NYSERDA FlexTech Study

Rhinebeck Village Hall
76 East Market Street

Submitted to:

NYSERDA
Efficiency Planning & Engineering
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Village of Rhinebeck
Rhinebeck Village Hall
76 East Market Street
Rhinebeck, New York 12572

Submitted from:

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EXECUTIVE SUMMARY

A comprehensive analysis of the Rhinebeck Village Hall, located at 76 East Market Street, in Rhinebeck NY, was conducted, with the primary goal of identifying and analyzing energy conservation measure upgrades that will have the largest impact on reducing the building's energy use. The services included performing an ASHRAE Level 1+ Audit and energy analysis to calculate and compare the annual energy consumption of various energy conservation measures and determine an estimated first cost, simple payback, estimated maintenance impact, and basic feasibility associated with each option.

M/E Engineering, P.C. performed a site inspection in September, 2021. For the purposes of this study, existing HVAC, lighting, electrical, domestic hot water and envelope systems were surveyed. The walk-through entailed observing existing systems and their operations, including obtaining equipment nameplate data, reviewing drawings, discussing concerns of the building owner, and verifying operational schedules. Energy Conservation Measures have been evaluated, and are summarized below.

Table 1: Energy Efficiency Measure Summary

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual Fossil Fuel Savings [Gal]	Annual Fossil Fuel Savings [mmBtu]	Annual Fossil Fuel Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]
1	High-Efficiency Lighting	15,500	7.71	$2,581	-185	-26	-275	26.95	$2,306	$29,500	12.8
2	Envelope Improvements- Roof and Wall	2,351	2.19	$392	1,114	156	1,653	163.95	$2,044	$142,305	69.6
3a	Code RTU with DX cooling	-113,144	4.46	-$18,843	4,329	606	6,424	219.84	-$12,419	$118,947	-9.6
3b	High Efficient RTU w/DX cooling	-93,463	8.82	-$15,566	5,045	706	7,487	387.26	-$8,079	$160,158	-19.8
3c	High Efficient Heat Pump	3,226	10.12	$537	5,045	706	7,487	717.26	$8,024	$212,902	26.5
3d	VRF System	5,067	12.53	$844	5,045	706	7,487	723.54	$8,330	$240,506	28.9
3e	Geothermal System	6,144	10.09	$1,023	5,045	706	7,487	727.22	$8,510	$487,178	57.2
4a	DHW Propane Fired Unit	7,676	0.17	$1,278	-48	1	-234	26.90	$1,044	$10,740	10.3
4b	DHW Electric Unit	224	0.04	$37	120	17	178	17.53	$215	$9,240	43.0
4c	DHW Air Source Heat Pump	5,019	0.06	$836	120	17	178	33.89	$1,014	$16,224	16.0
4d	DHW Geothermal Well Field	5,603	0.07	$933	120	17	178	35.89	$1,111	$19,224	17.3
5	Appliance Replacement & Hood Controls	6,026	1.02	$1,004	163	23	241	43.32	$1,245	$15,427	12.4

Several of the energy efficiency measures evaluated for this project have shown that their implementation will reduce the energy and carbon use of the facility. Some of these measures would also provide an additional benefit of improving occupant comfort by eliminating drafts, improving the lighting, optimizing system controls, consolidating air conditioning equipment and providing a more uniform space temperature profile, as well as addressing ventilation and filtration for a healthier building environment.

The measures that are recommended include EEM 1 high-efficiency lighting, EEM 2 addressing air infiltration, EEM3 3d VRF selecting an HVAC system upgrade, EEM 4c selecting a domestic hot water system upgrade, and EEM 5 appliance replacement and hood heat/smoke control. Discussion of these recommendations can be found in the "Energy Analysis" section of the report. Implementation incentives may be available but are not guaranteed, subject to change, are contingent on available funding, program eligibility and acceptance.

NYSERDA PROJECT SUMMARY SHEET

BASELINE ENERGY SUMMARY

	Electric (kWh)	Natural Gas (therms)	#2 Oil (gallons)	#4 Oil (gallons)	#6 Oil (gallons)	Steam (lbs.)	Propane (gallons)	Coal (tons)	Other (MMBtu)	Total Baseline Use (MMBtu)
Baseline Energy Use	34,663.0		6,131.1				286.1			**996.7**
										Total Annual Cost ($)
Average Utility Rate	$0.17		$1.48				$2.45			
Baseline Annual Cost	$5,773		$9,099				$700			**$15,572**

ENERGY SAVINGS SUMMARY

Measure Description	Measure Status [1]	Fuel Savings Type [2]	Electric Supply Savings (kWh)	Electric Demand Savings (kW)	Fuel Savings (MMBtu)	Energy Savings to Total Baseline Use (%) [3]	Annual Cost Savings	Cost Savings to Total Annual Cost (%) [4]	Project Cost	Simple Payback (Years)
EEM - 1 High Efficency Lighting	R	Oil2	15,500	7.71	-26.0	2.7%	$2,306	14.8%	$29,500	12.8
EEM - 2 Evelope Improvments- Roof, Wall	R	Oil2	2,351	2.19	155.9	16.4%	$2,044	13.1%	$142,305	69.6
EEM - 3a Code RTU with DX cooling	NR	Oil2	-113,144	4.46	606.0	22.1%	-$12,419	-79.8%	$118,947	-9.6
EEM - 3b High Efficient RTU w/DX Cooling	NR	Oil2	-93,463	8.82	706.2	38.9%	-$8,079	-51.9%	$160,158	-19.8
EEM - 3c High Efficient Heat Pump	NR	Oil2	3,226	10.12	706.2	72.0%	$8,024	51.5%	$212,902	26.5
EEM - 3d VRF System	R	Oil2	5,067	12.53	706.2	72.6%	$8,330	53.5%	$240,506	28.9
EEM - 3e Geothermal System	NR	Oil2	6,144	10.09	706.2	73.0%	$8,510	54.6%	$487,178	57.2
EEM - 4a DHW Propane Fired Unit	NR	Oil2	7,676	0.17	0.7	2.7%	$1,044	6.7%	$10,740	10.3
EEM - 4b DHW Electric Unit	NR	Oil2	224	0.04	16.8	1.8%	$215	1.4%	$9,240	43.0
EEM - 4c DHW Air Source Heat Pump	R	Oil2	5,019	0.06	16.8	3.4%	$1,014	6.5%	$16,224	16.0
EEM - 4d DHW Geothermal Well Field	RNE	Oil2	5,603	0.07	16.8	3.6%	$1,111	7.1%	$19,224	17.3
EEM - 5 Appliance Repl & Hood Ctrl	R	Oil2	6,026	1.02	22.8	4.3%	$1,245	8.0%	$15,427	12.4
		TOTAL (All):	-149,771	57.29	3,635	313.4%	$13,345	85.7%	$1,462,352	109.6
		TOTAL (Recommended Only):	**39,566**	**23.58**	**892**	**103.1%**	**$16,050**	**103.1%**	**$463,186**	**28.9**

Measure Status[1]

I	Implemented
R	Recommended
RS	Further Study Recommended
NR	Not Recommended
RME	Recommeded Mutually Exclusive
ME	Mutually Exclusive to Recommended Option
RNE	Recommended Non-Energy

Fuel Saved

Elec	Electric
NGas	Natural Gas
Oil2	#2 Oil
Oil4	#4 Oil
Oil6	#6 Oil
Steam	District Steam
LPG	Propane
Coal	Coal
Other	Other

MMBtu Conversion Factors

Btu	1,000,000
kWh	0.003412
therms	0.1
#2 gallon	0.139
#4 gallon	0.1467
#6 gallon	0.15
Steam lbs.	0.0012
LPG gallon	0.0915
Coal tons	24

Notes:

[2] Fuel Savings Type: Indicate the reported MMBtu savings fuel type. Select the predominant fuel type if there are MMBtu savings from multiple fuel sources

[3] Energy Savings to Total Fuel Baseline Use is a comparison of the total electric & fuel savings to the total baseline energy use

[4] Cost Savings to Total Annual Cost is a comparison of the total annual cost savings to the total baseline annual energy cost

Instructions:

* Fill in the light blue cells, as appropriate. White cells will auto-calculate.
* Energy savings must be presented as savings at the customer's utility meter(s), not at the individual building or tenant space
* Update the baseline energy use conversion factors in the 'References' tab, as necessary
* Unhide rows to enter more measures, as necessary

PROJECT OVERVIEW

The overall goal of this project is to provide a comprehensive analysis of the Rhinebeck Village Hall to identify options for energy improvements including upgrading / replacing the building HVAC systems, and to quantify the energy and cost impact of implementing the measures. This study is intended to focus on eligible areas of study under the NYSERDA FlexTech Program, which consists of the investigation of opportunities to reduce energy. An additional goal is to achieve carbon savings via load reduction and load shifting, and conversion to carbon free fuel. This study includes energy conservation measure analysis and strategic carbon footprint reduction planning, the integration of renewable generation, and the feasibility of incorporating clean heating and cooling technologies where possible. An additional objective is for the Owner to make use of the study as a roadmap to aid in identifying and planning for potential future capital projects, including potential clean energy projects. This includes calculating the annual energy savings associated with various energy efficiency measures, determining an estimated first cost, simple payback, estimated maintenance impact, and basic feasibility associated with each measure.

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EXISTING CONDITIONS

The Village of Rhinebeck, located in Central Hudson territory, Duchess County NY, is committed to mitigate climate change. The Village is participating in NY State's Climate Smart Communities Program and have set up a Climate Smart Task Force, which is "working to encourage, implement, and quantify the village's efforts to address the climate crisis". The goal is to make the village a more "just, resilient, and livable future in Rhinebeck".

The Rhinebeck Village Hall, is a 12,000 square foot, two-story facility built in 1970, comprised of a Village Hall and Fire Station in the same building that serves the community. In addition to the firetruck storage and maintenance bays, the facility houses Mayoral offices, clerk, radio/dispatch, offices of zoning and planning, meeting/court, kitchen, lounge/recreation and support spaces such as storage, restroom, lobby, corridor, stairs, and mechanical/electrical. The building contains a partial basement, a first, and a second floor. The building is of masonry construction with a brick façade with CMU backup and painted gypsum interior finish with no insulation, and flat EPDM roofs above a ventilated interstitial attic space. The roof was replaced in 2001 with a 20 year warranty by Carlisle (expired May 16, 2021). The building's windows replaced in 2011, are generally double panes with argon and low-e double hung, operable sash type. The fire hall contains four overhead garage doors. The typical operating hours are 10am-4pm, Monday-Friday.

The lighting in the facility is mostly fluorescent tube T-8 fixtures with prism lenses, with some lighting replaced with LED (i.e. track lighting in Radio/Dispatch room). Other spaces have track lighting with MR-16 halogen bulbs. Primary electrical service is 200A, 208V/3Ph and enters at the basement mechanical room. A generator is onsite for back-up power in case of an outage. Roof mounted solar PV panels produce power to supplement the building's purchased electricity.

The existing HVAC heating system consists of an oil fired hot water boiler with a 2-pipe pipe distribution system. The Weil McLain Series 84 cast iron boiler, original to the building, is fired by a Beckett model 301 CRD burner indicating 3 - 7.0 Gallons per hour of fuel consumption (depending on the combustion head adjustment). Number 2 heating oil has an energy content between 135 to 140 kBTU/gallon which translates to a burner input of 400 - 1,000 MBH. With a combustion efficiency of 80% the boiler's peak output would be approximately 800 MBH.

The boiler receives its oil from two 330 gallon (319 usable) residential fuel tanks also in the basement adjacent to the boiler in the former location of the generator (now at grade). The tanks were installed new in 2018. The flue is routed up through the building in a masonry chimney. Combustion air is provided to the room via a wall mounted intake louver at the areaway. There are reportedly three (3) thermostats within the building which will enable the boiler to fire. The heating is routed to fin-tube radiation and convectors around the building's perimeter via a circulator pump. The fire house garage has four (4) horizontal unit heaters controlled by a single thermostat.

No central cooling nor ventilation systems are present within the building. Some rooms have openings under the windows (original to the building) for through-wall air conditioners. Other office spaces and the Lounge have window air conditioners installed in the operable windows. In one case a portable 'Move-n-cool' style portable AC unit rejects heat via a duct through a window panel. Natural ventilation is only accessible via operable windows. Ventilation and comfort control is of concern in the facility especially in areas that have been reworked and walls constructed. No whole building BMS is present, only equipment manufacturer controls (either built-in or remote).

The restrooms are equipped with ceiling exhaust fans that are ducted to the exterior of the building. They are enabled by wall mounted switches. The kitchen has a hood over the ranges and exhaust fan on roof. The fire house has vehicle exhaust capture systems.

Heating hot water for the kitchen and restrooms is provided by single-block model 32E oil-fired 32- gallon tank type water heaters located adjacent to the heating boilers. The Village desires to eliminate the fuel oil.

A generator is on site, providing emergency power. This is fired by propane. Propane also serves the kitchen ranges and cooktops. There is no natural gas on site.

UTILITY ANALYSIS

Utility Rates

Utilities to the building are being delivered via Central Hudson Gas and Electric Corporation for electric. The building is also provided with #2 Fuel Oil and Propane. The utility rate utilized for the calculations are indicated in the summary table below which is based on utility bills. Due to low occupancy and gaps in data during the COVID pandemic, the 2018-2019 utility bills were utilized for electric, and the 2019-2020 utility bills for fuel oil and propane were utilized, generating the average combined rates below. As you can see the fuel oil usage in February and March of 2020.

Table 2: Utility Rate Summaries

Rhinebeck Village Hall - Electrical								
2018-2019			2019-2020			2020-2021		
Month	Electric Usage (kWh)	Electric Cost ($)	Month	Electric Usage (kWh)	Electric Cost ($)	Month	Electric Usage (kWh)	Electric Cost ($)
Jun-18	1,743	$414.22	Jun-19	428	$278.63	Jun-20	COVID19	COVID19
Jul-18	3,772	$576.26	Jul-19	2,260	$414.72	Jul-20	COVID19	COVID19
Aug-18	3,980	$623.17	Aug-19	3,267	$607.55	Aug-20	COVID19	COVID19
Sep-18	3,314	$596.26	Sep-19	1,838	$406.94	Sep-20	11479	$3,440.66
Oct-18	2,343	$438.41	Oct-19	1,461	$376.14	Oct-20	1188	$409.37
Nov-18	3,292	$547.06	Nov-19	2,460	$406.80	Nov-20	2488	$464.23
Dec-18	4,385	$486.07	Dec-19	4,103	$542.99	Dec-20	3841	$540.15
Jan-19	4,697	$514.32	Jan-20	2,965	$525.02	Jan-21	0	$0.00
Feb-19	3,404	$510.19	Feb-20	3,775	$541.38	Feb-21	9029	$1,351.83
Mar-19	1,631	$461.78	Mar-20	0	COVID19	Mar-21	1967	$555.20
Apr-19	876	$305.16	Apr-20	0	COVID19	Apr-21		$405.54
May-19	1,226	$299.92	May-20	0	COVID19	May-21		$271.34
TOTAL	**34,663**	**$5,772.82**	**TOTAL**	**22,557**	**$4,100.17**	**TOTAL**	**29,992**	**$7,438.32**

Rhinebeck Village Hall - Fuel Oil					
2019-2020			**2020-2021**		
Month	Fuel Oil (gallons)	Fuel Oil Cost ($)	Month	Fuel Oil (gallons)	Fuel Oil Cost ($)
Jun-19	0	$0.00	Jun-20	0	$0.00
Jul-19	0	$0.00	Jul-20	0	$0.00
Aug-19	0	$0.00	Aug-20	0	$0.00
Sep-19	0	$0.00	Sep-20	0	$0.00
Oct-19	494	$1,068.68	Oct-20	105	$138.10
Nov-19	90	$196.82	Nov-20	441	$622.75
Dec-19	503	$1,094.54	Dec-20	922	$1,555.79
Jan-20	999	$2,245.89	Jan-21	544	$1,004.27
Feb-20*	772	$1,598.43	Feb-21	1,426	$2,855.03
Mar-20*	482	$920.23	Mar-21	1,882	$1,440.69
Apr-20	505	$849.35	Apr-21	503	$1,034.44
May-20	187	$310.07	May-21	310	$447.87
TOTAL	**4,032**	**$8,284.01**	**TOTAL**	**6,131**	**$9,098.94**

*COVID greatly impacted the fuel consumption during these months

Rhinebeck Village Hall - Propane					
2019-2020			**2020-2021**		
Month	Propane (gallons)	Propane Cost ($)	Month	Propane (gallons)	Propane Cost ($)
Jun-19	0	$0.00	Jun-20	0	$0.00
Jul-19	0	$0.00	Jul-20	0	$0.00
Aug-19	0	$0.00	Aug-20	0	$0.00
Sep-19	0	$0.00	Sep-20	0	$0.00
Oct-19	163.3	$332.23	Oct-20	0	$0.00
Nov-19	119.6	$266.71	Nov-20	81.3	$179.06
Dec-19	0	$0.00	Dec-20	0	$0.00
Jan-20	0	$0.00	Jan-21	0	$0.00
Feb-20	0	$0.00	Feb-21	0	$0.00
Mar-20	0	$0.00	Mar-21	204.8	$521.22
Apr-20	0	$0.00	Apr-21	0	$0.00
May-20	0	$0.00	May-21	0	$0.00
TOTAL	**283**	**$598.94**	**TOTAL**	**286**	**$700.28**

Rhinebeck Village Hall - Utility Cost		
Electricity	$0.17	$/kWh
Fuel Oil	$1.48	$/gallon
Propane	$2.45	$/gallon

Benchmarking

The calculated existing Energy Utilization Index (EUI) for the existing 12,000 square foot building is 91.0 kBtu/sf. The national median EUI, according to Energy Star Portfolio Manager, for a similar type buildings is 52.9 kBtu/sf for Office and 63.5 kBtu/sf for Fire Station.

Table 3: Benchmarking Summary

Benchmarking			
Area Description	Area (SF)	Energy Consumption (mmBtu)	EUI (kBtu/sf)
Typical Office	8,400	444	52.9
Typical Fire Station	3,600	229	63.5
Total	**12,000**	**673**	**56.1**
Rhinebeck Village Hall	**12,000**	**994**	**93.5**

APPROACH / METHODOLOGY

The analysis to estimate annual energy consumption and cost was performed using NYS Technical Resource Manual (TRM) v 8.0 spreadsheet analysis unless otherwise noted below. Typically NYS Technical Resource Manual (TRM) 8.0 calculations often are more than adequate to address HVAC system comparisons so this is the traditional first choice. BIN data spreadsheet analysis typically are used where TRM is not appropriate i.e. additional detail and exceptional calculations. A simplified eQuest whole building zoned block modeling may be used where there are interactive measures or complex systems (i.e. hybrid system type not addressed by the TRM). Assumptions are made for components not yet designed. The intent is to capture the incremental savings of the measures identified for study.

