Facility Energy Audit Report

For:

Town of Greenwich / Town Hall

101 Field Point Road
Greenwich, CT 06830

Prepared by:

Maria Rode, CEM
Steven Winter Associates, Inc.
(203) 857-0200

TABLE OF CONTENTS

1 EXECUTIVE SUMMARY 4
1.1 REVISION HISTORY 5
2 AUDIT PARTICPANTS AND APPROACH 6
3 FACILITY AND EXISTING SYSTEMS DESCRIPTION 8
3.1 BUILDING CHARACTERISTICS 8
3.2 BUILDING ENVELOPE 8
3.3 HVAC SYSTEMS 8
3.4 ELECTRICAL SYSTEMS 17
4 ENERGY USE ANALYSIS WITH EPA PORTFOLIO MANAGER RESULTS 18
4.1 OVERALL ENERGY PERFORMANCE 18
4.2 ENERGY BENCHMARKING 22
5 LEVEL I AUDIT – ASSESSMENT OF PRIOR RESULTS & RECOMMENDATIONS 23
6 LEVEL II AUDIT - RESULTS & RECOMMENDATIONS 30
6.1 METHODOLOGY 30
6.2 LEVEL II AUDIT RECOMMENDED ENERGY CONSERVATION MEASURES 32
6.3 OTHER OBSERVATIONS 39
6.4 ENERGY PURCHASING AND PROCUREMENT STRATEGIES 40
APPENDIX A: PORTFOLIO MANAGER STATEMENT OF ENERGY PERFORMANCE 41
APPENDIX B: ECM CALCULATIONS 42
APPENDIX C: PROJECT SUMMARY SHEET 52
APPENDIX D: GLOSSARY AND METHOD OF CALCULATIONS 53
APPENDIX E: IPMVP PROTOCOLS 54
APPENDIX F: METHOD OF ANALYSIS 55
APPENDIX G: QUALIFICATIONS 56
DISCLAIMER 57

1 EXECUTIVE SUMMARY

Steven Winter Associates, Inc. (SWA) conducted an energy audit for the Greenwich Town Hall, a property owned and operated by the Town of Greenwich, CT. The audit was performed under the guidelines of an ASHRAE Level II Energy Audit. The initial site visit was performed on February 21st, 2018. This Level II energy audit was performed as a follow-up to a Level I walkthrough audit commissioned by Eversource on February 22, 2017, as part of the Eversource Clean Communities Municipal Technical Assistance Program. The Level I walkthrough audit identified eighteen (18) potential energy conservation measures, which were explored in further detail during the Level II audit. The Level II audit performed by SWA also investigated additional measures not included in the Level I walkthrough audit.

Greenwich Town Hall is a historic 4-story, 130,000 ft^2 commercial building located at 101 Field Point Road in Greenwich, CT. The facility was originally built in 1925 and used as a high school. In 1979, the building underwent a major renovation and was converted to the Town Hall. The facility is fully owned and occupied by the Town of Greenwich. Major mechanical equipment is located throughout the building. The condenser water pumps (CWPs) and boilers are located in the basement. The cooling tower is located outside of the building. The outdoor air (OA) supply unit is located on the roof, and air handling units (AHUs) are located on each floor. The facility has undergone interior renovations in a piecemeal manner over the past 18 years, as needed, to accommodate the changing needs of each department. The Town Hall is a U-shaped building with four (4) main stairwells and two (2) elevators. The Town of Greenwich is responsible for mechanical equipment and utility billing attributed to all systems in the building.

Eversource provided SWA with an electric utility billing summary from June 2016 through December 2017. Connecticut Natural Gas provided SWA with the Town Hall's December 2017 natural gas bill. Annual energy consumption and cost totals were calculated for the 12-month period between January 2017 and December 2017. Energy Star® benchmarking was conducted for that same period. Electricity is supplied by Transcanada and delivered by Eversource and natural gas is provided by Connecticut Natural Gas Corporation. On average, the Town Hall pays a blended rate of $0.15 per kWh of electricity and $0.80 per ccf of natural gas. Total energy consumption and cost at the building over the analyzed period was 7,932 MMbtu and $317,372, respectively

SWA reviewed the building's energy data entered into the EPA's Energy Star® Portfolio Manager energy benchmarking system by Eversource. The system generated Site and Source Energy Use Intensities for the building, indicators of the total building's efficiency based on square footage. The building has a Site EUI of 61.4 kBtu/ft^2/yr, as compared to a national median of 93 kBtu/ft^2/yr, for similar building types. The building has a Source EUI of 177.1 kBtu/ft^2/yr, as compared to a national median of 268.3 kBtu/ft^2/yr. These EUIs suggest that the building is performing better than the average for buildings of a similar type across the nation, according to the Portfolio Manager system. The building earns an Energy Performance Rating of 82, indicating that the building performs better than 82% of similar buildings. The high Energy Star score does not necessarily reflect the actual performance of the building. Please refer to Appendix A for the Portfolio Manager Statement of Energy Performance.

The table below represents the evaluated energy conservation measures (ECM) and the proposed strategy of energy savings developed under the Level II audit for the Town Hall:

Table1.1: Project Summary Sheet

ENERGY CONSERVATION MEASURES										
Measure Description		Measure Status (See notes)	Fuel Type Saved (See notes)	Electric Supply Savings (kWh)	Electric Demand Savings (kW)	Fuel Savings (non-electric) (MMBtus)	Percent (%) Savings to Total Fuel Consumption	Annual Cost Savings	Estimated Implementation Costs	Simple Payback (Years)
1	Assess and repair condenser water system	R	N/A	0	0	0	0.0%	$ -	Cannot Verify	
2	Optimize Reznor Unit	R	Electricity / Natural Gas	72,851	0	345	7.5%	$13,729	$9,568	0.7
3	Control AHUs with Occupancy Sensors or One-Hour Timers	R	Electricity / Natural Gas	18,079	0	274	4.2%	$4,868	$4,433	0.9
4	Install thermostats at stairwell radiators	R	Electricity	9,744	0	0	0.4%	$1,479	$4,556	3.1
5	Install Premium Efficiency Motors	R	Electricity	9,970	2	0	0.4%	$1,513	$23,461	15.5
ECM Total (Recommended Only)				110,643	2	619	13%	$21,588	$42,018	1.9

Notes:
Measure Status: Implemented (I); Recommended (R); Further Study Recommended (RS); Not Recommended (NR); Recommended Mutually Exclusive (RME).
Fuel Saved: Elec, Steam, NGas, Oil2, Oil4, Oil6, Coal, LPG. MMBtu = 1,000,000 Btu

If both ECM-2 and ECM-3 are implemented, Eversource anticipates that the combined energy savings for these two measures would be 3,742 ccf of natural gas and 85,856 kWh of electricity. If both measures were to be implemented together, any potential incentive would be based on the combined savings value, not the individual savings values. The interactivity between these two measures is described in section 5.2, under ECM-2: OPTIMIZE REZNOR UNIT.

1.1 REVISION HISTORY

The draft Level II Energy Audit Report was originally submitted to Eversource for review on June 29, 2018. Eversource forwarded the draft to the Town of Greenwich and performed a parallel in-house review of the report. In response to Eversource's comments, the audit report was revised and resubmitted to Eversource for distribution to the team on August 3, 2018. This revision 2 involved some changes to the description of energy conservation measures and changes to the savings calculations for the associated measures. Also added as part of this revision was the inclusion of interactive savings calculations.

On August 6, 2018, the Town of Greenwich expressed concern that the electric rate used in the report was incorrect. Steven Winter Associates (SWA) had performed the utility rate analysis using data made available through the Town Hall's web-based Portfolio Manager account. Eversource investigated and found that the electric supply cost from Transcanada had gone unreported in Portfolio Manager since December 2016. This discovery had unknowingly impacted the second year of the two-year rate analysis period. On September 13, 2018, Eversource obtained the electric supply costs for the Town Hall since December 2016 and provided the updated cost information to SWA. Using the new data, SWA updated the report and all associated calculations with the revised electric rates and distributed the revised report on September 18, 2018 as revision 3.

Note: The updated electric rate of $0.15/kWh increased the estimated annual electricity cost savings but did not change the recommendation status of any energy conservation measures, since none of the original measures had previously been discarded as a result of insufficient payback period. Additionally, the electric utility data provided did not include a cost breakdown sufficient for SWA to determine the associated electric demand charges. Only blended electric rates could be determined.

A meeting between the Town of Greenwich, Eversource, and SWA was held on September 19, 2018 to discuss the recommendations of the report. A draft version 4 was issued for Eversource review on October 1, 2018. A final version of the report was distributed by SWA on November 2, 2018 to address additional comments raised by Greenwich. Refer to Section 2 - AUDIT PARTICPANTS AND APPROACH and Section 6.4 - ENERGY PURCHASING AND PROCUREMENT STRATEGIES for further details.

2 AUDIT PARTICPANTS AND APPROACH

Steven Winter Associates, Inc. (SWA) conducted an energy audit for the Greenwich Town Hall, a property owned and operated by the Town of Greenwich, CT. The audit was performed under the guidelines of an ASHRAE Level II Energy Audit. The initial site visit was performed on February 21st, 2018. As part of the site visit, an onsite kick-off meeting was also held on February 21, 2018 with attendees selected by the Town. SWA encouraged all key stakeholders be invited to share their feedback and objectives before SWA performed the walk-through with facilities staff.

This kick-off meeting was coordinated with Sarah (Nahabedian) Coccaro, who served as the primary point of contact for this audit. Kick-off Attendees included: Sarah (Nahabedian) Coccaro, Conservation Resource Manager 1; Denise Savageau, Conservation Director; Steve O'Hurley, Facilities; Alan Monelli, Superintendent of Building Construction and Maintenance; as well as Amanda Magee, Maria Rode, and Srikanth Puttagunta of Steven Winter Associates, Inc. During the subsequent walk-through, Steve O'Hurley served as the escort and answered additional questions and Alan Monelli provided input throughout the day as well. Following the site visit, Steve O'Hurley gathered additional information requested by the auditors and provided it via email. Sarah Coccaro remained the primary point of contact for all coordination and report distribution and review.

The feedback gathered during the kick-off helped the auditors become familiar with any budgeted or planned projects already identified by the Town, as well as any challenges or barriers that may have posed challenges in the past. Based on the initial Level 1 energy audit report (by others), the Town had already investigated a number of strategies. Briefly, the following items were noted:

- Implementation costs for high efficiency motors had been obtained and determined to only be cost-effective at the time of replacement. The Town plans to incorporate motor efficiency upgrades as a procurement best practice.
- Windows are all thermal pane and were re-caulked with backer rod within the last few years.
- Manual isolation valves are now being installed on all heat pumps at the time of retrofit.
- Lighting management has been implemented as part of the cleaning crew nightly process and are shut-off by 8 pm daily. The parking deck lighting is controlled by a time clock. The parking lot lighting is controlled via a photocell and tied to the existing building management system. An LED lighting retrofit scope has already been identified and will not include occupancy or daylighting controls, due to maintenance and occupant education concerns by facilities.
- The existing electric boiler has not been used in the past 23 years. The gas-fired boilers are already budgeted for replacement.
- Sink aerators have already been getting installed.
- Cooling towers were replaced within the last three years and VFDs were considered as part of that replacement but ultimately disregarded due to concerns by facilities associated with the potential for increased failure and/or added maintenance. The existing building management system was installed as part of the cooling tower purchase.
- As renovations are undertaken, electric domestic water heaters are being installed locally and decentralized.
- Areas of existing comfort concern were discussed.
- No major capital improvements for HVAC are planned, other than the pending boiler replacement project.

While this feedback did not dictate the selection of measures recommended for the building, SWA was cognizant of the desire expressed for less complex control strategies. To the extent possible, SWA included a "low-tech" alternative with some measures that would still enable the Town to meet the energy reduction objective but minimize system complexity. For example, under Section 6 - LEVEL II AUDIT - RESULTS & RECOMMENDATIONS SWA recommended ECM #3: CONTROL AC UNITS WITH ONE-HOUR TIMERS OR OCCUPANCY CONTROLS. This measure provides the same savings using two different control strategies, enabling the Town to select their preferred approach.

Following the walk-through, SWA prepared the energy audit report to include all measures that were identified in the scope of an ASHRAE Level II energy audit. SWA did not exclude any energy opportunities from the report based on feedback from the kick-off meeting or any other conversations with staff. SWA recommended an array of measures with payback that extend up to 15.5 years, many of which result in a simple payback of less than 1 year. With any energy audit, the simple payback of a measure must be weighed against the useful life of the equipment.

SWA did not eliminate any potential measures based on a predetermined payback threshold. SWA followed industry best practice for identifying all measures and the associated simple payback period for each measure. SWA presents all identified measures, unless otherwise directed by the Owner during project development. In some cases, an Owner will introduce their own requirements for eliminating measures that exceed an Owner-defined payback criteria or some other threshold. In this case, no such custom evaluation criteria were provided by Greenwich and all measures, both those that were recommended and not recommended, were presented. Given the short payback periods, none of the measures in any version of the report were found not to be viable and all were recommended.

When the electric rate was updated, all payback periods were also updated. Had the rate update resulted in a change in the original recommendation to proceed with implementing a measure, the report would have reflected that change. Similarly, if the updated rate had resulted in an improved payback period~~s~~ that made a previously eliminated measure (based on an Owner-directed threshold) become viable, the newly viable measure would also have been reflected in the updated report. As previously stated, there were no measures previously eliminated or not recommended and, thus, the rate update did not result in the addition of any previously discarded recommendations or a shift in the status of recommended items.

During a follow-up call on September 19th, the Town Energy Committee posed a number of comments and questions related to long-term planning opportunities for the Town Hall. The Committee expressed a desire to explore dramatic improvements to the building, including the complete replacement of all existing equipment and envisioning new systems that could lead the building into the future. While these objectives fall outside the scope of an energy audit, SWA applauds the Committee on their vision to seek a broader perspective that could build upon the savings identified in this report. Given the very fast payback associated with many of the measures identified in this report, SWA recommends that the recommended energy measures be implemented in parallel with the Town's ongoing pursuit of long-term upgrades. The Town can investigate and define the future vision for the Town Hall, while concurrently the implemented measures can return energy savings.

To support the long-term planning, SWA recommends the following further studies be undertaken:

1. Physical Needs Assessment (PNA) – This study is an important step in capital and operations planning. Following an on-site inspection and review of documents, this report identifies the Capital projects necessary and provides a cost estimate for the recommended scope of work. Given the significant amount of mechanical equipment in this building that has reached or exceeded its useful life, this investigation would help Greenwich better quantify and plan for expenditures required to maintain or improve the performance of the building. PNAs can include a review of the building for resiliency and health concerns, as well as accessibility. These studies can focus on equipment or be broad enough to include the building envelope.
2. Energy Master Planning – An assessment of the entire portfolio of Town buildings is recommended to determine the highest priority buildings to target with energy improvements, both near- and long-term. This study will help Greenwich determine where to focus their future efforts across all Town buildings.
3. Long-Term Capital Planning – Informed by the other two items above, long-term capital planning can include upgrading the existing equipment to be more efficient or completely re-envisioning the building with new equipment and systems well into the future. Long-term planning should also consider the maintenance costs associated with the upgrades. Once the Energy Master Plan has been developed, the Town can determine which building(s) to target for Capital Planning and investment.

