November 20, 2023

MERP Level 2 Energy Assessment for

Municipal Energy Resilience Program
Canaan Town Office
Canaan, Vermont

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I. Executive Summary

Cx Associates has performed a MERP[1] Level 2 energy assessment for the Canaan Town Office in Canaan, Vermont. This assessment included a detailed building survey and energy analysis of the building systems to identify and quantify savings opportunities.

The energy assessment consisted of a comprehensive review of the building systems and controls, analysis of historical utility data, a mechanical and building envelope on-site assessment, a blower-door measurement, and a detailed investigation of the energy consumption of the building by end use.

Based on this in-depth analysis, Cx Associates developed a recommended package of building envelope improvements and energy saving measures that will:

- Cost-effectively reduce energy consumption
- Reduce building air leakage
- Extend equipment life
- Increase comfort
- Improve resiliency

Table 1 provides an overview of recommended measures, the implementation of which would significantly improve occupant comfort due to the improved building envelope as well as achieve an estimated energy cost savings of over $2,000 annually. Measures investigated but not recommended are also documented[2].

[1] Municipal Energy Resilience Program
[2] Measures are generally listed as not recommended if the simple payback period exceeds the expected measure life. However, these measures can still be considered if included as part of a larger upgrade package or upon failure of existing equipment.

Table 1: Energy Efficiency Measure Summary

ID	Measure Description	Electricity Savings	Peak Demand Reduction	Fuel Oil Savings	Energy Cost Savings	Measure Cost	Return on Investment (ROI)	Recom-mended?
		kWh/yr	kW	gal/yr	$/yr	$	%	Y/N
1	Relocating Air and Thermal Barrier to Underside of Roof	-	-	315	$1,068	$26,000	4%	Y
2	Sealing Around Chimney in Attic Space[1]	-	-	88	$298	$1,530	19%	Y
3	Adding/Upgrading Weather Stripping at all Doors	-	-	41	$139	$820	17%	Y
4	Installing Window Inserts	-	-	84	$284	$4,428	6%	Y
5	Increasing Insulation at the Concrete Vault	-	-	26	$89	$1,830	5%	Y
6	Comprehensive LED Lighting Upgrade	674	0.7	-	$122	$1,100	11%	Y
7	Heat Pump Hot Water Heater	746	1	-	$135	$3,080	4%	Y
8	Heat Pumps for Space Heating[2]	(12,948)	(7.5)	921	$773	$19,000	4%	Y
9	Programmable Thermostats[2]	-	-	90	$303	$680	45%	Y
	Recommended Total[2]	**(11,528)**	**(5.8)**	**1,565**	**$3,212**	**$58,468**	**5%**	

[1] Only applicable if item #1 is not pursued (relocating air and thermal barrier to underside of roof).
[2]Note that savings for these measures are compared to existing conditions, savings would be lower depending on which envelope measures are implemented due to interactive effects.

II. Introduction

Cx Associates has been retained by the State of Vermont to provide building energy assessment services for municipal buildings across the state as part of the Municipal Energy Resilience Program (MERP).

This report focuses on the energy assessment performed for the Canaan Town Office building in Canaan, Vermont (Figure 1). The assessment team spent one day on site (September 19th 2023) gathering detailed information on all energy-using equipment in the building.

Figure 1: Building exterior (north façade)

The report details the findings of the existing facility operating conditions, along with recommendations on energy efficiency opportunities and associated energy savings estimates and project implementation costs. These findings have been developed using the following sources:

- In depth conversations with facilities staff and occupants
- Detailed observations from the September 19th 2023 site visit
- Blower door and envelope assessment conducted on September 19th 2023
- Historical electricity and fuel oil data

III. Facility Description

GENERAL INFORMATION

The Canaan Town Office building is a municipal government office building located at 318 Christian Hill in Canaan, Vermont, and is home to town offices including Town Clerk and Treasurer. The facility is two stories (including basement) and comprises approximately 3,700 square feet. The building was originally constructed as a bank around 1974 and was acquired by the town in 1980.

The primary functional space types in the building include open office areas, enclosed offices, and conference rooms. There are also two unconditioned vaults used for document storage. Ancillary spaces include stairwell, restrooms, storage, and mechanical / electrical room.

The building is generally occupied Monday to Thursday from 8:00 a.m. to 4:00 p.m. and Friday from 8:00 a.m. to 3:00 p.m. (around 39 hours per week). Staff occasionally come in on weekends, as well as the cleaning crew. There are typically only two building occupants during the day, with more people coming in during community meetings or events. Several areas of the first floor and most of the basement are usually unoccupied.

BUILDING ENVELOPE

The foundation of the building is poured concrete, and the superstructure is comprised of wood wall framing with wood floor joists and roof trusses. The exterior walls of the building are primarily brick, with wooden clapboards on the gable ends of the roof and wood trim. The roof is standing seam, although the original construction plans indicate asphalt shingles. This indicates a roof replacement has been performed, however the year is unknown.

Building plans indicate that the concrete foundation is uninsulated on the exterior, and no insulation was observed on the interior. The wall assemblies of the building are insulated with fiberglass batts, primarily within 2x4 wood framing with some locations being 2x6 wood framing. The exterior wall assembly around the concrete vault does not include wood framing or fiberglass batts, but per the construction plans 1” of rigid insulation is present. The floor of the attic space is insulated with fiberglass batts between and on top of wood trusses, with the average depth of insulation being approximately 13”.

Overall, the condition of the exterior assemblies appears to be in good condition. The brick shows no major signs of efflorescence, mildew, or spalling. The wooden clapboards and trim do not show any signs of paint peeling or rotting. As previously mentioned, the roof has recently been replaced and appears to be in very good condition, although this inspection was performed from the ground as access to the roof was not available. The condition of the windows and doors throughout the building is fair, and will be discussed further in the recommendations section of this report.

ELECTRICAL SYSTEMS

Electrical Distribution

Electrical service for the building consists of single-phase distribution at 120/240 volts, with 200-amp switchgear. The utility meter and main electrical panel are located in the basement utility room. There is a 20-kW propane-fired emergency generator that is exercised weekly and can carry the building load during power outages.

Lighting

A lighting retrofit was performed within the past couple of years and most of the fixtures are now LED. These consist of recessed 2’x4’ troffers as well as surface mounted fixtures. There are just a few remaining fixtures that are T12 fluorescent and incandescent, which we recommend replacing with LED. All interior lighting is controlled manually through wall-mounted switches.

Figure 2: Recessed LED troffer

Exterior lighting consists of an LED floodlight controlled with a timer to operate dusk to dawn, as well as canopy lighting controlled through wall switches, which is almost never used.

Plug Loads

Plug loads consist of standard office equipment such as computers, monitors, printers, and copiers. There is also a small server closet, as well as a kitchenette area with a mini-fridge, microwave, and coffeemaker.