The following energy conservation measures were evaluated:

- EEM-1 High Efficiency Lighting - This measure includes the evaluation of replacing fixtures with LED lighting, and the addition of occupancy sensors.
- EEM-2 Envelope Improvements - This measure included the addition of wall insulation, and roof replacement. This measure required an inventory of existing wall construction and insulation thicknesses, roof types and insulation thicknesses, and the associated square footages associated with each of these envelope components.
- EEM-3 HVAC system replacement - Possible upgrades to improve efficiency. The existing HVAC system is an oil fired how water boiler with a 2-pipe pipe heating system with perimeter fintube, hydronic unit heaters, and through-wall and portable A/C units, with ventilation limited to natural ventilation and some exhaust. The desire is to incorporate air conditioning and ventilation, so a one for one replacement is not being considered. Five (5) options were evaluated for HVAC system replacement:
    - Traditional code compliant packaged constant volume rooftop unit with DX cooling and electric resistance heating.
    - High efficiency packaged variable volume rooftop unit with DX cooling and electric resistance heating. Electric reheat.
    - Packaged variable air volume roof-mounted heat pump high efficiency unit with reversible modes and energy recovery, ducted to provide both conditioning and ventilation air, and electric reheat. Split systems to handle remaining load if there are spaces that cannot be addressed by the roof unit or have loads that significantly deviate from the rest of the building.
    - Variable Refrigerant Flow (VRF) System - Distributed indoor units with heat recovery capability, and a dedicated outdoor air unit (heat pump with reversible flow) with energy recovery.
    - Geothermal System - geothermal heat pump system, including well field, heat pumps, ventilation and control upgrades.
- EEM-4 Domestic Hot Water Heating - Replacement of existing electric domestic water heaters with a DHW system that aligns with the HVAC upgrades. Four (4) were evaluated for DHW system replacement:
    - Propane Fired Heater
    - Electric Resistance Heater
    - High Efficiency Air Source Heat Pump
    - Hot water heater served by geothermal well field
- EEM-5 Appliance Replacement and Hood Controls
    - Reduction in plug loads due to kitchen appliance replacement.
    - VFD smoke/heat sensing for kitchen hoods

For each measure analyzed, the following has been provided:

- Measure Description. Brief description of each system, system comparison, and feasibility overview (i.e. pros / cons, project impact, etc.).
- Detailed annual energy and cost analysis complete with anticipated savings.
- High level budgetary order of magnitude opinion of probable construction cost using a combination of RS Means, project experience, and other industry standard methods. This includes a breakdown for equipment, material, and labor.
- Simplified annual maintenance costs estimated using RS Means Facilities Maintenance and Repair Costs as a guide. These will include the identification of differences between the HVAC systems only and will not identify all maintenance associated with the building.
- Simple payback of each measure.
- Measure reporting in tabular format utilizing NYSERDA's project summary template.

ENERGY ANALYSIS

EEM-1: HIGH-EFFICIENCY LIGHTING

This measure is intended to include the evaluation of replacing fixtures with LED lighting, and the addition of occupancy sensors. A survey of the existing light fixtures and controls was performed, with space usage types, square footage, and hours of operation noted.

Most of the lighting in the existing buildings is provided by standard T8 tube florescent fixtures with prism lenses. Some room's track lighting have had the bulbs replaced with LED such as in the Radio/Dispatch. Other spaces' tracking lighting is still MR-16 halogen bulbs. Replacing all existing lighting with LED lighting technology provides energy savings by reducing the required input energy to obtain the same lighting levels. Due to the low (inadequate) lighting levels in the building and some replacements already taking place, a combination of the inventory and assumed code compliant levels were used to determine the baseline watts per square foot for the calculations.

Baseline (Existing) Assumptions:

- Office: 1.1 W/SF lighting power density (LPD).
- Firetruck Parking: 0.9 W/SF lighting power density (LPD).
- Exterior: 6 building mounted fixtures, 150W each

Proposed Assumptions:

- Office: This was assumed to be a 30% LPD improvement over code as is typical of high efficient buildings. This resulted in an LPD of 0.55 W/sf and a 10% credit was taken for Occupancy Sensors resulting in a 0.50 W/sf LPD
- Firetruck Parking: This was assumed to be a 30% LPD improvement over code as is typical of high efficient buildings. This resulted in an LPD of 0.37 W/sf and a 10% credit was taken for Occupancy Sensors resulting in a 0.33 W/sf LPD.
- Exterior: 6 building mounted fixtures, 54W each

Table 4: EEM-1 Summary

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]
1	High-Efficiency Lighting	15,500	7.71	$2,581.46	-185	-25.96	-$275.16	26.95	$2,306.30	$29,500.00	12.8

The payback associated with providing high efficient LED lighting is approximately 13 years. **This measure is recommended to be implemented.**

EEM-2: ENVELOPE IMPROVEMENTS

This measure is intended to include the addition of wall insulation and a roof replacement with the addition of insulation. This also is intended to address the loss of heat via air infiltration at the second floor which cause the ceiling tiles to move due to the significant draft. Existing wall construction and insulation thickness, roof types and insulation thickness were noted, and the associated square footages associated with each of these envelope components was calculated. It is assumed that the roof insulation is roughly 2001 code compliant, and likely that the wall contains little to no insulation. This measure addresses the replacement of the existing roof with 6" of insulation and the furring out of the interior walls.

<u>EEM-2 Envelope Improvements - Roof and Wall</u>

Baseline (Existing) Assumptions:

- Built-up roof, 2001 installed, R=13
- Wall construction of face brick, air gap, CMU backup, painted gypsum board R=7
- Roof square footage calculated from plans, 5,400 sf
- Walls surface area calculated from plans, 6,888 sf
- Air Infiltration at ceiling of second floor

Proposed Assumptions:

- Roof: 4 inches of rigid insulation, R=5/inch, R=30 total
- Walls same as baseline with an additional 3.5" stud cavity with 4" of compressed batt insulation at R-5/inch, R-23 total.
- Air Infiltration minimized, air barrier installed.

Values modeled the same in both:

- Wall square footage minus windows calculated from plans
- Roof square footage calculated from plans
- Existing Cooling Efficiency 11.2 EER (maximum, 9.0 EER average), 11.6 IPLV maximum, small through-window and self-contained/portable AC Units
- Existing Heating Efficiency Existing Steam Boiler 80% efficiency.

Table 5: EEM-2 Summary

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]
2	Envelope Improvements - Roof and Walls	2,351	2.19	$391.59	1,114	155.92	$1,652.88	163.95	$2,044.47	$142,304.53	69.6

The existing roof has solar panels mounted on it so the roof replacement will be somewhat more complex than a simple roof removal/replacement as the supports of the roofers will need to work around the solar panels. It may be more advantageous to apply the additional insulation inside the building IF a thermos-hydro analysis shows that the dewpoint is located in an acceptable layer. Furring out of the interior walls may be costly due to the need to relocate wall mounted items. **EEM-2 is listed as recommended, however, we only partially recommend this measure.** When combining all EEM-2 items together, the payback is longer than the life of the systems, however addressing the air infiltration as a standalone measure is lucrative. **We encourage addressing the air infiltration - making the improvement to the infiltration to reduce the draft will not only have an energy impact, but will also have a positive impact on occupant comfort.** When you look at these measures separately, the approximate annual energy savings is as follows: Roof = $380/yr; Walls = $1,520/yr; Infiltration = $2,050/yr.

EEM-3: HVAC SYSTEM REPLACEMENT

The existing system is an oil fired hot water boiler with a 2-pipe pipe heating system utilizing fintube and unit heaters, with through-wall and portable A/C units scattered throughout. The desire is to eliminate fuel oil and to incorporate air conditioning and ventilation, so a one for one replacement is not being considered. We have evaluated five (5) options for HVAC system replacement for possible upgrades to improve efficiency:

EEM-3a Traditional baseline code compliant constant volume rooftop unit with DX cooling and electric heating.
EEM-3b High efficient variable volume rooftop unit with DX cooling and electric heat with energy recovery and electric reheat.
EEM-3c High efficient variable volume packaged roof-mounted heat pump unit with reversible modes and energy recovery, ducted to provide both conditioning and ventilation air.
EEM-3d Variable Refrigerant Flow (VRF) System - distributed indoor units with heat recovery capability, and a dedicated outdoor air unit (heat pump with reversible flow) with energy recovery.
EEM-3e Geothermal System - geothermal heat pump system, including well field, heat pumps, ventilation and control upgrades.

For all scenarios, the intent would be to separate out the Fire Truck Bay area so it could operate as relatively independent as a stand-alone zone, with its own controls, and likely dedicated AHU.

EEM-3a: Code RTU with DX Cooling

A traditional code compliant constant volume rooftop unit utilizing electric heating and DX cooling, has been evaluated as a proposed replacement system. One roof-mounted air handling unit was modeled, however in practice this would likely be divided up into a minimum of two, possibly three units to handle the varying exposures and uses i.e. Fire truck Bay, Second Floor, First Floor or meeting room. This would allow for better control especially since there are two floors and an assembly area with denser occupancy. A constant volume unit(s) would be a relatively simple system with the temperature and air flow delivered to each space designed according to the worst-case zone. Outdoor air would be delivered to the spaces as mixed air, so the unit(s) would be required to run continuously during all occupied hours to provide proper ventilation air. Energy recovery is not required for the system, and has not been included, however this is an option that could be included in the design and would make the system better than code.

Baseline (Existing) Assumptions:

- Oil fired hot water boiler, 800 mbh heating, 80% efficiency (oversized with system inefficiencies beyond boiler)
- Existing cooling via small through-window and portable A/C units, Cooling Efficiency 11.2 EER (maximum, 9.0 EER average), 11.6 IPLV

Proposed Assumptions:

- Rooftop unit, DX cooling, electric heating, constant volume
- 12,000 CFM, 2,750 CFM OA
- 300 mbh heating, 23 tons cooling
- Code: 11.0 EER, 12.4 IEER cooling, 100% efficient heating (COP 1.0).

Table 6: EEM-3a Summary

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]
3a	Code RTU with DX cooling	-113,144	4.46	-$18,843.10	4,329	606.00	$6,423.90	219.84	-$12,419.20	$118,946.80	-9.6

This measure shows a significant increase in electric consumption. This is because the existing facility is not fully air conditioned, not fully ventilated, and this minimally compliant system type includes electric resistance heating. This measure would require ductwork to extend throughout the space, Likely run above ceilings or exposed and ceiling hung. In some areas the ducts could be run in the corners of the rooms and displacement ventilation diffusers could be installed to create a healthier environment (supply low, return high, remove contaminants). Chases may be necessary to run between floors for the ductwork. The existing fintube could be removed or a supplemental electric boiler may be installed to provide greater comfort at the perimeter. Perimeter fintube was not modeled and the demolition/wall repair costs were not included in the budgetary pricing. Roof mounting of the air handling unit may be an issue due to the existing solar array, and a structural engineer should be consulted, so consideration for ground or perhaps indoor units (Mech room or interstitial attic) might be an option to explore. Indoor units would require ducted or louvered openings for ventilation air. **EEM 3a is listed as not recommended because the payback is poor.**

<u>EEM-3b: High Efficient RTU with DX Cooling</u>

A high efficient variable volume rooftop unit utilizing electric heating and DX cooling, with energy recovery is evaluated as the proposed replacement system. We have evaluated this system with variable air volume terminal units with electric reheat to allow for zone control and improved comfort conditions. One roof-mounted air handling unit was modeled however in practice this would likely be split into two units to have the Fire Truck bay separate. The temperature and air flow delivered to each space is optimized with reset. Outdoor air is delivered to the spaces as mixed air via the VAV system, so the unit will run continuously during all occupied hours. Energy recovery has been included.

Baseline (Existing) Assumptions:

- Oil fired hot water boiler, 800 mbh heating, 80% efficiency (oversized with system inefficiencies beyond boiler)
- Existing cooling via small through-window and portable A/C units, Cooling Efficiency 11.2 EER (maximum, 9.0 EER average), 11.6 IPLV, Existing

Proposed Assumptions:

- Rooftop unit, DX cooling, electric heating, VAV
- Enthalpy Energy Recovery 60% efficient
- 12,000 CFM, 2,750 CFM OA
- 300 mbh heating, 23 tons cooling
- Improved Efficiency: 12.0 EER, 13.7 IEER, 100% efficient heating (COP 1.0).

Table 7: EEM-3b Summary

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]
3b	High Efficient RTU with DX cooling	-93,463	8.82	-$15,565.50	5,045	706.25	$7,486.60	387.26	-$8,078.90	$160,158.19	-19.8

This option is an improvement over EEM-3a because it is slightly higher in efficiency, includes energy recovery, variable air volume, and better zone control. This option makes sense when some amount of energy efficiency is desirable, without requiring the investment that more extreme measures would involve. Similar to 3a, this measure would require ductwork to extend throughout the space, likely run above ceilings or exposed and ceiling hung. Chases may be necessary to run between floors for the ductwork. Roof mounting may be an issue due to the existing solar array, and a structural engineer should be consulted, so consideration for ground or perhaps indoor units (Mech room or interstitial attic) might be an option to explore. Indoor units would require ducted or louvered openings for ventilation air. **EEM 3b is listed as not recommended because the payback is poor.**

EEM-3**c**: High Efficient Heat Pump

A packaged roof-mounted heat pump HVAC unit complete with variable air volume and energy recovery ducted to provide both conditioning and ventilation air. This unit is able to use heat pump technology to provide both heating and cooling, with the heating much more efficient and electric resistance heat.

Baseline (Existing) Assumptions:

- Oil fired hot water boiler, 800 mbh heating, 80% efficiency (oversized with system inefficiencies beyond boiler)
- Existing cooling via small through-window A/C units and various window fans, Cooling Efficiency 11.2 EER (maximum, 9.0 EER average), 11.6 IPLV, Existing

Proposed Assumptions:

- Heat pump roof mounted unit, VAV
- Enthalpy Energy Recovery 60% efficient
- 12,000 CFM, 2,750 CFM OA
- 300 mbh heating, 23 tons cooling
- Improved Efficiency: 13.0 EER, 14.2 IEER, 3.4 COP heating

Table 8: EEM-3c Summary

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]
3c	High Efficient Heat Pump	3,226	10.12	$537.28	5,045	706.25	$7,486.60	717.26	$8,023.88	$212,902.31	26.5

Heat pumps are generally more than two to three times as efficient as electric resistance, so we would encourage the use of heat pump technology. We'd recommend including energy recovery and variable air volume with terminal units to allow for zone control and improved comfort conditions. Electric reheat in the terminal units would be optional but not included in the calculation. Similar to the code-compliant and better-than-code measures 3a and 3b, this measure would require ductwork to extend throughout the space, likely above the ceiling or exposed and ceiling hung. Chases may be necessary to run between floors. Multiple HPs will likely be utilized if this HVAC system is implemented. This would allow for better control especially since there are two floors and an assembly area with denser occupancy. Roof mounting may be an issue due to the existing solar array, and a structural engineer should be consulted, so consideration for ground or perhaps indoor units (Mech room or interstitial attic) might be an option to explore. Indoor units would require ducted or louvered openings for ventilation air. **EEM 3c is listed as recommended because EEM 3d performs slightly better, is better suited to serving the multiple space types and occupancies, and is not expected to be significantly more in cost.**

EEM-3d: VRF System

A VRF system is a variable refrigerant flow system, with distributed indoor units coupled with a modular bank of outdoor condensing style air cooled units, interconnected with small refrigerant piping. The indoor VRF units may be console, wall, or ceiling mounted and may be selected with heat recovery capability. A dedicated outdoor air unit as VRF or heat pump with reversible flow and energy recovery would provide ventilation air to the space. The VRF system performs at a very high efficiency. The calculations include a heat recovery type VRF system.

Baseline (Existing) Assumptions:

- Oil fired hot water boiler, 800 mbh heating, 80% efficiency (oversized with system inefficiencies beyond boiler)
- Existing cooling via small through-window and portable A/C units, Cooling Efficiency 11.2 EER (maximum, 9.0 EER average), 11.6 IPLV,

Proposed Assumptions:

- HP or VRF DOAS with Enthalpy Energy Recovery 60% efficient, 13.0 EER, 14.2 IEER, COP 3.4
- 12,000 CFM, 2,750 CFM OA
- 300 mbh heating, 23 tons cooling
- VRF = 11.2 EER, 17 IEER, COP 3.4

Table 9: EEM-3d Summary

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]
3d	VRF System	5,067	12.53	$843.84	5,045	706.25	$7,486.60	723.54	$8,330.44	$240,506.34	28.9

The benefit of the VRF system is that the piping is small, units are very quiet, easily located and mounted, the system is modular in nature providing for great comfort control and redundancy, has energy sharing capabilities to optimize performance, and ventilation may be provided by a demand controlled dedicated ventilation unit with energy recovery this would allow for small ductwork and precise control to avoid under or over ventilating. Roof mounted condensing equipment would be relatively compact and could be located at grade if the existing solar array does not afford any pace under or beside the panels. Panels could be elevated somewhat to accommodate the condensing unit. The dedicated ventilation unit would be relatively small and similarly could be placed on the roof or indoor in the mechanical room or in the interstitial attic space. **EEM 3d is listed as recommended due to its energy and carbon reduction, flexibility and versatility.** This type of system does require careful selection and design and a contractor certified by the manufacturer to ensure the systems operate at low temperatures and in the desired conditions.

EEM-3e: Geothermal System

A geothermal heat pump system utilizes a geo-exchange well field coupled with extended range water source heat pump type units to efficiently provide space conditioning. The indoor units contain compressors, which extract energy from the attached water loop to condition the air. The water loop is pumped through underground vertical wells, and use the naturally constant ground temperature of the earth as both a heat source and sink as needed. To a greater degree than a VRF system, this system allows for sharing of energy throughout a water heat pump loop.