3 FACILITY AND EXISTING SYSTEMS DESCRIPTION

3.1 BUILDING CHARACTERISTICS

Greenwich Town Hall is a historic 4-story, 130,000 ft^2 commercial building located at 101 Field Point Road in Greenwich, CT. The facility was originally built in 1925 and used as a high school. In 1979, the building underwent a major renovation and was converted to the Town Hall. The facility is fully owned and occupied by the Town of Greenwich.

There are approximately 300 full-time employees working in the Town Hall from 8:00AM – 4:00 PM Monday – Friday. Facility staff reports that during these hours, the Town Hall has approximately 100 visitors at any one time and can get up to 300 visitors at once. In addition to regular working hours, the Town Hall hosts frequent community meetings after-hours. These meetings regularly run until 10:00 PM and can attract an audience of 200-300 people. Many employees have access to the facility outside of working hours, and the facility is frequently occupied on weekends.

Major mechanical equipment is located throughout the building. The condenser water pumps (CWPs) and boilers are located in the basement. The cooling tower is located outside the building. The outdoor air (OA) supply unit is located on the roof, and air handling units (AHUs) are located on each floor. The facility has undergone interior renovations in a piecemeal manner over the past 18 years. The Town Hall is a U-shaped building with four (4) main stairwells and two (2) elevators.

3.2 BUILDING ENVELOPE

Greenwich Town Hall is a 4-story structure with a brick exterior. Exterior walls have foam insulation. During the renovations that have been occurring over the past 18 years, the walls have remained closed and no additional insulation has been added. The facility's windows are not operable. Some windows have been replaced but the facility has not undergone a thorough window replacement project. Within the past few years, the facility's windows were all recaulked to stop water infiltration. The main entrance consists of five (5) pairs of double-swing doors. Three (3) pairs of entrance doors open into a vestibule while the other two (2) pairs of doors open into stairwells. There are three (3) additional egresses along the back of the building. One section of the roof is flat with a brick parapet and is constructed with built up rigid insulation of unknown thickness below an ethylene propylene diene monomer (EPDM) membrane. The remainder is a sloped shingle roof.

3.3 HVAC SYSTEMS

3.3.1 Heating Plant

The Town Hall uses two (2) gas-fired condensing boilers manufactured by Aerco (model number KC-1000-GWB) to produce heating hot water (HHW) for the facility's condenser water loop. The boilers each have an input capacity of 1000 MBH and an output capacity of 930 MBH. These boilers were installed approximately 20 years ago. When the facility underwent its major renovation in 1979, an electric boiler with a capacity of 1,430 MBH was installed. This boiler has since been decommissioned.

The boilers are controlled by an Aerco Boiler Management System, located in the basement. This system operates the boilers to maintain a constant HHW supply temperature of 85 °F. This HHW is supplied to the condenser water loop via a 3-way bypass valve. Because there is no automatic isolation or control valve at the boilers, condenser water circulates through the boilers even when there is no call for the boilers to operate.

The facility plans to replace the existing boilers in the near future. The project has been included in the budget and was being prepared for bidding at the time of the audit.

Image 1: Boiler-2

Image 2: Aerco Boiler Management System

3.3.2 Condenser Water System

Two (2) pumps serve the facility's condenser water loop, providing condenser water to six (6) packaged cooling-only DX units and approximately 400 perimeter heat pumps. The condenser water has a 40% ethylene glycol concentration. Heat is produced for the condenser water loop via the boilers and heat rejection is performed by the two (2) cooling towers.

The two (2) condenser water pumps, manufactured by Weinman (model number 5L2), are constant volume 25-hp pumps located in the basement. According to the mechanical equipment schedules provided by the facility and drafted in 1977, the pumps are sized to provide 820 GPM at 85 feet of head. The pump motors have an estimated nominal efficiency of 91.7%, based on NEMA EPACT 1992 induction motor efficiency standards. Premium efficiency motors of an equivalent size have a nominal efficiency of 93.6%. One pump operates at full speed at all times while the other pump serves as a standby pump. The pumps do not have variable frequency drives (VFDs). The facility staff reported that one pump must remain running at all times to prevent air from getting entrained in the condenser water system. In the event that a pump shuts down, air infiltrates the system and purging the system takes approximately one month.

Image 3: Condenser water pump

Two (2) two-cell cooling towers perform heat rejection for the condenser water loop. These towers are located outside the facility. The cooling towers are closed-loop towers manufactured by Baltimore Air Coil (model number XV-662-MM). Each tower has one (1) 7.5-hp spray pump, one (1) cell with a 10-hp fan, and one (1) cell with two (2) 10-hp fans. The cooling towers were installed in 2012. The cooling tower fans are constant-speed. Although variable speed options were considered at the time of installation, facilities preferred constant-speed fans to avoid any new maintenance issues.

There is a three-way bypass valve on the condenser water loop located in the basement, downstream of the boilers but upstream of the cooling towers. This valve allows condenser water to bypass the cooling towers when heat rejection is not needed. The cooling towers are operated to maintain a condenser water supply temperature of 88-92 °F.

Image 4: Cooling towers

Image 5: Cooling tower bypass valve

Condenser water is delivered to six (6) packaged cooling-only DX units, which provide ventilation air to each floor of the facility, and to the perimeter heat pumps located throughout the facility, which provide space conditioning. Neither the heat pumps nor the packaged units have automatic control valves on the condenser water piping, which could modulate closed when the units do not require condenser water. The heat pumps were originally installed without manual isolation valves. More recently, manual isolation valves have been added to some heat pumps to facilitate maintenance as part of the department-by-department renovation process.

Condenser water is delivered to all six packaged units first. The piping then runs to the perimeter heat pumps. As a result, when the packaged units are operating in cooling mode, the condenser water received by the heat pumps is warmer than the condenser water supplied to the packaged units. The condenser water piping configuration is shown in Image 6 and 7 below.

Image 6: Condenser water system flow diagram

Image 7: Condenser water flow diagram with heat pump connection detail

3.3.3 Ventilation

A single, heating-only rooftop unit supplies pre-heated outdoor air to the entire building through a shaft that feeds the six (6) packaged AC units that serve each floor in the facility. This rooftop unit is manufactured by Reznor (model number PACR-150) and includes a 7.5-hp constant speed supply fan and a gas-fired burner with a capacity of 1,875 MBH.

The rooftop unit provides no cooling, relying on the (6) packaged, cooling-only AC units for fresh air cooling. A switch in the operator workstation room allows the facility staff to manually select whether the unit operates in summer mode or winter mode. When the unit is in winter mode, it maintains a supply air temperature of 60 °F, as determined by a manually-adjustable thermostat located inside the unit. The unit can deliver up to 18,000 CFM of fresh air.

The Reznor unit is not original to the building. It is not shown on the original design drawings. According to building staff, it is about 20 years old and is nearing the end of its useful life. It is assumed that the unit was added because cold ventilation air led to comfort complaints during the winter months, since the AC units lack the capability to raise the air temperature. Facilities also indicated the building used to have motorized louvers at the shaft but those are no longer present and/or operational.

Image 8: Outdoor air damper for AC-6

Image 9: Reznor rooftop unit

Outdoor air is delivered to each of the four (4) mechanical rooms housing the facility's packaged units via a shaft. Dampers in each mechanical room allow fresh air to enter the mechanical rooms from the outdoor air shaft. These dampers are currently set to a fixed position, and do not have controls associated with them. Facility staff reports that the system was balanced such that the packaged units each have an outdoor air fraction of 20%. With an outdoor air fraction of 20%, the total amount of outdoor air supplied to the packaged units by the rooftop unit is approximately 14,500 CFM.

The facility has a total of six (6) exhaust fans. EF-1 is a 3,300 CFM toilet exhaust fan serving the bathrooms on the ground floor through the second floor. EF-2 is a 1,000 CFM toilet exhaust fan serving the bathrooms on the third floor only. EF-3 is a 7,600 CFM fan providing general exhaust for the facility. Three (3) smaller exhaust fans located on the roof provide exhaust for the Department of Health laboratory space. The lab exhaust fans were installed in 2013 and have fractional horsepower (HP) motors.

The Reznor unit, the toilet exhaust fans, and the general exhaust fan are interlocked with the facility's packaged units such that the fans will turn on when the packaged units turn on.

3.3.4 Space Conditioning

Six (6) packaged AC units manufactured by Trane (model SWUA-x00) supply conditioned air to the interior of the facility. Each unit is equipped with a constant-speed supply fan and two (2) compressors. These units are water-cooled and receive condenser water from the facility's condenser water loop. For each packaged unit, there is also a corresponding constant-speed return fan which delivers air from the interior of the facility to the mechanical rooms. Each mechanical room serves as a mixed air chamber, combining the return air from the building core and the fresh air delivered from the rooftop unit. The supply and return fan information shown in the table below was taken from the 1977 mechanical equipment schedules.

Tag	Location/Service	Supply CFM	Supply Fan Motor Horsepower	Return CFM	Return Fan Motor Horsepower
AC-1	Ground Floor	13,600	10	10,250	7.5
AC-2	First Floor	14,000	10	10,000	7.5
AC-3	First Floor	8,600	7.5	7,500	5
AC-4	Second Floor	12,800	10	9,500	7.5
AC-5	Second Floor	9,600	7.5	7,500	5
AC-6	Third Floor	14,000	10	10,500	7.5

Table 1: Supply and return fan data

Return air temperature is measured at the return duct in each mechanical room. Each packaged unit compressor is controlled by its own manually adjustable thermostat. When the return air temperature exceeds the value set at the thermostat, the corresponding compressor stages on. For several units, the thermostats controlling the compressors were set to the same value. This results in both compressors for a single unit staging on at the same time. The return air temperature setpoints varied throughout the building but were typically between 73-76 °F.

The packaged units have an occupied/unoccupied schedule programmed into the building management system (BMS). Each packaged unit also has an associated timer located outside the mechanical room. This timer can be manually adjusted by building occupants, and allows Town Hall employees to call for the units to run even after scheduled hours. When a timer is started, the packaged unit, associated return fan, rooftop Reznor unit, and building exhaust fans all turn on and run for the duration of the timer.

The conditioned air from the packaged units is distributed across each floor of the building via ductwork run above the ceiling. For the core spaces in the building, the ducted air from the AC units provides the only space conditioning. For the perimeter spaces, additional air tempering is provided by perimeter heat pumps.

Image 10: Packaged AC unit

Image 11: Packaged AC unit timers

The packaged units were installed during the 1979 renovation. The layout of some of the facility's mechanical rooms impedes access to these units and may hinder the future implementation of major equipment replacement and/or upgrades.

Envelope loads at the perimeter of the building are conditioned with water-source heat pumps. These HP units receive condenser water from the facility's condenser water loop, after condenser water has passed through the interior packaged AC units first. In the 1979 renovation, three (3) different models of heat pumps were installed. As departments were renovated, some heat pumps were replaced, leaving the building with three different generations of heat pumps. The original installations did not include isolation valves; maintenance was performed by clamping the piping down to prevent the system from draining. When heat pumps are replaced, manual isolation valves are added to the piping. None of the HP units have automatic control valves.

The heat pumps are manually controlled by occupants with local on-board controls. The amount of control occupants have over these units varies based on unit model. In general, occupants can turn the fan on or off, select a fan speed, and command the unit to call for heating or cooling. Some units, particularly ceiling-mounted units, have corresponding thermostats in the spaces they serve. Town Hall employees have access to these thermostats and can change space temperature settings at will.

Image 12: Heat pump, 3rd generation

Image 13: Heat pump, 2nd generation

Each day, the BMS sends a signal to the electrical panels connected to these heat pumps, commanding all heat pumps off at three separate times: 7:00 AM, 5:00 PM and 11:00 PM. These “sweeps” are meant to ensure that the heat pumps do not run when the building is not occupied. After the contactor is disconnected during each of these sweeps, occupants must manually restart their heat pumps. The intent of the 7:00 AM sweep is unclear and may be contributing to the known problems with quickly heating up the building after a cold weekend. As a result of an oversight during the renovation process, some second-generation units automatically restart after the sweep is done.

Some stairwell landings have electric baseboard radiators. These units are manually controlled by local dials, which can be accessed and adjusted by building occupants and visitors. All baseboards observed during the audit were on, while the outdoor air temperature was 70 °F.

Image 14: Electric baseboard radiator

A dedicated split AC unit provides space cooling to the Town Hall Meeting Room. This unit is controlled by a thermostat located within the mechanical room, maintaining a mechanical room space temperature of 72 °F. The IT data room, located on the ground floor, is served by two (2) Mitsubishi split AC units. These units are both thermostatically controlled and maintain a space temperature of 67-68 °F. Condensers for all of these units are located outside the building on the ground level.

Image 15: Town Hall Meeting Room unit

Image 16: Data room AC unit

3.3.5 Building Management System

Major equipment at the facility is tied into the Andover Continuum Building Management System (BMS), which Facilities indicated was added as part of the Cooling Tower project. The BMS monitors the boilers, cooling towers, and condenser water pumps. The boiler management system and condenser water control panel are not tied into the BMS. Condenser water pumps are operated locally. The BMS also includes schedules for the six (6) packaged AC units and the two (2) toilet exhaust fans, but these schedules can be overridden by the units' local timers. The BMS monitors the status of the perimeter heat pumps but has no control over them. Exterior lighting is monitored by the BMS. The BMS does not monitor any space temperatures.

3.3.6 Domestic Hot Water

Domestic hot water (DHW) is generated by electric tank water heaters. DHW is delivered to fixtures at 125 °F. Facilities indicated DHW is typically decentralized as part of a renovation.

Image 17: Domestic hot water heater

3.4 ELECTRICAL SYSTEMS

3.4.1 Lighting

The majority of the facility has linear fluorescent fixtures with electronic ballasts. Fixtures are a combination of 2' and 4' and have either two (2) or three (3) T8 lamps. Outdoor lighting fixtures are metal halides. All interior lighting is switch-operated. Lighting for the parking deck is controlled by a timeclock. All other exterior lighting is controlled by photocell sensors and is tied into the BMS. There is a lighting replacement project already planned for the facility. Fluorescent fixtures will be replaced with LED fixtures. Lighting controls will not be upgraded as part of this project.

Image 18: Corridor lighting

3.4.2 Conveying System

Two traction passenger elevators provide access between the ground floor and 3rd floor.

4 ENERGY USE ANALYSIS WITH EPA PORTFOLIO MANAGER RESULTS

4.1 OVERALL ENERGY PERFORMANCE

Eversource provided SWA with an electric utility billing summary from June 2016 through December 2017, which SWA verified by reviewing the Town's Portfolio Manager account. Subsequently, Eversource provided additional electric supply costs for that same period from Transcanada. Connecticut Natural Gas provided SWA with the Town Hall's December 2017 natural gas bill.

SWA used electric and natural gas consumption data entered into Portfolio manager to develop a two-year energy consumption profile for the facility. The analysis shown in this section includes the facility's energy consumption for January 2016 through December 2017. Annual energy consumption and cost totals were calculated for the 12-month period between January 2017 and December 2017. Energy Star® benchmarking was conducted for that same period. Electricity is supplied by Transcanada and delivered by Eversource and natural gas is provided by Connecticut Natural Gas Corporation. On average, the Town Hall pays a blended rate of $0.15 per kWh of electricity and $0.80 per ccf of natural gas. Total energy consumption and cost at the building over the analyzed period was 7,932 MMbtu and $317,372, respectively.

As reflected in the table below, Portfolio Manager included total monthly cost data for the utility analysis period. Both electric consumption and electric demand usage were provided. However, the summary did not include detail on the electric demand charges for each bill. The utility analysis in this report uses an average blended utility rate based on electric consumption and cost.