MECHANICAL SYSTEMS

Space Heating

Space heating is provided by a relatively new ducted oil-fired furnace (140,000 btu/hr capacity), which was installed two years ago. A recent combustion efficiency test (dated January 6th 2023) indicated an efficiency of 86.1%, suggesting it is operating fairly efficiently, considering the nominal thermal efficiency is 80%. The furnace serves two thermal zones, with one thermostat on the first floor and one thermostat in the basement, which are both manually controlled. Building occupants indicated that the heating temperature setpoint is typically set between 68-70°F during weekdays and turned down to 67°F or so over the weekend.

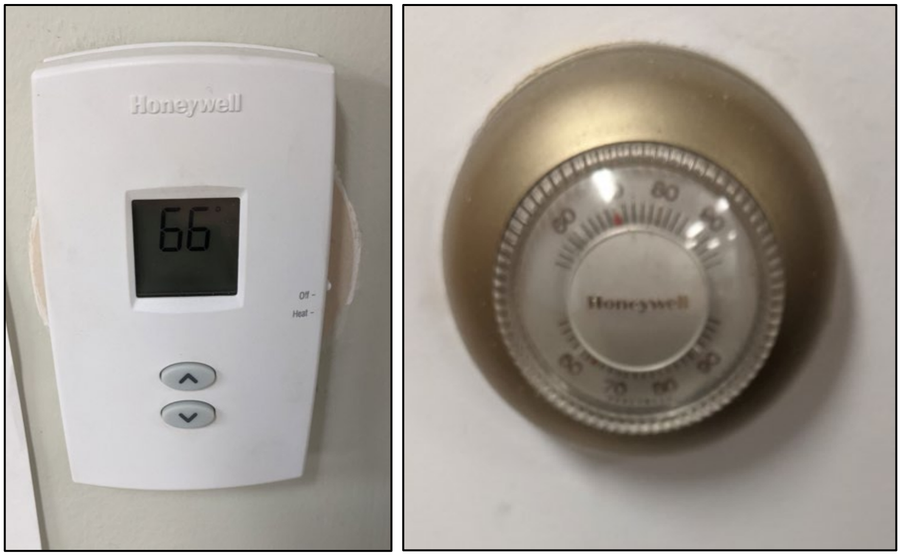

Figure 3: Building thermostats

Space Cooling

Space cooling is provided by a window-mounted air-conditioning unit located in the main office area (10,000 btu/hr capacity, 10.8 EER). This is removed during the winter months.

Figure 4: Window AC unit

Ventilation and Exhaust

There is a small kitchen area in the basement, with an electric range and manually controlled exhaust fan. This gets very little usage. Other than this fan, there is no mechanical ventilation for the building.

Domestic Hot Water

Domestic hot water is provided by an electric resistance 15-gallon hot water tank. The setpoint is at 120°F. Domestic hot water is used primarily for handwashing.

IV. Historical Energy Consumption

DESCRIPTION OF METERS AND TARIFFS

There is one electric meter serving the building. The electric utility is the Vermont Electric Coop. Fuel oil is delivered by C. Bean Transport, Inc. There is a 319-gallon fuel oil tank in the basement to store fuel oil. Electric rate structure details for the VEC Small Commercial tariff are shown in Table 2. There is a monthly customer charge, an energy charge, and an energy efficiency charge. The marginal electric cost is $0.18146 per kWh. Fuel oil cost is around $3.39 per gallon.

Table 2: Electric rate description

Utility:	Vermont Electric Coop
Meter ID:	81907734
Tariff:	Small Commercial
Customer Charge:	$20.810 per month
Energy Charge:	$0.180490 per kWh
Energy Efficiency Charge:	$0.000974 per kWh

ENERGY USAGE AND COST ANALYSIS

Utility Data

Analyzing historical utility data can yield valuable insight into how the building is operating and can help to identify and address any issues that may improve energy performance and/or reduce costs. Table 3 shows the annual utility summary for the year ending August 2023. Annual energy cost is around $5,000 per year, with an energy cost index (ECI) of $1.51/sf-yr.

Table 3: Annual energy consumption and cost

Commodity	Consumption	Cost
Electricity (kWh)	8,429	$1,779
Fuel Oil (gal)	903	$3,060
Total		**$4,839**

Figure 5 and Figure 6 show the energy cost breakdown by commodity. Fuel oil comprises around two thirds of the energy cost, and around 80% of energy consumption, suggesting that energy efficiency measures targeting reduced space heating such as increased insulation and air sealing would be highly beneficial.

