Savings (Btu/year)	Total Annual Fuel Savings (gal./year)	Energy Cost Savings ($/year)
Occupied	7,169,000	964,000	8,133,000	76	$ 260
Unoccupied	46,162,000	6,205,000	52,367,000	486	$ 1,675
Annual Savings:	53,331,000	7,169,000	60,500,000	562	$ 1,935

IMPLEMENTATION COST & PAYBACK PERIOD:

Item	Material & Labor $ / sq. ft.	Quantity	Total	
		0	$ 0	
	$ 90	409	$ 36,774	
	Implementation Cost:		$ 36,774	= 19 year payback
	Annual Energy Savings:		$ 1,935	

CALCULATIONS TO INSTALL DUCT INSULATION

EEM-6 Town of Pound Ridge - Town House

Input

Type		Units	Unit cost	BTU/Unit	Efficiency
Electricity		kwh	$ 0.114	3,412	266%

Present Annual Cooling Consumption:	6,955	kwh/ year
Example Ducts		
Duct length 1:	10	feet
Duct perimeter 1:	48	inches
Duct length 2:	20	feet
Duct perimeter 2:	48	inches
Duct temperature:	55	F
Ambient temperature:	85	F
AC EFLH	580	hours per year
Hours per year duct is cool:	638	hours per year
Proposed insulation thickness	2	inches

Calculations

Furnace run time = heating fuel use / furnace input capacity

Hours per year duct is hot = Furnace run time * 110%

Heat Loss = Heat Loss Factor * (Duct Temp - Ambient Temp) * Duct Area * Hours Per Year Duct Is Hot

Energy Savings = Existing Heat Loss - Proposed Heat Loss

Energy Cost Savings = (Energy Savings / Conversion Factor) x (Unit cost / Efficiency)

Natural convection heat transfer coefficient: 0.90 Btu/hr/SF/F

Assumes fiberglass insulation, k =.35 Btu-in/hr/F/ft2

Duct area	120	square feet		
Existing heat loss factor	0.90	Btuh/SF/°F	R-value:	1.1
Existing heat loss	-2,065,717	Btu per year		
Proposed heat loss factor	0.15	Btuh/SF/°F	R-value:	6.8
Proposed heat loss	-336,280	Btu per year		
Energy savings	1,729,438	Btu per year		
Energy savings	190	kwhs		
Energy cost savings	$22			

Implementation Cost and Payback Period

Item	Material & Labor ($ / sq ft)	Quantity	Total
2" fiberglass duct insulation	$10.00	120	$1,200
		Implementation Cost:	$1,200

Cost	$1,200	=	55.3	years
Annual Savings	$22			

CALCULATIONS TO INSULATE HEATING AND DOMESTIC HOT WATER PIPES

EEM-7 Town of Pound Ridge - Town House

Input Data

		Type:	Units:	Unit cost:	BTU/unit	Efficiency
Fuel Information						
	Heating System	Oil - No. 2	gal.	$ 3.443	138,000	78%
	DHW System	Oil - No. 2	gal.	$ 3.443	138,000	78%

	Type #1	Type #2	Type #3		
Fluid	Hot Water	DHW	DHW		
Pipe Material	Dull Copper	Dull Copper	Dull Copper		
O.D., inches (d)	2.00	0.50	1.00		
Total Length, ft	10	25	10		
Fluid Temperature Inside Pipe, °F (Ts)	160	123	123		
Ambient Temperature, °F (Ta)	65	65	65		
Annual Operating Hours	603	8,760	8,760		
New Insulation Thickness, inches	2.0	0.5	1.0		
Thermal Conductivity - "k" (Btu-in/hr-sq ft-°F)	0.260	0.250	0.250		
Heat Loss - Bare Pipe					
C factor	1.016	1.016	1.016		
emissivity based on pipe material	0.44	0.44	0.44		
Outside Radius Pipe, inches (Ri)	1.00	0.25	0.50		
h convection, Btu/hr - s.f. pipe surface area -°F	1.26	1.51	1.31		
h radiation, Btu/hr - s.f. pipe surface area - °F	0.57	0.51	0.51		
h total	1.83	2.02	1.83		
Pipe area, sq ft/lin ft of pipe	0.523	0.131	0.262		
Q bare, Btu/hr-lin ft	**91**	**15**	**28**		
Heat Loss - Insulated Pipe					
Outside Radius Insulation, inches (Rs)	3.00	0.75	1.50		
Q i, Btu/hr-sq ft of outer area of insulation	7.5	17.6	8.8		
Insulation Area - sq ft/lin ft of pipe	1.6	0.4	0.8		
Q insul, Btu/hr-lin ft	**11.8**	**6.9**	**6.9**		
Avoided Energy Loss					
Existing Loss - mmBtu/year	0.5	3.4	2.4		
Proposed Loss - mmBtu/year	0.1	1.5	0.6		
Avoided Loss - mmBtu/year	0.5	1.9	1.8		
Total Avoided Fuel Consumption					
39 — Units Saved	4	17	17		
Oil - No. 2 — Fuel Type	Oil - No. 2	Oil - No. 2	Oil - No. 2		
$ 133 — $/year	**$ 15**	**$ 59**	**$ 58**		

Formulae:

Based on ASHRAE 1993 Fundamentals Handbook pages 20.9 and 22.17

h convection = C x {(1 / d) ^ 0.2} x { (1 / ((Ts + Ta)/2)) ^ 0.181 } x { (Ts - Ta) ^ 0.266 }

h radiation = { emissivity x 0.1713 x 10 ^ -8 x [(Ta + 460) ^ 4 - (Ts +460) ^ 4]} / (Ta - Ts)

Q bare = h total x Pipe Area x (Ts - Ta)