Total Energy Consumption and Cost									
	Total Energy Consumption		*Site Energy in MMBtu*	*Source Energy in MMBtu*	*Cost*	*% Total Site Energy*	*% Total Source Energy*	*% Total Cost*	*$/Site MMBtu*
Electricity	2,042,120	kWh	6,968	23,272	$309,871	88%	95.8%	97.6%	$44
Natural Gas	9,403	ccf	965	1,010	$7,502	12%	4.2%	2.4%	$8
Total			7,932	24,282	$317,372	100%	100%	100%	$40

Table 3.1: Base Building Energy Consumption and Costs

Electricity

The electric consumption profile for the Town Hall is shown in Figure 3.1 below. Consumption profiles across both 12-month periods are relatively consistent, with the exception of the year-to-year change in the month of January. No specific reason was discovered for the drop in electrical consumption during January 2016. During the most recent 12-month analysis period, consumption peaked at 205,256 kWh in August and fell to a minimum of 146,304 kWh during March.

Figure 3.1: Electric Consumption Profile

Figure 3.2 below plots the monthly electrical consumption against Cooling Degree Days (CDD) to evaluate how weather affects electrical usage in the building. A CDD is the number of degrees that a day's average temperature is above a specified baseline temperature. For a commercial office building, a typical baseline temperature is 57.5°F. This baseline temperature is typical for the region and commonly used by utility companies to determine Cooling Degree Days. CDD is calculated by subtracting the baseline temperature from the daily average, as represented by the following equation:

CDD = Average Daily Temperature (>57.5°F) – 57.5

The curve clearly shows distinct peaks in Cooling Degree Days during the summer months in 2016 and 2017. Superimposing the electric consumption curve onto the CDD curve shows that electric usage peaks in correlation with CDD peaks, indicating that cooling equipment is a source of electrical consumption and that the equipment is operated in correspondence with the building's cooling load. The graph also shows smaller peaks in electrical consumption that do not correlate to CDD. This can be attributed to the use of electrical equipment, such as heat pumps, for heating throughout the facility.

Figure 3.2: Electrical Consumption vs. Cooling Degree Days for 2016 and 2017

Figure 3.3 below graphs the building's electric demand profile from June 2016 through December 2017. The graph shows a small demand increase during the summer months, when the facility is in cooling mode. During the most recent 12-month analysis period, demand peaked at 579.5 kW during July and fell to a minimum of 453.9 in March. This pattern correlates with the consumption profile shown in Figure 3.1 above. The minimum demand experienced in March represents the building's baseload and accounts for the operation of the building's non-weather dependent equipment.

Figure 3.3: Electrical Demand Profile

Natural Gas

The Greenwich Town Hall uses natural gas to fire its two (2) condensing boilers, and for heating outdoor air entering the building at the rooftop unit. Figure 3.6 below graphs a comparison of the building's monthly natural gas consumption from January 2016 through December 2017. During the most recent 12-month analysis period, natural gas consumption peaked in December at 2,756 ccf and fell to a minimum of 0 ccf in June, July, August and September. May and October 2017 also had minimal natural gas consumption, at 5 ccf and 10 ccf, respectively.

Figure 3.4: Natural Gas Consumption Profile

Monthly variations in natural gas consumption between 2016 and 2017 are largely due to weather conditions when comparing year to year. This is more apparent in the HDD graph below.

Similar to the graph above, on days when the average temperature is below 65°F, it is assumed that the building requires heating. When average temperature is above 65°F, heating is not required and HDD equals zero. Expectedly, monthly HDD are greatest during the winter months. Figure 3.5 below shows a strong correlation between monthly HDD and natural gas consumption at the facility.

Figure 3.5: Natural Gas Consumption vs. Heating Degree Days for 2016 and 2017

4.2 ENERGY BENCHMARKING

SWA reviewed the facility's energy consumption information entered by Eversource into the U.S. Environmental Protection Agency's (EPA) Energy Star® Portfolio Manager energy benchmarking system. Portfolio Manager allows many buildings to be rated based on their energy performance on a scale of 1 – 100 relative to similar building nationwide. The building is not compared to the other buildings entered into Portfolio Manager; rather, statistically representative models are used to compare the building against similar buildings from a national survey conducted by the Department of Energy's Energy Information Administration (EIA). This national survey, known as the Commercial Building Energy Consumption Survey (CBECS), is conducted every four years, and gathers data on building characteristics and energy use from thousands of buildings across the United States.

As of 2018, Portfolio Manager continues to use CBECS data from 2003 due to insufficient data from the 2007 survey. The facility peer group of comparison is those buildings in the CBECS survey that have similar building and operating characteristics. Because the Town Hall is categorized as an "Office" space type in Portfolio Manager, it is compared against other, similar "Office" space types across the nation. A rating of 50 indicates that the building, from an energy consumption standpoint, performs better than 50% of all similar buildings nationwide, while a rating of 75 indicates that the building performs better than 75% of all similar buildings nationwide. However, because the CBECS data is now 15 years old, the Energy Star rating that the building received may not accurately reflect the performance of the building.

Because over 50% of total square footage at the Town Hall is devoted to office space, the building as a whole is categorized as an "Office" space type in Portfolio Manager. The EPA considers Source Energy (energy used at point of generation) a more equitable assessment of building-level energy efficiency than Site Energy (energy used in the building). Source Energy incorporates system losses from transmission, delivery and generation, whereas Site Energy is a measure of the energy used by the building itself. The building has a Site EUI of 61.4 kBtu/ft^2/yr, as compared to a national median of 93 kBtu/ft^2/yr, for similar building types. The building has a Source EUI of 177.1 kBtu/ft^2/yr, as compared to a national median of 268.3 kBtu/ft^2/yr. These EUIs suggest that the building is performing better than the average for buildings of a similar type across the nation. The building earns an Energy Performance Rating of 82 based on the building characteristics and energy consumption entered into the account by the account administrators. This rating of 82% indicates that the building performs better than 82% of similar buildings, based on the 2003 CBECS data. Please refer to Appendix A for the Portfolio Manager Statement of Energy Performance.

5 LEVEL I AUDIT – ASSESSMENT OF PRIOR RESULTS & RECOMMENDATIONS

Overview

As noted previously, this Level II energy audit was performed as a follow-up to a Level I walkthrough audit commissioned by Eversource on February 22, 2017, as part of the Eversource Clean Communities Municipal Technical Assistance Program. As part of the Level II audit scope, SWA was asked to review the prior Level I audit recommendations and also to identify any additional energy conservation measures. Before discussing new recommendations, this section provides a review and assessment of the Level I measures. The next section contains the new energy measures identified as part of the more in-depth Level II audit.

The prior Level I audit report recommended a total of (18) Energy Conservation Measures for the building. Consistent with a typical walkthrough audit, or Level I scope of work, the report presented high-level recommendations but did not contain detailed calculations for all recommended measures. To support decision-making, SWA has provided the following assessment of each of the original recommendations. Where further analysis of a Level I measure was warranted, SWA provided a more detailed description and analysis of the measure in Section 6. LEVEL II AUDIT - RESULTS & RECOMMENDATIONS.

Assessment of Prior Findings

The following measures were identified during the Level I walkthrough audit:

1. **Upgrade Indoor Linear Fluorescent Lighting and Fixtures to 4' 18W LEDs and Outdoor Lights to LED**

   The majority of the facility has linear fluorescent fixtures with electronic ballasts. Fixtures are a combination of 2' and 4' and have either two (2) or three (3) T8 lamps. Outdoor lighting fixtures are metal halides. The Level I audit also recommended occupancy sensors or photocell controls.

   SWA Notes: A lighting replacement project is already planned for the facility. At the time of the Level II energy audit site visit, the lighting replacement project scope included interior fixtures on the first and second floors. Additional scope may be added in the future, as funding permits. Fluorescent fixtures will be replaced with LED fixtures.

   Eversource provided the Town with a list of providers and a proposal was submitted. However, it was noted that the work must be performed by Town employees due to union rules. The material cost had not been appropriated. The Town was reviewing options to phase the work or defer the project until the July 2019 budget cycle.

   While the Level I audit recommended lighting controls, the facilities staff indicated lighting controls had been evaluated and ultimately had not been included in the planned lighting project scope due to perceived challenges with occupant education and maintenance. Facilities has focused primarily on electrical savings associated with peak demand reductions, rather than electrical consumption savings. In lieu of occupancy controls, Facilities has implemented a protocol with the cleaning crews to shut all lights off by 8 pm. Additionally, exterior lighting is controlled by photocells and timeclocks for the parking garage lighting.

   Refer to the Level I audit report for original savings estimates. Updated savings calculations should be developed (by others) once the final project scope is determined. SWA recommends that the facility investigate dual-technology occupancy sensors for indoor lighting, which may address some of the concerns that were more prevalent with earlier generations of these devices Dual-technology sensors use both passive infrared and ultrasonic technology to detect occupancy, providing increased reliability over the single-technology occupancy sensors that require a direct line of sight between the occupants and the sensor.

2. **Reduce Air Infiltration through the Building Envelope**
   During the Level I walkthrough audit, auditors observed that windows and doors in the facility provided infiltration points for outdoor air.

   SWA Notes: Weather conditions at the time of the Level II energy audit prevented accurate data collection of infiltration issues at windows and doors. Sealing windows and doors is recommended as a best practice measure. Seal conditions should be checked periodically for degradation. Sealants and weather-stripping should be replaced as needed. This is a low-cost/no-cost measure that typically improves both occupant comfort and reduces energy use.

3. **Install a DDC System**
   To provide greater accuracy and control, the Level I audit recommended a Direct Digital Controls (DDC) system. The following types of controls and strategies were identified for further investigation: Demand Limiting, Heat Pump Loop Operations, Boiler Operation, Cooling Tower Operation, shift control of large pieces of equipment from individuals to building operators, and provide temperature control and scheduling.

   SWA Notes: Controls in the facility are primarily limited to a relay system and on-board packaged controls. This relay system allows for some limited central control over the perimeter heat pumps: The BMS sends a signal to the electrical panels connected to these heat pumps commanding all heat pumps off at 7:00 AM, 5:00 PM and 11:00 PM every day. After the contactor is disconnected during these sweeps, occupants must manually restart their heat pumps. This is meant to ensure that the heat pumps do not run when the building is not occupied. The existing controls also allow for scheduling the packaged DX units on each floor to turn on and off, although these schedules can be overridden by local timers.

   Installing a DDC system would allow for significantly improved centralized controls. A DDC system could provide for space temperature control; Demand Controlled Ventilation and improved boiler, cooling tower, and condenser water pump sequencing and operation. However, taking full advantage of the benefits of a DDC system would require controls work at all major existing building equipment, as well as at each of the perimeter heat pumps.

   As the perimeter heat pumps have been replaced over time, facilities staff have encountered challenges because the existing relay controls are not compatible with more advanced onboard heat pump controls. As a result, the perimeter heat pumps have consistently been replaced in-kind, utilizing less sophisticated equipment that is able to function with the older relay controls but sacrificing improved energy performance. During the course of interior space renovations, this strategy has resulted in the majority of the 400 perimeter heat pumps having already been replaced with units that are not DDC compatible.

   Thus, implementation of a DDC controls system would require a significant investment to upgrade perimeter heat pump units to similar units with more sophisticated onboard controls and, ideally, with automated flow control valves. Unfortunately, the existing relay controls make it challenging to slowly implement such a change to the existing retro-fit strategy over time. A DDC system also has the benefit of providing the facility with increased control and improved sequencing of the six (6) air handling units and the rooftop unit. Because these units run throughout the day and whenever occupants initiate a call for HVAC, there is likely opportunity for energy savings in increasing centralized control over these units.

   A DDC system is expected to improve occupant comfort, simplify building operations, and reduce energy use, resulting in associated operational savings. Unfortunately, the savings cannot be quantified, since they will vary depending upon the scope of the DDC system integration, However, given the large investment required, SWA recommends planning for and installing a DDC system as a capital improvement measure for the facility.

4. Integrate Occupancy Sensors Controlling Lights with Heat Pumps

The Level I audit recommended the integration of occupancy sensors to control both the lights and the heat pumps. The occupancy sensor control would enable the heat pump to shut off during unoccupied periods, resulting in savings in space conditioning. To maximize the benefit of the occupancy sensors, the Level I audit also recommended that the same device be used to also shut off the lights when the space is unoccupied and provide additional lighting energy savings.

SWA Notes: Perimeter heat pumps in the facility are currently controlled manually by occupants, with an automatic shutdown several times a day from the relay system. Occupancy sensors are not currently installed in the facility. Similarly, the lights in the facility are currently manually controlled.

Although Facilities has implemented a protocol to have cleaning staff turn the lights off before leaving at night, SWA recommends installing occupancy sensors as a best-practice measure. Implementation of lighting occupancy controls is a proven energy measure that results in reliable energy savings. During the site visit, Facilities indicated that the recommendation for occupancy sensors had already been reviewed and the decision was made not to implement occupancy sensors in the pending lighting project. Facilities has a number of reservations about occupancy sensors related to occupant education and maintenance requirements. This recommendation was rejected and no further analysis was warranted.

SWA also agrees with the second portion of this Level I audit recommendation, which involves maximizing the benefit of the occupancy sensors by tying these devices into the heat pump controls. SWA agrees this would provide improved comfort and better unoccupied control than the existing controls relay sweep, although continuously-occupied spaces will realize minimal incremental energy savings in switching from the sweep to occupancy-based controls. Thus, this is not a standalone measure and lighting occupancy sensors should be installed first. Any future considerations for occupancy sensor control of the heat pumps should involve a comprehensive assessment of the heat pump integration noted in recommendation #3 above, as well as a review of the existing relay controls also identified in #3 and in the building description section.

5. Tie Units That Bring in Outside Air to CO2 based Ventilation

The Level I audit recommends that the rooftop outdoor air unit, which provides dedicated ventilation air, should be tied to occupancy. Commonly referred to as “Demand Control Ventilation”, this strategy uses carbon dioxide (CO2) sensors to determine the occupancy load of the building. The ventilation air can then be reduced only to satisfy the needs of the building, preventing over-ventilation and excessive energy use to condition the associated ventilation air.

SWA Notes: Outdoor air is provided to the facility via the rooftop unit. This unit delivers fresh air to the six (6) packaged cooling-only DX units that distribute from the building’s core. SWA agrees that this building presents opportunities to reduce energy use and cost by modifying the ventilation system, including potentially incorporating the use of Demand Control Ventilation.

Refer to Section 6- LEVEL II AUDIT - RESULTS & RECOMMENDATIONS *under ECM #:2 Optimize Rooftop Unit Operation. ECM #2 includes adding modulating dampers to the outdoor air intake louvers in the fresh air shaft and modulating the dampers based on space comfort needs. Given the current configuration of the outdoor air delivery system, true Demand Controlled Ventilation (DCV) cannot yet be recommended. It is unclear whether sufficient static pressure will build up in the outdoor air delivery shaft to allow for DCV. SWA recommends installing modulating dampers at each floor, controlling the RTU as described in ECM #2, and evaluating the feasibility of DCV as an advanced controls strategy at a later date.*

The addition of DCV would also require the installation of CO2 sensors throughout the occupied space and some controls programming in the existing controls system. These costs would be in addition to those presented in ECM #2.