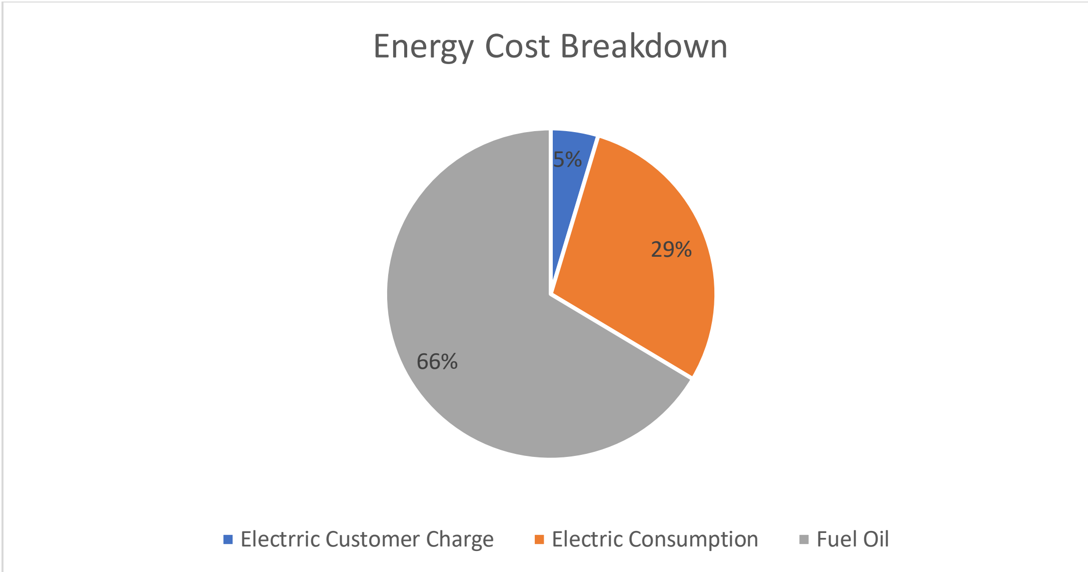

Figure 5; Energy cost breakdown

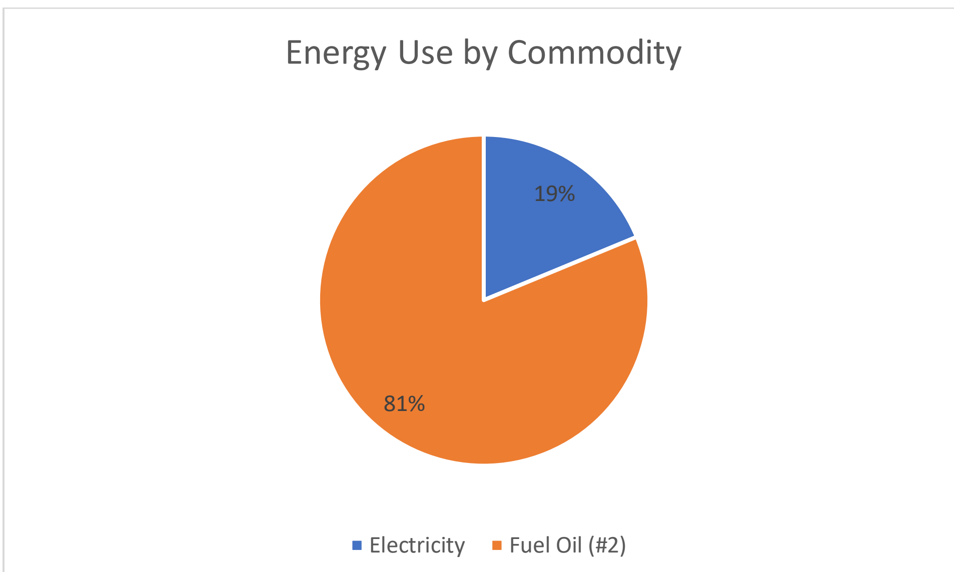

Figure 6: Energy use by commodity

Figure 6 shows monthly electric consumption over the past three years. There is a significant reduction starting October 2021, presumably due to the LED lighting retrofit that took place.

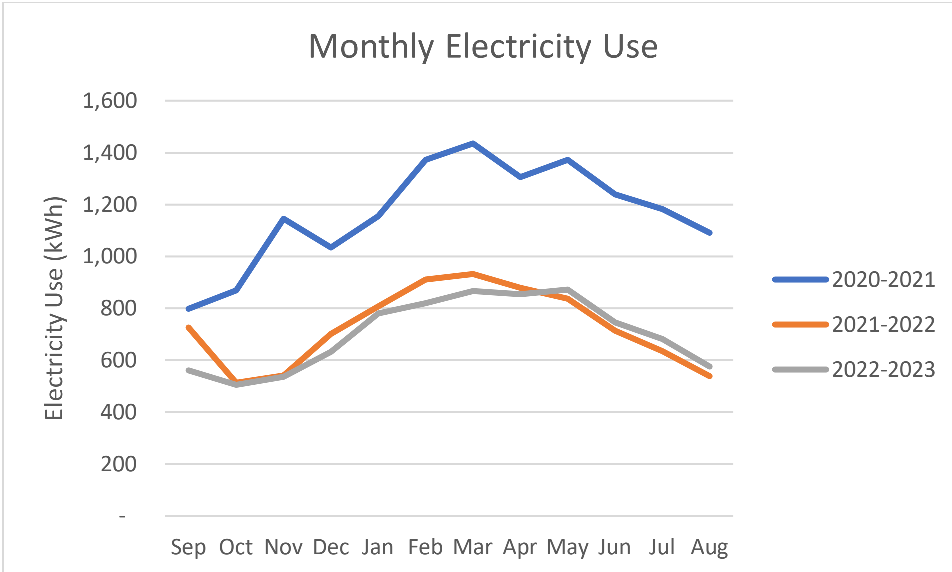

Figure 7: Monthly Electric Consumption

BENCHMARKING

Benchmarking involves comparing a building's energy performance to other buildings of similar type in a similar climate. The utility data for the year ending August 2023 was used to calculate the overall building performance in ENERGY STAR Portfolio Manager (Figure 8). The site Energy Use Intensity (EUI) is 41.0 kBtu/sf/yr, which compares to the national median of 59.7 kBtu/sf/yr for buildings with a primary property type of "Office" located in similar climates. This results in an ENERGY STAR score of 75, indicating the building is performing better than 75% of similar peer buildings. However, there are still opportunities available for improvement, as discussed in Section V.

ENERGY STAR® Statement of Energy Performance

LEARN MORE AT energystar.gov

75

ENERGY STAR® Score[1]

Canaan - Town Office

Primary Property Type: Office
Gross Floor Area (ft²): 3,738
Built: 1974

For Year Ending: August 31, 2023
Date Generated: November 03, 2023

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
Canaan - Town Office 318 Christian Hill Canaan, Vermont 05903	________________ , (___)___-_____	____ ________ , (___)___-_____ ________________

Property ID: 30509185

Energy Consumption and Energy Use Intensity (EUI)

Site EUI
41 kBtu/ft²

Source EUI
55.2 kBtu/ft²

Annual Energy by Fuel	
Electric - Grid (kBtu)	28,696 (19%)
Fuel Oil (No. 2) (kBtu)	124,573 (81%)

National Median Comparison	
National Median Site EUI (kBtu/ft²)	59.7
National Median Source EUI (kBtu/ft²)	80.3
% Diff from National Median Source EUI	-31%
Annual Emissions	
Total (Location-Based) GHG Emissions (Metric Tons CO2e/year)	11

Figure 8: ENERGY STAR Statement of Energy Performance

END USE BREAKDOWN

An energy model was created in order to disaggregate energy end uses at the building. The model is informed by historical utility data, equipment nameplate and data gathered on site, and engineering estimates. An energy end use breakdown is useful for identifying the end uses with the largest consumption and thereby targeting those areas for improvements. Additionally, the model can be used as a baseline to which energy savings estimates can be compared to ensure reasonability. Figure 9 shows the percentage attributable to each end use. The major electric end uses for the building are lighting, plug loads, fans, and space cooling.