Baseline (Existing) Assumptions:

- Oil fired hot water boiler, 800 mbh heating, 80% efficiency (oversized with system inefficiencies beyond boiler)
- Existing cooling via small through-window and portable A/C units, Cooling Efficiency 11.2 EER (maximum, 9.0 EER average), 11.6 IPLV

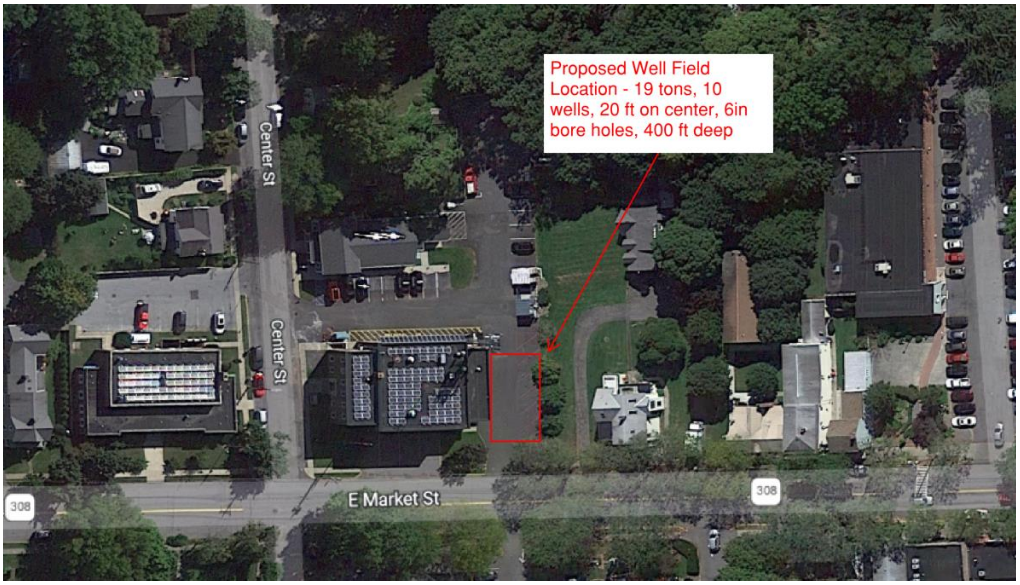
Proposed Assumptions:

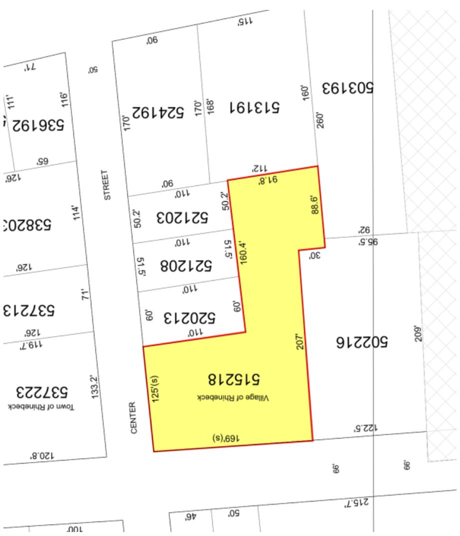
- Geothermal heat pump AHU, VAV
- Enthalpy Energy Recovery 60% efficient
- 12,000 CFM, 2,750 CFM OA
- 300 mbh heating, 23 tons cooling
- 18.1 EER, 3.6 COP
- 19 W/gpm loop pumps

Table 10: EEM-3e Summary

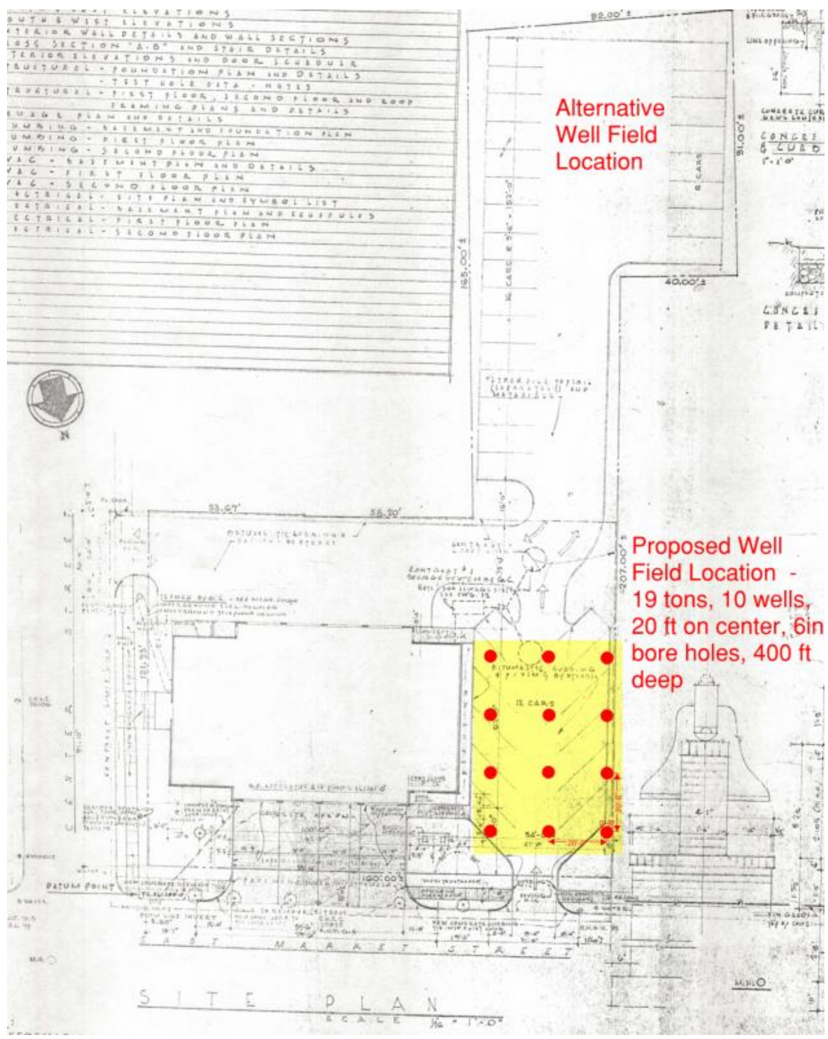
EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]
3e	Geothermal System	6,144	10.09	$1,023.20	5,045	706.25	$7,486.60	727.22	$8,509.80	$487,178.33	57.2

A location for the well field will need to be determined. An open green space is usually the best option because there is some horizontal piping required to connect to the vertical wells. However an area under a parking lot is acceptable as well. The downside of using a parking lot is likely and increase in restoration costs. Coordination cost with drainage piping, and utility lines will also be required. The spacing of the wells generally is 20 feet on center, with 400 feet deep wells and 6 inches diameter bores. A 48-hour test well is recommended to confirm ground composition and thermal conductivity. Shallower sample borings can be performed but this information generally only offers depth of casing needed (depth of loose soil to bedrock). There is a higher upfront cost of a geothermal system, with a large portion of the costs in the well field. Once the system is in place, the maintenance costs are relatively low as the underground piping does not have any moving parts requiring maintenance. **EEM 3e is listed as not recommended, due to a high first cost when incentives are not considered.**





Tax Parcel



Site Plan

EEM-4: DOMESTIC HOT WATER REPLACEMENT

The existing electric domestic water heaters are to be replaced. Four (4) options were evaluated according to the HVAC system upgrades:

EEM-4a - DHW Propane Fired Unit
EEM-4b - Electric Water Unit
EEM-4c - DHW Air Source Heat Pump
EEM-4d - Geothermal Heat Pump Unit

Fixtures may be upgraded to water saving type, however due to the use, there is limited benefit and this has not been evaluated separately.

<u>EEM-4a: DHW Propane Fired Unit</u>

Tank type semi-instantaneous propane fired water heaters were evaluated. This is a traditional system that is generally cost-effective.

Baseline (Existing) Assumptions:

- 32E oil-fired 32 gallon tank type water heater, 80% efficiency, 0.62 Uniform Energy Factor
- 2x66 gallon electric water heater manufactured by Bock, 0.84 Uniform Energy Factor

Proposed Assumptions:

- Office : Three 50 gallon, propane fired, tank type water heater 92% efficiency

Table 11: EEM-4a Summary

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual Fossil Fuel Savings [gallons]	Annual Fossil Fuel Savings [mmBtu]	Annual Fossil Fuel Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]
4a	DHW Propane Fired Unit	7,676	0.17	$1,278.44	-48	0.70	-$233.95	26.90	$1,044.48	$10,740.00	10.3

This measure provides some energy savings, but is not recommended due to the lengthy payback.

<u>EEM-4b: DHW Electric Unit</u>

Tank type semi-instantaneous electric water heaters were evaluated.

Baseline (Existing) Assumptions:

- 32E oil-fired 32 gallon tank type water heater, 80% efficiency, 0.62 Uniform Energy Factor
- 2x66 gallon electric water heater manufactured by Bock 0.84 Uniform Energy Factor

Proposed Assumptions:

- Office : Three 50 gallon, electric tank type water heaters , 0.92 Uniform Energy Factor, COP 1.0

Table 12: EEM-4b Summary

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]
4b	DHW Electric Unit	224	0.04	$37.27	120	16.76	$177.69	17.53	$214.96	$9,240.00	43.0

This measure provides some energy savings, but is not recommended due to the limited energy benefit and lengthy payback.

EEM-4c: DHW Air Source Heat Pump

The existing water heaters are to be replaced with air source heat pump water heaters. ASHP water heaters use electricity to move heat from one place to another instead of generating heat directly, therefore they can be two or three times more energy efficient than conventional water heaters. Because these units extract energy from the ambient air they require a room of sufficient size to extract the heat from. In general rooms of sufficient size below grade are often the preferred installation location.

Baseline (Existing) Assumptions:

- 32E oil-fired 32 gallon tank type water heater, 80% efficiency, 0.62 Uniform Energy Factor
- 2x66 gallon electric water heater manufactured by Bock 0.84 Uniform Energy Factor

Proposed Assumptions:

- Office : Three 50 gallon, air source heat pump, tank type domestic water heaters, Uniform Energy Factor of 2.5, HSPF 8.2

Table 13: EEM-4c Summary

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]
4c	DHW Air Source Heat Pump	5,019	0.06	$835.90	120	16.76	$177.69	33.89	$1,013.59	$16,224.00	16.0

The air source heat pump water heaters would need to be located inside and in an area that can maintain 40° or higher because they do not operate at optimal efficiency when in a colder area. **This measure is recommended, as the simple payback is reasonable.**

EEM-4d: DHW Geothermal Well Field

The existing water heaters are to be replaced with a connection to a geothermal well field. This option would be a water to water heat pump and tank option.

Baseline (Existing) Assumptions:

- 32E oil-fired 32 gallon tank type water heater, 80% efficiency, 0.62 Uniform Energy Factor
- 2x66 gallon electric water heater manufactured by Bock 0.84 Uniform Energy Factor

Proposed Assumptions:

- Office : Three 50 gallon, domestic water heater, Uniform energy factor of 3.0, connected to the well field, HSPF 9.6

Table 14: EEM-4d Summary

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]
4d	DHW Geothermal Well Field	5,603	0.07	$933.13	120	16.76	$177.69	35.89	$1,110.82	$19,224.00	17.3

This system would be connected to the HVAC system geothermal loop with a water to domestic water heat pump. The ground source heat pumps selected would be constructed for potable water use and separate the ground loop from the domestic water loop. **This measures is listed as recommended non-energy reasons since it relies on the HVAC geothermal option being selected. This measure saves slightly more energy than EEM 4c ASHP water heater, is a slightly longer payback, and has slightly higher first cost when incentives are not considered.**

EEM-5: APPLIANCE REPLACEMENT AND HOOD CONTROLS

The existing appliances in the office/kitchen area may be replaced with ENERGY Star certified appliances. This would create a reduction in plug loads. Kitchen demand control ventilation would also be provided. This would be tied into a hood control module, which determines the need for exhaust based on smoke and temperature beneath the kitchen hood via hood smoke and temperature sensors. The controls would be linked to the system fans, modulating as needed. Energy is saved by reduced fan power at the supply and exhaust fans, from the reduced airflow, reduced operating hours, as well as the reduction of outdoor air requiring conditioning.

Baseline Assumptions:

- Existing appliances
- Four (4) refrigerators, US Federal Standard efficiency
- One(1) Ice Maker, US Federal Standard efficiency
- No heat/smoke control present

Proposed Assumptions:

- ENERGY Star Appliances
- Four (4) refrigerators, ENERGY Star efficiency
- One (1) Ice Maker, ENERGY Star efficiency
- Heat/smoke controlled kitchen hood

Table 13: EEM-5 Summary

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]
5	Appliance Replacement	6,026	1.02	$1,003.51	163	22.75	$241.18	43.32	$1,244.69	$15,427.00	12.4

This measure with appliance replacement and integration of kitchen hood controls is recommended because the simple payback is less than the expected useful life of the systems. However, if the kitchen hood is rarely used, the benefit might in reality be limited.

CONCLUSION

Based on the findings of the study, we recommend pursing energy efficiency measures EEM 1 high-efficiency lighting, EEM 2 addressing air infiltration, EEM3 selecting an HVAC system upgrade 3d, EEM 4 selecting a domestic hot water system upgrade from 4c, and EEM 5 appliance replacement and hood heat/smoke control. We also encourage leveraging the various incentive program available however these incentive programs are not guaranteed, are subject to change, and are contingent on program acceptance, eligibility, and available funding. These measures will help improve the efficiency of building, reduce the carbon footprint and have a positive impact on the occupants of your facility and the environment. We hope the findings of this report will assist you in making decisions about energy efficiency improvements in your facility.

ADDITIONAL CONSIDERATIONS

Although the main considerations in selecting an HVAC system are typically energy and cost implications, there are several other factors at play.

Existing Useful Life of Equipment

A full life cycle cost analysis has not been performed as part of this study. However, each system has a different lifespan. For example, a rooftop unit has an expected useful life of 20 years before replacement becomes necessary, while a heat pump can be expected to last 25 years.

Expected Useful Life			
Equipment Description	Years	Equipment Description	Years
DX Rooftop Unit	20	Fossil Fuel DWH	15
Envelope Improvements	30	ASHP DHW	20
Heat Pump	25	VRF	25
Fossil Fuel Boiler	25	Pumps	15
Energy Star Appliances	14		

In order to fully capture the replacement and the true cost of each system type, a full life cycle cost analysis may be warranted.

Carbon Reduction

Much of the motivation to reduce fossil fuel usage is to address climate change by reducing carbon and greenhouse gas emissions. New York State currently has one of the cleanest electric grids in the nation, and has goals of 1000% zero emission electricity by 2040. However, today natural gas still remains slightly less carbon intensive per unit of energy than electricity, due to the fossil fuels required to produce and distribute electricity, which is often counter-intuitive. With the New York's focus on renewable energy, that is likely to change, especially over the lifespan of equipment with long expected life.

Greenhouse Gas Emissions			
Tag	Carbon Consumption ($mt\ CO_2e$)	Savings vs. Baseline Consumption ($mt\ CO_2e$)	Savings vs. Baseline Consumption (%)
BASELINE	63.0	--	--
EEM- 1	56.6	6.4	10.1%
EEM- 2	53.5	9.5	15.0%
EEM-3A	87.4	-24.4	-38.7%
EEM-3B	72.2	-9.2	-14.6%
EEM-3C	23.8	39.2	62.2%
EEM-3D	22.9	40.1	63.6%
EEM-3E	22.4	40.6	64.5%
EEM-4A	59.5	3.5	5.5%
EEM-4B	59.6	3.4	5.4%
EEM-4C	59.3	3.7	5.9%
EEM-5	58.7	4.2	6.7%

Utility Cost Inflation

New York State has aggressive carbon-reduction goals, which require the electrification of heating systems to succeed. One method of encouraging the switch from fossil fuels to electric heating in our climate is to provide financial incentives and penalties. Already, NYSERDA and the major utility companies have incentive programs to mitigate first costs. In the future, the economic incentives may migrate to utility rates themselves, in the form of electric rate subsidies or carbon taxes. For example, in 2018, Canada implemented a carbon tax based on consumption meant to penalize excessive fossil fuel use. While the future of energy is unknown, it is a possibility to consider.

Additional Energy Efficiency Measures

When designing a high-efficiency HVAC system with a high first cost, such as a high-efficiency ground source heat pump system, it is important to include a range of additional energy efficiency measures. If the load of the HVAC system can be reduced, so can the equipment size, which decreases the cost premium required for the high-efficiency option. It is encouraged to include as many energy efficiency measures as feasible to ensure both a high-performing building as well as to mitigate some of the equipment costs. At the current design phase, due to the level of detail, not all of these energy efficiency measures can be captured or are even known, and the interactive effects have not been accounted for in this report.

The following potential measures were identified during the site visit, but were not studied as part of this project.

- Additional Photovoltaic
- Additional electric vehicle charging stations
- Upgrade of compressed air systems with premium equipment with possible energy recovery

Project Stage

This project is in the study phase and as such, many assumptions and generalizations were made in the analyses. It is prudent to make conservative assumptions in order to avoid overstating energy savings or cost implications. As the design progresses, the models may be refined, and typically more energy savings are demonstrated.

CALCULATIONS

All calculations generally follow NYS 8.0 Technical Resource Manual methods, unless noted.