Q i = (Ts - Ta) / { [Rs x (ln (Rs / Ri)] / k }

Q insul = Q i x Insul Area

Total Avoided Consumption = (Q bare - Q insul) x Total length of pipe x Annual Operating Hours

Payback Period:

Implementation Cost:	$ 349	= 2.6 years payback
Annual Energy Savings:	$ 133	

CALCULATIONS TO Install Motor Controls

EEM-8 Town of Pound Ridge - Town House

DATA AND CALCULATIONS:

Electricity costs:

kWh:	$ 0.114	per kWh
Demand:	$ 10.85	per kW

Formulae:

Demand kW = (Qty x HP x 0.746 kW/HP x % Load) / % Efficiency

Annual kWh = Demand kW x Annual Hours

Demand $ Savings = (Present kW - New kW) x months of demand x Monthly demand charge

kWh $ Savings = (Present kWh - New kWh) x Cost per kWh

		Motor			Motor		Annual Motor		Months of
		Nominal		Loading	Efficiency		Run Hours		Demand
#	Description	HP	Qty	vs. Nom.	Present	New	Existing	New	Savings
1	CHW/HHW Pump	1/3	1	75%	68.0%	68.0%	4,380	2,190	0
2	CHW/HHW Pump	1/2	1	75%	68.0%	70.0%	4,380	2,190	0
3									0
4									0
5									0
6									0

		Total	Demand kW		Annual kWh		Motor	$ Savings	Cost
#	Description	BHP/	Present	New	Present	New	Type	Total	$
1	CHW/HHW Pump	0.2	0.3	0.3	1,189	595		$ 68	
2	CHW/HHW Pump	0.4	0.4	0.4	1,802	875		$ 106	
3									
4									
5									
6									
		0.6	0.7	0.7	2,991	1,470		$ 173	$ 0

ODP = open drip-proof

TEFC = totally enclosed fan-cooled

Peak KW Demand Savings:	0.0	kW	
Annual KW Demand Savings:	0.0	kW	$ 0
Annual kWh Savings:	1,521	kWh	$ 173
Total:			$ 173

IMPLEMENTATION COST AND PAYBACK PERIOD:

Implementation Cost	$300	= 1.7 years payback
Annual Energy Savings	$173	

CALCULATIONS TO REPLACE CONDENSING UNITS

EEM-9 **Town of Pound Ridge - Town House**

INPUT DATA

kWh:	$ 0.114	per kWh
Demand:	$ 10.85	per kW
months /yr. demand:	5	
Coincidence Factor CF:	0.80	

Location or Area Served	Main Office	Addition			
Unit Tag	Trane	Lennox			
tons/unit	3.0	3.5			
# of Units	2	1			
Unit Type (AC or HP)	AC	AC			
EFLH cool	580	497			
Present Efficiency EER *	9.0	9.0			
Present Efficiency SEER *	10.0	10.0			
Proposed Efficiency EER **	13.0	13.0			
Proposed Efficiency SEER **	17.0	17.0			

CALCULATIONS:

						Sum
Present kwh/year Cooling	4,173	2,087				6,260
Present kwh/year Heating	-	-				-
Proposed kwh/year Cooling	2,455	1,227				3,682
Proposed kwh/year Heating	-	-				-
Efficiency ΔkWh =	1,718	859				2,578
Economizer ΔkWh =	-	-				0
<u>Demand Savings</u>						
Present kW (peak)	6.4	3.7				10.1
Proposed kW (peak)	4.4	2.6				7.0
ΔkW =	2.0	1.1				3.1

FORMULAE:

New York Standard Approach for Estimating Energy Savings-Residential, Multi-Family and Commercial/Industrial Measures:

ΔkWh eff cooling = units x tons/unit x (12/SEERbase-12/SEERee) x EFLHcooling

ΔkWh eff heating = units x kBtuh/unit /3.412 x (1/COPbase-1/COPee) x EFLHheating

ΔkWh econ = units x tons/unit x kwh economizer savings per ton (from Tech Manual Appendix J)

ΔkW = units x tons/unit x (12/EERbase-12/EERee) x CF

EFLHcool = Annual kWhcooling/kWpeak cooling without economizer (from Appendix G)

** Present EER and SEER are based on 2000*

*** Proposed EER and SEER are based on NYSECCC (IECC-2015)*

Existing Energy Consumption	6,260	kwh/yr	10.1	kW peak
Proposed Energy Consumption	3,682	kwh/yr	7.0	kW peak
Annual Energy Savings	2,578	kwh/yr	3.1	kW peak

IMPLEMENTATION COST AND PAYBACK PERIOD:

Replacement cost is estimated at $ 2,000 per installed ton of capacity

Implementation Cost	$19,000	= 41 years payback
Annual Energy Savings	$463	

CALCULATIONS TO INSTALL A MORE EFFICIENT BOILER

EEM-10 Town of Pound Ridge - Town House

INPUT DATA:

Present Annual Heating Fuel Consumption:	2,232	gal.s
% of Building Served by Boiler	86%	
Boiler Fuel Use	1,918	gal.s

Fuel Data	Present		Proposed	
Type:	Oil - No. 2		Oil - No. 2	
Units:	gal.		gal.	
Unit cost:	$ 3.443	/gal.	$ 3.443	/gal.
BTU/Unit	138,000	Btu/gal.	138,000	Btu/gal.