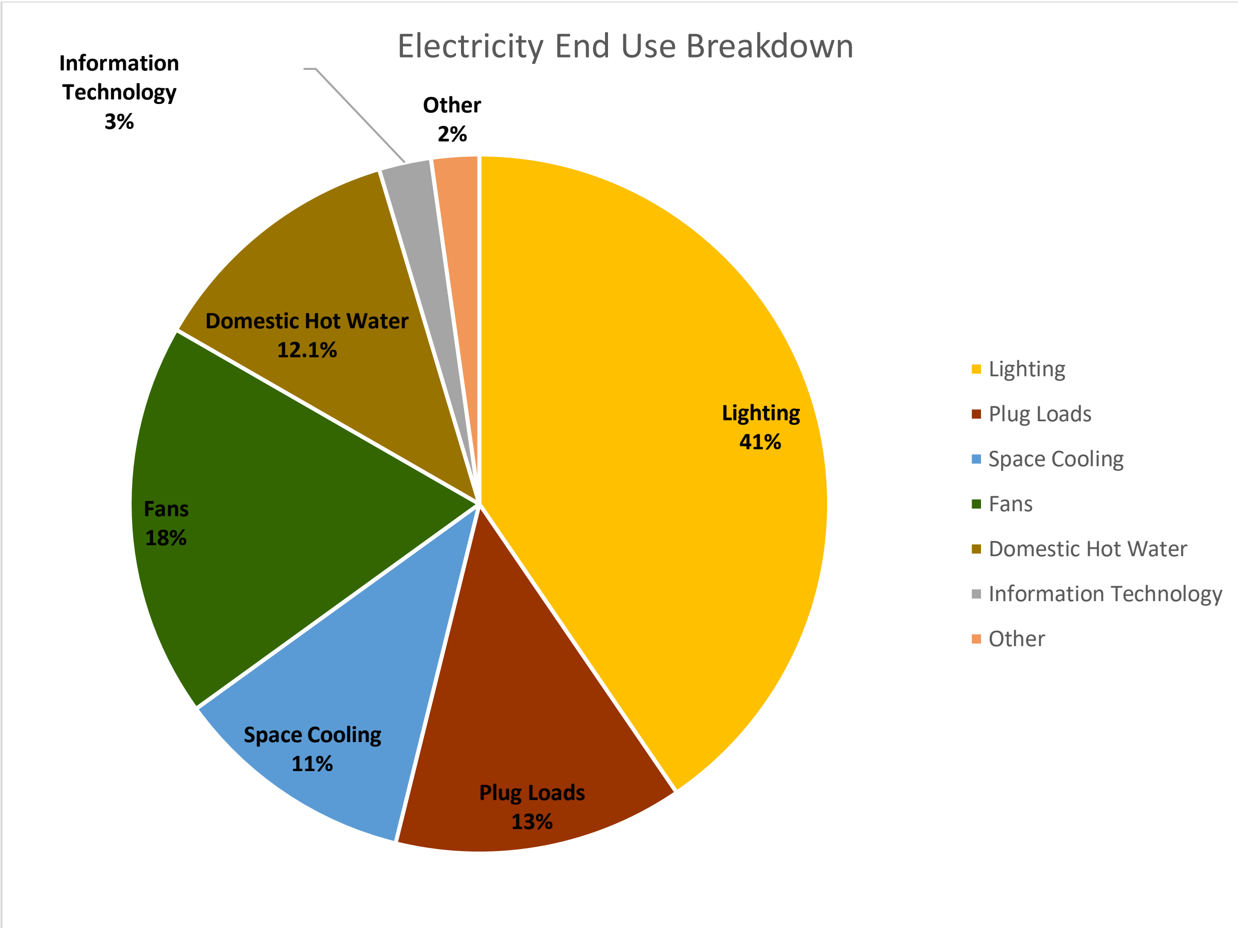

Figure 9: Annual Electric End Use Breakdown

V. Energy Efficiency and Resiliency Opportunities

As presented in Table 1 (shown again below), if all recommended energy efficiency opportunities are implemented, there would be an estimated energy cost savings of over $2,000.

Table 4: Energy Efficiency Measure Summary

ID	Measure Description	Electricity Savings	Peak Demand Reduction	Fuel Oil Savings	Energy Cost Savings	Measure Cost	Return on Investment (ROI)	Recom-mended?
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5	Increasing Insulation at the Concrete Vault	-	-	26	$89	$1,830	5%	Y
6	Comprehensive LED Lighting Upgrade	674	0.7	-	$122	$1,100	11%	Y
7	Heat Pump Hot Water Heater	746	1	-	$135	$3,080	4%	Y
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	Recommended Total[2]	**(11,528)**	**(5.8)**	**1,565**	**$3,212**	**$58,468**	**5%**	

[1] Only applicable if item #1 is not pursued (relocating air and thermal barrier to underside of roof).
[2]Note that savings for these measures are compared to existing conditions, savings would be lower depending on which envelope measures are implemented due to interactive effects.

This section provides a description of the energy efficiency measures that have been analyzed. For each measure, high-level implementation costs were estimated by Cx Associates using RS Means and/or previous project experience. The measures are quantified in the previous summary table and described in the text below.

MEASURES RECOMMENDED FOR INCLUSION IN AN UPGRADE

1: Air Barrier at 1st Floor Ceiling

During the assessment, the major source of air leakage that was identified was at the first-floor ceiling, which separates the conditioned space from the unconditioned attic. This assembly is comprised of acoustical ceiling tiles (ACTs) and grid, an approximately 23" plenum space for electrical wiring and ductwork, and fiberglass insulation between and on top of roof trusses. This assembly lacks an effective air barrier, as neither the fiberglass insulation nor ACT ceiling is truly airtight. The ACTs themselves do not allow airflow, however each tile sits on a metal grid system and does not create an air-tight seal. Small amounts of air could be felt moving around the perimeter of each of these tiles, with larger amounts felt where tiles were not sitting firmly on the grid or where penetrations were present.

A view of the ACT grid at the first floor ceiling. This was consistent on the first floor except for the vestibule, which had a drywall ceiling.

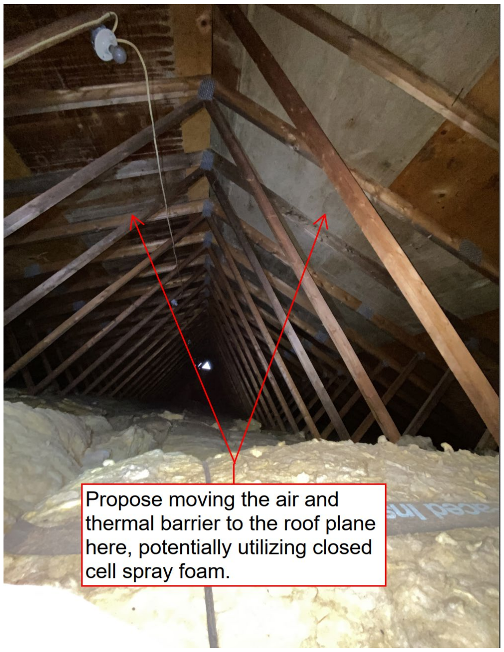
Looking above the ACT, there is a plenum space for electrical and ductwork, then the faced fiberglass insulation is visible in between roof trusses (facing is stabled to the bottom of trusses).

Difficult to see in the photo, but fog is being blown down and to the left from the air movement coming through the corner of the ACT where it is not fitting tightly to the grid.

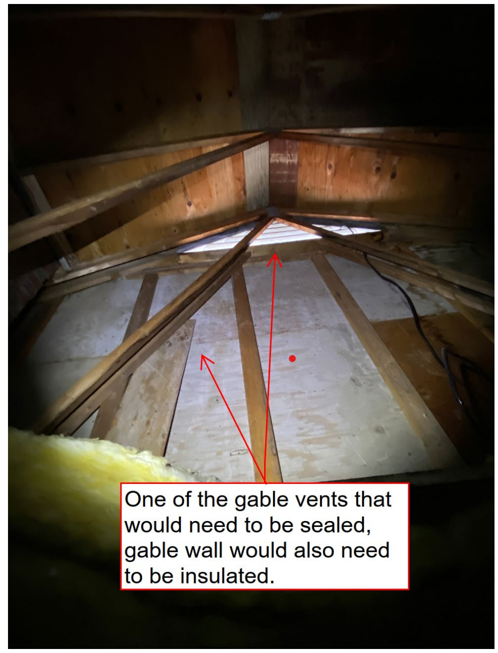
An example of the small gaps present around the ACTs, they do not create and air-tight seal to the grid.