6. Replace Heat Pumps

The walkthrough audit listed the installation date of the facility's heat pumps as 1981 and recommended newer models that would use less water and power and reduce the reliance on R-22 refrigerant.

SWA Notes: Discussion with the facility operators revealed that there are several generations of heat pumps in the facility, as noted in Section 3.3.4. The facility currently replaces heat pumps as departments are renovated. Not all heat pumps are currently at the end of their useful life.

SWA does agree that modifications to the existing heat pumps could yield savings, when done as a comprehensive strategy. As discussed under #3 of this section, any changes to the heat pumps should take into consideration a tie-in with BMS controls, which would enable the use of newer models with more sophisticated onboard controls. At the time of replacement, adding automated control valves would enable pump energy savings if a VFD were to be incorporated, as discussed in item #7 below. As noted in item #4 of this section, the heat pumps could also be tied into occupancy sensors to provide further savings during unoccupied periods. All of these benefits would be in addition to any energy improvements that may result from advancements in the heat pump technology that improve the performance of components such as the fan and compressor equipment. There may also be maintenance benefits, such as eliminating R-22 refrigerant and eliminating the need to repair and stock parts for numerous types of heat pumps.

7. Install Isolation Valves on Heat Pumps

The Level I audit recommended the use of isolation valves on the heat pumps to enable the coil to close when there is no call for heating or cooling. The recommendation envisioned associated pump energy savings.

SWA Notes: The heat pumps serving the facility's perimeter were originally installed without any isolation valves. Maintenance was performed on units by clamping the condenser water piping prior to disconnecting the units from the system. As the heat pumps are replaced, manual isolation valves are being installed. While the manual isolation valves greatly facilitate maintenance, they do not achieve the savings associated with this recommendation. To prevent water flow through the coils, it would require automated isolation valves.

The addition of automated isolation valves alone would not result in significant energy savings. To achieve the energy savings envisioned in the Level I report, the valves would need to be implemented in conjunction with a variable speed drive on the condenser water pumps. When individual heat pump valves close, the flow requirement of the system would reduce and a variable speed pump could ramp down, resulting in electrical energy savings.

SWA recommends installed automatic isolation valves as part of the larger heat pump and DDC controls system capital upgrade. If automatic isolation valves are added, the project scope should include a variable speed drive for the condenser water pumps to yield pump energy savings. Since the existing condenser water system is constant flow and significant capital improvements would be required to implement a variable flow system, no recommendations for a variable frequency drive (VFD) are included in the Phase II report. Prior to implementing this project, the facility should pursue ECM 1: Condenser Water System Assessment and Repair, detailed in section 5.2 of this report. An assessment of the facility's condenser water system can determine the proper configuration for installing automatic isolation valves to ensure that no additional condenser water flow issues are introduced to the system.

8. Replace Motors Less Than 1 HP with ECM Motors

The Level I report broadly suggested replacing any motor less than 1 HP with an ECM motor. These motors are capable of ramping up the speed gradually, rather than incurring a larger instantaneous electrical demand. The Level I report did not identify specific motors in the building for which this recommendation is applicable.

SWA Notes: During the Level II audit walkthrough, SWA located three (3) fractional-horsepower motors serving the laboratory exhaust fans. These fans were installed in 2013 and likely have efficient motors in place. SWA recommends waiting until these motors reach the end of their useful lives before replacing them with higher-efficiency models.

9. Photocells for Outdoor Light Operations

The Level I audit recommended that exterior lighting be controlled via photocells, rather than a combination of switches and time clocks. This would provide greater automation.

SWA Notes: The exterior lighting at the facility was found to already be controlled by photocell sensors. However, the lighting in the parking deck is controlled by a timeclock. With diligence, the same level of savings can be achieved through a timeclock. Use of the timeclock does require some adjustments as the seasons change, to ensure adequate light is provided during changing daylight hours. No further action is required for this measure.

10. Install 0.5 GPM Aerators on Lavatory Sinks and Kitchen Sinks

During the Level I audit, it was noted that the bathroom sinks used 2.2 GPM aerators. It was recommended to switch these to 0.5 GPM aerators on both the bathroom and kitchen sinks to reduce water consumption and hot water energy consumption.

SWA Notes: At the time of the Level II audit site visit, this measure was already in progress.

11. Tie Exhaust Fans with Occupancy Controls

The Level I audit recommended that the bathroom exhaust fans be tied to occupancy, rather than the existing schedule control. The suggested strategy involved interlocking the fan operation with occupancy controls. Additional savings may also be possible through the use of either VFDs or ECM motors.

SWA Notes: The facility's two (2) toilet exhaust fans and one (1) general exhaust fan are interlocked with the packaged AC units such that the exhaust fans operate when any of the packaged AC units operate. This is also interlocked with the operation of the rooftop outdoor air unit, which provides the make-up air for the ventilation fans. All of this equipment is currently controlled based on schedule but it can be over-ridden by occupants via the wall-mounted timer controls.

While SWA agrees with the concept of this Level I recommendation, the Level II investigation revealed additional complexity. An expansion of this concept is Refer to Section 6- LEVEL II AUDIT - RESULTS & RECOMMENDATIONS *under ECM #:3 Control Air Conditioning Units with Occupancy Sensors or One-Hour Timers.*

12. Relocate and Replace Electric Resistance Water Heater with Heat Pump Water Heaters

The Level I audit recommended that the existing electric resistance water heaters be replaced with heat pump water heaters. It was noted that these units require approximately 12'x12' of space to operate properly. The recommendation included relocating the existing water heaters to the mechanical room to accommodate this operating criterion.

SWA Notes: The domestic hot water consumption at the Town Hall is too small for this measure to yield significant energy savings to overcome the cost of new equipment and changes to plumbing necessary to relocate the equipment. However, Facilities indicated that domestic hot water is currently being decentralized, as floors are renovated. This has resulted in numerous smaller water heaters. As new equipment is being selected and relocated, the facility may want to explore the applicability of this recommendation.

13. Control Motors with a Variable Speed Drive

The Level I audit recommended variable speed drives to control motors for fans and pumps. An estimated payback of 2.8 years was presented. The report also noted the added benefit of upgrading to high efficiency motors.

SWA Notes:

During the Level II audit, SWA updated the motor data as presented below:

Equipment	Quantity	Motor HP
Cooling Tower Fans	6	10
Condenser Water Pumps	2	25
Condenser Water Pumps	2	25
AC Unit Supply Fan	4	10
AC Unit Supply Fan	2	7.5
AC Unit Return Fan	4	7.5
AC Unit Return Fan	2	5
Conference AC Unit	1	3

As noted in this report, Facilities has already reviewed VFDs for the cooling tower and elected not to implement them in the project. Implementing VFDs would have been most cost-effective when done as part of the larger project, although there is still opportunity for energy savings at the cooling tower fans should the facility choose to pursue the project. The existing AC units are all constant speed equipment, which would not result in significant savings from the installation of a VFD. Similarly, the existing condenser water pumps are constant speed and would not benefit from a VFD.

With the exception of the cooling tower fans, installing VFDs on these motors will not save energy as a standalone measure. If automatic isolation valves are added to the heat pumps, the facility should definitely consider incorporating a VFD on the condenser water system. For situation where VFDs are applicable, they should always be evaluated in conjunction with compatible motor replacement. At the time of replacement and/or when VFDs are being considered, motors should also be upgraded to premium efficiency motors.

Similarly, VFDs on the AC unit supply and return fans would require substantial upgrades to the facility's air distribution systems in order to save energy. To ensure the proper volume of ventilation air is maintained, a code review would first be required. The existing constant volume duct system may need to be converted a variable volume system to ensure adequate fresh air distribution to all spaces. When in cooling mode, the AC units may require higher airflow to prevent compressor failure. Together, the ventilation and compressor requirements may limit the opportunity for energy savings associated with ramping down the supply and return fan speeds.

14. **Replace Electric Baseboard Heater with Heat Pump Mini Ductless Split**
The Level I report recommended the replacement of electric baseboard heat with a ductless mini-split heat pump system to reduce electrical energy use. This recommendation would shift traditional resistance heat to a heat pump.

SWA Notes: The Level I audit recommended removing the electric baseboard heaters located in the stairwells and replacing them with heat pump mini ductless split units. During the Level II audit site visit, SWA observed that the baseboard heaters do not have thermostats and are frequently left on at full capacity during the winter. ECM 4: Install Thermostats at Radiator Stairwells investigates the feasibility of controlling these radiators with thermostats. SWA estimates that the radiators consume 53,172 kWh of electricity per year and can consume 43,428 kWh if controlled by thermostats. With an electric rate of $0.15/kWh and thermostat controls, the radiators will cost less than $8,000 to operate annually, leaving little room for substantial equipment replacement to be cost effective.

15. **Small Outdoor Condenser Head Pressure Control with ECM Motor**
The Level I report recommended an electronic head pressure controller to modulate the condenser fan motor speed, which would vary the airflow through the outdoor condenser. The specific equipment applicable to this recommendation was not identified.

SWA Notes: The facility has a total of four (4) outdoor condensing units. The Level I audit recommended installing electronic head pressure controllers on each of these units. The controllers modulate condenser motor fan speed based on refrigerant temperature. Because of the small size of these condensing units, this measure presents limited opportunity for energy savings.

16. **Specify Premium Efficiency Motors**
For all motor applications, the Level I report recommends standard efficiency motors be replaced with premium efficiency motors, which are 1-2% more efficient on average.

SWA Notes: This recommendation is investigated further in Section 6- LEVEL II AUDIT - RESULTS & RECOMMENDATIONS *ECM 5: Install Premium Efficiency Motors.*

17. **PC Power Management**
The Level I report recommends the facility-wide incorporation of automatic power management to control computer energy use. This includes setting monitors to go to sleep, enabling hard drive power management controls, and user education. This is a no cost recommendation that utilizes existing equipment and staff resources.

SWA Notes: As of the Level II audit site visit, this program has already been implemented.

18. **Employee Energy Education Program**
The Level I report recommended the implementation of an employee education program to raise awareness among employees about the energy use in the building and provide recommendations on how employees can help save energy and reduce costs. Common strategies include instruction on proper operation of: thermostats, personal computers, light switches, copy machines, and printers.

SWA Notes: Savings for this measure are difficult to quantify but SWA strongly recommends that the Town Hall implement an energy education program. This facility allows occupants significant control over equipment. With increased occupant control over equipment, there is an increase in the potential for energy waste, and therefore an increase in the potential benefit of implementing an energy education program. In addition to the topics listed in the Level I audit recommendation, the education program should also instruct employees about the impact of using the floor-by-floor AC timers and stairwell radiators.

6 LEVEL II AUDIT - RESULTS & RECOMMENDATIONS

Overview

The Project Summary Sheet that follows the Executive Summary lists estimated costs and savings for each recommended ECM. Each ECM is discussed in detail in the following section with a brief recommendation on how to measure and verify the savings after implementation. These Measurement and Verification (M&V) methods are recommended in accordance with the International Performance for Measurement and Verification Protocol (IPMVP) guidelines. The recommended options (A, B, C or D) were determined based on a combination of cost, magnitude of savings, and reasonableness of methods. This process is described in more detail in Appendix E.

6.1 METHODOLOGY

Potential Energy Conservation Measures (ECMs) were evaluated after the site survey, operator interviews and collection of data necessary to perform the technical and economic analyses. This evaluation was completed to ASHRAE Level II standards through spreadsheet analysis. Prior to implementation, the customer may elect to further evaluate the facility measures to Level III audit standards.

Table 4.1: Methodology Flow Chart

To assess energy savings associated with each measure, the baseline for consumption was compared individually to consumption totals calculated for each measure. The baseline for equipment was obtained from monthly utility bills and gas and electric data and analyzed against daily weather data. Results were then calibrated as necessary.

Energy consumption associated with each measure was then assessed individually based on the technical performance of the recommended measure scope and then compared to the corresponding baseline in order to determine energy savings. Cost savings were determined using the projected energy savings and energy rates determined from the utility analysis and based on the recent energy bills.

All potential ECMs were evaluated. They are listed in this section of the report as *Recommended* or *Considered but Not Recommended* based on technical and/or economic feasibility. Prior to implementation, confirmation of projected savings and cost may be required for capital intensive measures.

The following assumptions were used in calculating the savings:

1. Building energy usage patterns remain relatively unchanged in the near future (no significant occupancy change and/or space conversion).
2. Energy costs remain relatively stable (although electricity costs may escalate much more than natural gas).
3. Building systems operation remains relatively unchanged (unless change is related to a recommended ECM).

An economic analysis was performed for each measure using historical cost estimates from similar projects and pricing references, such as R.S. Means. The cost savings were divided by implementation costs in order to determine simple payback for each measure.

6.2 LEVEL II AUDIT RECOMMENDED ENERGY CONSERVATION MEASURES

ECM #1: CONDENSER WATER SYSTEM CONDITION ASSESSMENT AND REPAIR

The condenser water system at this facility serves the floor-by-floor AC units and the water source heat pumps located along the building's perimeter. This system provides heat rejection during the cooling season and heat injection during the heating season. Building staff reports that this system experiences significant air entrainment issues such that if the condenser water pumps shut off at all, air gets trapped in the condenser water loop and takes up to a month to completely purge the system. To avoid the air entrainment and binding issues, the condenser water pumps run continuously (24 hours per day/7 days per week/ year-round), regardless of building occupancy or equipment demand.

SWA recommends a thorough condenser water system condition assessment. An assessment of all condenser water piping, connected equipment, and air eliminating components will identify the underlying cause of the air entrainment issue. Once the air entrainment issue is resolved, SWA recommends shutting the condenser water pumps off as outdoor air conditions permit. Implementing this measure will save energy at the condenser water pumps, reduce operating hours on the pumps, and will also decrease the maintenance time staff must spend on this building.

A condition assessment is the initial step required to determine the corrective scope of work that may be needed. Resolution of the underlying problems may result in other opportunities to optimize equipment performance beyond the benefits identified above. The condenser water system piping configuration should also be reviewed, as noted later in this section.

Savings

Although there are no energy savings directly associated with this measure, performing the condition assessment and diagnosing the condenser water system issues will allow the facility to proceed with condenser water system energy conservation measures in the future. In addition to the operations and maintenance benefits of correcting the air binding issue, identifying the source of the issue and assessing the general condition of the condenser water system will allow the facility to determine whether automatic isolation valves can be installed at the heat pumps. With automatic isolation valves at the heat pumps, the facility could install VFDs on the condenser water pumps and could see additional savings at the boilers and cooling towers. Further operational savings may be realized, such as decreased glycol use if purging is minimized. The scope of work and associated implementation cost for this measure could be estimated after a scoping session with an assessor.

ECM #2: OPTIMIZE ROOFTOP UNIT

A rooftop unit (RTU), manufactured by Reznor, provides outdoor air to the facility. The unit has a 5-HP fresh air intake fan and a gas-fired furnace for preheating. Outdoor air is delivered from this unit to the six (6) AC units that distribute the fresh air across each floor of the facility. SWA recommends the following upgrades to this system:

1. Add a variable frequency drive (VFD) to the RTU supply fan. Adding a VFD to the supply fan will allow the fan to modulate its speed, and ramp down when the full design airflow is not required. For this measure to be successful, the shaft dampers at each AC unit must be connected to automatic actuators. Each actuator should modulate the outdoor air damper open when its corresponding AC unit is operating. When an AC unit shuts off, its outdoor air damper should modulate closed. A static pressure sensor should be installed in the outdoor air shaft and should be used to modulate the RTU's supply fan VFD. The RTU's supply fan currently operates whenever any one of the AC units is called on. Because building occupants have the ability to call for the AC units to stay on for a long period of time, via the timer for each unit, the RTU typically operates at full speed for much longer than normal building operating hours. With a supply fan VFD, the RTU will still operate at full speed during building occupied hours but will be able to ramp down and realize energy savings outside of occupied hours.