Boiler Type	Present		Proposed	
Boiler Firing Rate	245	kBtuh Input	245	kBtuh Input
Combustion Efficiency	85.0%		95.0%	annual avg.
Jacket Losses	3.0%	of capacity	1.0%	of capacity
Boiler Capacity	**201**	kBtuh Outpu	**230**	kBtuh Output
Off-cycle Flue Losses	4.0%	of capacity	0.5%	of capacity
Boiler is hot when OAT<	65	°F.	65	°F.
Hours/ Yr. Unit is Hot	5,052	hrs.	5,052	hrs.
Off-Cycle Hours/Year	3,972	hrs.	4,303	hrs.
Standby Losses	30	MMBtu	12	MMBtu
Off-Cycle Flue Losses	32	MMBtu	5	MMBtu
Useful Heat Output	163	MMBtu	163	MMBtu

CALCULATIONS:

Off-Cycle Flue Losses = Boiler kBtuh Output x 1000 x % Off-Cycle Flue Losses x Hrs Off-Cycle per Year / 1,000,000

Jacket Losses = Boiler kBtuh Output x 1000 x % Jacket Losses x Hrs Hot per Year / 1,000,000

Useful Heat Output = Htg Fuel Use x BTU per Unit x Present Efficiency / 1,000,000 - Off Cycle Losses - Jacket Losses

Proposed Annual Fuel Consumption =

(Proposed Standby Losses + Useful Heat Output) / Proposed Efficiency x 1,000,000 / BTU per Unit

	Annual Fuel Consumption		Annual Cost
Present:	1,918	gal.	$ 6,603
Proposed:	1,367	gal.	$ 4,706
Annual Savings:	551	gal.	$ 1,897

IMPLEMENTATION COST & PAYBACK PERIOD:

Item	Quantity	Material	Labor	Total
New Boiler	1	$ 12,500	$ 2,500	$ 15,000
	0	$ 0	$ 0	$ 0
Totals:				$ 15,000

Implementation Cost	$ 15,000	= 7.9 year payback
Annual Energy Savings	$ 1,897	

CALCULATIONS TO INSTALL A TANKLESS WATER HEATER

BE-1 Town of Pound Ridge - Town House

INPUT DATA:					
		Present Fuel		Proposed Fuel	
	Fuel:	**Oil - No. 2**		Electricity	
	Units:	gal.		kwh	
	Fuel Cost:	$ 3.44	per gal.	$ 0.11	per kwh
	BTU / unit:	138,000	Btu per gal.	3,412	Btu per kwh
	kW Demand cost:	$ 0.00	per kW	$ 10.85	per kW
	Average kW demand:	**0.0**	kW	**1.6**	kW
	Demand Diversity:	**33%**		**90%**	
	Net kW Demand Savings:	-	kW per month	1.5	kW per month
	Months of demand:	**12**	per year	**12**	per year
Annual DHW Consumption:		Present		Proposed	
	Hot Water Usage:	**2.0**	Gallons/person	2.0	Gallons/person
	Number of persons:	**40**	(estimate)	40	(estimate)
	Days of Usage:	**250**	per year	250	per year
	Hours of Usage per Day:	8	hours	8	hours
	Average inlet water Temp	57	degrees F	57	degrees F
	Average hot water temp:	123	degrees F	123	degrees F
Storage Tank Losses:		Present Tank		Proposed Tank	
	Tank U factor:		Btu/SF/Hour	0.09	Btu/SF/Hour
	Height of Tank:		inches	15.0	inches
	Diameter of Tank:		inches	10.0	inches
			gallons/tank	3	gallons/tank
	# of Tanks		Qty.	1	Qty.
	Hours Tank is Hot:		Hours	8,760	
	Water Temperature:		Deg. F.	123	
	Ambient Temperature:		Deg. F.	65	
Recirculation Losses:		0.0%	of boiler capacity =	0	BTUh
		0	hours/year	8,760	hours/year =
Boiler Jacket & Flue Losses:					
	Burner Input	245,000	BTUH	8,533	BTUH
	COP:	**0.78**		1.00	COP
	Boiler Output Capacity	191,100	BTU output	8,533	BTU output
	Jacket & Flue Losses:	1.5%	of boiler capacity	0.0%	of boiler capacity
	Boiler is Hot:	8,760	hours/year	8,760	hours/year =
CALCULATIONS:					
		Present		Proposed	
	Consumption Energy:	11,061,525	BTU output rqd/yr	11,061,525	BTU output rqd/yr
	Tank Energy Losses:	0	BTU/year	201,500	BTU/year
	Recirculation Losses:	0	BTU/year	0	BTU/year
	Boiler Jacket Losses:	25,110,540	BTU/year	0	BTU/year
	Output BTU/Year	36,172,065		11,263,024	
	Annual Fuel Consumption	336	gal.	3,301	kwh
	Demand	0	billed kW /yr.	18	kW
	Annual Fuel Cost	$ 1,157		$ 567	
	Annual Savings:	**336**	**gal.**	**$ 590**	**per year**
		(3,301)	**kwh**		
		(18)	billed kW /yr.		

CALCULATIONS TO INSTALL CLEAN HEATING SYSTEM - AIR SOURCE HEAT PUMP

BE-2 — **Town of Pound Ridge - Town House**

			Fuel Information			
Building Information	Assembly			Heating	Cooling	
Location	NYC	Climate Zone 4	Type:	Oil - No. 2	Electricity	
Portion of Building HP will serve:	100%		Units:	gal.	kwh	
Building Heating Load (BHL)	146,157	BTU/h	Unit cost:	$ 3.443	$ 0.114	/kwh
Building Cooling Load (BCL)	93,386	BTU/h	BTU/unit	138,000	3,412	/kwh
BEFLHheating	1,647	Hours	Heating Eff.	85%	$ 10.85	/kW
BEFLHcooling	670	Hours	CO2	22.48	1.16	lbs/unit

Existing System

Is baseline heating system electric?	N
Is baseline heating system fossil fuel?	Y
If yes, will it remain in place in the efficient case?	N
Present Heating System	Boiler, Hot Water, Oil Fired < 300 kBTU/h
Present Cooling System	Split System – Air Conditioner (<65 kBTU/h)
% of Portion to be served by ASHP that is presently cooled	100%