Recommended Actions

The most effective way to reduce this air leakage from the 1st floor ceiling would be to install an air barrier. Installing an air barrier at the 1st floor ceiling itself would require extensive remodeling given the presence of HVAC and electrical components in the ceiling's plenum space. A simpler method to achieve this would be to shift the building's air and thermal barrier from the 1st floor ceiling to the roof plane. Utilizing a material such as closed cell spray foam on the underside of the roof sheathing would establish both an air and thermal barrier. The gable walls of the attic would also need to be insulated and the venting sealed, same with the roof soffits. This would be creating a "hot" roof and turning the attic into a conditioned space. If this approach is pursued it is critical that the installation of spray foam is of high quality. Using the appropriate material, following manufacturers installation instructions, and installing under appropriate conditions are all extremely important factors to ensure a high quality and durable final product. Issues such as cracking of the spray foam and poor adhesion to the roof sheathing could occur if not installed properly. Cx Associates recommends engaging a subcontractor that is familiar and has experience with this type of application on the underside of roof sheathing.



Looking inside the attic at the underside of the roof sheathing.



One of the gable ends of the roof that would need to be sealed and insulated.

Looking at a gable vent and soffit venting on the exterior.

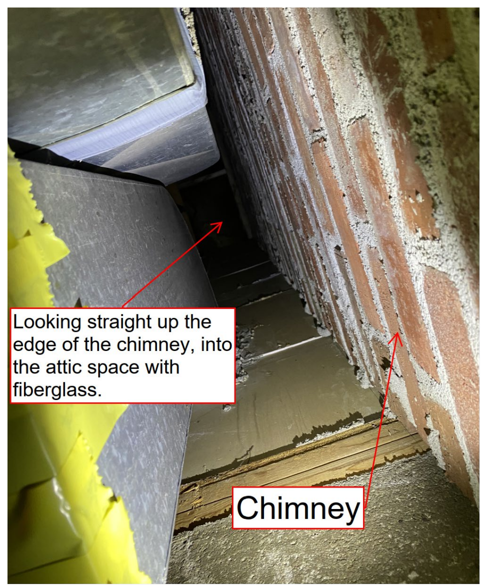
2: Air Leakage Around Chimney

While the building was under negative pressure, a major source of air leakage was identified at the basement level, inside the mechanical/furnace room. The furnace and other exhaust fans exhaust through the original brick chimney, which extends through the roof of the building. It appears that there is no air barrier or sealing present around the chimney where it enters the unconditioned attic space, which is vented on the gable ends of the roof to allow air flow. Attic access did not allow for a close-up inspection, but fiberglass insulation was visible wrapping the base of the chimney. Fiberglass insulation improves the R-value; however it is not an effective air barrier. The lack of sealing or air barrier around the chimney allows air to flow between the conditioned basement and the unconditioned attic space. The airflow at this location during testing was very noticeable and is assumed to be a major source of leakage.

Chimney where mechanical systems exhaust.

Attic venting in the gable end of the roof.

A view of the chimney inside the attic, partially wrapped with fiberglass insulation. Attic access did not allow closer inspection of this area.



Looking up the edge of the chimney from the furnace room in the basement. This is where heavy airflow was felt originating from.

<u>Recommended Actions</u>

Cx Associates recommends that an air barrier be installed/constructed at the chimney in the attic space. This could be accomplished in a number of ways; without a closer inspection of the current conditions, it is difficult to say which would be most effective. Utilizing wood framing and sheathing to close this shaft around the chimney and then installing a layer of closed cell spray foam would accomplish both establishing an air barrier and adding R-value around the base of the chimney. <u>Please note that if the air and thermal barrier is shifted to the roof plane as discussed in item 1 above, then this recommendation is no longer applicable. Making the attic part of the conditioned space would eliminate the concern of air leakage from the attic to the basement (however the chimney penetration through the roof would still need to be detailed to ensure air tightness).</u>

3: Adding /Upgrading Weather Stripping at all Doors

The building has three (3) doors on the first floor that lead to the exterior and one (1) door in the basement that leads to the exterior bulkhead. The two doors at the main entrance vestibule performed similarly, with minimal air leakage around the jambs and head but significant leakage around the thresholds. Weather stripping was present around the jambs and heads of these doors, but nothing was installed at the threshold. The blower door setup was installed at the northeast exterior door location so this leakage could not be observed, however the door construction is similar to the entrance doors and assumed to perform similarly.

The basement door leading to the exterior bulkhead did not have any weather-stripping present. There was another door at the top of the bulkhead stairs leading to the exterior, but since the bulkhead is not a conditioned space the basement door is considered the air barrier. Air leakage at this door was consistent around the head, jambs, and threshold.

One of the main entry vestibule doors, similar to the side entrance where the blower door setup was installed.

Fog shows that a strong current of air is present at the bottom of the door. This was consistent at both exterior vestibule doors.

A view of the bottom of these doors, not brush sweep or weatherstripping is present at the threshold.

Weather stripping was present around the head and jambs of the doors, however they were quite compressed and dirty.

A view of the door in the basement that leads to the exterior bulkhead.

Air was consistently observed flowing around this door, as no weather stripping was present.

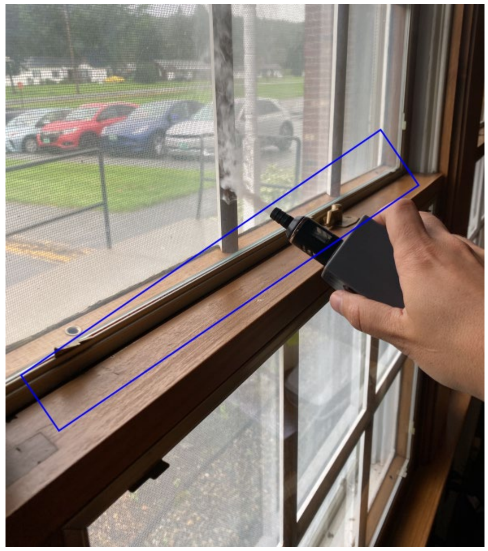
<u>Recommended Actions</u>

To improve the performance of the exterior doors, Cx Associates recommends installing and upgrading weather stripping. The exterior doors on the first floor currently have weather stripping around the head and jambs, however it is quite worn, compressed, and dirty. Replacing this weather stripping would be relatively easy and inexpensive and would improve performance. Installing under-door weather stripping or door bottoms is also recommended at these doors. Most of the air leakage observed at these doors was around the door bottoms/thresholds. Similarly at the basement door, installing weather stripping around the entire perimeter would be an improvement.