EEM-1 : Lighting

closest TRM location Poughkeepsie		
Office Areas		
Proposed :		
Typical Office LPD (ASHRAE 90.1 2016 +30% improvement)	0.55	W/sf
Interior hours from TRM, reduce to account for 10am-4pm	1988.58	hours
$HVAC_c$	0.066	
$HVAC_d$	0.175	
$HVAC_{ff}$	-0.002	
Office wattage	4535	W
Office wattage +10% credit for OS Controls	4394	W`
Existing:		
Assumed wattage/sf based on site visit observations	1.1	W/sf
SF of office	8200	SF
baseline wattage	9020	W
LPD with 10% credit for OS Controls	0.50	W/sf
Firetruck Storage/ Maintenance		
Proposed :		
Typical Auto/Fire Station Avg (ASHRAE 90.1 2016 +30% improvement)	0.37	W/sf
Interior hours from TRM, reduce to account for 10am-4pm	1854.6	hours
$HVAC_c$	0.066	
$HVAC_d$	0.175	
$HVAC_{ff}$	-0.002	
Maintenace wattage	1336	W
Maintenace wattage +10% credit for OS Controls	1202	W`
Existing:		
Assumed wattage/sf based on site visit observations	0.9	W/sf
SF of firetruck storage	3600	SF
baseline wattage	3240	W
LPD with 10% credit for OS Controls	0.33	W/sf
Exterior		
Proposed :		
6x Building Mounted, 54W each	324	W
Exterior Hours, reduced	2,891	hours
Existing:		
6x Building Mounted, 150W each	900	W

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Office Areas

ΔkWh	=	units	x((	W_{base}	-	W_{ee}	)/	1000	)x	hrs_{op}	x(	1	+	$HVAC_c$	)
ΔkWh	=	1	x((	9020.0	-	4394.0	)/	1000	)x	1988.58	x(	1	+	0.066	)
ΔkWh	**=**	**9806**													

ΔkW	=	units	x((	W_{base}	-	W_{ee}	)/	1000	)x(	1	+	$HVAC_d$	)x	CF
ΔkW	=	1	x((	9020.0	-	4394.0	)/	1000	)x(	1	+	0.175	)x	0.92
ΔkW	**=**	**5.001**												

ΔMMBtu	=	units	x(	W_{base}	-	W_{ee}	)/	1000	x	hrs	x	$HVAC_{ff}$
ΔMMBtu	=	1	x(	9020.0	-	4394.0	)/	1000	x	1988.58	x	-0.002
ΔMMBtu	**=**	**-18**										
ΔFuel Oil	**=**	**-131**										

Firetruck Storage

ΔkWh	=	units	x((	W_{base}	-	W_{ee}	)/	1000	)x	hrs_{op}	x(	1	+	$HVAC_c$	)
ΔkWh	=	1	x((	3240.0	-	1202.0	)/	1000	)x	1854.6	x(	1	+	0.066	)
ΔkWh	**=**	**4029**													

ΔkW	=	units	x((	W_{base}	-	W_{ee}	)/	1000	)x(	1	+	$HVAC_d$	)x	CF
ΔkW	=	1	x((	3240.0	-	1202.0	)/	1000	)x(	1	+	0.175	)x	0.89
ΔkW	**=**	**2.131**												

ΔMMBtu	=	units	x(	W_{base}	-	W_{ee}	)/	1000	x	hrs	x	$HVAC_{ff}$
ΔMMBtu	=	1	x(	3240.0	-	1202.0	)/	1000	x	1854.6	x	0.00
ΔMMBtu	**=**	**-8**										
ΔFuel Oil	**=**	**-54**										

Exterior

ΔkWh	=	units	x((	W_{base}	-	W_{ee}	)/	1000	)x	hrs_{op}	x(	1	+	$HVAC_c$	)
ΔkWh	=	1	x((	900.0	-	324.0	)/	1000	)x	2,891	x(	1	+	0	)
ΔkWh	**=**	**1665**													

ΔkW	=	units	x((	W_{base}	-	W_{ee}	)/	1000	)x(	1	+	$HVAC_d$	)x	CF
ΔkW	=	1	x((	900.0	-	324.0	)/	1000	)x(	1	+	0	)x	1
ΔkW	**=**	**0.576**												

Total ΔkWh	=	**15500**
Total ΔkW	=	**7.71**
Total Δfuel Oil	=	**-185.411**
Δ$ kWh	=	**$2,581.46**
Δ$ fuel oil	=	**($275.16)**

EEM-2: Envelope Improvements

Room Temp Setpoint Cooling	75	°F
OA Temp Setpoint Cooling	89	°F
Room Temp Setpoint Heating	70	°F
OA Temp Setpoint Heating	0	°F
EFLH Cooling and Heating, Poughkeepsie		
Small Office/Auto , Cooling	575.5	$EFLH_{cool}$
Small Office/Auto , Heating	1616	$EFLH_{heat}$
page 926		
Roof		
Roof SF	5400	SF
Existing: Built-Up roofing, no insulation R=13	0.077	U
New: 6" Insulation, R=5/in, R-30 total	0.033	U
Cooling Efficiency (Existing wall a/c 9,000 btu, 11.2 EER max, use avg)	9	EER
Cooling Efficiency, existing average	11.6	IPLV
Heating Elec Efficiency (~~Suppl. heat from plug-in and A/C, assume 10%~~)	2.5	COP
Heating Fuel Efficiency (existing boiler)	80%	Eff

Roof

ΔkWh_a	=(((	Roof $Uvalue_{base}$	x	Roof SF_{base}	)-(	Roof $Uvalue_{ee}$	x	Roof SF_{ee}	))x(	$T_{outdoor, design}$	-	$T_{indoor, setpoint}$	)/	1000	)x	$EFLH_{cool}$	/	IPLV
ΔkWh_a	=(((	0.077	x	5400	)-(	0.033	x	5400	))x(	89	-	75	)/	1000	)x	576	/	11.6
ΔkWh_a	=	163																

ΔkWh_{cool}	**=**	**163**

ΔkWh_a	=(((	Roof $Uvalue_{base}$	x	Roof SF_{base}	)-(	Roof $Uvalue_{ee}$	x	Roof SF_{ee}	))x(	$T_{indoor, setpoint}$	-	$T_{outdoor, design}$	)/	1000	)x	$EFLH_{heat}$	/	COPx3.412
ΔkWh_a	=(((	0.077	x	5400	)-(	0.033	x	5400	))x(	70	-	0	)/	1000	)x	1616	/	68.24
ΔkWh_a	=	390																

ΔkWh_{heat}	**=**	**390**	No Electric Heat, but slight pumping power (converted btu and HP to COP)

ΔkW_a	=(((	Roof $Uvalue_{base}$	x	Roof SF_{base}	)-(	Roof $Uvalue_{ee}$	x	Roof SF_{ee}	))x(	$T_{outdoor, design}$	-	$T_{indoor, setpoint}$	)/	1000	)/	EER
ΔkW_a	=(((	0.077	x	5400	)-(	0.033	x	5400	))x(	89	-	75	)/	1000	)/	9.0
ΔkW_a	=	0.366														

ΔkW_{cool}	**=**	**0.366**

ΔkW_a	=(((	Roof $Uvalue_{base}$	x	Roof SF_{base}	)-(	Roof $Uvalue_{ee}$	x	Roof SF_{ee}	))x(	$T_{outdoor, design}$	-	$T_{indoor, setpoint}$	)/	1000	)/	COPx3.412
ΔkW_a	=(((	0.077	x	5400	)-(	0.033	x	5400	))x(	89	-	75	)/	1000	)/	68.2
ΔkW_a	=	0.048														

ΔkW_{heat}	**=**	**0.048**	No Electric Heat, but slight pumping power (converted btu and HP to COP)

$\Delta MMbtu_a$	=(((	Roof $Uvalue_{base}$	x	Roof SF_{base}	)-(	Roof $Uvalue_{ee}$	x	Roof SF_{ee}	))x(	$T_{indoor, setpoint}$	-	$T_{outdoor, design}$	)/	1000	)x	$EFLH_{heat}$	/	$Eff_{FuelHeat}$	/	1000
$\Delta MMbtu_a$	=(((	0.077	x	5400	)-(	0.033	x	5400	))x(	70	-	0	)/	1000	)x	1616	/	80%	/	1000
$\Delta MMbtu_a$	=	33																		

ΔMMBtu	**=**	**33.273**
Δ Fuel Oil	**=**	**238**

Total ΔkWh	**=**	**163**
Total ΔkW	**=**	**0.414**
Δ Fuel Oil	**=**	**238**
Δ$ kWh	**=**	**$27.14**
Δ$ fuel oil	**=**	**$352.71**

Walls

Wall SF	6888	SF
Glaz SF	240	SF
Existing: 0" Insulation, R7 total	0.143	U
New: 6" Insulation, R=5/in, R-38 total	0.026	U
Cooling Efficiency (Existing wall a/c 9,000 btu, 11.2 EER max, use avg)	9	EER
Cooling Efficiency, existing average	11.6	IPLV
Heating Elec Efficiency (~~Suppl. heat from plug-in and A/C, assume 10%~~)	2.5	COP
Heating Fuel Efficiency (existing boiler)	80%	Eff

Use Heat COP to estimate slight heating pump power

Walls

ΔkWh_a	=(((	Wall Uvalue$_{base}$	x	Wall SF$_{base}$	)-(	Wall Uvalue$_{ee}$	x	Wall SF$_{ee}$	))x(	$T_{outdoor, design}$	-	$T_{indoor, setpoint}$	)/	1000	)x	EFLH$_{cool}$	/	IPLV		
ΔkWh_a	=(((	0.143	x	6888	)-(	0.026	x	6888	))x(	89	-	75	)/	1000	)x	576	/	11.6		
ΔkWh_a	=	556																		
ΔkWh_{cool}	**=**	**556**																		
ΔkWh_a	=(((	Wall Uvalue$_{base}$	x	Wall SF$_{base}$	)-(	Wall Uvalue$_{ee}$	x	Wall SF$_{ee}$	))x(	$T_{indoor, setpoint}$	-	$T_{outdoor, design}$	)/	1000	)x	EFLH$_{heat}$	/	COPx3.412		
ΔkWh_a	=(((	0.143	x	6888	)-(	0.026	x	6888	))x(	70	-	0	)/	1000	)x	1616	/	68.24		
ΔkWh_a	=	1330																		
ΔkWh_{heat}	**=**	**1330**		No Electric Heat, but slight pumping power (converted btu and HP to COP)																
ΔkW_a	=(((	Wall Uvalue$_{base}$	x	Wall SF$_{base}$	)-(	Wall Uvalue$_{ee}$	x	Wall SF$_{ee}$	))x(	$T_{outdoor, design}$	-	$T_{indoor, setpoint}$	)/	1000	)/	EER				
ΔkW_a	=(((	0.143	x	6888	)-(	0.026	x	6888	))x(	89	-	75	)/	1000	)/	9.0				
ΔkW_a	=	1.249																		
ΔkW_{cool}	**=**	**1.249**																		
ΔkW_a	=(((	Wall Uvalue$_{base}$	x	Wall SF$_{base}$	)-(	Wall Uvalue$_{ee}$	x	Wall SF$_{ee}$	))x(	$T_{outdoor, design}$	-	$T_{indoor, setpoint}$	)/	1000	)/	COPx3.412				
ΔkW_a	=(((	0.143	x	6888	)-(	0.026	x	6888	))x(	89	-	75	)/	1000	)/	68.2				
ΔkW_a	=	0.165																		
ΔkW_{heat}	**=**	**0.165**		No Electric Heat, but slight pumping power (converted btu and HP to COP)																
$\Delta MMbtu_a$	=(((	Wall Uvalue$_{base}$	x	Wall SF$_{base}$	)-(	Wall Uvalue$_{ee}$	x	Wall SF$_{ee}$	))x(	$T_{indoor, setpoint}$	-	$T_{outdoor, design}$	)/	1000	)x	EFLH$_{heat}$	/	Eff$_{FuelHeat}$	/	1000
$\Delta MMbtu_a$	=(((	0.143	x	6888	)-(	0.026	x	6888	))x(	70	-	0	)/	1000	)x	1616	/	80%	/	1000
$\Delta MMbtu_a$	=	113																		

ΔMMBtu	**=**	**113.472**
Δfuel oil	**=**	**811**

Total ΔkWh	**=**	**1886**
Total ΔkW	**=**	**1.413**
Δfuel oil	**=**	**811**
Δ$ kWh	**=**	**$314.09**
Δ$ fuel oil	=	**$1,202.86**

Air Infiltration Reduction -
air barrier, ceiling system - page 57

CF	0.69
ΔkWh/1000 ft^2	56
ΔkW/1000 ft^2	0.098
ft^2	5400
ft^2/1000	5.4
Δtherms/1000 ft^2	17

ΔkWh	=	ft^2/1000	x(	ΔkWh/1000 ft^2)			
ΔkWh	=	5.4	x(	56			
ΔkWh	**=**	**302.4**					
ΔkW	=	ft^2/1000	x(	ΔkW/1000 ft^2)	x	CF	
ΔkW	=	5.4	x(	0.098	x	0.69	
ΔkW	**=**	**0.365148**					
ΔMMbtu	=	ft^2/1000	x(	Δtherms/1000 ft^2	)/	10	
ΔMMbtu	=	5.4	x(	17	)/	10	
ΔMMbtu	**=**	**9.18**					
Δfuel oil	**=**	**66**					

Total ΔkWh	**=**	**302**
Total ΔkW	**=**	**0.365**
Δfuel oil	**=**	**66**
Δ$ kWh	**=**	**$50.36**
Δ$ fuel oil	=	**$97.31**

TOTAL EEM-2		
Total ΔkWh	**=**	**2351**
Total ΔkW	**=**	**2.19**
Δfuel oil	**=**	**1113.76**
Δ$ kWh	**=**	**$391.59**
Δ$ fuel oil	=	**$1,652.88**

EEM-3: HVAC Systems

EEM-3a : RTU with DX cooling

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Code:DX Cooling, >=135 kbtuh <240 kbtu, 11.0 EER, 12.4 IEER

electric

$CF_{cooling}$	0.8	
$IEER_{ee}$	12.4	
EER_{ee}	11	
(COP 1.0 w/ hot gas reheat) COP_{ee}	1	
$EFLH_{heat}$	1616	
$EFLH_{Cool}$	575	
baseline steam boiler heating equipment capacity	800	MBH
proposed heating load	300000	btuh
heat load	300	kBTU
proposed cooling load	23	tons
$Eff_{heating,baseline}$	80%	Eff
(Existing wall a/c 9,000 btu, 11.2EER max, use average) $IEER_{baseline}$	9	
~~(Supplemental heat from plug-in and A/C, assume 10%) COP~~$_{baseline}$	2.5	
0.170	COP_{base}	

ΔkWh_{RTU}	=	units	x(	tons/unit	x(	$12/IEER_{baseline}$	-	$12/IEER_{ee}$	)x	$EFLH_{Cool}$	+	(kBTU/h)/unit	/	3.412	x(	$1/COP_{baseline}$	-	$1/COP_{ee}$	)x	$EFLH_{heat}$	)
ΔkWh_{RTU}	=	1	x(	12/1	x(	12 / 9	-	12 / 12.2	)x	575	+	300	/	3.412	x(	1 / 2.5	-	1 / 1	)x	1616	)
ΔkWh_{RTU}	=	1	x(	23	x(	1.33	-	0.97	)x	575	+	87.92			x(	0.170	-	1.000	)x	1616	)
ΔkWh_{RTU}	**=**	**(113,143.72)**																			

ΔkW_{RTU}	=	units	x(	tons/unit	x(	$12/EER_{baseline}$	-	$12/EER_{ee}$	)x	$CF_{cooling}$
ΔkW_{RTU}	=	1	x(	12/1	x(	12 / 9	-	12 / 11	)x	0.8
ΔkW_{RTU}	=	1	x(	23	x(	1.33	-	1.09	)x	0.8
ΔkW_{RTU}	**=**	**4.461**								

Δ$ kWh	**=**	**($18,843.10)**

ΔMMBtu	=	units	x((	$kBTU/h_{heating}$	/	unit	)x(	$F_{fuelheat}$	/	$Eff_{heating,baseline}$	)x (	$EFLH_{heating}$	/	1000	))
ΔMMBtu	=	1	x((	300	/	1	)x(	1	/	80%	)x (	1616	/	1000	))
ΔMMBtu	**=**	**606.000**													
Δfuel oil	**=**	**4329**													
Δ$ fuel oil	=	**$6,423.90**													

EEM-3a		
Total ΔkWh	**=**	**-113144**
Total ΔkW	**=**	**4.461**
Δfuel oil	**=**	**4328.597**
Δ$ kWh	**=**	**($18,843.10)**
Δ$ fuel oil	**=**	**$6,423.90**

EEM-3b : High Efficient RTU with DX cooling

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DX Cooling, >=135 kbtuh <240 kbtu, 12.0 EER, 13.7 IEER

$CF_{cooling}$	0.8
$IEER_{ee}$	13.7
EER_{ee}	12
(COP 1.0 w/ hot gas reheat) COP_{ee}	1
$EFLH_{heat}$	1616
$EFLH_{Cool}$	575
baseline steam boiler heating equipment capacity	800 MBH
proposed heating load	300000 btuh
heat load	300 kBTU
proposed cooling load	23 tons
$Eff_{heating,baseline}$	80% Eff
(Existing wall a/c 9,000 btu, 11.2EER max, use average) $IEER_{baseline}$	9
~~(Supplemental heat from plug-in and A/C, assume 10%) $COP_{baseline}$~~	2.5

ΔkWh_{RTU} = units x(tons/unit x(12/$IEER_{baseline}$ - 12/$IEER_{ee}$)x $EFLH_{Cool}$ + (kBTU/h)/unit / 3.412 x(1/$COP_{baseline}$ - 1/COP_{ee})x $EFLH_{heat}$)

ΔkWh_{RTU} = 1 x(12/1 x(12 / 9 - 12/13.7)x 575 + 300 / 3.412 x(1 / 2.5 - 1 / 1)x 1616)

ΔkWh_{RTU} = 1 x(23 x(1.33 - 0.88)x 575 + 87.92 x(0.170 - 1.000)x 1616)

ΔkWh_{RTU} = (111,929.28)

ΔkW_{RTU} = units x(tons/unit x(12/$EER_{baseline}$ - 12/EER_{ee})x $CF_{cooling}$

ΔkW_{RTU} = 1 x(12/1 x(12 / 9 - 12 / 12.0)x 0.8

ΔkW_{RTU} = 1 x(23 x(1.33 - 1.00)x 0.8

ΔkW_{RTU} = 6.133

Δ$ kWh = ($18,640.84)

ΔMMBtu = units x((kBTU/$h_{heating}$ / unit)x($F_{fuelheat}$ / $Eff_{heating,baseline}$)x ($EFLH_{heating}$ / 1000))

ΔMMBtu = 1 x((300 / 1)x(1 / 0.8)x (1616 / 1000))

ΔMMBtu	=	**606.000**
Δfuel oil	=	**4329**
Δ$ fuel oil	=	**$6,423.90**

Add VAV operation

Motor hp	10 hp
(Appendix K, office, Poughkeepsie) ΔkWh/hp	1606
(Appendix K, Office) ΔkW/hp	0.07
CF	0.8
qty	1 unit

ΔkWh_{fan} = units x hp x(ΔkWh/hp)

ΔkWh_{fan} = 1 x 10 x(1606)

ΔkWh_{fan} = 16,060.00

ΔkWh_{fan} = units x hp x(ΔkW/hp)x CF

ΔkWh_{fan} = 0.8 x 10 x(0.07)x 0.8

ΔkW_{fan} = 0.448

Δ$ kWh = $2,674.65

Energy Recovery

Ventilation, 100% OA	2750	cfm OA
	575	$EFLH_{cool}$
	1616	$EFLH_{heat}$
	70	$T_{indoor, heating}$
	42.15	$T_{outdoor, heating}$
	28.8	$H_{outdoor, cooling}$
	25.3	$H_{indoor, cooling}$
Cooling	12.0	EER
(When EER <= 14)	14.44	SEER
	1	COP
Additional fan power due to ER PD only	0.09	kW_{fan}
	0.6	$Eff_{hx, total}$
	0.6	$Eff_{hx, sens ee}$
baseline - boiler 800MBH , 0.80ET	0.8	
(Existing wall a/c 5,000 btu, 10.7 EER max) $EER_{baseline}$	9	EER
~~(Supplemental heat from plug-in and A/C, assume 10%) $COP_{baseline}$~~	2.5	COP
	0	$Eff_{hx, total base}$
	0	$Eff_{hx, sens base}$

ΔkWh_{ERU1} =[((4.5 x cfm OA x($Eff_{hx, total}$ - $Eff_{hx, total base}$)x($H_{outdoor, cooling}$ - $H_{indoor, cooling}$))/(1000 x $Eff_{ElecCool}$))- kW_{fan}]x $EFLH_{cool}$

ΔkWh_{ERU1} =[((4.5 x 2750 x(0.60 - 0.00)x(28.80 - 25.30))/(1000 x 9.0))- 0.09]x 575

ΔkWh_{ERU1} = 1609

ΔkWh_{cool} = 1609

ΔkWh_{ERU1} =[((1.08 x cfm OA x($Eff_{hx, sens ee}$ - $Eff_{hx, sens base}$)x($T_{indoor, heating}$ - $T_{outdoor, heating}$))/(1000 x $Eff_{ElecHeat}$))x $F_{ElecHeat}$)- kW_{fan}]x $EFLH_{heat}$

ΔkWh_{ERU1} =[((1.08 x 2750 x(0.60 - 0.00)x(70.00 - 42.15))/(1000 x 85.30))x 1)- 0.09]x 1616