   Note: Additional savings could be achieved if this recommendation were to be implemented in conjunction with CO2 sensors to determine space occupancy during the occupied building periods. See Section 4, item #5 for details. Also, the controls described above could be implemented through stand-alone devices. For ease of use and monitoring, it is preferred to tie these controls into the BMS.

2. Reduce the heating setpoint for the RTU to 30 °F. The RTU is set to maintain a fresh air temperature of 60 °F, as measured by a thermostat located downstream of the RTU's burner but upstream of the mixed air chambers for the AC units. The RTU's burner will operate whenever the RTU is on and outdoor air temperature is below 60 °F. This 60 °F air is then delivered to the mixed air chambers of each AC unit, where it mixes with warm return air before passing over the AC unit's cooling coil. By mixing preheated outdoor air with warm return air, the resulting mixed air temperature is higher than required. In turn, excess energy must be used by the AC units to condition supply air. Reducing the heating setpoint at the RTU will allow for colder mixed air to enter the AC units and will decrease the AC unit compressor operation in the winter and shoulder seasons. SWA recommends reducing this discharge air temperature setpoint to 30 °F. With a 30 °F outdoor air supply temperature, the mixed air at each AC unit will remain warm enough to protect the AC unit's internal components from freezing. Because these interior units are not used for heating, there is no benefit to supplying heated fresh air to the AC units beyond freeze prevention.

   Note: Item #2 is a no cost measure that could be implemented independent of item #1. Implementing this measure will impact the estimated savings shown in the following measure (ECM-3: Control AHUs with Occupancy Sensors or One-Hour Timers). The savings analysis for each ECM shows the energy and cost savings associated with implementing either measure independently. If ECM-3 is implemented the savings for ECM-2 will be less than the savings calculated here. ECM-3 involves reducing the annual operating hours for the AC units and the rooftop unit. If these units operate less frequently, their baseline energy consumption will be reduced. A reduced baseline energy consumption diminishes the potential impact of any additional changes to the equipment, such as those recommended in this measure. Similarly, if ECM-2: Optimize Rooftop Unit is implemented, the savings for ECM-3 will be lower than the savings shown in this report. ECM-2 involves reducing gas and electricity consumption at the rooftop unit, which will in turn reduce the cooling requirements and therefore the electricity consumption at the AC

units located downstream. With reduced cooling requirements at the AC units, the impact of reducing the AC unit operating hours, as described in ECM-3, will be diminished.

The interactivity of these two measures is not accounted for in the savings calculations shown in this section, or in the summary table at the beginning of this report. If both measures were to be implemented, the cumulative energy savings would be less than the sum of the individual measure savings shown in the savings calculations. Individually, each measure has a simple payback of less than 1.5 years. Taking interactivity into account would increase the simple payback of each measure.

Eversource anticipates these measures may be implemented together. If so, the associated incentive for the combined measure would be based on the interactive measure savings, not the individual measure savings. Eversource estimates that the combined savings resulting from implementing both measures would be 3,743 ccf of natural gas and 85,866 kWh of electricity, for a total annual cost savings of $16,013.58.

Savings

ECM #	Description	ECM Status[1]	Fuel Type Saved	Energy Saved			Annual Savings ($)	Estimated Implementation Cost ($)	Simple Payback
				kWh	kW	MMBtu			
2	Optimize Reznor Unit	R	Electricity / Natural Gas	72,851	0.00	345.0	$13,729	$9,568	0.7

1. Status: R = Recommended; I = Implemented; NR = Not Recommended; RS = Further Study Required

Measurement and Verification

Option (C) Whole Facility can be used to evaluate energy savings for this measure. This measure will affect the energy consumption of the rooftop unit and the AC units. Reduced operation of the AC units may also affect the condenser water system. Because this measure affects the majority of the building's HVAC systems, a whole facility analysis is appropriate.

ECM #3: CONTROL AC UNITS WITH ONE-HOUR TIMERS OR OCCUPANCY CONTROLS

The air conditioning (AC) units serving each floor are controlled by timers. The units have schedules programmed into the BMS to ensure that they operate during building occupied hours. In addition, each unit also has a local, wall-mounted crank timer located in the corridor outside the mechanical room that is accessible to all building occupants. Any occupant can use the timer to call for an AC unit to operate for up to twelve hours.

Due to equipment interlocks, initiating the AC unit via the timer has a larger effect. Triggering the AC unit to run results in operation of the rooftop unit, which supplies fresh air to the AC units. When the rooftop is running to provide fresh air, the return fans and exhaust fans are also initiated to draw air from the building. The result is a significant amount of equipment running during periods of very limited occupancy. While each AC unit only serves a floor or a portion of a floor, the related ventilation equipment operates at full capacity, providing the level air exchange required for a fully-occupied building.

Building staff reports that a number of employees frequently work on the weekends and utilize the timer controls, often setting the timer for many hours after a space is actually occupied. Some employees may trigger the timer out of habit, while others may only do so if the building feels uncomfortable. As a no-cost measure, proper use of these systems should be included in the Employee Education Program noted in Section 4, item #18. Employees should understand that the primary role of this system is to provide ventilation air and to condition interior spaces. During periods of sporadic occupancy, the building may not require any mechanical ventilation. For those employees that work at or near the building perimeter, any comfort concerns associated with temperature should first be addressed through the use of the perimeter heat pumps. Employees that work in the core of the building may need to utilize the central systems for comfort. To the extent possible, employees that frequently work during the weekend may benefit from a work space at the building perimeter that offers localized control via the heat pumps, rather than the air system.

To avoid excess run-time incurred when the timers are set incorrectly, SWA recommends installing occupancy sensors to control these AC units in lieu of the timers. Occupancy sensors will shut an AC unit off when occupancy is no longer detected on that floor. This will reduce the total operating time of the AC units. Alternatively, if occupancy sensors are not installed, SWA recommends replacing the existing 12-hour mechanical countdown timers with 1-hour mechanical countdown timers or similar electronic 1-hour touch-pad controls, which will still allow occupants the ability to call for fresh air but will limit the amount of time the units can run and will eliminate AC unit operation overnight. Occupants can reassess their comfort needs each hour and re-initiate the system, as needed.

Savings

The interactive effect of implementing both this measure and ECM-2: OPTIMIZE REZNOR UNIT is explained in the measure description for ECM-2.

ECM #	Description	ECM Status[1]	Fuel Type Saved	Energy Saved			Annual Savings ($)	Estimated Implementation Cost ($)	Simple Payback
				kWh	kW	MMBtu			
3	Control AHUs with Occupancy Sensors or One-Hour Timers	R	Electricity / Natural Gas	18,079	0.00	274.0	$4,868	$4,433	0.9

1. Status: R = Recommended; I = Implemented; NR = Not Recommended; RS = Further Study Required

Measurement and Verification

Option (C) Whole Facility can be used to evaluate energy savings for this measure. This measure will affect the energy consumption of AC units, the rooftop unit, and may affect the condenser water system. Because this measure affects the majority of the building's HVAC systems, a whole facility analysis is appropriate.

ECM #4: INSTALL THERMOSTATS AT RADIATOR STAIRWELLS

Electric resistance radiators are installed at stairwell landings throughout the facility. These radiators have outdated local controls that cannot be programmed. The building staff reports that these radiators are generally turned on for the heating season and shut off once winter is over. However, building occupants can change the radiators' settings easily. During the site visit, SWA observed that many radiators were on at 100% while the space was warm and the outdoor air temperature was 70 °F.

SWA recommends installing remotely-mounted programmable thermostats with lock boxes to control these radiators. The savings presented are based on programming the thermostats to maintain a stairwell space temperature of 65 °F during building occupied hours and 55 °F during unoccupied hours. To ensure occupants do not over-ride the program settings, SWA also recommends locking these thermostats.

Savings

ECM #	Description	ECM Status[1]	Fuel Type Saved	Energy Saved			Annual Savings ($)	Estimated Implementation Cost ($)	Simple Payback
				kWh	kW	MMBtu			
4	Install thermostats at stairwell radiators	R	Electricity	9,744	0.00	0.0	$1,479	$4,556	3.1

1. Status: R = Recommended; I = Implemented; NR = Not Recommended; RS = Further Study Required

Measurement and Verification

Option (B) Retrofit Isolation: All Parameter Measurement can be used to measure and verify savings for this measure. An energy and power meter can log the electrical demand of the radiators and can calculate the total electrical consumption of the radiators over the logging period.

ECM #5: INSTALL PREMIUM EFFICIENCY MOTORS

Currently, the motors for the two (2) condenser water pumps, six (6) air handling unit supply fans, and six (6) return fans are NEMA standard efficiency motors. The condenser water pumps operate 24/7, alternating so that one pump runs at a time. The air handling units and their return fans operate during building occupied hours, and whenever an occupant calls for space conditioning at a unit's timer.

At the time of motor replacement, SWA recommends replacing the standard efficiency HVAC motors with premium efficiency motors. Premium efficiency motors require less electricity to generate the brake horsepower needed to operate equipment. SWA recommends replacing the motors for the following pieces of equipment:

Equipment			Baseline	Proposed
Description/Tag	Type	Motor HP	Motor Efficiency (%)	Motor Efficiency (%)
Condenser Water Pump 1	Pump	25	91.7%	93.6%
Condenser Water Pump 2	Pump	25	91.7%	93.6%
AC-1	Supply Fan	10	89.5%	91.7%
AC-2	Supply Fan	10	89.5%	91.7%
AC-3	Supply Fan	7.5	88.5%	91.0%
AC-4	Supply Fan	10	89.5%	91.7%
AC-5	Supply Fan	7.5	88.5%	91.0%
AC-6	Supply Fan	10	89.5%	91.7%
RF-1	Return Fan	7.5	88.5%	91.0%
RF-2	Return Fan	7.5	88.5%	91.0%
RF-3	Return Fan	5	87.5%	89.5%
RF-4	Return Fan	7.5	88.5%	91.0%
RF-5	Return Fan	5	87.5%	89.5%
RF-6	Return Fan	7.5	88.5%	91.0%

Refer to Appendix B for details on the savings associated with each type of motor, as well as the estimated costs. Facilities staff indicated that they had already investigated the savings and costs associated with premium efficiency motors. Facilities is considering this recommendation as part of future procurement best practices.

Savings

ECM #	Description	ECM Status[1]	Fuel Type Saved	Energy Saved			Annual Savings ($)	Estimated Implementation Cost ($)	Simple Payback
				kWh	kW	MMBtu			
5	Install Premium Efficiency Motors	R	Electricity	9,970	2.29	0.0	$1,513	$23,461	15.5

1. Status: R = Recommended; I = Implemented; NR = Not Recommended; RS = Further Study Required

Option (B) Retrofit Isolation: All Parameter Measurement can be used to measure and verify savings for this measure. An energy and power meter can log the electrical demand of the pumps and fans and can calculate the total electrical consumption of the pumps and fans over the logging period.

6.3 OTHER OBSERVATIONS

During the audit, three key observations arose that do not present currently quantifiable energy saving opportunities but are worth noting for use in strategic planning related to building operations and management. The three observations are intertwined but broadly address the following opportunities for capital investment:

1. Building Management Controls
2. Heat Pump Optimization
3. Condenser Water Piping Configuration

As has been noted throughout this report, the existing building operates primarily through local controls that relinquish a significant amount of control to the occupants and also make it challenging to implement any level of operational automation. Together, these resulting concerns present a significant barrier to achieving long-term, reliable system performance and, in turn, make it difficult to achieve and maintain consistent comfort without sacrificing energy savings.

This lack of building automation is further compounded by the large number of stand-alone systems in this building. Each heat pump represents a local point of control and there are over 400 heat pumps. Many of the heat pumps have already been replaced, which introduces a significant first cost consideration into any discussion related to switching this facility over to a more automated controls system. While these capital costs cannot be discounted, there is still tremendous opportunity to improve the building performance through the development of a comprehensive strategy that addresses the long-term automation control needs.

Although selection of terminal equipment has historically been governed by the limitations of the existing controls system, the future performance of this facility would greatly benefit from taking the opposite view. Consideration should first be given to the benefits of upgrading to a more automated controls system, working backwards to determine how best to integrate the existing equipment and all future equipment around that vision. Given that the building is already predominantly fueled by electricity, opportunities for renewable energy could be explored. However, renewables cannot be cost-effectively implemented until energy usage has been minimized and can be consistently controlled and maintained.

In conjunction with developing a comprehensive controls strategy, the auditing team noted that the combination of existing systems and equipment may present unique opportunities for optimization, particularly optimization of the heat pumps. However, any optimization would require greater controls capabilities to achieve improved comfort and energy performance.

The concept of optimizing the heat pump system centers around the balance between using the central systems versus the perimeter systems to achieve space comfort. Where comfort concerns within the core arise, it may make sense to reduce the supply air temperature of the central systems to provide greater cooling capacity. The trade-off of shifting the load from the perimeter systems to the central systems should be evaluated. Since the central systems must run to provide ventilation, any decreased run time at the perimeter units would be of benefit. Each of the 400 perimeter heat pumps has a compressor and a fan, which represents a significant amount of energy that could be decreased at the terminal level. Additionally, the reduced run-time of the units could decrease maintenance costs and equipment wear.

However, the optimization effort must also take into consideration the differing efficiencies of the systems, as well as the potential for the two systems to “fight” – where one system over-conditions the space, forcing the other system to compensate by reconditioning the air. To optimize the system, further investigation would be needed on the equipment operating efficiencies and space comfort conditions. Additionally, greater controls and capabilities to monitor both the systems and spaces would be needed to implement an effective assessment.

When considering optimization of the heat pump system, the existing condenser water piping configuration should also be reviewed. As was noted in Section 3.3.2 - Condenser Water System, the original building drawings (Images 6 and 7) show that the condenser water piping system was designed to first deliver water to the six packaged units. The piping then runs to the perimeter heat pumps. As a result, when the packaged units are operating in cooling mode, the condenser water received by the heat pumps is warmer than the condenser water supplied to the packaged units.

As a result of this piping configuration and the lack of system temperature sensors, there is no reliable way to estimate the actual condenser water loop temperature received by the heat pumps. While Facilities may monitor and adjust the condenser water loop temperature routinely, these changes only directly impact the packaged AC units, since the operation of the AC unit has a direct impact on the temperatures delivered to the downstream heat pumps.

Verification of the as-built pipe routing is outside the scope of this energy audit. Although the drawings reflect this design intent, the piping may not have been installed per the documents or it may have later been reconfigured. Further investigation is required to field verify the piping details. The savings associated with this pipe reconfiguration cannot be reasonably quantified without data on the varying heat pump inlet condenser water temperatures. SWA recommends that further investigation of the piping system configuration be incorporated into the scope of ECM #1 - CONDENSER WATER SYSTEM CONDITION ASSESSMENT AND REPAIR.

Reconfiguration of the condenser water piping may be considered viable as a stand-alone effort. However, it should also be considered with respect to the other two observations noted here, improved building automation and heat pump optimization. Through the incorporation of increased building automation control and monitoring, this pipe reconfiguration could play a significant role in optimization of the heat pump system performance.

These three observations were presented simply for use in strategic planning for the facility.