4: Installing Window Inserts

Per the staff at the town offices, the windows have not been replaced since the original construction in the 1970s. The windows all appeared to be functioning properly, all could be closed and latched for the blower door testing. Some windows had more air leakage than others, however typically leakage was observed around the operable sashes, the storm inserts, and in the upper corners. Some windows also had cracks in the glazing.

The top corners of windows was a consistent point of leakage. Each operable window has a small opening in the corner where the pully system penetrates this frame, this appeared to be a path for air flow.



Along operable sashes was another location where leakage was consistently observed. This is common in operable windows, as it is difficult to create a tight seal between operable components.

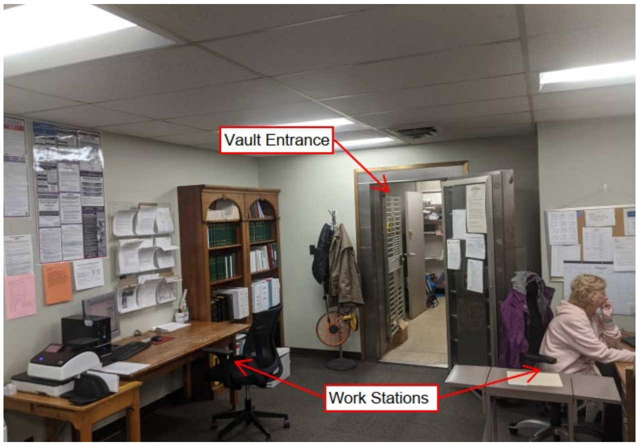
Recommended Actions

Air leakage around the windows was fairly consistent, although it was not as significant as what might be expected for 50+ year old windows. Replacing these windows with newer, more modern windows would be the most effective way to reduce air leakage and improve overall performance, however this typically results in long payback periods given the price of new windows and their installation. Cx Associates recommends an alternative option which would be interior window inserts. These inserts can be customized to fit snuggly into the existing window openings to create a tight seal. If sized and installed properly this would reduce air leakage at the windows, and slightly improve their R-value. As shown in Table 1, window inserts have a relatively high cost and low ROI, but this is only a fraction of what could be expected if a full window replacement was considered.

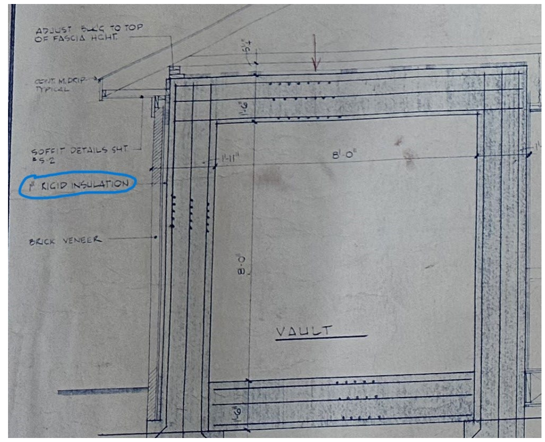
5: Thermal Barrier at Vault

A concrete vault is located on both the first floor and at the basement level. Since these vaults are solid concrete with very few penetrations there was minimal air leakage observed. However, occupants did comment that the vault on the first floor becomes quite cold during the winter months. Looking at the building's original construction drawings, it shows that the first floor vault is 18" of concrete with only 1" of rigid insulation on the exterior behind the brick façade. This creates an assembly with a relatively low R-value (R-8), especially for an area that does not have any heating. Typically the fault remains closed, however once the concrete becomes cold it can lower the temperature of the adjacent areas as well.

The vault in the basement is surrounded by space that is typically unoccupied, and it is underground and is therefore less of a concern.



The 1st floor vault is adjacent to the works stations set up in the office area. In the winter, occupants feel the cold air from the vault.



As shown in the plans the vault is 1'6" of concrete, with only 1" of rigid insulation on the exterior behind the brick veneer.

<u>*Recommended Actions*</u>
Increasing the R-value of the vault on the exterior would require major remodeling and would not be a cost-effective solution. Adding a heating component to the vault would increase energy consumption, and likely impact the security/protection requirements of the space. Cx Associates would recommend installing an additional layer of insulation inside the vault on the exterior walls to create a more effective thermal barrier. Installing additional materials would reduce the usable space within the vault, however an additional 2" of rigid insulation on the interior would raise the effective R-value from 8 to 18.

6: Comprehensive LED Lighting Upgrade

Most of the lighting in the building has already been replaced with LED retrofit kits, LED fixtures, or LED lamps. However, there are still a few remaining fixtures that we recommend be upgraded to LED, including the wraparound fluorescent T12 fixtures in the lower level (Figure 10) and incandescent bulbs in the entryway.


Figure 10: T12 wraparound fixtures in downstairs vault (left) and potential LED replacement (right)

Along with the benefit of lower wattage compared to fluorescents, most LED fixtures have advanced control capabilities, including options for continuous dimming and integration of occupancy sensors and daylighting control. Incorporating these controls could result in additional energy savings, as well as allowing for adjusting light levels to exactly meet illuminance requirements. LED lamps also have a longer life than fluorescent lamps, leading to maintenance savings on lamp and ballast replacements. We recommend procuring LED products with dimming capability, so that light levels can be fine-tuned as needed, and ensuring that any retrofits meet the rating requirements of ENERGY STAR or the Design Lights Consortium (DLC), which set criteria for minimum efficacy levels and equipment life.

There are several options for LED upgrades, including the following, listed in order from lowest to highest capital cost and potential energy savings:

- Lamp-only replacements that leave the ballast in place (TLEDs)
- Fixture retrofits that include integral LED lamps and drivers installed in the existing fixture housing
- Complete fixture replacements

Cx Associates recommends using retrofit kits as a minimum, as lamp-only replacements are less efficient, along with the fact that fluorescent ballasts vary and not all ballasts will work with all TLEDs.

While building occupants appear to be diligent about turning off lights when not in use, we also recommend installing occupancy sensors in areas that are used intermittently such as restrooms and storage rooms. This way, lights will turn off automatically when no occupants are present. These can also be configured as "vacancy" sensors (i.e. manual on, auto off), so that manual input is required to turn on the controlled lighting, but the control automatically turns the lighting off, potentially leading to additional energy savings.

Savings and costs for this measure were estimated based on assuming one-for-one fixture retrofits. A more detailed lighting design analysis and illumination study may be warranted prior to implementation in order to ensure illuminance targets are met, but not exceeded, and occupant visual comfort is maintained.

7: Heat Pump Hot Water Heater

The existing domestic hot water heater is a 15-gallon electric resistance unit. Heat pump water heaters are much more efficient than electric resistance water heaters, and can also help dehumidify and cool the surrounding space. For the type of use in this building, the unit could operate in heat pump only mode, which has a slower recovery time but is three times more efficient than an electric water heater. Hybrid mode uses the heat pump for most hours but will also use an electric resistance element to achieve faster recovery times if required. We recommend procuring a heat pump water heater that exceeds the minimum ENERGY STAR requirements.