ΔkWh_{ERU1} = 797

ΔkWh_{heat} = 797

ΔkW_{ERU1} =[((4.5 x cfm OA x($Eff_{hx, total}$ - $Eff_{hx, total base}$)x($H_{outdoor, cooling}$ - $H_{indoor, cooling}$))/(1000 x $Eff_{ElecCool}$))- kW_{fan}]x CF

ΔkW_{ERU1} =[((4.5 x 2750 x(0.60 - 0.00)x(28.80 - 25.30))/(1000 x 9.0))- 0.09]x 0.8

ΔkW_{ERU1} = 2.239

ΔkW = 2.239

Δ$ kWh = $400.69

$\Delta MMbtu_{ERU1}$ =[(1.08 x cfm OA x($Eff_{hx, sens ee}$ - $Eff_{hx, sens base}$)x($T_{indoor, heating}$ - $T_{outdoor, heating}$))/(1000000 x $Eff_{FuelHeat}$)]x $F_{FuelHeat}$ x $EFLH_{heat}$

$\Delta MMbtu_{ERU1}$ =[(1.08 x 2750 x(0.60 - 0.00)x(70.00 - 42.15))/(1000000 x 0.80)]x 1 x 1616

$\Delta MMbtu_{ERU1}$ = 100.250

ΔMMBtu	=	**100.250**
Δfuel oil	=	**716**
Δ$ fuel oil	=	**$1,062.70**

EEM-3b		
Total ΔkWh	=	**-93463**
Total ΔkW	=	**8.820**
Δfuel oil	=	**5044.673**
Δ$ kWh	=	**($15,565.50)**
Δ$ fuel oil	=	**$7,486.60**

EEM-3c: High Efficient Heat Pump
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$CF_{cooling}$	0.8	
$IEER_{ee}$	14.2	
COP_{ee}	3.4	
EER_{ee}	13	
$EFLH_{heat}$	1616	
$EFLH_{Cool}$	575	
baseline boiler heating equipment capacity	800	MBH
proposed heating load	300000	btuh
	300	kBTU
proposed cooling load	23	tons
$Eff_{heating,baseline}$	80%	Eff
(Existing wall a/c 5,000 btu, 10.7 EER max) $IEER_{baseline}$	9	
~~(Supplemental heat from plug-in and A/C, assume 10%)~~ $COP_{baseline}$	2.5	

ΔkWh_{RTU}	=	units	x(	tons/unit	x(	$12/IEER_{baseline}$	-	$12/IEER_{ee}$	)x	$EFLH_{Cool}$	+	(kBTU/h)/unit	/	3.412	x(	$1/COP_{baseline}$	-	$1/COP_{ee}$	)x	$EFLH_{heat}$)
ΔkWh_{RTU}	=	1	x(	12 / 1	x(	12 / 9	-	12 / 14.2	)x	575	+	300	/	3.412	x(	1 / 2.5	-	1 /3.4	)x	1616)
ΔkWh_{RTU}	=	1	x(	23	x(	1.33	-	0.85	)x	575	+	87.92			x(	0.170	-	0.29	)x	1616)
ΔkWh_{RTU}	**=**	**(11,224.86)**																		

ΔkW_{RTU}	=	units	x(	tons/unit	x(	$12/EER_{baseline}$	-	$12/EER_{ee}$	)x	$CF_{cooling}$
ΔkW_{RTU}	=	1	x(	12 / 1	x(	12 / 9	-	12 / 14.2	)x	0.8
ΔkW_{RTU}	=	1	x(	23	x(	1.33	-	0.92	)x	0.8
ΔkW_{RTU}	**=**	**7.549**								

Δ$ kWh	**=**	**($1,869.40)**

ΔMMBtu	=	units	x((	$kBTU/h_{heating}$	/	unit	)x(	$F_{fuelheat}$	/	$Eff_{heating,baseline}$	)x (	$EFLH_{heating}$	/	1000	))
ΔMMBtu	=	1	x((	300	/	1	)x(	1	/	80%	)x (	1616	/	1000	))
ΔMMBtu	**=**	**606.000**													
Δfuel oil	**=**	**4329**													
Δ$ fuel oil	**=**	**$6,423.90**													

Add VAV operation

Motor hp	7.5	hp
(Appendix K, office, Poughkeepsie) ΔkWh/hp	1606	
(Appendix K, Office) ΔkW/hp	0.07	
CF	0.8	
qty	1	unit

ΔkWh_{fan}	=	units	x	hp	x(	ΔkWh/hp	)	
ΔkWh_{fan}	=	1	x	7.5	x(	1606	)	
ΔkWh_{fan}	**=**	**12,045.00**						
ΔkWh_{fan}	=	units	x	hp	x(	ΔkW/hp	)x	CF
ΔkWh_{fan}	=	0.8	x	7.5	x(	0.07	)x	0.8
ΔkW_{fan}	**=**	**0.336**						

Δ$ kWh	**=**	**$2,005.99**

Energy Recovery

Ventilation, 100% OA	2750	cfm OA
	575	$EFLH_{cool}$
	1616	$EFLH_{heat}$
	70	$T_{indoor, heating}$
	42.15	$T_{outdoor, heating}$
	28.8	$H_{outdoor, cooling}$
	25.3	$H_{indoor, cooling}$
Cooling	13.0	EER
(When EER <= 14)	16.42	SEER
	3.4	COP
Additional fan power due to ER PD only	0.09	kW_{fan}
	0.6	$Eff_{hx, total}$
	0.6	$Eff_{hx, sens\ ee}$
baseline - boiler 800MBH , 0.80ET	0.8	
(Existing wall a/c 5,000 btu, 10.7 EER max) $EER_{baseline}$	9	EER
~~(Supplemental heat from plug-in and A/C, assume 10%)~~ $COP_{baseline}$	2.5	COP
	0	$Eff_{hx, total\ base}$
	0	$Eff_{hx, sens\ base}$

ΔkWh_{ERU1}	=[((	4.5	x	cfm OA	x(	$Eff_{hx, total}$	-	$Eff_{hx, total\ base}$	)x(	$H_{outdoor, cooling}$	-	$H_{indoor, cooling}$	))/(	1000	x	$Eff_{ElecCool}$	))-	kW_{fan}	]x	$EFLH_{cool}$
ΔkWh_{ERU1}	=[((	4.5	x	2750	x(	0.60	-	0.00	)x(	28.80	-	25.30	))/(	1000	x	9.0	))-	0.09	]x	575
ΔkWh_{ERU1}	=	1609																		
ΔkWh_{cool}	**=**	**1609**																		

ΔkWh_{ERU1}	=[((	1.08	x	cfm OA	x(	$Eff_{hx, sens\ ee}$	-	$Eff_{hx, sens\ base}$	)x(	$T_{indoor, heating}$	-	$T_{outdoor, heating}$	))/(	1000	x	$Eff_{ElecHeat}$	))x	$F_{ElecHeat}$	)-	kW_{fan}	]x	$EFLH_{heat}$
ΔkWh_{ERU1}	=[((	1.08	x	2750	x(	0.60	-	0.00	)x(	70.00	-	42.15	))/(	1000	x	85.30	))x	1	)-	0.09	]x	1616
ΔkWh_{ERU1}	=	797																				
ΔkWh_{heat}	**=**	**797**																				

ΔkW_{ERU1}	=[((	4.5	x	cfm OA	x(	$Eff_{hx, total}$	-	$Eff_{hx, total\ base}$	)x(	$H_{outdoor, cooling}$	-	$H_{indoor, cooling}$	))/(	1000	x	$Eff_{ElecCool}$	))-	kW_{fan}	]x	CF
ΔkW_{ERU1}	=[((	4.5	x	2750	x(	0.60	-	0.00	)x(	28.80	-	25.30	))/(	1000	x	9.0	))-	0.09	]x	0.8
ΔkW_{ERU1}	=	2.239																		
ΔkW	**=**	**2.239**																		

$\Delta MMbtu_{ERU1}$	=[(	1.08	x	cfm OA	x(	$Eff_{hx, sens\ ee}$	-	$Eff_{hx, sens\ base}$	)x(	$T_{indoor, heating}$	-	$T_{outdoor, heating}$	))/(	1000000	x	$Eff_{FuelHeat}$	)]x	$F_{FuelHeat}$	x	$EFLH_{heat}$
$\Delta MMbtu_{ERU1}$	=[(	1.08	x	2750	x(	0.60	-	0.00	)x(	70.00	-	42.15	))/(	1000000	x	0.80	)]x	1	x	1616
$\Delta MMbtu_{ERU1}$	=	100.250																		

ΔMMBtu	**=**	**100.250**
Δfuel oil	**=**	**716**

EEM-3c		
Total ΔkWh	**=**	**3226**
Total ΔkW	**=**	**10.124**
Δfuel oil	**=**	**5044.673**
Δ$ kWh	**=**	**$537.28**
Δ$ fuel oil	**=**	**$7,486.60**

EEM-3d: VRF System (pg 151/168)

page 168
$EFLH_{cooling}$ 575
$EFLH_{heating}$ 1616
cool tons 23
$kBTU/h_{cooling}$ 276
$kBTU/h_{heating}$ 300
F_{cec} 1
EER_{ee} 17
COP_{ee} 3.4

																								0.233		
ΔkWh	=	units	x((	$kBTU/h_{cooling}$	/	unit	x(	F_{cec}	/	$EER_{baseline}$	-	$1/EER_{ee}$	)x	$EFLH_{cooling}$	+(	$kBTU/h_{heating}$	/	unit X 3.412	X(	$F_{elecheat}$	/	$COP_{baseline}$	-	$1/COP_{ee}$	)x	$EFLH_{heating}$
ΔkWh	=	1	x((	276	/	1	x(	1	/	9	-	1 / 17	)x	575	+(	300	/	3.41200	X(	1	/	2.5	-	1 / 3.4	)x	1616
ΔkWh	=	1	x((	276	/	1	x(	1	/	9	-	0.06	)x	575	+(	87.92			X(	0.170			-	0.294	)x	1616
ΔkWh	**=**	**(9,384.10)**																								
										1682.345																
										0.061																

ΔkW	=	units	x[(	$kBTU/h_{cooling}$	/	unit	)x((	F_{cec}	/	$EER_{baseline}$	) - (	$1/EER_{ee}$	))x	CF	]
ΔkW	=	1	x[(	276	/	1	)x((	1	/	9	) - (	1 / 17	))x	0.69	]
ΔkW	**=**	**9.958**													

CF 0.69
$F_{fuelheat}$ 1
$Eff_{heating,baseline}$ 0.8
$F_{elecheat}$ 1

ΔMMBtu	=	units	x((	$kBTU/h_{heating}$	/	unit	)x(	$F_{fuelheat}$	/	$Eff_{heating,baseline}$	)x (	$EFLH_{heating}$	/	1000	))
ΔMMBtu	=	1	x((	300	/	1	)x(	1	/	0.8	)x (	1616	/	1000	))
ΔMMBtu	**=**	**606.000**													
Δfuel oil	**=**	**4329**													

baseline - boiler 800MBH , 0.80ET
(Existing wall a/c 9,000 btu, 11.2 EER max) $EER_{baseline}$ 9
~~(Supplemental heat from plug-in and A/C, assume 10%) $COP_{baseline}$~~ 2.5

Add VAV operation

Motor hp 7.5 hp
(Appendix K, office, Poughkeepsie) ΔkWh/hp 1606
(Appendix K, Office) ΔkW/hp 0.07
CF 0.8
qty 1 unit

ΔkWh_{fan}	=	units	x	hp	x(	ΔkWh/hp	)		
ΔkWh_{fan}	=	1	x	7.500	x(	1606	)		
ΔkWh_{fan}	**=**	**12,045.00**							
ΔkWh_{fan}	=	units	x	hp	x(	ΔkW/hp	)x	CF	
ΔkWh_{fan}	=	0.8	x	7.500	x(	0.07	)x	0.8	
ΔkW_{fan}	**=**	**0.336**							
Δ$ kWh	**=**	**$2,005.99**							

Energy Recovery

Ventilation, 100% OA 2750 cfm OA
$EFLH_{cooling}$ 575 $EFLH_{cool}$
$EFLH_{heating}$ 1616 $EFLH_{heat}$
70 $T_{indoor, heating}$
42.15 $T_{outdoor, heating}$
28.8 $H_{outdoor, cooling}$
25.3 $H_{indoor, cooling}$
Cooling 13.0 EER
(When EER <= 14) 16.42 SEER
3.4 COP
Additional fan power due to ER PD only 0.09 kW_{fan}
0.6 $Eff_{hx, total}$
0.6 $Eff_{hx, sens ee}$
baseline - steam boiler 800MBH , 0.80ET 0.8
(Existing wall a/c 9,000 btu, 11.2 EER max) $EER_{baseline}$ 9 EER
~~(Supplemental heat from plug-in and A/C, assume 10%) $COP_{baseline}$~~ 2.5 COP
0 $Eff_{hx, total base}$
0 $Eff_{hx, sens base}$

ΔkWh_{ERU1}	=[((	4.5	x	cfm OA	x(	$Eff_{hx, total}$	-	$Eff_{hx, total base}$	)x(	$H_{outdoor, cooling}$	-	$H_{indoor, cooling}$	))/(	1000	x	$Eff_{ElecCool}$	))-	kW_{fan}	]x	$EFLH_{cool}$	
ΔkWh_{ERU1}	=[((	4.5	x	2750	x(	0.60	-	0.00	)x(	28.80	-	25.30	))/(	1000	x	9.0	))-	0.09	]x	575	
ΔkWh_{ERU1}	=	1609																			
ΔkWh_{cool}	**=**	**1609**																			
ΔkWh_{ERU1}	=[((	1.08	x	cfm OA	x(	$Eff_{hx, sens ee}$	-	$Eff_{hx, sens base}$	)x(	$T_{indoor, heating}$	-	$T_{outdoor, heating}$	))/(	1000	x	$Eff_{ElecHeat}$	))x	$F_{ElecHeat}$	)-	kW_{fan}]x	$EFLH_{heat}$
ΔkWh_{ERU1}	=[((	1.08	x	2750	x(	0.60	-	0.00	)x(	70.00	-	42.15	))/(	1000	x	85.30	))x	1	)-	0.09]x	1616
ΔkWh_{ERU1}	=	797																			
ΔkWh_{heat}	**=**	**797**																			
ΔkW_{ERU1}	=[((	4.5	x	cfm OA	x(	$Eff_{hx, total}$	-	$Eff_{hx, total base}$	)x(	$H_{outdoor, cooling}$	-	$H_{indoor, cooling}$	))/(	1000	x	$Eff_{ElecCool}$	))-	kW_{fan}	]x	CF	
ΔkW_{ERU1}	=[((	4.5	x	2750	x(	0.60	-	0.00	)x(	28.80	-	25.30	))/(	1000	x	9.0	))-	0.09	]x	0.8	
ΔkW_{ERU1}	=	2.239																			
ΔkW	**=**	**2.239**																			
$\Delta MMbtu_{ERU1}$	=[(	1.08	x	cfm OA	x(	$Eff_{hx, sens ee}$	-	$Eff_{hx, sens base}$	)x(	$T_{indoor, heating}$	-	$T_{outdoor, heating}$	))/(	1000000	x	$Eff_{FuelHeat}$	)]x	$F_{FuelHeat}$	x	$EFLH_{heat}$	
$\Delta MMbtu_{ERU1}$	=[(	1.08	x	2750	x(	0.60	-	0.00	)x(	70.00	-	42.15	))/(	1000000	x	0.80	)]x	1	x	1616	
$\Delta MMbtu_{ERU1}$	=	100.250																			
ΔMMBtu	**=**	**100.250**																			
Δfuel oil	**=**	**716**																			

EEM-3d		
Total ΔkWh	=	5067
Total ΔkW	=	12.533
Δfuel oil	=	5044.673
Δ$ kWh	=	$843.84
Δ$ fuel oil	=	$7,486.60

EEM-3e: GSHP (pg 562)

EFLH$_{heating}$	1616	
COPseason, ee - Closed loop	3.6	
~~COP season,base~~	2.500	
Felecheat	0	
BHL - heating load (BTU/h)	300000	
BCL - cooling load (BTU/h)	276000	
EFLHcooling	575	
EERseason,ee - closed loop	15	
EERseason,base ,	9	
EERpeak,season	11.2	
EERGSHP,full,ee	18.1	
CF, Coincidence Factor	0.8	
F$_{fuelHeat}$	1	
Eff$_{baseline}$	0.8	
baseline - boiler 800MBH , 0.80ET		

ΔkWh	=[	BCL/1000	x(	1/EER$_{season,base}$	-	1/EER$_{season,ee}$	)x	EFLH$_{cooling}$	]+[	BHL/3,412	x(	F$_{elecheat}$	/	COP $_{season,base}$	- 1/COP$_{season, ee}$	)x EFLH$_{heating}$
ΔkWh	=[	235208/1000	x(	1/9	-	1/15	)x	575	]+[	326521/3,412	x(	0	/	2.500	- 1/3	)x 1616
ΔkWh	=[	276	x(	0.111	-	0.067	)x	575	]+[	87.925	x(	0.170			- 0.278	)x 1616
ΔkWh	**=**	**-8307**														

ΔkW	=	BCL/1000	x(	1/EER$_{peak,season}$	-	1/EER$_{GSHP,full,ee}$	)x	CF
ΔkW	=	235208/1000	x(	1/11.2	-	1/14.1	)x	0.8
ΔkW	=	276	x(	0.089	-	0.055	)x	0.8
ΔkW	**=**	**7.515**						

ΔMMBtu	=	BHL/1,000,000	x	F$_{fuelHeat}$	/	Eff$_{baseline}$	x	EFLH$_{heating}$
ΔMMBtu	=	326521/1,000,000	x	1	/	0.8	x	1616
ΔMMBtu	=	0.3	x	1	/	0.8	x	1616
ΔMMBtu	**=**	**606.000**						
Δfuel oil	**=**	**4329**						

Add VAV operation

Motor hp	7.5	hp
(Appendix K, office, Poughkeepsie) ΔkWh/hp	1606	
(Appendix K, Office) ΔkW/hp	0.07	
CF	0.8	
qty	1	unit

ΔkWh$_{fan}$	=	units	x	hp	x(	ΔkWh/hp	)	
ΔkWh$_{fan}$	=	1	x	7.500	x(	1606	)	
ΔkWh$_{fan}$	**=**	**12,045.00**						
ΔkWh$_{fan}$	=	units	x	hp	x(	ΔkW/hp	)x	CF
ΔkWh$_{fan}$	=	0.8	x	7.500	x(	0.07	)x	0.8
ΔkW$_{fan}$	**=**	**0.336**						
Δ$ kWh	**=**	**$2,005.99**						