Proposed System

Does proposed ASHP require supplemental resistance heat?	Y			
ASHP Type	Central Ducted			
ASHP Application	Whole	(the ASHP will meet all of the heating load)		
Control Type	Integrated/Modulating			
Heating Capacity	150,000	BTU/h at 17°F	1.0	HP Sizing Ratio
Energy Efficiency Ratio	13.1	EERee		
Seasonal Energy Efficiency Ratio	15.0	SEER		
Heating Season Performance Factor	10.0	HSPF		
Resulting system to be modeled	**Scenario**	**1d**		

Central Ducted ASHP with Integrated/ Modulating controls sized to 100%

Adjusted Efficiency Values	Baseline	Energy Efficient				
SEERbaseline	9.0	14.4	EERseason,ee	1.520	c	cooling offset
EERbaseline	9.0	13.1	EERee	0.859	d	cooling slope
COPseason,baseline	1.00	2.52	COPseason,ee	0.824	a	heating offset
FElecHeat	0.00	1.00	FElecHeat,new	0.777	b	heating slope
EFFbaseline	0.78	1.00	Fload,cooling			
FFuelHeat	1.00	1.00	Fload,heating			
		1.00	Fload,heating,FuelHeat		0.69	CF
		1.00	Fload,heating,ElecHeat			

	Baseline	Energy Efficient	Savings	Units	Savings $	Savings CO2 Lbs/yr.
Cooling Electric Use (kWh/yr.)	6,953	4,344	2,609	kWh		
Heating Electric Use (kWh/yr.)	0	28,017	(28,017)	kWh		
Total Electric Use (kWh/yr.)	**6,953**	**32,361**	**(25,408)**	**kWh**	**($ 2,897)**	**(29,473)**
Peak Demand (kW)	7.2	4.9	2.2	kW	($ 611)	
Fossil Fuel Energy Use (MMBTU)	309	0	309	MMBtu		
Fossil Fuel Energy Use : gal.	**2,237**	**0**	**2,237**	**gal.**	**$ 7,702**	**50,285**
Annual Energy Costs	**$ 8,832**	**$ 4,638**	**$ 4,194**		$ 4,194	20,812
Estimated Project Cost	**$ 3,872**	**per ton =**	**$ 47,160**	**11**	**year payback**	

CALCULATIONS TO INSTALL CLEAN HEATING SYSTEM - GROUND SOURCE HEAT PUMP						
BE-3	**Town of Pound Ridge - Town House**					
			Fuel Information			
Building Information	Assembly			Heating	Cooling	
Location	NYC	Climate Zone 4	Type:	Oil - No. 2	Electricity	
Portion of Building HP will serve:	100%		Units:	gal.	kwh	
Building Heating Load (BHL)	146,157	BTU/h	Unit cost:	$ 3.443	$ 0.114	/kwh
Building Cooling Load (BCL)	93,386	BTU/h	BTU/unit	138,000	3,412	/kwh
BEFLHheating	1,647	Hours	Heating Eff.	85%	$ 10.85	/kW
BEFLHcooling	670	Hours	CO_2	22.48	1.16	lbs/unit
Existing System						
Is baseline heating system electric?	N					
Is baseline heating system fossil fuel?	Y					
Present Heating System	Boiler, Hot Water, Oil Fired < 300 kBTU/h					
Present Cooling System	Split System – Air Conditioner (<65 kBTU/h)					
% of Portion to be served by GSHP that is presently cooled		100%				
Proposed System						
GSHP Loop Type	Closed Loop	GLHP				
GSHP Compressor Type	Variable-Speed	0.40	Capacity Ratio			
Estimated Pump Power	45 watts per ton					
Pumping Control Strategy	Variable					
Heating Capacity	150,000	BTU	rating condition			
Energy Efficiency Ratio Full Load	17.0	EER GLHP,full	77	° EWT		
Energy Efficiency Ratio Part Load	22.0	EER GLHP,par	68	° EWT		
Heating COP Full Load	3.6	COP GLHP,full	32	° EWT		
Heating COP Part Load	4.1	COP GLHP,par	41	° EWT		
Adjusted Efficiency Values	Baseline	Energy Efficient				
EERseason,baseline	9.0	18.87	EERseason,ee			
EERpeak,baseline	9.0	17.0	EER GSHP, full,ee			
COPseason,baseline	1.00	3.68	COPseason,ee			
FElecHeat	0.00					
EFFbaseline	0.85	0.69	CF			
FFuelHeat	1.00					
					Savings	Savings
	Baseline	Energy Efficient	Savings	Units	$	CO_2 Lbs/yr.
Cooling Electric Use (kWh/yr.)	6,953	3,316	3,637	kWh		
Heating Electric Use (kWh/yr.)	0	19,168	(19,168)	kWh		
Total Electric Use (kWh/yr.)	**6,953**	**22,484**	**(15,531)**	**kWh**	**($ 1,771)**	**(18,016)**
Peak Demand (kW)	7.2	3.8	3.4	kW	($ 152)	
Fossil Fuel Energy Use (MMBTU)	283	0	283	MMBtu		
Fossil Fuel Energy Use : gal.	**2,053**	**0**	**2,053**	**gal.**	**$ 7,067**	**46,144**
Annual Energy Costs	**$ 8,535**	**$ 3,390**	**$ 5,145**		$ 5,145	28,128
Estimated Project Cost	**$ 11,965**	**per ton =**	**$ 145,730**	**28**	**year payback**	

Appendix D

Assumptions/Data Used to Develop Energy and Dollar Savings Figures

Building and Occupancy Information

Floor Area: 6,420 square feet

	Avg. # of occupants	Heating Setpoint	Cooling Setpoint		% of base electricity use resulting in internal heat gains
days /occupied	20	70	74	days	100%
nights/unoccupied	0	70	74	nights	100%
# of computer	20				

Interior lighting, people and occupied levels of internal loads occur for 40 hours per week

Electricity use at night is usually 40% of the usual electricity use during day periods

(This results in an average daytime kW that is 89% of the peak metered kW)

Heating System Information

		% of bldg. served	COP heat	EER	Heat kBTUH	Heating Fuel	Efficiency	
Primary system:	Non-Condensing Boiler	100%	0.85	9.00	245	Oil - No. 2	85.0%	Et
Secondary:		0%						Et

100% of building is air conditioned Does the cooling system have economizer?