8: Heat Pumps for Space Heating

It is important to note that before exploring any major heating system upgrades, we recommend first implementing any feasible building envelope improvements that are described above. By reducing the building heating load as much as possible through air sealing and insulation, any new equipment can be sized appropriately to meet the reduced load, potentially resulting in a lower first cost.

The existing heating system consists of a forced-air oil-fired furnace that was replaced relatively recently. Since this system is fairly new, it may not make sense to replace it with an entirely new system at this time. One option that could result in a significant reduction in the consumption of fuel oil would be to install ductless mini-split or multi-split air-source heat pumps throughout the space. This would also have the ancillary benefit of providing cooling for the building and allow for the removal of the inefficient window air-conditioning unit.

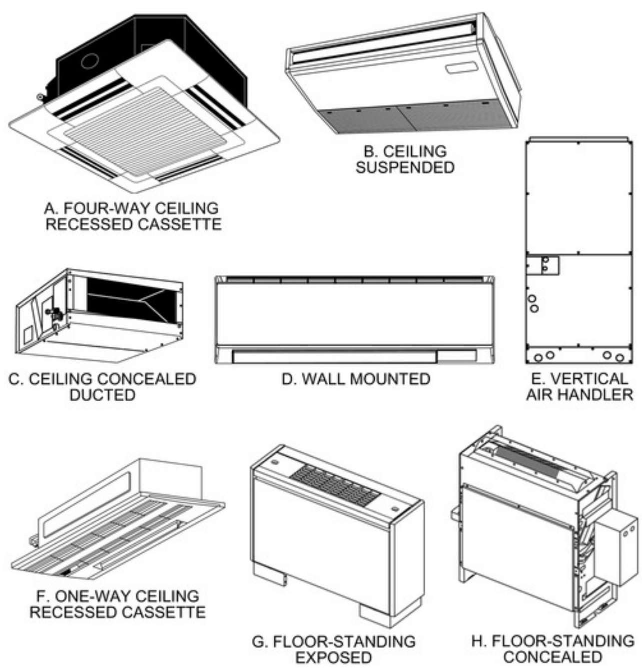


Figure 11: Heat pump indoor unit types

While air-source heat pump systems lose capacity and efficiency as outdoor air temperature decreases, major strides have been made in recent years to mitigate these effects in cold climates. Heat pumps designed for cold climates utilize technology that allows for operation at 100% nominal heating capacity down to 5°F and can operate at temperatures as low as -13°F. Therefore, while a heat pump could meet the heating requirements for most of the year, in a climate like Vermont's it is important to have some form of backup or supplemental heating. This can take the form of electric resistance heat, but this would require significant electrical panel capacity and is very expensive to operate. Since the building already has a relatively new functioning furnace, the building can be heated using a hybrid approach, whereby the heat pumps provide heating under most conditions, but during very cold weather the furnace will kick on to provide the heat. This is typically accomplished using an outdoor air switchover temperature, so that the heat pumps will operate when the outdoor air temperature is above the switchover, and the furnace will operate below. The optimal switchover temperature from an energy cost standpoint is dependent on the relative prices of electricity and fuel oil, so may change over time. Table 4 shows a comparison of electric and fuel oil consumption and cost for various switchover temperatures. In this case the lowest total heating cost occurs at a switchover temperature of 0°F, essentially allowing the heat pumps to operate for almost all hours.

Table 5: Heat Pump / Furnace Switchover Temp Comparison

Switchover Temp (°F)	Electric Consumption (kWh)	Fuel Oil Consumption (gal)	Electric Cost	Fuel Oil Cost	Total Cost
70	0	990	$0	$3,356	$3,356
60	78	982	$14	$3,329	$3,343
50	740	917	$134	$3,109	$3,243
40	2082	800	$378	$2,712	$3,090
30	5670	513	$1,029	$1,739	$2,768
20	7926	363	$1,438	$1,231	$2,669
10	10778	191	$1,956	$647	$2,603
0	12948	69	$2,350	$234	$2,583
-10	13979	17	$2,537	$58	$2,594

9: Programmable Thermostats

Currently, space heating temperature setpoints are controlled manually through two wall-mounted thermostats. Building occupants indicated that the heating temperature setpoint is typically set between 68-70°F during weekdays and turned down to 67°F or so over the weekend. We recommend installing programmable thermostats to automatically enable unoccupied temperature setbacks during nights and weekends. Note that temperature setbacks are not recommended with heat pump systems, so this measure would not apply if heat pumps are installed as recommended in Measure 7.

MEASURES INVESTIGATED BUT NOT RECOMMENDED

The measures described below were investigated but ultimately not recommended due to poor economic performance, whereby the simple payback period exceeds the expected life of the measure.

10: Foundation Insulation

As previously described the building foundation consists of 10" poured concrete, and the majority of the basement is finished with ½" drywall on ¾" wood strapping. No insulation was present on the interior side of the foundation, and the original plans do not show any insulation on the exterior. Adding insulation to the exterior of the foundation would require major excavation and would not be cost effective. Adding insulation to the interiors walls is more realistic, however given the current construction it would also likely not be cost effective. The small cavity behind the drywall (3/4") would make materials such as blown-in cellulose insulation ineffective, while other materials such as spray foam, rigid insulation, or batt insulation would require drywall demolition and re-framing the wall cavity. Adding insulation to the interior side of the foundation walls should only be considered if major renovations to the basement space are desired. In which case the work could be done concurrently with the remodeling. Given the amount of work required for a relatively small improvement, this option was not evaluated further and is not recommended at this time.

OTHER RECOMMENDATIONS

Energy Recovery Ventilation

Currently there is no mechanical ventilation for the building other than the fan in the downstairs kitchen area. The COVID-19 pandemic has brought to the forefront the importance of well-ventilated spaces for reducing viral transmission and enhancing occupant well-being.

While adding mechanical ventilation will increase energy consumption due to the additional fan energy and conditioning of outdoor air, this can be mitigated by using efficient equipment and smart control strategies.

Energy recovery ventilators (ERVs) use heat from exhaust air to preheat incoming outdoor air, significantly reducing the amount of energy needed to condition the outdoor air (Figure 11). These can recover up to 80% of the heat being exhausted.