Energy Recovery

Ventilation, 100% OA	2750	cfm OA	
EFLH$_{cooling}$	575	EFLH$_{cool}$	
EFLH$_{heating}$	1616	EFLH$_{heat}$	
	70	T$_{indoor, heating}$	
	42.15	T$_{outdoor, heating}$	
	28.8	H$_{outdoor, cooling}$	
	25.3	H$_{indoor, cooling}$	
Cooling	17.0	EER	
(When EER > 14)	19.43	SEER	
	4.3	COP	
Additional fan power due to ER PD only	0.09	kW$_{fan}$	
	0.6	Eff$_{hx, total}$	
	0.6	Eff$_{hx, sens ee}$	
baseline - boiler 800MBH , 0.80ET	0.8		
(Existing wall a/c 9,000 btu, 11.2 EER max) EER$_{baseline}$	9	EER	
~~(Supplemental heat from plug-in and A/C, assume 10%) COP$_{baseline}$~~	2.5	COP	
	0	Eff$_{hx, total base}$	
	0	Eff$_{hx, sens base}$	

ΔkWh$_{ERU1}$	=[((	4.5	x	cfm OA	x(	Eff$_{hx, total}$	-	Eff$_{hx, total base}$	)x(	H$_{outdoor, cooling}$	-	H$_{indoor, cooling}$	))/(	1000	x	Eff$_{ElecCool}$	))-	kW$_{fan}$	]x EFLH$_{cool}$
ΔkWh$_{ERU1}$	=[((	4.5	x	2750	x(	0.60	-	0.00	)x(	28.80	-	25.30	))/(	1000	x	9.0	))-	0.09	]x 575
ΔkWh$_{ERU1}$	=	1609																	
ΔkWh$_{cool}$	**=**	**1609**																	
ΔkWh$_{ERU1}$	=[((	1.08	x	cfm OA	x(	Eff$_{hx, sens ee}$	-	Eff$_{hx, sens base}$	)x(	T$_{indoor, heating}$	-	T$_{outdoor, heating}$	))/(	1000	x	Eff$_{ElecHeat}$	))x	F$_{ElecHeat}$	)- kW$_{fan}$]x EFLH$_{heat}$
ΔkWh$_{ERU1}$	=[((	1.08	x	2750	x(	0.60	-	0.00	)x(	70.00	-	42.15	))/(	1000	x	85.30	))x	1	)- 0.09]x 1616
ΔkWh$_{ERU1}$	=	797																	
ΔkWh$_{heat}$	**=**	**797**																	
ΔkW$_{ERU1}$	=[((	4.5	x	cfm OA	x(	Eff$_{hx, total}$	-	Eff$_{hx, total base}$	)x(	H$_{outdoor, cooling}$	-	H$_{indoor, cooling}$	))/(	1000	x	Eff$_{ElecCool}$	))-	kW$_{fan}$	]x CF
ΔkW$_{ERU1}$	=[((	4.5	x	2750	x(	0.60	-	0.00	)x(	28.80	-	25.30	))/(	1000	x	9.0	))-	0.09	]x 0.8
ΔkW$_{ERU1}$	=	2.239																	
ΔkW	**=**	**2.239**																	
ΔMMbtu$_{ERU1}$	=[(	1.08	x	cfm OA	x(	Eff$_{hx, sens ee}$	-	Eff$_{hx, sens base}$	)x(	T$_{indoor, heating}$	-	T$_{outdoor, heating}$	))/(	1000000	x	Eff$_{FuelHeat}$	)]x	F$_{FuelHeat}$	x EFLH$_{heat}$
ΔMMbtu$_{ERU1}$	=[(	1.08	x	2750	x(	0.60	-	0.00	)x(	70.00	-	42.15	))/(	1000000	x	0.80	)]x	1	x 1616
ΔMMbtu$_{ERU1}$	=	100.250																	
ΔMMBtu	**=**	**100.250**																	
Δfuel oil	**=**	**716**																	

EEM-3e		
Total ΔkWh	**=**	**6144**
Total ΔkW	**=**	**10.090**
Δfuel oil	**=**	**5044.673**
Δ$ kWh	**=**	**$1,023.20**
Δ$ fuel oil	**=**	**$7,486.60**

EEM-4: Domestic Hot Water

Occupied days per year	365	Days/yr
UEF baseline	0.8400	UEF
PoughkeepsieT_{main}	55.8	°F
Poughkeepsie Annual Average outdoor temp	49.8	°F
Tset	140	
GPD from p449 table	110	
Et_{ee}, $AFUE_{ee}$, assumed eff of fossil fuel htg sys	92%	
Et_{base}, AFUE , assumed eff of fossil fuel htg sys	80%	
ASHP SEER	13	
ASHP HSPF	8.2	
F_{eDHW}	1	
$UEF_{ee,}$ Propane and Electric	0.92	UEF
$UEF_{ee,}$ ASHP	2.5	UEF
$UEF_{ee,}$ GSHP	3	UEF
F_{derate}	1.00	
F_{cool}	0.51	
F_{LOC}	1	
$F_{elecheat}$	1	
F_{heat}	0.49	
$F_{fuelheat}$	0	
FboilerDHW	1	
FFFDHW	1.0	
Electric SEER	3.412	
Electric HSPF	3.412	
GSHP SEER	15	
GSHP HSPF	9.6	

EEM-4a: DHW served by Propane Unit

ΔkWh	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	3412	x(	F_{eDHW}	/	$Et_{baseline}$	-(1/	Et_{ee}	))x(	F_{eDHW}	/	$UEF_{baseline}$	-(	1/	UEF_{ee}	x	F_{derae}	))+	$\Delta kWh_{cooling}$	-	$\Delta kWh_{heating}$
ΔkWh	=	1	x(	88.537	x	365	x	8.33	x	140-55.8	)/	3412	x(	1	/	1.000	-(0/	92%	))x(	1	/	0.840	-(	0/	0.92	x	1.00	))+	442	-	674
ΔkWh	=	1	x(	88.537	x	365	x	8.33	x	84.2	)/	3412	x(	1.000			-(0.000		))x(	1.190			-(	0.000				))+	442	-	674
ΔkWh	=	1	x(	22665887.334							)/	3412	x(	1.000					))x(	1.190								))+	442	-	674
ΔkWh	**=**	**7676**																													

ΔkW	=	units	x(	ΔkW	/	unit)
ΔkW	=	1	x	0.17		
ΔkW	**=**	**0.170**				

ΔMMBtu	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	1000000	x(	F_{eDHW}	/	$Et_{baseline}$	-(1/	Et_{ee}	x((	FFFDHW	/	UEFbaseline	)+(	FboilerDHW /	AFUE	)-(	1/UEFee	x	Floc	x	Ffuelheat	x	Fheat/AFUE
ΔMMBtu	=	1	x(	21.463	x	365	x	8.33	x	140-55.8	)/	1000000	x(	1	/	0.800	-(0/	92%	x((	1.0	/	0.840	)+(	1/	80%	)-(	0/.92	x	1	x	0	x	0.49/80%
ΔMMBtu	=	1	x(			5494760.566					)/	1000000	x(	1.250			-(0.000		x((	1.0	/	0.840	)+(	1.25		)-(	0.000	x	1	x	0	x	0.6125
ΔMMBtu	=	16.762											x(	1.250																			
Δfuel oil	**=**	**120**																															

ΔMMBtu	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	1000000	x(	F_{eDHW}	/	$Et_{baseline}$	-(1/	Et_{ee}	x((	FFFDHW	/	UEFbaseline	)+(	FboilerDHW /	AFUE	)-(	1/UEFee	x	Floc	x	Ffuelheat	x	Fheat/AFUE
ΔMMBtu	=	1	x(	110	x	365	x	8.33	x	140-55.8	)/	1000000	x(	0	/	0.800	-(1/	92%	x((	1.0	/	0.840	)+(	0/	80%	)-(	1/.92	x	1	x	1	x	0.49/80%
ΔMMBtu	=	1	x(			28160647.900					)/	1000000	x(	0.000			-(1.087		x((	1.0	/	0.840	)+(	0		)-(	1.087	x	1	x	1	x	0.6125
ΔMMBtu	=	-16.061											x(	-1.087																			
Δpropane	**=**	**-168**																															

EEM-4a		
Total ΔkWh	**=**	**7676**
Total ΔkW	**=**	**0.170**
Δ fuel oil	**=**	**119.731**
Δpropoane	**=**	**-168.177**
Δ$ kWh	**=**	**$1,278.44**
Δ$ fuel oil	**=**	**$19.94**
Δ$ Propane	**=**	**-$249.58**

EEM-4b: DHW served by Electric Unit

ΔkWh	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	3412	x(	F_{eDHW}	/	$UEF_{baseline}$	-(1/	UEF_{ee}	x	F_{derae}	))+	$\Delta kWh_{cooling}$	-	$\Delta kWh_{heating}$
ΔkWh	=	1	x(	88.537	x	365	x	8.33	x	140-55.8	)/	3412	x(	0	/	0.8400	-(1/	0.92	x	1.00	))+	442	-	674
ΔkWh	=	1	x(	88.537	x	365	x	8.33	x	84.2	)/	3412	x(	0.000			-(1.087				))+	442	-	674
ΔkWh	=	1	x(	22665887.334							)/	3412	x(	-1.087							))+	442	-	674
ΔkWh	**=**	**-7453**																						

$\Delta kWh_{cooling}$	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	3412	x(	$1/UEF_{ee}$	)x	F_{LOC}	x(	F_{cool} /	SEER/3.412	)
$\Delta kWh_{cooling}$	=	1	x(	88.537	x	365	x	8.33	x	140-55.8	)/	3412	x(	1/.92	)x	1	x(	0.51/	3.412/3.412	)
$\Delta kWh_{cooling}$	=	1	x(	88.537	x	365	x	8.33	x	84.2	)/	3412	x(	1.087	)x	1	x(	0.510		)
$\Delta kWh_{cooling}$	=	1	x(	22665887.334							)/	3412	x(	1.087	)x	1	x(	0.510		)
$\Delta kWh_{cooling}$	**=**	**3683**																		

$\Delta kWh_{heating}$	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	3412	x(	$1/UEF_{ee}$	)x	F_{LOC}	x	$F_{elecheat}$	x	F_{heat}/	HSPF/3.412
$\Delta kWh_{heating}$	=	1	x(	88.537	x	365	x	8.33	x	140-55.8	)/	3412	x(	1/.92	)x	1	x	1	x	0.49/	3.412/3.412
$\Delta kWh_{heating}$	=	1	x(	88.537	x	365	x	8.33	x	84.2	)/	3412	x(	1.087	)x	1	x	1	x	0.49/	1.000
$\Delta kWh_{heating}$	=	1	x(			22665887.334					)/	3412	x(	1.087	)x	1	x	1	x	0.490	
$\Delta kWh_{heating}$	**=**	**3538**																			

ΔkW	=	units	x(	ΔkW	/	unit)
ΔkW	=	1	x	0.211		
ΔkW	**=**	**0.211**				

ΔMMBtu	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	1000000	x((	FFFDHW	/	UEFbaseline	)+(	FboilerDHW /	AFUE	)-(	1/UEFee	x	Floc	x	Ffuelheat	x	Fheat/AFUE	)
ΔMMBtu	=	1	x(	21.463	x	365	x	8.33	x	140-55.8	)/	1000000	x((	1.0	/	0.8400	)+(	1/	80%	)-(	0/.92	x	1	x	0	x	0.49/80%	)
ΔMMBtu	=	1	x(			5494760.566					)/	1000000	x((	1.0	/	0.8400	)+(	1.25		)-(	1.087	x	1	x	0	x	0.6125	)
ΔMMBtu	=	13.410																										
Δfuel oil	**=**	**96**																										

EEM-4b		
Total ΔkWh	**=**	**224**
Total ΔkW	**=**	**0.041**
Δfuel oil	**=**	**119.731**
Δ$ kWh	**=**	**$37.27**
Δ$ fuel oil	**=**	**$177.69**

EEM-4c: DHW served by Air Source Heat Pump

ΔkWh	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	3412	x(	F_{eDHW}	/	$UEF_{baseline}$	-(1/		UEF_{ee}	x	F_{derae}	))+	$\Delta kWh_{cooling}$	-	$\Delta kWh_{heating}$
ΔkWh	=	1	x(	110.000	x	365	x	8.33	x	140-55.8	)/	3412	x(	1	/	0.8400	-(1/		2.5	x	1.00	))+	442	-	674
ΔkWh	=	1	x(	88.537	x	365	x	8.33	x	84.2	)/	3412	x(	1.190			-(	0.400				))+	442	-	674
ΔkWh	=	1	x(	22665887.334							)/	3412	x(	0.790								))+	442	-	674
ΔkWh	**=**	**5019**																							

$\Delta kWh_{cooling}$	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	3412	x(	$1/UEF_{ee}$	)x	F_{LOC}	x(	F_{cool} /	SEER/3.412	)
$\Delta kWh_{cooling}$	=	1	x(	110.000	x	365	x	8.33	x	140-55.8	)/	3412	x(	1/2.5	)x	1	x(	0.51/	13/3.412	)
$\Delta kWh_{cooling}$	=	1	x(	110.000	x	365	x	8.33	x	84.2	)/	3412	x(	0.400	)x	1	x(	0.134		)
$\Delta kWh_{cooling}$	=	1	x(	28160647.900							)/	3412	x(	0.400	)x	1	x(	0.134		)
$\Delta kWh_{cooling}$	**=**	**442**																		

$\Delta kWh_{heating}$	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	3412	x(	$1/UEF_{ee}$	)x	F_{LOC}	x	$F_{elecheat}$	x	F_{heat}/	HSPF/3.412
$\Delta kWh_{heating}$	=	1	x(	110.000	x	365	x	8.33	x	140-55.8	)/	3412	x(	1/2.5	)x	1	x	1	x	0.49/	8.2/3.412
$\Delta kWh_{heating}$	=	1	x(	110.000	x	365	x	8.33	x	84.2	)/	3412	x(	0.400	)x	1	x	1	x	0.49/	2.401
$\Delta kWh_{heating}$	=	1	x(			28160647.900					)/	3412	x(	0.400	)x	1	x	1	x	0.204	
$\Delta kWh_{heating}$	**=**	**674**																			

ΔkW	=	units	x(	ΔkW	/	unit)
ΔkW	=	1	x	0.061		
ΔkW	**=**	**0.061**				

ΔMMBtu	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	1000000	x((	FFFDHW	/	UEFbaseline	)+(	FboilerDHW /	AFUE	)-(	1/UEFee	x	Floc	x	Ffuelheat	x	Fheat/AFUE	)
ΔMMBtu	=	1	x(	21.463	x	365	x	8.33	x	140-55.8	)/	1000000	x((	1.0	/	0.8400	)+(	1/	80%	)-(	1/2.5	x	1	x	0	x	0.49/80%	)
ΔMMBtu	=	1	x(			5494760.566					)/	1000000	x((	1.0	/	0.8400	)+(	1.25		)-(	0.400	x	1	x	0	x	0.6125	)
ΔMMBtu	=	13.410																										
Δfuel oil	**=**	**96**																										

EEM-4c		
Total ΔkWh	**=**	**5019**
Total ΔkW	**=**	**0.061**
Δfuel oil	**=**	**119.731**
Δ$ kWh	**=**	**$835.90**
Δ$ fuel oil	**=**	**$177.69**

EEM-4d: DHW served by geothermal well field

ΔkWh	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	3412	x(	F_{eDHW}	/	$UEF_{baseline}$	-(1/		UEF_{ee}	x	F_{derae}	))+	$\Delta kWh_{cooling}$	-	$\Delta kWh_{heating}$
ΔkWh	=	1	x(	88.537	x	365	x	8.33	x	140 -55.8	)/	3412	x(	1	/	0.8400	-(1/		3	x	1.00	))+	296	-	387
ΔkWh	=	1	x(	88.537	x	365	x	8.33	x	84.2	)/	3412	x(	1.190			-(	0.333				))+	296	-	387
ΔkWh	=	1	x(	22665887.334							)/	3412	x(	0.857								))+	296	-	387
ΔkWh	**=**	**5603**																							

$\Delta kWh_{cooling}$	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	3412	x(	$1/UEF_{ee}$	)x	F_{LOC}	x(	F_{cool} /	SEER/3.412	)
$\Delta kWh_{cooling}$	=	1	x(	88.537	x	365	x	8.33	x	140 -55.8	)/	3412	x(	1/3.0	)x	1	x(	0.51/	13/3.412	)
$\Delta kWh_{cooling}$	=	1	x(	88.537	x	365	x	8.33	x	84.2	)/	3412	x(	0.333	)x	1	x(	0.134		)
$\Delta kWh_{cooling}$	=	1	x(	22665887.334							)/	3412	x(	0.333	)x	1	x(	0.134		)
$\Delta kWh_{cooling}$	**=**	**296**																		

$\Delta kWh_{heating}$	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	3412	x(	$1/UEF_{ee}$	)x	F_{LOC}	x	$F_{elecheat}$	x	F_{heat}/	HSPF/3.412
$\Delta kWh_{heating}$	=	1	x(	88.537	x	365	x	8.33	x	140 -55.8	)/	3412	x(	1/3.0	)x	1	x	1	x	0.49/	9/6/3.412
$\Delta kWh_{heating}$	=	1	x(	88.537	x	365	x	8.33	x	84.2	)/	3412	x(	0.333	)x	1	x	1	x	0.49/	2.801
$\Delta kWh_{heating}$	=	1	x(			22665887.334					)/	3412	x(	0.333	)x	1	x	1	x	0.175	
$\Delta kWh_{heating}$	**=**	**387**																			

ΔkW	=	units	x(	ΔkW	/	unit)
ΔkW	=	1	x	0.071		
ΔkW	**=**	**0.071**				

ΔMMBtu	=	units	x(	GPD	x	365	x	8.33	x	ΔT_{main}	)/	1000000	x((	FFFDHW	/	UEFbaseline	)+(	FboilerDHW /	AFUE	)-(	1/UEFee	x	Floc	x	Ffuelheat	x	Fheat/AFUE	)
ΔMMBtu	=	1	x(	21.463	x	365	x	8.33	x	140 -55.8	)/	1000000	x((	1.0	/	0.8400	)+(	1/	80%	)-(	1/3.0	x	1	x	0	x	0.49/80%	)
ΔMMBtu	=	1	x(			5494760.566					)/	1000000	x((	1.0	/	0.8400	)+(	1.25		)-(	0.333	x	1	x	0	x	0.6125	)
ΔMMBtu	=	13.410																										
Δfuel oil	**=**	**96**																										

EEM-4d		
Total ΔkWh	**=**	**5603**
Total ΔkW	**=**	**0.071**
Δfuel oil	**=**	**119.731**
Δ$ kWh	**=**	**$933.13**
Δ$ fuel oil	**=**	**$177.69**

EEM-5: Kitchen Appliances

Refrigerator

CF, coincidence factor	1
$HVAC_c$, interaction factor for annual elec energy consumption	0.066
$HVAC_d$, interaction factor at utility summer peak hour	0.175
$HVAC_{ff}$, interaction factor for annual fossil fuel consumption	-0.002
8,760 , hours in one year	
$kWh_{baseline}$, US federal standard	495
kWh_{ee} , ENERGY STAR	214
page - 381	