Describe the **direct outside air** or **central make-up air** system: Fuel: ___ Eff. ___ EER for DOAS

cfm outside air, running

hours / week ___ heat recovery efficiency

Domestic Hot Water

	Fuel	Efficiency					
DHW system energy type	Oil - No. 2	85%	Is there a pump to circulate DHW?	No			
Hot Water usage is	1.0	gallons per	person	/ day for	20	persons on	250 days/year

Weather & Schedule Information:

Select nearest weather station for bin data:	WHITE PLAINS		for TRM:	NYC
Base temperature for heating degree days:	65 °F. yields	5,950 HDD base65	for TRM:	Assembly
Base temperature for cooling degree days:	70 °F. yields	342 CDD base70	for TRM:	AC with Gas Heat

Present Schedule for Occupied/Day HVAC setpoints

Day of week		Start	End	Hours
Sun	1	12:00 AM	12:00 AM	-
Mon	2	9:00 AM	5:00 PM	8.0
Tue	3	9:00 AM	5:00 PM	8.0
Wed	4	9:00 AM	5:00 PM	8.0
Thu	5	9:00 AM	5:00 PM	8.0
Fri	6	9:00 AM	5:00 PM	8.0
Sat	7	12:00 AM	12:00 AM	-
White Plains, 40 hrs./week				40.0
				128.0

Proposed Schedule for Occupied/Day HVAC setpoints

Day of week	Start	End	Hours
1	12:00 AM	12:00 AM	-
2	9:00 AM	5:00 PM	8.0
3	9:00 AM	5:00 PM	8.0
4	9:00 AM	5:00 PM	8.0
5	9:00 AM	5:00 PM	8.0
6	9:00 AM	5:00 PM	8.0
7	12:00 AM	12:00 AM	-
White Plains, 40 hrs./week			40.0

ESTIMATE OF BUILDING LOAD COEFFICIENT & TRUE-UP TO BILLED ENERGY USE

Town of Pound Ridge - Town House
179 Westchester Ave.
Pound Ridge, NY 10576

Building Information

Width (typical)	54	feet	Building Floor Area	6,420	sq. ft.
Equivalent Length	60	feet	Roof Area	3,589	sq. ft.
Number of Floors	2.0	floors	Gross Wall Area	4,086	sq. ft.
Avg. Floor to Floor Height	9	feet per floor	Building Volume	57,780	cubic feet
Roof or Ceiling rise is	6	feet in 12' run			

Estimate of Conductive Heat Loss

Surface			Area	R-value	U Factor	U x A Btuh/deg. F.	% of BLC w/o ventilation
Roof	n/a		3,589	10.0	0.100	359	17%
Walls	85.6%	of GWA	3,497	3.7	0.272	950	44%
Glazing 1	2.3%	of GWA	96	2.0	0.500	48	2%
Glazing 2	10.0%	of GWA	409	0.9	1.111	454	21%
Doors 1	4	3x7 doors	84	2.0	0.500	42	2%
Doors 2	0	3x7 doors	0	1.7	0.588	0	0%
	Total Exterior Surface Area		7,675	sq.ft.		1,853	86%

		ACH	equiv. cfm	Btuh/deg. F.	BLC (without ventilation)	
Est. Infiltration Rate	Occupied	0.30	289	312	1,840	Btuh/deg. F. Occupied
Est. Infiltration Rate	Unoccupied	0.30	289	312	2,165	Btuh/deg. F. Unoccupied

		cfm	Fraction	Btuh/deg. F.	**Total BLC with Ventilation**	
Est. Ventilation Rate	Occupied	0	100%	0	**1,840**	**Btuh/deg. F. Occupied**
Est. Ventilation Rate	Unoccupied		100%	0	**2,165**	**Btuh/deg. F. Unoccupied**

Heat Gain Estimation

Estimated Solar Gain 15% of building heat loss during occupied periods will be met by solar gains

		kW	# People	Total BTUH	Hours/wk.
Loads & People	Occupied	**11.8**	**20**	44,988	40.0
	Unoccupied	**4.7**	**0**	16,075	128.0

Heat Loss Study - continued

Town of Pound Ridge - Town House
179 Westchester Ave.
Pound Ridge, NY 10576

		Current	
Heating T Setpoint:	Occupied	70	deg. F.
	Unoccupied	70	deg. F.
Cooling T Setpoint:	Occupied	74	deg. F.
	Unoccupied	74	deg. F.
HVAC Schedule	Occupied	40	Hrs. per week
	Unoccupied	128	Hrs. per week
Q internal gains:	Occupied	44,988	Btuh
	Unoccupied	16,075	Btuh
Q internal gains:	Schedule	40	Hrs. per week
BLC:	Occupied	1,840	Btuh/deg. F.
	Unoccupied	2,165	Btuh/deg. F.