6.4 ENERGY PURCHASING AND PROCUREMENT STRATEGIES

During the walk-through, SWA did not identify any significant opportunities for reducing electrical demand. All of the major heating, ventilation, and air conditioning (HVAC) equipment must run during operating hours to provide and distribute the code-required ventilation air. Ventilation air requires operation of the Reznor, packaged AC units, exhaust fans, pumps, etc. Further, while there may be an opportunity to shut off the local space conditioning heat pumps that are distributed throughout the building, these units have no centralized control system. Since there is no automated means to disable this equipment during a period of peak electrical demand, it would require a manual strategy. Additionally, the building staff reported comfort complaints during cooling season, so it may not be acceptable to the occupants to shut-off cooling equipment during a peak electrical event. Finally, the lack of building automation controls makes the introduction of demand-management controls much less cost-effective. Given all of these barriers, SWA does not recommend that demand-management strategies be the first priority for this building.

As part of the long-term planning efforts, SWA does recommend that the Town consider demand management as a key design criterion for the evaluation of any future system upgrades and when implementing any building automation controls. SWA recommends that the Town contact Eversource for further information on available demand response programs. Within the first year following the implementation of the planned lighting retrofit, SWA also recommends that the Town contact Eversource to review their electric rate schedule and confirm any potential billing structure benefits for which they may be eligible following the decrease in demand associated with the lighting retrofit.

APPENDIX A: PORTFOLIO MANAGER STATEMENT OF ENERGY PERFORMANCE

ENERGY STAR® Statement of Energy Performance

LEARN MORE AT energystar.gov

82

ENERGY STAR® Score[1]

CTLG_Greenwich_Town Hall_101 Field Point Road

Primary Property Type: Office
Gross Floor Area (ft²): 130,000
Built: 1937

For Year Ending: December 31, 2017
Date Generated: February 12, 2018

1. The ENERGY STAR score is a 1-100 assessment of a building's energy efficiency as compared with similar buildings nationwide, adjusting for climate and business activity.

Property & Contact Information

Property Address	Property Owner	Primary Contact
CTLG_Greenwich_Town Hall_101 Field Point Road 101 Field Point Road Greenwich, Connecticut 06830	_____ , (___)___-_____	___ _____ , (___)___-_____ _____

Property ID: 2689872

Energy Consumption and Energy Use Intensity (EUI)

Site EUI
61.4 kBtu/ft²

Source EUI
177.1 kBtu/ft²

Annual Energy by Fuel	
Electric - Grid (kBtu)	7,006,593 (88%)
Natural Gas (kBtu)	972,399 (12%)

National Median Comparison	
National Median Site EUI (kBtu/ft²)	93
National Median Source EUI (kBtu/ft²)	268.3
% Diff from National Median Source EUI	-34%
Annual Emissions	
Greenhouse Gas Emissions (Metric Tons CO2e/year)	589

Signature & Stamp of Verifying Professional

I _____ (Name) verify that the above information is true and correct to the best of my knowledge.

Signature: _____Date: _____

Licensed Professional

___ _____
,
(___)___-_____
_____

Professional Engineer Stamp
(if applicable)

APPENDIX B: ECM CALCULATIONS

ECM #1: ASSESS AND REPAIR CONDENSER WATER SYSTEM

ECM #	Description	ECM Status[1]	Fuel Type Saved	Energy Saved			Annual Savings ($)	Estimated Implementation Cost ($)	Simple Payback
				kWh	kW	MMBtu			
1	Assess and repair condenser w ater system	R	N/A	0	0.00	0.0	$0	Cannot Verify	

1. Status: R = Recommended; I = Implemented; NR = Not Recommended; RS = Further Study Required

Although there are no energy savings directly associated with this measure, performing the condition assessment and diagnosing the condenser water system issues will allow the facility to proceed with condenser water system energy conservation measures in the future. In addition to the operations and maintenance benefits of correcting the air binding issue, identifying the source of the issue and assessing the general condition of the condenser water system will allow the facility to determine whether automatic isolation valves can be installed at the heat pumps. With automatic isolation valves at the heat pumps, the facility could install VFDs on the condenser water pumps and could see additional savings at the boilers and cooling towers. Further operational savings may be realized, such as decreased glycol use if purging is minimized. The scope of work and associated implementation cost for this measure could be estimated after a scoping session with an assessor.

ECM #2: OPTIMIZE REZNOR UNITS

ECM #	Description	ECM Status[1]	Fuel Type Saved	Energy Saved kWh	Energy Saved kW	Energy Saved MMBtu	Annual Savings ($)	Estimated Implementation Cost ($)	Simple Payback
2	Optimize Reznor Unit	R	Electricity / Natural Gas	72,851	0.00	345.0	$13,729	$9,568	0.7

1. Status: R = Recommended; I = Implemented; NR = Not Recommended; RS = Further Study Required

Assumptions

Utilities Cost			Energy Content per Type		
$0.15	$/kWh		102.9	kBtu/ccf	
$0.80	$/ccf				

Energy Savings			Cost Savings		
Electrical Energy Savings	72,851	kWh/year	Electric Cost Savings	$11,054	/Year
Gas Savings	3,352	ccf/year	Gas Cost Savings	$2,675	/Year

Equations

Heating Load (MBH) = (1.08) x (CFM) x (Leaving Temperature - Entering Temperature) / 1,000

Cooling Load (MBH) = (4.5) x (CFM) x (Entering Enthalpy - Leaving Enthalpy) / 1,000

Fan Energy (kWh) = (Fan Speed) ^(2.4) x (HP) x (0.746) x (Hours of Operation)

Annual Heating Energy (ccf) = (Heating Load) x (Hours of Operation) x (Furnace Duty Cycle) / (Energy Content of Gas)

Annual Cooling Energy (kWh) = (Cooling Load) x (Compressor kW/MBH) x (Hours of Operation)

Cost Savings = [Energy Savings] x [$]

Simple Payback = [Implementation Cost] / [Cost Savings]

Reznor Unit	Model # PACR-150	
Fan Motor	7.5	hp
Draft Inducer	0.75	hp
Burner	0.5	hp
Burner max input	1875	MBH
Burner min input	625	MBH
Rated CFM	18000	CFM

Occupancy & Ventilation		**OA Ventilation Requirement**
Full occupied hours	8am-4pm Mon - Fri	100%
Partial occupied hours	7am-8am Mon - Fri 4pm - 10pm Mon-Fri	80%

Baseline Airflow	
OA CFM	18,150
RA CFM	54,450
SA CFM	72,600
Reznor Unit Fan Speed	100%

Reznor Heating Setpoint	OAT (°F)
Existing Reznor heating setpoint	60
Proposed Reznor heating setpoint	30

Design Supply Air Conditions (AHUs)	
57	°F DB
55	°F WB
23.17	Btu/lb

Furnace duty cycle	0.25

Return Air Temperature (°F)	75
Return Air Enthalpy (btu/lb)	28.1

Proposed Airflow			
	Full Occupied Hours	Partial Occupied Hours, No Economizer Mode	Partial Occupied Hours, Economizer Mode
OA CFM	18,150	14,520	18,150
RA CFM	54,450	58,080	54,450
SA CFM	72,600	72,600	72,600
Reznor Unit Fan Speed	100%	80%	100%

		Baseline Conditions			Full Occupied Hours - 8am-4pm Mon-Fri							Partial Occupied Hours - 7am-8am Mon - Fri, 4pm - 10pm Mon-Fri, 8am-4pm Sat				Total Annual Energy Consumption	
						Heating		Cooling			Ventilation	Partial Occupied Hours					
OAT	OA Enthalpy	Enthalpy After Furnace (Preheated OA)	Mixed Air Temperature	Mixed Air Enthalpy	Annual Hours - Full Occupancy	Reznor Unit Heating Load (MBH)	Reznor Unit Annual Heating Energy (ccf)	AHU Cooling Load (MBH)	AHU Cooling Electric Demand (kW)	Annual Cooling Electric Consumption (kWh)	Annual Fan Energy Consumption (kWh)	Annual Hours - Partial Occupied	Reznor Unit Annual Heating Energy (ccf)	Annual Cooling Electric Consumption (kWh)	Annual Fan Energy Consumption (kWh)	Natural Gas (ccf)	Electricity (kWh)
91	39.2	39.2	79.0	30.9	0	0	0	2,517	197	0	0	0	0	0	0	0	0
89	38.3	38.3	78.5	30.7	0	0	0	2,447	191	0	0	0	0	0	0	0	0
87	34.5	34.5	78.0	29.7	0	0	0	2,137	167	0	0	3	0	502	17	0	518
85	33.7	33.7	77.5	29.5	19	0	0	2,069	162	3,076	106	12	0	1,943	67	0	5,193
83	32.7	32.7	77.0	29.3	56	0	0	1,990	156	8,722	313	13	0	2,025	73	0	11,132
81	32.7	32.7	76.5	29.3	67	0	0	1,990	156	10,432	375	46	0	7,162	257	0	18,226
79	32.8	32.8	76.0	29.3	68	0	0	1,998	156	10,630	380	59	0	9,223	330	0	20,564
77	31.8	31.8	75.5	29.0	62	0	0	1,912	150	9,277	347	47	0	7,032	263	0	16,919
75	31.2	31.2	75.0	28.9	89	0	0	1,862	146	12,969	498	100	0	14,571	560	0	28,597
73	31.0	31.0	74.5	28.8	106	0	0	1,846	144	15,316	593	112	0	16,183	627	0	32,716
71	30.2	30.2	74.0	28.6	102	0	0	1,784	140	14,238	571	108	0	15,076	604	0	30,489
69	28.5	28.5	73.5	28.2	81	0	0	1,640	128	10,398	453	91	0	11,676	509	0	23,032
67	27.0	27.0	73.0	27.8	117	0	0	1,521	119	13,923	655	98	0	11,862	548	0	26,787
65	25.7	25.7	72.5	27.5	51	0	0	1,415	111	5,646	285	84	0	9,299	470	0	15,700
63	24.5	24.5	72.0	27.2	61	0	0	1,320	103	6,299	341	66	0	6,816	369	0	13,825
61	23.6	23.6	71.5	27.0	62	0	0	1,240	97	6,015	347	63	0	6,112	352	0	12,827
59	22.5	22.5	71.3	26.8	22	625	33	1,176	92	2,024	123	28	43	2,576	157	76	4,860
57	21.2	22.0	71.3	26.6	73	625	111	1,109	87	6,337	408	48	73	4,167	269	184	11,180
55	20.3	21.5	71.3	26.4	71	625	108	1,069	84	5,941	397	70	106	5,857	392	214	12,586
53	19.1	20.8	71.3	26.3	78	625	118	1,016	80	6,201	416	68	103	5,406	380	222	12,424
51	18.1	20.3	71.3	26.1	76	625	115	972	76	5,783	425	92	140	7,000	515	255	13,723
49	17.1	19.8	71.3	26.0	139	625	211	931	73	10,127	778	129	196	9,398	722	407	21,025
47	15.7	18.9	71.3	25.8	76	625	114	856	67	5,526	420	84	128	5,629	470	241	11,546
45	15.1	18.7	71.3	25.8	63	625	96	844	66	4,160	352	88	134	5,811	492	229	10,815
43	14.4	18.5	71.3	25.7	62	625	94	830	65	4,027	347	97	147	6,300	543	241	11,216
41	13.8	18.4	71.3	25.7	26	625	39	820	64	1,669	145	37	56	2,376	207	96	4,397
39	12.9	18.0	71.3	25.6	47	625	71	784	61	2,885	263	77	117	4,727	431	188	8,306
37	12.1	17.6	71.3	25.5	65	625	99	755	59	3,840	364	77	117	4,549	431	216	9,183
35	11.3	17.3	71.3	25.4	66	625	100	730	57	3,772	369	71	108	4,058	397	208	8,596
33	10.5	17.0	71.3	25.3	66	625	100	706	55	3,649	369	75	114	4,146	420	214	8,584
31	9.7	16.7	71.3	25.2	94	625	143	679	53	4,996	526	97	147	5,154	543	290	11,218
29	8.8	16.3	71.3	25.1	40	625	61	648	51	2,022	224	44	67	2,224	246	128	4,715
27	8.1	16.1	71.3	25.1	32	647	50	627	49	1,571	179	49	77	2,406	274	127	4,431
25	7.5	15.9	71.3	25.1	23	686	38	615	48	1,107	129	28	47	1,348	157	85	2,740
23	7.0	15.9	71.3	25.0	7	725	12	613	48	336	39	14	25	672	78	37	1,126
21	6.3	15.6	71.3	25.0	16	764	30	593	46	742	90	27	50	1,253	151	80	2,236
19	5.8	15.6	71.3	25.0	13	804	25	593	46	603	73	16	31	742	90	57	1,508
17	5.2	15.6	71.3	25.0	6	843	12	587	46	276	34	3	6	138	17	18	454
15	4.6	15.5	71.3	24.9	2	882	4	578	45	90	11	8	17	362	45	21	508
13	4.1	15.4	71.3	24.9	1	921	2	575	45	45	6	3	7	135	17	9	203
11	3.2	15.0	71.3	24.8	8	960	19	537	42	336	45	8	19	336	45	37	762
							1,808			**204,500**	**11,817**		**2,073**	**204,051**	**12,533**	**3,881**	**434,900**