Refrigerator

ΔkWh	=	units	x(	$kWh_{baseline}$	-	kWh_{ee}	)x(	1	+	$HVAC_c$	)			
ΔkWh	=	4	x(	495	-	214	)x(	1	+	0.066	)			
ΔkWh	=	4	x(		281		)x(		1.066		)			
ΔkWh	**=**	**1198.184**												
ΔkW	=	units	x(	$kWh_{baseline}$	-	kWh_{ee}	/	8760	)x(	1	+	$HVAC_d$	)x	CF
ΔkW	=	4	x(	495	-	214	/	8760	)x(	1	+	0.175	)x	1
ΔkW	=	4	x(		281		/	8760	)x(		1.175		)x	1
ΔkW	**=**	**0.151**												
ΔMMBtu	=	units	x(	$kWh_{baseline}$	-	kWh_{ee}	)x	$HVAC_{ff}$						
ΔMMBtu	=	4	x(	495	-	214	)x	-0.002						
ΔMMBtu	=	4	x(		281		)x	-0.002						
ΔMMBtu	**=**	**-2.248**												
ΔFuel Oil	**=**	**-16**												

Ice maker

$kWh_{baseline}$, Batch type, self-contained	10.3345
kWh_{ee} , Batch type, self-contained	8.7795
Cycle , compressor duty cycle	0.75
IHR - Ice Harvest Rate	95
CF, coincidence factor	0.9
page - 355	

Ice Maker

ΔkWh	=	units	x(	$kWh_{baseline}$	-	kWh_{ee}	)x	365	x	Cycle	x(	IHR/100	)
ΔkWh	=	1	x(	10.3345	-	8.7795	)x	365	x	0.75	x(	95/100	)
ΔkWh	=	1	x(		1.5550		)x	365	x	0.75	x(	0.95	)
ΔkWh	**=**	**404.397**											
ΔkW	=	((ΔkWh	/(	8,760	x	Cycle	))x	CF					
ΔkW	=	((51363.982	/(	8,761	x	0.75	))x	0.9					
ΔkW	**=**	**0.055**											

Kitchen Demand Control Ventilation

page 583 - kitchen demand control vent	
hp- horsepower of exhaust fan	1
ΔkWh/hp	4,423
258 cfm / linear foot	3,870
kilowatts	1.161
kilowatts to hp	0.865758
ΔkW/hp	0.612
CF, coincidence factor	0.9
ΔMMBtu/hp (Poughkeepsie)	25

Kitchen Demand Control Ventilation

ΔkWh	=	units	x	hp	x(	ΔkWh/hp	)	
ΔkWh	=	1	x	1	x(	4423	)	
ΔkWh	**=**	**4423**						
ΔkW	=	units	x	hp	x(	ΔkW/hp	)x	CF
ΔkW	=	1	x	1	x(	0.9	)x	0.9
ΔkW	**=**	**0.81**						
ΔMMBtu	=	units	x	hp	x	ΔMMBtu/hp		
ΔMMBtu	=	1	x	1	x	25		
ΔMMBtu	**=**	**25**						
ΔFuel Oil	**=**	**179**						

Total ΔkWh	**=**	**6026**
Total ΔkW	**=**	**1.016**
Δ$ kWh	**=**	**$1,003.51**
Total Δ Fuel Oil	**=**	**163**
Total Δ$ Fuel Oil	**=**	**$241.18**

Mechanical/Electrical
Engineering Consultants
60 LAKEFRONT BLVD, SUITE 320
BUFFALO, NY 14202

Budget Pricing Cost Estimate			
PROJECT NAME: Rhinebeck Village Hall			
M/E REFERENCE:	211222	DATE:	2/14/2022
DIVISION:	**ENERGY**	BY:	KEW

ITEM	DESCRIPTION	QTY.	UNIT	LABOR COST	MATERIAL COST	TOTAL ITEM COST
EEM-1: High-Efficiency Lighting						
	Code Compliant Fixtures - Office	8200	SF	$1.50	$0.80	$18,860
	Code Compliant Fixtures - Firetruck	3600	SF	$1.50	$0.80	$8,280
	TOTAL BASECASE					$27,140
	LED Lighting & Controls-Office	8200	SF	$1.50	$1.00	$20,500
	LED Lighting & Controls-Firetruck	3600	SF	$1.50	$1.00	$9,000
	TOTAL PROPOSED					$29,500
	EEM-1 TOTAL INCREMENTAL COST					**$29,500**
EEM-2: Envelope Improvements						
	Existing Roof To Remain	5400	SF	$0.00	$0	$0
	Existing Walls To Remain	6888	SF	$0.00	$0	$0
	TOTAL BASECASE					$0
EEM-2	Add Roof, 4" insulation R-30 total	5400	SF	$12.00	$4.94	$91,449
	Furr out Walls, 3.5" studs with 4" batt insul	6888	SF	$3.75	$2.66	$44,105
	Ceiling System - Air Barrier	5400	SF	$0.75	$0.50	$6,750
	TOTAL EEM-2 PROPOSED			$94,644.96	$47,659.57	$142,305
	EEM-2 TOTAL INCREMENTAL COST					**$142,305**
*EEM-3: HVAC Options **						
EEM-3a Code RTU with DX cooling						
	Code RTU with DX cooling	1	EA	$51,209.50	$67,737	$118,947
EEM-3b High Efficient RTU with DX cooling						
	High Eefficient RTU with DX cooling, energy recovery	1	EA	$58,890.93	$101,267	$160,158
EEM-3c High Efficient Heat Pump						
	RTU w/ enthalpy ER, high efficiency	1	EA	$61,507.75	$151,395	$212,902
EEM-3d VRF System						
	DOAS w/ enthalpy ER, high efficiency	1	EA	$6,158.25	$9,665	$15,823
	VRF System	1	EA	$96,496.50	$128,186.59	$224,683
	Total VRF			$102,654.75	$137,851.59	$240,506

ITEM	DESCRIPTION	QTY.	UNIT	LABOR COST	MATERIAL COST	TOTAL ITEM COST
EEM-3e Geothermal System						
	Geothermal wells (23 tons)	10	EA	$17,250.00	$5,750	$230,000
	Heat Pumps	2	EA	$5,175.00	$6,497.50	$23,345
	Piping	1	LS	$8,625.00	$8,625.00	$17,250
	Controls	1	LS	$17,250.00	$17,250.00	$34,500
	HP AHUs	2	EA	$13,397.50	$41,745.00	$110,285
	Pumps	2	EA	$8,414.17	$27,485.00	$71,798
	Total Geothermal			$199,678.33	$125,465.00	$487,178
	EEM-3a TOTAL INCREMENTAL COST					**$118,947**
	EEM-3b TOTAL INCREMENTAL COST					**$160,158**
	EEM-3c TOTAL INCREMENTAL COST					**$212,902**
	EEM-3d TOTAL INCREMENTAL COST					**$240,506**
	EEM-3e TOTAL INCREMENTAL COST					**$487,178**
EEM-4: DHW Options						
EEM-4a DHW Propane Fired Unit						
	50 gallon propane fired	3	EA	$1,080.00	$2,500	$10,740
EEM-4b DHW Electric Unit						
	50 gallon unit	3	EA	$1,080.00	$2,000	$9,240
EEM-4c DHW Air Source Heat Pump						
	50 gallon , heat pump type	3	EA	$1,080.00	$4,328	$16,224
EEM-4d DHW Geothermal Well Field						
	50 gallon water to water heat pump system	3	EA	$1,080.00	$5,328	$19,224
	EEM-4a TOTAL INCREMENTAL COST					**$10,740**
	EEM-4b TOTAL INCREMENTAL COST					**$9,240**
	EEM-4c TOTAL INCREMENTAL COST					**$16,224**
	EEM-4d TOTAL INCREMENTAL COST					**$19,224**
EEM-5: Kitchen Appliance Replacement						
	Exisiting Refrigerator remain	4	EA	$0.00	$0	$0
	Exisiting Ice Maker	1	EA	$0.00	$0	$0
	NO heat/smoke control	1	EA	$0.00	$0	$0
	ENERGY Star Refrigerator	4	EA	$450.00	$2,750	$12,800
	ENERGY Star Ice Maker	1	EA	$450.00	$678	$1,128
	Demand Control Ventilation	1	EA	$450.00	$1,049	$1,499
	TOTAL EEM-5 INCREMENTAL COST					**$15,427**

Pricing from RSMeans Building Cost Data. Includes differences between options and items related to energy efficiency.

* *Energy Efficeincy Measure pricing does not include costs associated with contingincies, TAB, design fees, electrical upgrades, general construction related costs etc. (unless otherwise identified).*

MAINTENACE COST

Mechanical/Electrical
Engineering Consultants
60 LAKEFRONT BLVD, SUITE 320
BUFFALO, NY 14202

Annual Maintenance Cost Estimate			
PROJECT NAME: Rhinebeck Village Hall			
M/E REFERENCE: 211222		DATE:	2/14/2022
DIVISION:	ENERGY	BY:	KEW

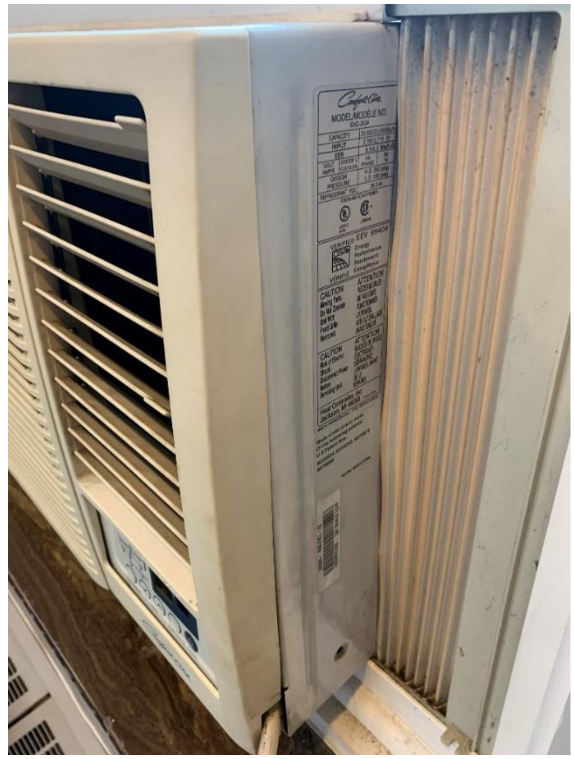
ITEM	DESCRIPTION	QTY.	UNIT	LABOR COST	MATERIAL COST	TOTAL ITEM COST
EEM-1: High-Efficiency Lighting						
	LED Lighting & Controls-Office	8200	SF	$0.50	$0.25	$6,150
	LED Lighting & Controls-Firetruck	3600	SF	$0.50	$0.25	$2,700
	TOTAL PROPOSED					$8,850
	EEM-1 TOTAL INCREMENTAL COST					**$8,850**
EEM-2: Envelope Improvements						
	Add Roof, 6" insulation R-30	5400	SF	$0.00	$0	$0
	Furr out Walls, 3.5" studs with 4" batt insul	6888	SF	$0.00	$0	$0
	Ceiling System	5400	SF	$0.00	$0	
	TOTAL EEM-2 PROPOSED			$0.00	$0.00	$0
	EEM-2 TOTAL INCREMENTAL COST					**$0**
*EEM-3: HVAC Options **						
EEM-3a Code RTU with DX cooling						
	Code RTU with DX cooling	1	EA	$550.00	$325	$875
EEM-3b High Efficient RUT with DX cooling						
	High Eefficient RTU with DX cooling, energy recovery	1	EA	$550.00	$423	$973
EEM-3c High Efficient Heat Pump						
	RTU w/ enthalpy ER, high efficiency	1	EA	$550.00	$549	$1,099
EEM-3d VRF System						
	DOAS w/ enthalpy ER, high efficiency	1	EA	$550.00	$150	$700
	VRF System	1	EA	$500.00	$250.00	$750
	Total VRF			$1,050.00	$400.00	$1,450

ITEM	DESCRIPTION	QTY.	UNIT	LABOR COST	MATERIAL COST	TOTAL ITEM COST
EEM-3e Geothermal System						
	Geothermal wells (19 tons)	20	EA	$0.00	$0	$0
	Heat Pumps	10	EA	$450.00	$423.00	$8,730
	Pumps	2	EA	$258.00	$320.00	$1,156
	Total Geothermal			$5,016.00	$4,870.00	$9,886
	EEM-3a TOTAL INCREMENTAL COST					**$875**
	EEM-3b TOTAL INCREMENTAL COST					**$973**
	EEM-3c TOTAL INCREMENTAL COST					**$1,099**
	EEM-3d TOTAL INCREMENTAL COST					**$1,450**
	EEM-3e TOTAL INCREMENTAL COST					**$9,886**
EEM-4: DHW Options						
EEM-4a DHW Gas Fired Unit						
	3, 50 gallon gas fired	3	EA	$100.00	$125	$675
EEM-4b DHW Air Source Heat Pump						
	3, 50 gallon , heat pump type	3	EA	$100.00	$145	$735
EEM-4c DHW Geothermal Well Field						
	3, 50 gallon water to water heat pump	3	EA	$100.00	$178	$834
	EEM-4a TOTAL INCREMENTAL COST					**$675**
	EEM-4b TOTAL INCREMENTAL COST					**$735**
	EEM-4c TOTAL INCREMENTAL COST					**$834**
EEM-5: Kitchen Appliance Replacement						
	ENERGY Star Refrigerator	4	EA	$100.00	$100	$800
	ENERGY Star Ice Maker	1	EA	$100.00	$100	$200
	Demand Control Ventilation	1	EA	$100.00	$100	$200
	TOTAL EEM-5 INCREMENTAL COST					**$1,200**

Pricing from RSMeans Facility Maintenance & Repair Data. Includes differences between options and items related to energy efficiency.