Fuel Data	Heating	Cooling	
Type:	Oil - No. 2	Electricity	Economizer?
Units:	gal.	kwh	0.0
Unit cost:	$ 3.443	$ 0.114	
BTU/unit	138,000	3,412	
Nom. Eff, COP	0.85	2.638	COP
Avg. Eff, COP	0.78	2.64	Avg. COP
		9.0	Avg. EER
		100%	of bldg. cooled

DOAS Energy Use		
	0	cfm
	0%	heat recov. Eff.
Heating	0	
	0	
	0%	eff.
	0.00	COP cool
	0	hrs/week

Current — White Plains, 40 hrs./week

Bin Mid Pt.	Occupied Hours	Unoccupied Hours	Occ Net Heat Loss BTUH	Unocc Net Heat Loss BTUH	Heating Fuel Use gal.	Cooling Energy kwh	DOAS Hours	DOAS Heating kBtu/yr.
2.5	0	17	79,245	130,081	21	0	0	0
7.5	2	41	70,043	119,255	47	0	0	0
12.5	6	84	60,840	108,429	88	0	0	0
17.5	39	179	51,638	97,602	181	0	0	0
22.5	52	421	42,436	86,776	360	0	0	0
27.5	97	332	33,233	75,949	264	0	0	0
32.5	142	509	24,031	65,123	340	0	0	0
37.5	148	553	14,828	54,297	299	0	0	0
42.5	117	661	5,626	43,470	273	0	0	0
47.5	179	685	0	32,644	208	0	0	0
52.5	136	457	(5,417)	21,817	93	82	0	0
57.5	196	615	(14,620)	10,991	63	318	0	0
62.5	214	834	(23,822)	165	1	567	0	0
67.5	220	626	(33,025)	(2,001)	0	947	0	0
72.5	225	326	(44,303)	(14,903)	0	1,648	0	0
77.5	152	182	(54,118)	(26,342)	0	1,447	0	0
82.5	100	113	(63,667)	(37,515)	0	1,179	0	0
87.5	42	29	(74,877)	(50,349)	0	512	0	0
92.5	18	6	(84,019)	(61,115)	0	209	0	0
97.5	3	2	(93,386)	(72,106)	0	47	0	0
102.5	0	0	(97,442)	(77,786)	0	0	0	0
107.5	0	0	(106,644)	(88,612)	0	0	0	0
112.5	0	0	(115,847)	(99,438)	0	0	0	0
117.5	0	0	(125,049)	(110,265)	0	0	0	0
	8,760	hours			2,237	6,955	DOAS fuel use	0
							DOAS cool use	0

Cross Check Against Historic Consumption

	Historic		Calculated	Difference
Present Annual Heating Fuel Use is	308	mmBTU	309	100% of present fuel use

Appendix E

Clean Heating and Cooling Technology Overview

BENEFITS OF CLEAN HEATING AND COOLING (CHC) TECHNOLOGIES

Commercial building owners are becoming increasing aware of how their choice of HVAC system impacts bottom line operating costs and the environment. Most conventional heating systems either burn fuel or convert electricity into heat. CHC technologies, such as heat pumps, are different because they don't generate heat. Instead, they move existing heat energy from outside into your facility, which makes them more efficient since they deliver more heat energy than the electrical energy they consume.

There are many compelling reasons to install a CHC System in commercial buildings.

CHC systems:

- Can cost less to run than a traditional fossil fuel heating system.
- Integrate well with renewable and resilient building designs
- Offer the highest efficiency and most cost-effective space conditioning for HVAC
- Offer reduced maintenance costs because the exterior equipment is buried underground
- Offers flexible design and installation with many configurations available.
- Provides superior thermal comfort for all seasons.

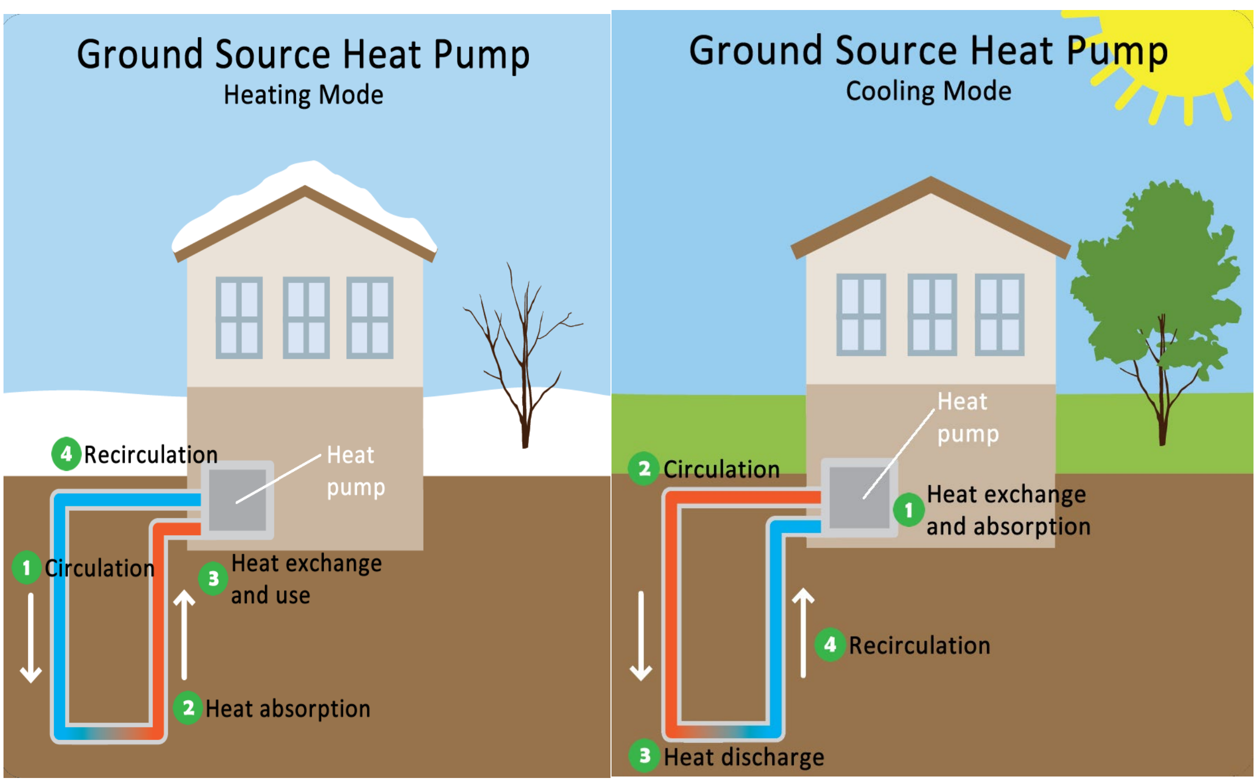
TYPES OF CLEAN HEATING AND COOLING (CHC) TECHNOLOGIES

What is a Ground Source Heat Pump (GSHP)?