		Propose d Conditions			Full Occupied Hours - 8am-4pm Mon-Fri							Partial Occupied Hours - 7am-8am Mon - Fri, 4pm - 10pm Mon-Fri, 8am-4pm Sat								Total Annual Energy Consumption	
						Heating		Cooling			Ventilation	Partial Occupied Hours									
OAT	OA Enthalpy	Enthalpy After Furnace (Preheated OA)	Mixed Air Temperature - Full Occupancy	Mixed Air Enthalpy - Full Occupancy	Annual Hours - Full Occupancy	Reznor Unit Heating Load (MBH) - Full Occupancy	Reznor Unit Annual Heating Energy (ccf)	AHU Cooling Load (MBH)	AHU Cooling Electric Demand (kW)	Annual Cooling Electric Consumption (kWh)	Annual Fan Energy Consumption (kWh)	Mixed Air Temperature - Partial Occupancy	Mixed Air Temperature - Partial Occupancy	Annual Hours - Partial Occupied	Reznor Unit Heating Load (MBH) - Partial Occupancy	Reznor Unit Annual Heating Energy (ccf)	AHU Cooling Load (MBH)	Annual Cooling Electric Consumption (kWh)	Annual Fan Energy Consumption (kWh)	Natural Gas (ccf)	Electricity (kWh)
91	39.2	39.2	79.0	30.9	0	0	0	2,517	197	0	0	78.2	30.3	0	0	0	2,355	0	0	0	0
89	38.3	38.3	78.5	30.7	0	0	0	2,447	191	0	0	77.8	30.1	0	0	0	2,279	0	0	0	0
87	34.5	34.5	78.0	29.7	0	0	0	2,137	167	0	0	77.4	29.4	3	0	0	2,031	502	10	0	511
85	33.7	33.7	77.5	29.5	19	0	0	2,069	162	3,076	106	77.0	29.2	12	0	0	1,977	1,943	39	0	5,165
83	32.7	32.7	77.0	29.3	56	0	0	1,990	156	8,722	313	76.6	29.0	13	0	0	1,914	2,025	43	0	11,102
81	32.7	32.7	76.5	29.3	67	0	0	1,990	156	10,432	375	76.2	29.0	46	0	0	1,914	7,162	151	0	18,119
79	32.8	32.8	76.0	29.3	68	0	0	1,998	156	10,630	380	75.8	29.0	59	0	0	1,920	9,223	193	0	20,427
77	31.8	31.8	75.5	29.0	62	0	0	1,912	150	9,277	347	75.4	28.8	47	0	0	1,852	7,032	154	0	16,810
75	31.2	31.2	75.0	28.9	89	0	0	1,862	146	12,969	498	75.0	28.7	100	0	0	1,812	14,571	328	0	28,365
73	31.0	31.0	74.5	28.8	106	0	0	1,846	144	15,316	593	74.6	28.7	112	0	0	1,799	16,183	367	0	32,458
71	30.2	30.2	74.0	28.6	102	0	0	1,784	140	14,238	571	74.2	28.5	108	0	0	1,749	15,076	354	0	30,239
69	28.5	28.5	73.5	28.2	81	0	0	1,640	128	10,398	453	73.8	28.2	91	0	0	1,634	11,676	298	0	22,821
67	27.0	27.0	73.0	27.8	117	0	0	1,521	119	13,923	655	73.5	28.2	98	0	0	1,640	11,862	321	0	26,360
65	25.7	25.7	72.5	27.5	51	0	0	1,415	111	5,646	285	73.0	27.8	84	0	0	1,521	9,299	275	0	15,506
63	24.5	24.5	72.0	27.2	61	0	0	1,320	103	6,299	341	72.5	27.5	66	0	0	1,415	6,816	216	0	13,672
61	23.6	23.6	71.5	27.0	62	0	0	1,240	97	6,015	347	72.0	27.2	63	0	0	1,320	6,112	206	0	12,681
59	22.5	22.5	71.0	26.7	22	0	0	1,156	90	1,990	123	71.5	27.0	28	0	0	1,240	2,532	92	0	4,737
57	21.2	21.2	70.5	26.4	73	0	0	1,050	82	5,996	408	71.0	26.7	48	0	0	1,156	3,943	157	0	10,905
55	20.3	20.3	70.0	26.1	71	0	0	970	76	5,388	397	70.5	26.4	70	0	0	1,050	5,314	229	0	11,330
53	19.1	19.1	69.5	25.9	78	0	0	877	69	5,355	436	70.0	26.1	68	0	0	970	4,868	223	0	10,882
51	18.1	18.1	69.0	25.6	76	0	0	794	62	4,723	425	69.5	25.9	92	0	0	877	5,717	301	0	11,167
49	17.1	17.1	68.5	25.4	139	0	0	713	56	7,760	778	69.0	25.6	129	0	0	794	7,202	422	0	16,162
47	15.7	15.7	68.0	25.0	75	0	0	600	47	3,519	420	68.5	25.4	84	0	0	713	3,942	275	0	8,136
45	15.1	15.1	67.5	24.8	63	0	0	548	43	2,700	352	68.0	25.0	88	0	0	600	3,771	288	0	7,111
43	14.4	14.4	67.0	24.7	62	0	0	494	39	2,399	347	67.5	24.8	97	0	0	548	3,753	318	0	6,816
41	13.8	13.8	66.5	24.5	26	0	0	445	35	906	145	67.0	24.7	37	0	0	494	1,290	121	0	2,463
39	12.9	12.9	66.0	24.3	47	0	0	370	29	1,362	263	66.5	24.5	77	0	0	445	2,231	252	0	4,108
37	12.1	12.1	65.5	24.1	65	0	0	302	24	1,534	364	66.0	24.3	77	0	0	370	1,817	252	0	3,967
35	11.3	11.3	65.0	23.9	66	0	0	258	19	1,228	369	65.5	24.1	71	0	0	302	1,321	233	0	3,152
33	10.5	10.5	64.5	23.7	66	0	0	175	14	903	369	65.0	23.9	75	0	0	258	1,026	246	0	2,544
31	9.7	9.7	64.0	23.5	94	0	0	108	8	797	526	64.5	23.7	97	0	0	175	822	318	0	2,463
29	8.8	9.1	63.8	23.3	40	625	61	56	4	175	224	66.0	24.3	44	625	67	367	192	144	128	736
27	8.1	8.8	63.8	23.3	32	625	49	38	3	95	179	66.0	24.2	49	625	74	352	146	160	123	579
25	7.5	8.7	63.8	23.2	23	625	35	26	2	46	129	66.0	24.2	28	625	43	343	96	92	77	323
23	7.0	8.7	63.8	23.2	7	625	11	24	2	13	39	66.0	24.2	14	625	21	341	26	46	32	124
21	6.3	8.4	63.8	23.2	16	625	24	4	0	5	90	66.0	24.2	27	625	41	325	8	88	65	190
19	5.8	8.4	63.8	23.2	13	625	20	4	0	4	73	66.0	24.2	16	625	24	325	5	52	44	133
17	5.2	8.4	63.8	23.2	6	625	9	0	0	0	34	66.0	24.2	3	625	5	321	0	10	14	43
15	4.6	8.2	63.8	23.1	2	625	3	0	0	0	11	66.0	24.1	8	625	12	313	0	26	15	37
13	4.1	8.2	63.8	23.1	1	625	2	0	0	0	6	66.0	24.1	3	625	5	311	0	10	6	15
11	3.2	7.8	63.8	23.0	8	625	12	0	0	0	45	66.0	24.0	8	625	12	281	0	26	24	71
							228			**173,834**	**11,817**					**304**		**169,043**	**7,336**	**528**	**362,050**

ECM #3: CONTROL AIR HANDLING UNITS WITH OCCUPANCY SENSORS OR ONE-HOUR TIMERS

ECM #	Description	ECM Status[1]	Fuel Type Saved	Energy Saved			Annual Savings ($)	Estimated Implementation Cost ($)	Simple Payback
				kWh	kW	MMBtu			
3	Control AHUs with Occupancy Sensors or One-Hour Timers	R	Electricity / Natural Gas	18,079	0.00	274.0	$4,868	$4,433	0.9

1. Status: R = Recommended; I = Implemented; NR = Not Recommended; RS = Further Study Required

Assumptions

Utilities Cost			Energy Content per Type		
$0.15	$/kWh		102.9	kBtu/ccf	
$0.80	$/ccf				

Energy Savings			Cost Savings		
Electrical Energy Savings	18,079	kWh/year	Electric Cost Savings	$2,743	/Year
Gas Savings	2,663	ccf/year	Gas Cost Savings	$2,125	/Year

Equations

Heating Load (MBH) = (1.08) x (CFM) x (Leaving Temperature - Entering Temperature) / 1,000
Cooling Load (MBH) = (4.5) x (CFM) x (Entering Enthalpy - Leaving Enthalpy) / 1,000
Fan Energy (kWh) = (Fan Speed) ^(2.4) x (HP) x (0.746) x (Hours of Operation)
Annual Heating Energy (ccf) = (Heating Load) x (Hours of Operation) x (Furnace Duty Cycle) / (Energy Content of Gas)
Annual Cooling Energy (kWh) = (Cooling Load) x (Compressor kW/MBH) x (Hours of Operation)
Cost Savings = [Energy Savings] x [$]
Simple Payback = [Implementation Cost] / [Cost Savings]

Inputs					Baseline	
Description/Tag	Type	Motor HP	Load Factor (%)	Cycle Rate (%)	Motor Efficiency (%)	Electrical Demand (kW)
AC-1	Supply Fan	10	80%	100%	89.5%	6.7
AC-2	Supply Fan	10	80%	100%	89.5%	6.7
AC-3	Supply Fan	7.5	80%	100%	88.5%	5.1
AC-4	Supply Fan	10	80%	100%	89.5%	6.7
AC-5	Supply Fan	7.5	80%	100%	88.5%	5.1
AC-6	Supply Fan	10	80%	100%	89.5%	6.7
RF-1	Return Fan	7.5	80%	100%	88.5%	5.1
RF-2	Return Fan	7.5	80%	100%	88.5%	5.1
RF-3	Return Fan	5	80%	100%	87.5%	3.4
RF-4	Return Fan	7.5	80%	100%	88.5%	5.1
RF-5	Return Fan	5	80%	100%	87.5%	3.4
RF-6	Return Fan	7.5	80%	100%	88.5%	5.1
Totals						**63.8**

AC Unit Compressor Information	kW/MBH
AC-1	0.08
AC-2	0.08
AC-3	0.10
AC-4	0.08
AC-5	0.09
AC-6	0.06
Total:	0.08

Reznor Heating Setpoint	OAT (°F)
Existing Reznor heating setpoint	60

Design Supply Air Conditions (AHUs)	
57	°F DB
55	°F WB
23.17	Btu/lb

Reznor Unit	Model # PACR-150	
Fan Motor	7.5	hp
Draft Inducer	0.75	hp
Burner	0.5	hp
Burner max input	1875	MBH
Burner min input	625	MBH
Rated CFM	18000	CFM

Furnace duty cycle	0.25
Return Air Temperature (°F)	75
Return Air Enthalpy (btu/lb)	28.1

Occupancy & Ventilation		OA Ventilation Requirement
Full occupied hours	8am-4pm Mon - Fri	100%
Partial occupied hours	7am-8am Mon - Fri 4pm - 10pm Mon-Fri 8am-4pm Sat	80%

Baseline Airflow	
OA CFM	18,150
RA CFM	54,450
SA CFM	72,600
Reznor Unit Fan Speed	100%

Implementation Costs	
Occupancy Sensors	$ 310.57
Controls wiring	$ 428.18
Quantity	6
Total	$4,432.50

Bin Data					Energy Demand					Partial Occupied Hours - 7am-8am Mon - Fri; 4pm - 10pm Mon-Fri; 8am-4pm Sat		Annual Savings		
OA Temp	OA Enthalpy	Enthalpy After Furnace (Preheated OA)	Mixed Air Temperature	Mixed Air Enthalpy	Reznor Unit Heating Load (MBH)	Reznor Unit Hourly Heating Energy (ccf)	AHU Cooling Load (MBH)	AHU Cooling Electric Demand (kW)	Annual Fan Energy Demand (kW)	Baseline Operating Hours	Proposed Operating Hours	Heating Savings (ccf)	Cooling Savings (kWh)	Ventilation Savings (kWh)
91	39.2	39.2	79	30.9	0	0	2,517	197	69	0	0	0	0	0
89	38.3	38.3	78.5	30.7	0	0	2,447	191	69	0	0	0	0	0
87	34.5	34.5	78	29.7	0	0	2,137	167	69	3	2.85	0	25	10
85	33.7	33.7	77.5	29.5	0	0	2,069	162	69	12	11.4	0	97	42
83	32.7	32.7	77	29.3	0	0	1,990	156	69	13	12.35	0	101	45
81	32.7	32.7	76.5	29.3	0	0	1,990	156	69	46	43.7	0	358	160
79	32.8	32.8	76	29.3	0	0	1,998	156	69	59	56.05	0	461	205
77	31.8	31.8	75.5	29.0	0	0	1,912	150	69	47	44.65	0	382	163
75	31.2	31.2	75	28.9	0	0	1,862	146	69	100	95	0	729	347
73	31.0	31.0	74.5	28.8	0	0	1,846	144	69	112	106.4	0	809	389
71	30.2	30.2	74	28.6	0	0	1,784	140	69	108	102.6	0	754	375
69	28.5	28.5	73.5	28.2	0	0	1,640	128	69	91	86.45	0	584	316
67	27.0	27.0	73	27.8	0	0	1,521	119	69	98	93.1	0	583	340
65	25.7	25.7	72.5	27.5	0	0	1,415	111	69	84	79.8	0	465	292
63	24.5	24.5	72	27.2	0	0	1,320	103	69	66	62.7	0	341	229
61	23.6	23.6	71.5	27.0	0	0	1,240	97	69	63	59.85	0	306	219
59	22.5	22.8	71.25	26.8	625	41	1,176	92	69	28	26.6	57	129	97
57	21.2	22.0	71.25	26.6	625	40	1,109	87	69	48	45.6	97	208	167
55	20.3	21.5	71.25	26.4	625	40	1,069	84	69	70	66.5	141	298	243
53	19.1	20.8	71.25	26.3	625	40	1,016	80	69	68	64.6	136	270	236
51	18.1	20.3	71.25	26.1	625	40	972	76	69	92	87.4	183	350	319
49	17.1	19.8	71.25	26.0	625	40	931	73	69	129	122.55	255	470	448
47	15.7	18.9	71.25	25.8	625	39	896	67	69	84	79.8	164	281	292
45	15.1	18.7	71.25	25.8	625	39	844	66	69	88	83.6	172	291	306
43	14.4	18.5	71.25	25.7	625	39	830	65	69	97	92.15	189	315	337
41	13.8	18.4	71.25	25.7	625	39	820	64	69	37	35.15	72	119	128
39	12.9	18.0	71.25	25.6	625	39	784	61	69	77	73.15	149	236	267
37	12.1	17.6	71.25	25.5	625	39	755	59	69	77	73.15	149	227	267
35	11.3	17.3	71.25	25.4	625	39	730	57	69	71	67.45	137	203	246
33	10.5	17.0	71.25	25.3	625	38	706	55	69	75	71.25	144	207	260
31	9.7	16.7	71.25	25.2	625	38	679	53	69	97	92.15	186	268	337
29	8.8	16.3	71.25	25.1	625	38	646	51	69	44	41.8	84	111	153
27	8.1	16.1	71.25	25.1	647	39	627	49	69	49	46.55	97	120	170
25	7.5	15.9	71.25	25.1	666	42	615	48	69	28	26.6	58	67	97
23	7.0	15.9	71.25	25.0	725	44	613	48	69	14	13.3	31	34	49
21	6.3	15.6	71.25	25.0	764	46	593	46	69	27	25.65	63	63	94
19	5.8	15.6	71.25	25.0	804	49	593	46	69	16	15.2	39	37	56
17	5.2	15.6	71.25	25.0	843	51	587	46	69	3	2.85	8	7	10
15	4.6	15.5	71.25	24.9	882	53	578	45	69	8	7.6	21	18	28
13	4.1	15.4	71.25	24.9	921	56	575	45	69	3	2.85	8	7	10
11	3.2	15.0	71.25	24.8	960	58	537	42	69	8	7.6	23	17	28
											Totals:	2,663	10,303	7,777

ECM #4: INSTALL THERMOSTATS AT STAIRWELL RADIATORS

ECM #	Description	ECM Status[1]	Fuel Type Saved	Energy Saved			Annual Savings ($)	Estimated Implementation Cost ($)	Simple Payback
				kWh	kW	MMBtu			
4	Install thermostats at stairwell radiators	R	Electricity	9,744	0.00	0.0	$1,479	$4,556	3.1

1. Status: R = Recommended; I = Implemented; NR = Not Recommended; RS = Further Study Required

Assumptions

Energy Type	Electricity					
Utilities Cost			Energy Content per Type			
Electricity	$0.15	/kWh	Electricity	3.413	kBtu/kWh	
Energy Savings			Cost Savings			
Energy Savings	9,744	kWh/Year	Cost Savings	$1,479	/Year	

Equations

Energy Savings = [Demand Savings] x [Operating Hours] x [Diversity Factor]
Cost Savings = [Energy Savings] x [$/kWh]
Simple Payback = [Implementation Cost] / [Cost Savings]

Radiator Schedule (HVAC-1)			
Tag(s)	Location	Quantity	Electric Demand (W, each)
EH #1-8	North and South Wing Stairs	8	1000
EH #9-12	West Stairs	4	1500