** Maintenance pricing does not include costs associated with other trades(unless otherwise identified).*

PHOTOS



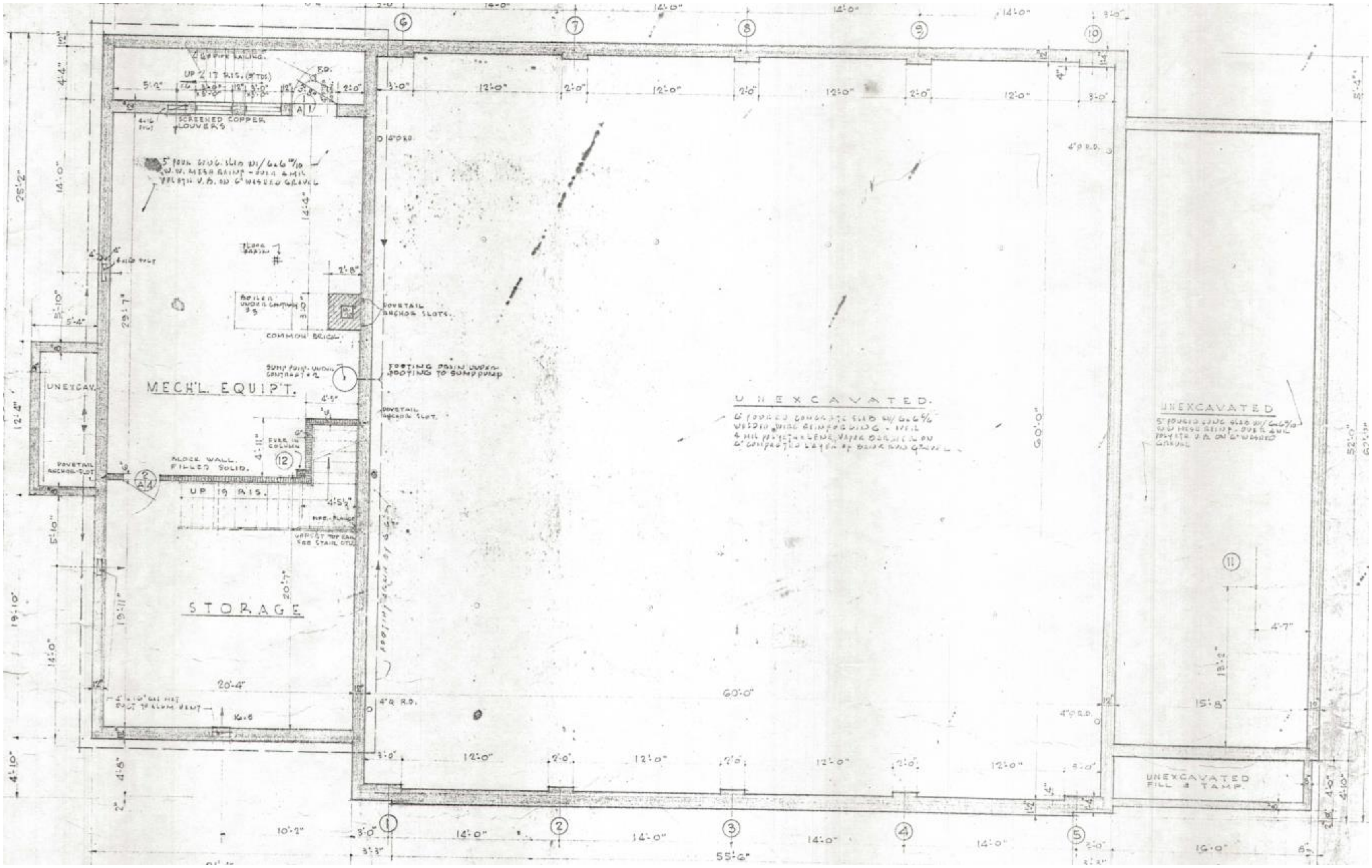

AUGUST 6, 1977
59-46


ONE
WAY

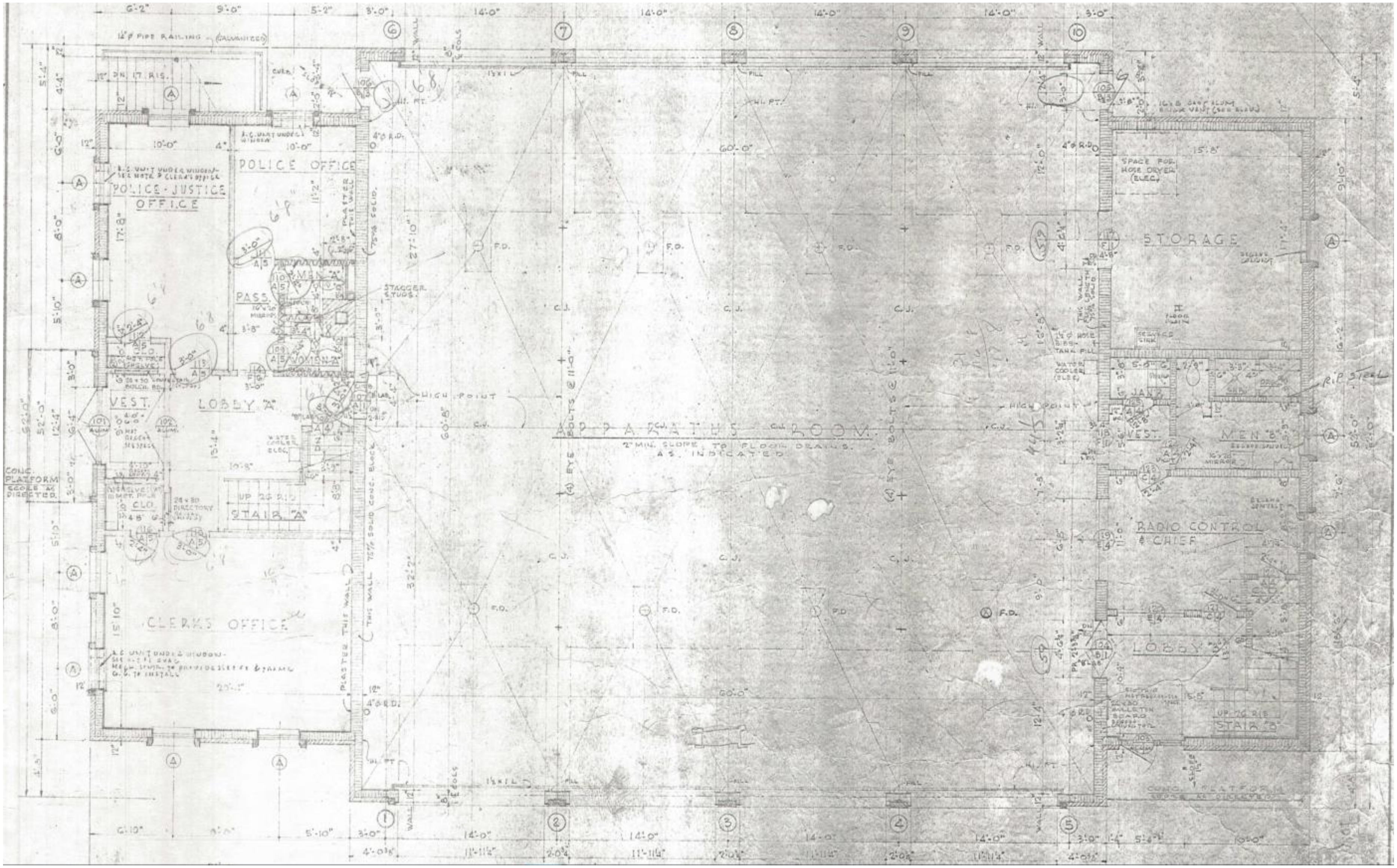

VILLAGE OF RHINEBECK

FLOOR PLANS

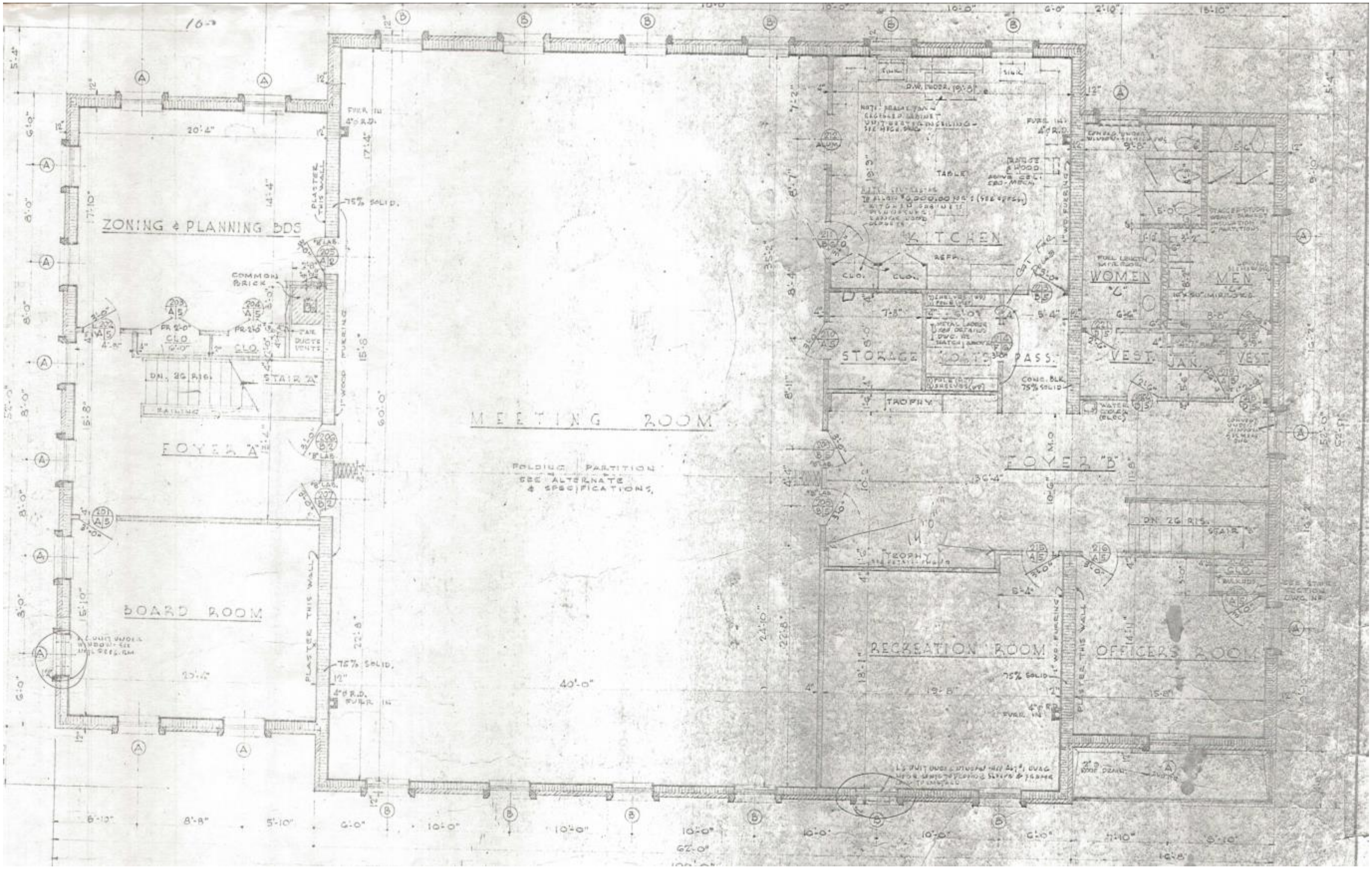
Basement Floor Plan



First Floor Plan



<u>Second Floor Plan</u>



INCENTIVE PROGRAMS

Many of the measures are eligible for implementation incentives through the Central Hudson Gas & Electric incentive programs. An estimate of the impact these incentives could have on the various measures are shown below. Please note that the incentive programs are updated and change regularly, and are subject to program requirements and eligibility, and therefore are not guaranteed

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]	**Potential Estimated Incentive* [$]**	**Estimated EEM Cost [$] (incremental, w/ incentives)**	**Simple Payback w/ Incentives [Years]**
1	High-Efficiency Lighting	15,500	7.71	$2,581.46	-185	-25.96	-$275.16	26.95	$2,306.30	$29,500.00	12.8	$2,600.00	$26,900.00	11.7

*Central Hudson Gas & Electric has programs for one for one lighting replacement, individual controls, and performanced based incentives, subject to program requirements, verify incentive elligibility with utility. Incentives are not guaranteed.

Incentives are available for LED fixtures that are listed are ENERGY Star or DLC listed. The incentives range from $15-$25 per interior fixture, $50-75 for high bay fixtures, $45-75 for exterior fixtures, and $10-$20 for controls, from a prequalified list on the Central Hudson Gas and Electric website.

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]	**Potential Estimated Incentive* [$]**	**Estimated EEM Cost [$] (incremental, w/ incentives)**	**Simple Payback w/ Incentives [Years]**
2	Envelope Improvements - Roof and Walls	2,351	2.19	$391.59	1,114	155.92	$1,652.88	163.95	$2,044.47	$142,304.53	69.6	*	$142,304.53	69.6

*Central Hudson Gas & Electric has programs for performance based incentives, subject to program requirements, verify incentive elligibility with utility. Incentives are not guaranteed.

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]	**Potential Estimated Incentive* [$]**	**Estimated EEM Cost [$] (incremental, w/ incentives)**	**Simple Payback w/ Incentives [Years]**
3a	Code RTU with DX cooling	-113,144	4.46	-$18,843.10	4,329	606.00	$6,423.90	219.84	-$12,419.20	$118,946.80	-9.6	$920.00	$118,026.80	-9.5

*Central Hudson Gas & Electric has programs for HVAC incentives, $40/ton for packaged units, subject to program requirements, verify incentive elligibility with utility. Incentives are not guaranteed.

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]	**Potential Estimated Incentive* [$]**	**Estimated EEM Cost [$] (incremental, w/ incentives)**	**Simple Payback w/ Incentives [Years]**
3b	High Efficient RTU with DX cooling	-93,463	8.82	-$15,565.50	5,045	706.25	$7,486.60	387.26	-$8,078.90	$160,158.19	-19.8	$920.00	$159,238.19	-19.7

*Central Hudson Gas & Electric has programs for HVAC incentives, $40/ton for packaged units, subject to program requirements, verify incentive elligibility with utility. Incentives are not guaranteed.

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]	**Potential Estimated Incentive* [$]**	**Estimated EEM Cost [$] (incremental, w/ incentives)**	**Simple Payback w/ Incentives [Years]**
3c	High Efficient Heat Pump	3,226	10.12	$537.28	5,045	706.25	$7,486.60	717.26	$8,023.88	$212,902.31	26.5	$46,977.75	$165,924.55	20.68

* Incentives are not guaranteed, Central Hudson Gas & Electric has programs for clean heat program, assuming $200/mmbtu saved, capped at 50% incremental cost, performance based incentives, subject to program requirements, verify incentive elligibility with utility.

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]	**Potential Estimated Incentive* [$]**	**Estimated EEM Cost [$] (incremental, w/ incentives)**	**Simple Payback w/ Incentives [Years]**
3d	VRF System	5,067	12.53	$843.84	5,045	706.25	$7,486.60	723.54	$8,330.44	$240,506.34	28.9	$60,779.77	$179,726.57	21.6

* Incentives are not guaranteed, Central Hudson Gas & Electric has programs for clean heat program, assuming $200/mmbtu saved, capped at 50% incremental cost, performance based incentives, subject to program requirements, verify incentive elligibility with utility.

NYS Clean Heat Statewide Heat Pump Incentive Program could be leveraged for implementation incentives.

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]	**Potential Estimated Incentive* [$]**	**Estimated EEM Cost [$] (incremental, w/ incentives)**	**Simple Payback w/ Incentives [Years]**
3e	Geothermal System	6,144	10.09	$1,023.20	5,045	706.25	$7,486.60	727.22	$8,509.80	$487,178.33	57.2	$145,443.77	$341,734.57	40.2

* Incentives are not guaranteed, ConEdison has programs for clean heat program, assuming $200/mmbtu saved, capped at 50% incremental cost, performance based incentives, subject to program requirements, verify incentive elligibility with utility.

There are significant implementation incentives that are available which could help mitigate the higher first cost of GSHP systems.

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual Fossil Fuel Savings [gallons]	Annual Fossil Fuel Savings [mmBtu]	Annual Fossil Fuel Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]	**Potential Estimated Incentive [$]**	**Estimated EEM Cost [$] (incremental, w/ incentives)**	**Simple Payback w/ Incentives [Years]**
4a	DHW Propane Fired Unit	7,676	0.17	$1,278.44	-48	0.70	-$233.95	26.90	$1,044.48	$10,740.00	10.3	$0.00	$10,740.00	10.3

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]	**Potential Estimated Incentive [$]**	**Estimated EEM Cost [$] (incremental, w/ incentives)**	**Simple Payback w/ Incentives [Years]**
4b	DHW Electric Unit	224	0.04	$37.27	120	16.76	$177.69	17.53	$214.96	$9,240.00	43.0	$0.00	$9,240.00	43.0

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]	**Potential Estimated Incentive* [$]**	**Estimated EEM Cost [$] (incremental, w/ incentives)**	**Simple Payback w/ Incentives [Years]**
4c	DHW Air Source Heat Pump	5,019	0.06	$835.90	120	16.76	$177.69	33.89	$1,013.59	$16,224.00	16.0	$2,000.00	$14,224.00	14.0

* Incentives are not guaranteed, Central Hudson Gas and Electric has programs for clean heat program, assumes $1000/water heater <120 gallon tank capacity, subject to program requirements, verify incentive elligibility with utility.

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]	**Potential Estimated Incentive* [$]**	**Estimated EEM Cost [$] (incremental, w/ incentives)**	**Simple Payback w/ Incentives [Years]**
4d	DHW Geothermal Well Field	5,603	0.07	$933.13	120	16.76	$177.69	35.89	$1,110.82	$19,224.00	17.3	$2,000.00	$17,224.00	15.5

* Incentives are not guaranteed, Central Hudson Gas and Electric has programs for clean heat program, assumes $1000/water heater <120 gallon tank capacity, subject to program requirements, verify incentive elligibility with utility.

EEM No.	Energy Efficiency Measure Description	Annual Electric Savings [kWh]	Electric Peak Demand Savings [kW]	Annual Electric Cost Savings [$]	Annual #2 Fuel Oil Savings [gallons]	Annual #2 Fuel Oil Savings [mmBtu]	Annual #2 Fuel Oil Cost Savings [$]	Total Energy Consumption Savings [mmBtu]	Total Annual Cost Savings [$]	Estimated EEM Cost [$] (total)	Simple Payback [Years]	**Potential Estimated Incentive* [$]**	**Estimated EEM Cost [$] (incremental, w/ incentives)**	**Simple Payback w/ Incentives [Years]**
5	Appliance Replacement	6,026	1.02	$1,003.51	163	22.75	$241.18	43.32	$1,244.69	$15,427.00	12.4	*	$15,427.00	12.4

* Central Hudon Gas and Electric has programs for performance based incentives, subject to program requirements, verify incentive elligibility with utility. Incentives are not guaranteed.

See below for a description of several potential incentive programs.

NYSERDA NEW CONSTRUCTION PROGRAM

***Applicable to **All-Electric** Projects Only
Support Level 1 – First Look:

- For Carbon Neutral Ready projects of any square footage and at any design phase prior construction.
  - Projects greater than 15,000 square feet and in schematic design phase or earlier may transition to Support Level 2 upon completion of the First Look, provided the Applicant commits to a Carbon Neutral Ready or better design.
- Technical Support provided by a NYSERDA-approved Primary Energy Consultant:
  - Meet with the Applicant to review design phase plans or proposed equipment selections, and
  - Provide a summary of energy savings suggestions.
- NYSERDA contribution for Support Level 1:
  - Technical Support is provided at no cost to the Applicant.
  - Fixed fee schedule for Primary Energy Consultant:
  - Projects up to 10,000 SF - $1,500
  - Projects 10,001 to 30,000 SF - $3,000
  - Projects over 30,000 SF - $5,000

Support Level 2 Carbon Neutral Ready (>15,000 SF)

- Project must be all electric, including cooking, laundry, domestic hot water, etc. The only exception is an emergency generator.
- Energy Modeling, Analysis and Report:
  - Engage with the Applicant and project design team to identify, model and analyze potential energy savings and electrification opportunities. Include analysis of ventilation and related building envelope and HVAC system needs to optimize buildings to meet COVID-19 related health and safety guidance.
- Integrated Project Delivery:
  - Provide additional technical support for Applicants who incorporate and execute Integrated Project Delivery in the project design.
- Smart Buildings:
  - Provide additional technical support for Applicants who incorporate and execute a suite of Smart Building features in the project design and construction.
- Embodied Carbon:
  - Suggest, evaluate and quantify embodied carbon reduction opportunities. Prepare and submit a separate report of the embodied carbon analysis to the Applicant and NYSERDA.
- NYSERDA Contribution:
  - NYSERDA will pay 100% of the technical support costs, including energy modeling and efficiency measure analysis, up to a maximum $200,000.
  - For projects seeking to reduce embodied carbon by at least 20%, NYSERDA will pay an additional 10% of the Technical Support costs to identify and quantify strategies that reduce embodied carbon.
  - Incentive of **$2/sf** if source energy is a least 15% less than a code-compliant baseline
- For more information: Commercial New Construction Program - NYSERDA

NYS CLEAN HEAT PROGRAM

NYS Clean Heat Statewide Heat Pump Program

- Heat pump system options only. Must utilize heat pump for heating.
- Custom performance incentives per MMBtu saved, according to type and size of full load heating capacity OR per equipment if smaller sizes
- Must utilize NYSERDA-participating contractor or designer, subject to installation requirements

- For more information: clean-heat-program-guide.pdf and https://ch-nyshp.programprocessing.com/

ELECTRIC VEHICLE CHARGING STATIONS

NYSERDA Charge Ready NY

- $4,000 per charging port for Level 2 charging stations
- For additional information: NYSERDA Charge Ready NY

Central Hudson Gas and Electric Vehicle PowerReady - Infrastructure

- Two categories of equipment or infrastructure are eligible for incentives under the EV Make-Ready Program:
  - Utility-side Make-Ready Infrastructure: Utility electric infrastructure needed to connect and serve a new EV charger. This may include traditional distribution infrastructure such as step-down transformers, overhead service lines, and utility meters that will continue to be owned and operated by the utility.
  - Customer-side Make-Ready Infrastructure: EV equipment or infrastructure necessary to make a site ready to accept an EV charger that is owned by the charging station Developer, Equipment Owner, or Site Host. This electric infrastructure may include conductors, trenching, and panels needed for the EV charging station.
- EV Charging in Disadvantaged Communities may be eligible for higher incentive level.
- For additional information: https://www.cenhud.com/en/my-energy/electric-vehicles/business-charging-incentives/NYS Electric Vehicle Recharging Property Tax Credit
- Credit the lesser of $5,000 or 50% of the cost of property less any cost paid from the proceeds of grants
- For additional information: NYS Electric Vehicle Recharging Property Tax Credit

CENTRAL HUDSON GAS AND ELECTRIC

- Commercial customers needing energy efficient improvements and flexibility to match project characteristics for lighting, HVAC (including ground and air-source heat pumps, refrigeration and plug loads.
- Commercial kitchen equipment.
- For additional information : https://www.cenhud.com/en/my-energy/save-energy-money/

FEDERAL ENERGY-EFFICIENCY TAX DEDUCTION

179D Commercial Buildings Energy-Efficiency Tax Deduction

- $1.80/sf deduction (adjusted annually) for property exceeding 50% energy savings utilizing the latest version of ASHRAE 90.1
- Partial deductions available for individual reductions for only envelope, HVAC/DHW, and lighting

For additional information: 179D Commercial Buildings Energy-Efficiency Tax Deduction