GSHP's are self-contained electrically powered systems that provide heating and cooling more efficiently than other types of conventional HVAC systems. This increase in efficiency is obtained due to the GSHP systems coupling with the earth's relatively stable ground temperature. For example, while the temperature of the of the outside air may vary drastically from summer to winter, the ground temperature remains relatively stable, making it an ideal heat "source" for heating and heat "sink" for cooling.

The GSHP system utilizes an electric vapor compression refrigeration cycle to exchange energy between the building load and a ground coupled loop. When in heating mode, energy is transferred from the low temperature ground loop source to the higher temperature heat sink (the load).

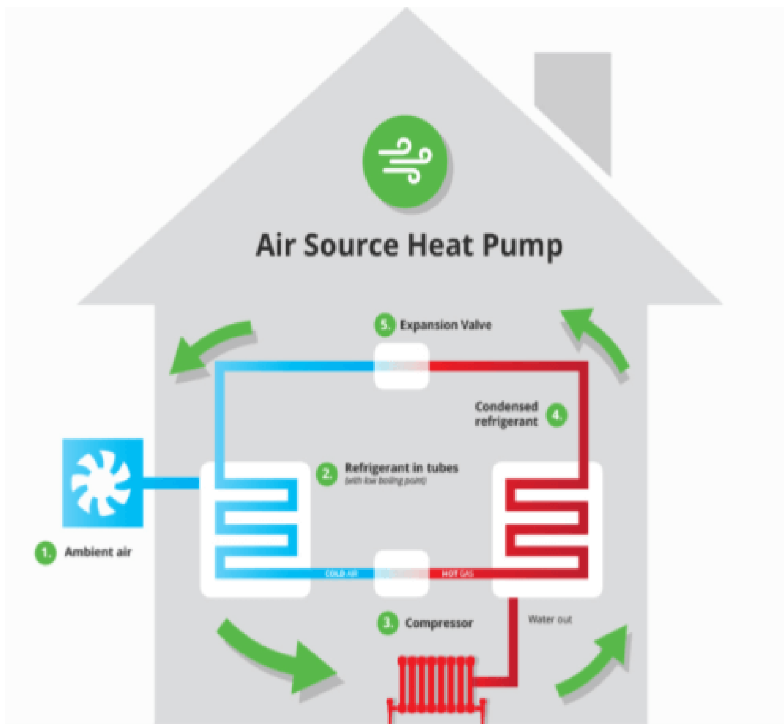
The system reverses during cooling, where the energy is absorbed by the ground loop.



Source: https://www.epa.gov/rhc/geothermal-heating-and-cooling-technologies

What is an Air Source Heat Pump (ASHP)?

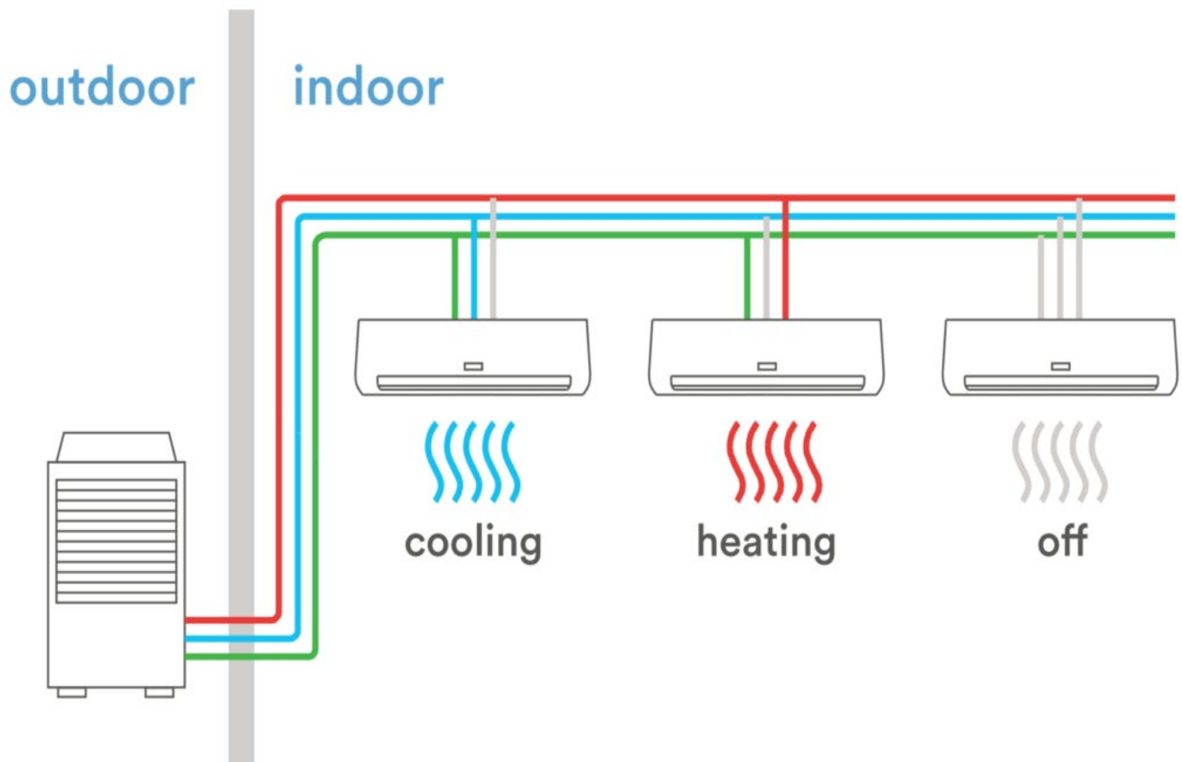
An air source heat pump works much like a refrigerator operating in reverse. Outside air is blown over a network of tubes filled with a refrigerant. This warms up the refrigerant, and it turns from a liquid into a gas. This gas passes through a compressor, which increases the pressure. Compression also adds more heat – similar to how the air hose warms up when you top up the air pressure in your tires. The compressed, hot gases pass into a heat exchanger, surrounded by cool air or water. The refrigerant transfers its heat to this cool air or water, making it warm. And this is circulated around your facility to provide heating and hot water. Meanwhile, the refrigerant condenses back into a cool liquid and starts the cycle all over again.