Baseline Conditions	
Electric Demand (kW)	14
Operating Conditions	7 days/week, 24 hrs/day, Oct. - Apr.
Annual Hours of Operation (hrs)	5064
Diversity Factor	0.75
Annual Consumption (kWh)	53,172

Proposed Conditions	
Electric Demand (kW)	14
Operating Conditions	OAT <= 55 °F during occupied hours, OAT <=50 °F during unoccupied hours
Annual Hours of Operation (hrs)	4136
Diversity Factor	0.75
Annual Consumption (kWh)	43,428

Implementation Costs	
Install Thermostat	$ 379.63
Quantity	12

Total	$ 4,555.56

Mid-pts	DP (F)	WB (F)	h (BTU/lb)	HR(gr/lb)	Heating					
					Occupied			Unoccupied		
					Hrs Dry Bulb	btu/hr	btu/year	Bulb	btu/hr	btu/year
91	70.0	75.9	39.2	110.3	0	-	-	-	-	-
89	69.4	75.0	38.3	108.0	0	-	-	-	-	-
87	63.3	70.8	34.5	87.0	0	-	-	-	-	-
85	62.6	69.8	33.7	84.8	0	-	-	-	-	-
83	61.6	68.6	32.7	81.8	0	-	-	-	-	-
81	62.6	68.6	32.7	84.9	0	-	-	-	-	-
79	63.8	68.7	32.8	88.6	0	-	-	-	-	-
77	62.7	67.4	31.8	85.1	0	-	-	-	-	-
75	62.4	66.6	31.2	84.3	0	-	-	-	-	-
73	63.0	66.3	31.0	86.2	0	-	-	-	-	-
71	62.5	65.3	30.2	84.4	0	-	-	-	-	-
69	59.6	63.0	28.5	76.3	0	-	-	-	-	-
67	57.3	60.9	27.0	70.1	0	-	-	-	-	-
65	55.2	59.0	25.7	64.9	0	-	-	-	-	-
63	53.3	57.2	24.5	60.5	0	-	-	-	-	-
61	51.9	55.7	23.6	57.4	0	-	-	-	-	-
59	50.2	54.0	22.5	53.9	0	-	-	-	-	-
57	47.5	51.8	21.2	48.7	0	-	-	-	-	-
55	45.8	50.0	20.3	45.5	0	-	-	-	-	-
53	43.3	47.9	19.1	41.3	64	27,456	585,733	-	-	-
51	41.0	46.0	18.1	37.9	64	30,346	647,389	-	-	-
49	38.8	44.0	17.1	34.6	138	33,236	1,528,878	273	33,236	3,024,520
47	34.1	41.1	15.7	28.7	75	36,127	903,165	191	36,127	2,300,061
45	33.2	39.8	15.1	27.7	63	39,017	819,352	203	39,017	2,640,133
43	32.2	38.3	14.4	26.7	62	41,907	866,075	266	41,907	3,715,743
41	31.6	37.0	13.8	25.9	26	44,797	388,241	174	44,797	2,598,226
39	29.1	34.8	12.9	23.1	47	47,687	747,098	237	47,687	3,767,283
37	26.8	32.8	12.1	20.7	65	50,577	1,095,841	250	50,577	4,214,772
35	24.7	30.9	11.3	18.8	66	53,467	1,176,283	240	53,467	4,277,391
33	22.5	29.1	10.5	16.9	66	56,358	1,239,865	269	56,358	5,053,391
31	19.7	27.0	9.7	14.8	94	59,248	1,856,426	299	59,248	5,905,016
29	15.7	24.7	8.8	12.1	40	62,138	828,504	118	62,138	2,444,086
27	13.1	22.8	8.1	10.7	32	65,028	693,631	141	65,028	3,056,312
25	11.2	21.1	7.5	9.7	23	67,918	520,705	95	67,918	2,150,738
23	10.9	19.7	7.0	9.6	7	70,808	165,219	87	70,808	2,053,437
21	7.3	17.6	6.3	8.0	16	73,698	393,058	81	73,698	1,989,854
19	7.3	16.1	5.8	8.0	13	76,588	331,883	81	76,588	2,067,887
17	6.1	14.5	5.2	7.5	6	79,479	158,957	31	79,479	821,278
15	4.1	12.6	4.6	6.8	2	82,369	54,912	39	82,369	1,070,793
13	3.6	11.0	4.1	6.6	1	85,259	28,420	44	85,259	1,250,463
11	-8.0	8.0	3.2	3.6	8	88,149	235,064	39	88,149	1,145,936
Totals					**978**	**1,271,657**	**15,264,699**	**3,158**	**1,213,854**	**55,547,321**

ECM #5: INSTALL PREMIUM EFFICIENCY MOTORS

ECM #	Description	ECM Status[1]	Fuel Type Saved	Energy Saved			Annual Savings ($)	Estimated Implementation Cost ($)	Simple Payback
				kWh	kW	MMBtu			
5	Install Premium Efficiency Motors	R	Electricity	9,970	2.29	0.0	$1,513	$23,461	15.5

1. Status: R = Recommended; I = Implemented; NR = Not Recommended; RS = Further Study Required

Assumptions

Energy Type: Electricity

Utilities Cost			Energy Content per Type		
Electricity	$0.15	/kWh	Electricity	3.413	kBtu/kWh

Energy Savings			Cost Savings		
Motor Energy Savings	9,970	kWh/Year	Cost Savings	$1,513	/Year

Equations

Load Factor = Based on Typical Design Criteria
Electrical Demand = ([Motor HP] x [Load Factor] x 0.746) / [Motor Efficiency]
Demand Savings = [Baseline Electrical Demand] - [Proposed Electrical Demand]
Energy Savings = [Demand Savings] x [Operating Hours] x [Cycle Rate]
Cost Savings = [Energy Savings] x [$/kWh]
Simple Payback = [Implementation Cost] / [Cost Savings]

Equipment						Baseline		Proposed		Savings		
Description/Tag	Type	Motor HP	Load Factor (%)	Operating Hours (Hrs/Yr)	Cycle Rate (%)	Motor Efficiency (%)	Electrical Demand (kW)	Motor Efficiency (%)	Electrical Demand (kW)	Demand Savings (kW)	Energy Savings (kWh)	Total Cost Savings ($)
Condenser Water Pump 1	Pump	25	80%	8,760	50%	91.7%	16.3	93.6%	15.9	0.3	1,447	$114.06
Condenser Water Pump 2	Pump	25	80%	8,760	50%	91.7%	16.3	93.6%	15.9	0.3	1,447	$114.06
AC-1	Supply Fan	10	80%	4,352	100%	89.5%	6.7	91.7%	6.5	0.2	696	$54.89
AC-2	Supply Fan	10	80%	4,352	100%	89.5%	6.7	91.7%	6.5	0.2	696	$54.89
AC-3	Supply Fan	7.5	80%	4,352	100%	88.5%	5.1	91.0%	4.9	0.1	605	$47.68
AC-4	Supply Fan	10	80%	4,352	100%	89.5%	6.7	91.7%	6.5	0.2	696	$54.89
AC-5	Supply Fan	7.5	80%	4,352	100%	88.5%	5.1	91.0%	4.9	0.1	605	$47.68
AC-6	Supply Fan	10	80%	4,352	100%	89.5%	6.7	91.7%	6.5	0.2	696	$54.89
RF-1	Return Fan	7.5	80%	4,352	100%	88.5%	5.1	91.0%	4.9	0.1	605	$47.68
RF-2	Return Fan	7.5	80%	4,352	100%	88.5%	5.1	91.0%	4.9	0.1	605	$47.68
RF-3	Return Fan	5	80%	4,352	100%	87.5%	3.4	89.5%	3.3	0.1	332	$26.15
RF-4	Return Fan	7.5	80%	4,352	100%	88.5%	5.1	91.0%	4.9	0.1	605	$47.68
RF-5	Return Fan	5	80%	4,352	100%	87.5%	3.4	89.5%	3.3	0.1	332	$26.15
RF-6	Return Fan	7.5	80%	4,352	100%	88.5%	5.1	91.0%	4.9	0.1	605	$47.68
Totals							**96.4**		**94.1**	**2.3**	**9,970**	**$786.07**

Implementation Costs			
Item	Cost per Unit	Quantity	Total Cost
25 hp PE motor	$ 3,424.73	2	$ 6,849.46
10 hp PE motor	$ 1,613.49	4	$ 6,453.96
7.5 hp PE motor	$ 1,369.29	6	$ 8,215.74
5 hp PE motor	$ 971.13	2	$ 1,942.26
			$ 23,461.42

APPENDIX C: PROJECT SUMMARY SHEET

ENERGY CONSERVATION MEASURES										
Measure Description		Measure Status (See notes)	Fuel Type Saved (See notes)	Electric Supply Savings (kWh)	Electric Demand Savings (kW)	Fuel Savings (non-electric) (MMBtus)	Percent (%) Savings to Total Fuel Consumption	Annual Cost Savings	Estimated Implementation Costs	Simple Payback (Years)
1	Assess and repair condenser water system	R	N/A	0	0	0	0.0%	$ -	Cannot Verify	
2	Optimize Reznor Unit	R	Electricity / Natural Gas	72,851	0	345	7.5%	$13,729	$9,568	0.7
3	Control AHUs with Occupancy Sensors or One-Hour Timers	R	Electricity / Natural Gas	18,079	0	274	4.2%	$4,868	$4,433	0.9
4	Install thermostats at stairwell radiators	R	Electricity	9,744	0	0	0.4%	$1,479	$4,556	3.1
5	Install Premium Efficiency Motors	R	Electricity	9,970	2	0	0.4%	$1,513	$23,461	15.5
ECM Total (Recommended Only)				110,643	2	619	13%	$21,588	$42,018	1.9

Notes:
Measure Status: Implemented (I); Recommended (R); Further Study Recommended (RS); Not Recommended (NR); Recommended Mutually Exclusive (RME).
Fuel Saved: Elec, Steam, NGas, Oil2, Oil4, Oil6, Coal, LPG. MMBtu = 1,000,000 Btu

If both ECM-2 and ECM-3 are implemented, Eversource anticipates that the combined energy savings for these two measures would be 3,742 ccf of natural gas and 85,856 kWh of electricity. If both measures were to be implemented together, any potential incentive would be based on the combined savings value, not the individual savings values. The interactivity between these two measures is described in section 5.2, under ECM-2: OPTIMIZE REZNOR UNIT.

APPENDIX D: GLOSSARY AND METHOD OF CALCULATIONS

Energy Conservation Measure (ECM)
A specific recommendation that is anticipated to result in energy savings for the facility.

Net ECM Cost
The net ECM cost is the cost experienced by the customer, which is the total cost (materials + labor) of installing the measure minus any available incentives. Both the total cost and the incentive amounts are expressed in the summary for each ECM.

Simple Payback
This is a simple measure that displays how long the ECM will take to break-even based on the annual energy and maintenance savings of the measure.

Operating Cost Savings (OCS)
This calculation is an annual operating savings for the ECM. It is the difference in the operating, maintenance, and/or equipment replacement costs of the existing case versus the ECM. In the case where an ECM lifetime will be longer than the existing measure (such as LED lighting versus fluorescent) the operating savings will factor in the cost of replacing the units to match the lifetime of the ECM. In this case or in one where one-time repairs are made, the total replacement / repair sum is averaged over the lifetime of the ECM.

Gas Rate and Electric Rate ($/ccf and $/kWh)
The gas rate and electric rate used in the financial analysis is the total annual energy cost divided by the total annual energy usage for the 12-month billing period studied. The graphs of the monthly gas and electric rates reflect the total monthly energy costs divided by the monthly usage and display how the average rate fluctuates throughout the year. The average annual rate is the only rate used in energy savings calculations.

APPENDIX E: IPMVP PROTOCOLS

IPMVP provides four Options for determining savings (A, B, C and D). The choice among the Options involves many considerations. The selection of an IPMVP Option is the decision of the designer of the M&V program for each project. These options are summarized below:

Option (A) Retrofit Isolation: Key Parameter Measurement
Savings are determined by field measurement of the key performance parameter(s) which define the energy use of the energy conservation measure's (ECM) affected system(s) and/or the success of the project. Parameters not selected for field measurement are estimated. Estimates can be based on historical data, manufacturer's specifications, or engineering judgment. Documentation of the source or justification of the estimated parameter is required.
Typical applications may include a lighting retrofit, where the power drawn can be monitored and hours of operation can be estimated.

Option (B) Retrofit Isolation: All Parameter Measurement
Savings are determined by field measurement of all key performance parameters which define the energy use of the ECM-affected system.
Typical applications may include a lighting retrofit where both power drawn and hours of operation are recorded.

Option (C) Whole Facility
Savings are determined by measuring energy use at the whole facility or sub-facility level. This approach is likely to require a regression analysis or similar to account for independent variables such as outdoor air temperature, for example.
Typical examples may include measurement of a facility where several ECMs have been implemented, or where the ECM is expected to affect all equipment in a facility.

Option (D) Calibrated Simulation
Savings are determined through simulation of the energy use of the whole facility, or of a sub-facility. Simulation routines are demonstrated to adequately model actual energy performance measured in the facility. This Option usually requires considerable skill in calibrated simulation.
Typical applications may include measurement of a facility where several ECMs have been implemented, but no historical energy data is available.

APPENDIX F: METHOD OF ANALYSIS

Assumptions and Tools

Savings Estimates: Established/standard industry spreadsheets

Cost Estimates: RS Means Online Version 8.7
RS Means 2018 (Commercial New Construction Cost Data)
Cost estimates also based on utility bill analysis and prior experience with similar projects.

APPENDIX G: QUALIFICATIONS

Energy Auditor Firm: Steven Winter Associates, Inc.

Energy Auditor: Maria Rode, CEM
CEM: # 23379

DISCLAIMER

Steven Winter Associates, Inc. (SWA) prepared this engineering assessment and was using the most current and accurate fuel consumption data available for the site. The estimated savings that are projected are intended to help guide the owner toward the best energy choices. The costs and savings are subject to fluctuations in weather, variations in quality of maintenance, changes in prices of fuel, materials, and labor, and other factors. Although we cannot guarantee savings or costs estimates, we suggest that you use this report for economic analysis of the building and as a means to estimate future cash flow.

* * *

PLEASE NOTE:

THE RECOMMENDATIONS PRESENTED IN THIS REPORT ARE BASED ON THE RESULTS OF ANALYSIS, INSPECTION, AND PERFORMANCE TESTING OF A SAMPLE OF COMPONENTS OF THE BUILDING SITE. ALTHOUGH CODE-RELATED ISSUES MAY BE NOTED, SWA STAFF HAVE NOT COMPLETED A COMPREHENSIVE EVALUATION FOR CODE-COMPLIANCE. THE OWNER(S) AND MANAGER(S) OF THE BUILDING(S) CONTAINED IN THIS REPORT ARE REMINDED THAT ANY IMPROVEMENTS SUGGESTED IN THIS SCOPE OF WORK MUST BE PERFORMED IN ACCORDANCE WITH ALL LOCAL, STATE, AND FEDERAL LAWS AND REGULATIONS THAT APPLY TO SAID WORK. PARTICULAR ATTENTION MUST BE PAID TO ANY WORK WHICH INVOLVES HEATING AND AIR MOVEMENT SYSTEMS AND ANY WORK WHICH WILL INVOLVE THE DISTURBANCE OF PRODUCTS CONTAINING MOLD, ASBESTOS, OR LEAD.