Source: https://www.ways2gogreenblog.com/2017/10/18/a-brief-introduction-to-air-source-heat-pumps/

What is a Variable Refrigerant Flow (VRF)?

VRF systems use heat pumps or heat recovery systems to provide heating and cooling for all indoor and outdoor units without the use of air ducts. With a VRF system, your building will have multiple indoor units utilized by a single outdoor condensing unit, either with a heat pump or heat recovery system. A VRF HVAC system can heat and cool different zones or rooms within a building at the same time. If the appropriate VRF system is selected, building occupants have the ability to customize the temperature settings to their personal preferences. VRF equipment can be used in conjunction with a wide range of heating and cooling products. This means that a VRF system can be scaled to meet the climate control needs.



Source: https://be-exchange.org/tech_primer/tech-primer-variable-refrigerant-flow-vrf-systems/

Appendix F

Energy Savings Summaries

Energy Efficiency Measures				GHG	Electric Savings			Fuel Savings			$ Savings & Cost		
EEM #	Measure Status	EEM Category	EEM Description	CO2e Lbs./Yr.	kWh	kW	Electric Cost Savings	Fuel Type	Fuel MMBtu Savings	Fuel Cost Savings	Total Annual Savings	Install Costs	Simple Payback (years)
EEM-1	R	Lighting	Interior Lighting Retrofit	5,655	6,914	4.5	$ 1,376	Oil - No. 2	(14.5)	($ 362)	$ 1,014	$ 5,518	5.4
EEM-2	R	Lighting	Exterior Lighting Retrofit	41	35	0.0	$ 4		0.0	$ 0	$ 4	$ 42	10.6
EEM-3	R	Controls	Improve Temperature Control	9,162	773	0.0	$ 88	Oil - No. 2	50.7	$ 1,266	$ 1,354	$ 2,700	2.0
EEM-4	RS	Envelope	Insulate Building Envelope	30,690	432	0.0	$ 49	Oil - No. 2	185.3	$ 4,623	$ 4,673	$ 52,918	11.3
EEM-5	RS	Envelope	Install Double Glazing	13,979	0	0.0	($ 206)	Oil - No. 2	85.8	$ 2,141	$ 1,935	$ 36,774	19.0
EEM-6	NR	HVAC	Install Duct Insulation	221	190	0.0	$ 22		0.0	$ 0	$ 22	$ 1,200	55.3
EEM-7	R	HVAC	Insulate Heating And Domestic Hot Water Pipes	868	0	0.0	$ 0	Oil - No. 2	5.3	$ 133	$ 133	$ 349	2.6
EEM-8	R	Motors	Install Motor Controls	1,765	1,521	0.0	$ 173		0.0	$ 0	$ 173	$ 300	1.7
EEM-9	NR	HVAC	Replace Condensing Units	2,990	2,578	3.1	$ 463		0.0	$ 0	$ 463	$ 19,000	41.0
EEM-10	ME	HVAC	Install A More Efficient Boiler	12,387	0	0.0	$ 0	Oil - No. 2	76.0	$ 1,897	$ 1,897	$ 15,000	7.9
			Total of Recommended Measures:	**17,491**	**9,243**	**4.5**	**$ 1,642**		**41.5**	**$ 1,037**	**$ 2,678**	**$ 8,909**	**3.3**

Building Electrification Measures					Savings & Cost								
EEM #	Measure Status	EEM Category	Building Electrification Measure Descriptions	CO2e Lbs./Yr.	kWh	kW	Electric Cost Savings	Fuel Type	Fuel MMBtu Savings	Fuel Cost Savings	Total Annual Savings	Install Costs	Simple Payback (years)
BE-1	R	DHW	Install A Tankless Water Heater	3,725	(3,301)	(1.5)	($ 567)	Oil - No. 2	46.4	$ 1,157	$ 590	$ 1,000	1.7
BE-2	RME	ASHP	Install Clean Heating System - Air Source Heat Pump	20,812	(25,408)	2.2	($ 3,508)	Oil - No. 2	308.7	$ 7,702	$ 4,194	$ 47,160	11.2
BE-3	ME	GSHP	Install Clean Heating System - Ground Source Heat Pump	28,128	(15,531)	3.4	($ 1,922)	Oil - No. 2	283.3	$ 7,067	$ 5,145	$ 145,730	28.3
			Total of Recommended Measures:	**24,537**	**(28,709)**	**0.8**	**($ 4,075)**	**$ 0**	**355.1**	**$ 8,859**	**$ 4,784**	**$ 48,160**	