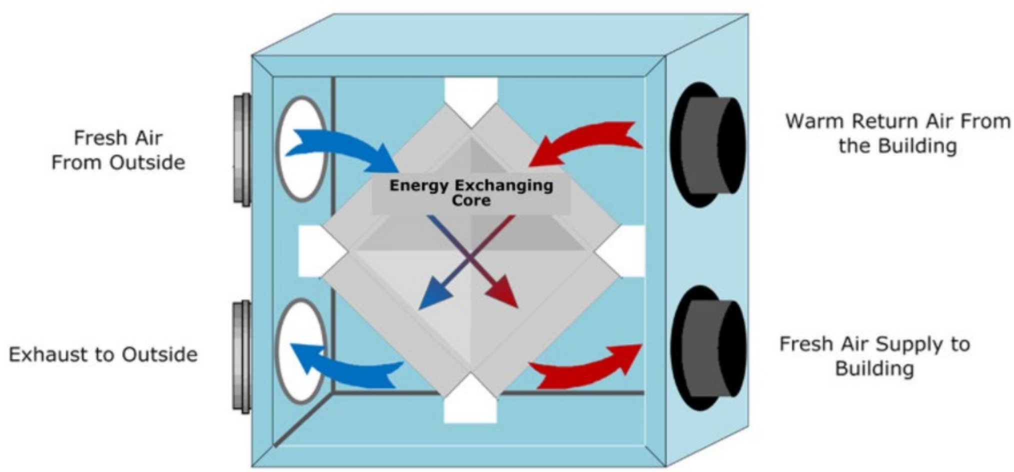


Figure 12: Energy recovery ventilation diagram

We recommend installing an energy recovery ventilator to provide fresh air for building occupants, improving indoor air quality. This is especially important if recommended air sealing measures are implemented, resulting in reduced uncontrolled infiltration of outdoor air.

RESILIENCY MEASURES

Battery Storage

Battery storage is increasingly being used in buildings as costs decline and potential applications increase. Some of the benefits may not be immediately available, but it is worth considering installing battery storage so that the building can take advantage in the future. Potential applications include the following:

- During power outages, use battery storage to provide power to the building rather than fossil fuel generator.
- Currently, the utility tariff does not include time-of-use or peak demand components, but this may change in the future. Batteries can be charged during off-peak hours when prices are lower, and then discharged during peak hours to save on energy costs.
- Batteries can contribute to grid stability, by providing power to the grid during periods of high demand, and absorbing power during periods of excess renewable energy production. Green Mountain Power, the largest utility in Vermont, is pursuing a strategy of installing battery storage in the buildings it serves in order to help manage power outages and the load on the grid.
- If on-site renewable energy generation is installed, excess energy can be stored in the battery.

There appears to be sufficient space in the mechanical / electrical room to install a battery (Figure 13). A single lithium-ion battery has a capacity of around 14 kWh, which would be able to meet the facility's electricity needs for around a day during shoulder seasons but less during winter and summer months[3] . Battery costs may amount to around $1,200 per kWh, so an installation may cost around $17,000.

[3] Based on existing conditions.

Figure 13: Electrical meter and panel

Electric Vehicle Charging

As electric vehicles become more common, it will be useful to have electric vehicle charging stations located at buildings for staff and visitors. There are three types of chargers available (Level 1, 2, and 3) – Level 2 chargers would be most appropriate for the facility, which charge at 240V and can typically add 10-20 miles per hour of range to the battery. There appears to be room in the electrical panel to add circuits for EV chargers, which typically require 40-amp circuits for Level 2 chargers. There is also room in the parking lot for chargers (Figure 14). Level 2 chargers cost around $800 for just the hardware, but total installation costs can be significantly higher as electrical service will need to be provided through a trench from the main panel to the charging area ($5,000-10,000).

Figure 14: Potential area for EV chargers

On-Site Renewable Energy Generation

Photovoltaic panels for solar power generation could be placed on the south side of the building's roof, amounting to around 600 square feet or 9.0 kW DC system size. This would result in an annual production of around 10,000 kWh. At a cost of $3 per installed watt, the system cost would be around $27,000.

VI. Conclusion

The Canaan Town Office building has multiple opportunities to reduce operating costs and concurrently upgrade aging infrastructure in a cost-effective manner.

Cx Associates' recommendations are based on a fundamental operational strategy to mitigate the equipment operating efficiency penalties while maintaining a very high level of indoor environmental quality. Cx Associates suggests the following fundamental core practices:

- Consider the building from a holistic perspective. The different systems must all work together.
- Size equipment based on current building loads and use.
- Establish a market opportunity practice of replacing failed equipment with new correctly-sized, high efficiency equipment.
- Include a quality assurance program (building commissioning) for building expansion/ renovation and equipment replacement.

The steps necessary to begin to reduce energy use and improve comfort at the Canaan Town Office are:

1. Select the desired measure package from this report and arrange for funding.
2. Retain the services of a design engineering firm[4] having the skills, knowledge and experience with efficient execution of high performance systems.
3. Obtain specifications and engineering design for the opportunities and any other projects prioritized for immediate implementation.
4. Procure contractor and commissioning pricing, and review pricing with the designer.
5. Ensure thorough review of contractor-proposed equipment and control sequences to confirm the design intent is being fulfilled and all assumptions within the audit analysis are included. This review should be undertaken by Cx Associates to help ensure the building upgrades will deliver the expected savings.
6. Implement measures and commission installation to ensure equipment is optimized and operates as designed.

[4] Cx Associates offers design engineering services for energy retrofits to building HVAC and control systems.

7. Perform measurement and verification of savings and survey occupants regarding thermal comfort.
8. Report out to stakeholders on the project outcomes.

End of report.

VII. Appendix A: Building Envelope Test Results

BLOWER DOOR TEST RESULTS

The whole-building air leakage was measured and normalized, resulting in an air leakage rate of **1.16** cubic feet per minute at 50 pascals of pressure per square foot (CFM50/SF) of exterior building shell, based on 6 quantified sides of the envelope.

Field Measured CFM @ 50 Pascals	Temperature Adjusted CFM @ 50 Pascals*	Square Feet of Building Shell (6 sides)	CFM50/SF (6 sides)	CFM75/SF (6 sides)
8,133	8,055	6,944	**1.16**	**1.42****

* Temperature adjusted CFM50 is a more accurate measurement of air flow as it accounts for air density differentials between conditioned and outdoor ambient space.
**Extrapolated utilizing air leakage values obtained at -50 pascals and -69 pascals (unable to achieve pressure -75 pascals during testing).

Environmental Conditions & Building Configurations

1. All exterior doors were closed.
2. All windows were closed and latched.
3. All interior doors were propped open.
4. Attic hatch was closed.
5. Furnace was shut down.
6. Exterior fresh air louver was masked.
7. Furnace and exhaust fan exhaust through chimney was left unmasked.
8. One (1) blower door setup was installed at the northeast side entrance.

Outside Temperature	**56 °F**
Inside Temperature	**66 °F**
Wind Conditions	**0-5mph**
Time of Test	**9:30am**

RESULT BENCHMARKING

The table below is used to compare the results of this building to common whole-building air tightness benchmarks, as normalized by the indicated number of sides.

Air Tightness Benchmarks for Envelopes w/ 6-sided Surface Area Calculations	CFM50/SF of Shell	CFM75/SF of Shell
Canaan Town Offices	**1.16**	**1.42**
US Passive House (PHIUS+ 2021 – prescriptive)	0.06	0.08
Beyond High-Performance Air Barriers (approx.)	<0.11	<0.15
2020 VT CBES Reduced Air Infiltration (C406.9)		<0.25
High Performance Air Barriers (approx.)	<0.21	<0.25
US Army Corps of Engineers Air Leakage Test Protocol		0.25
2020 VT CBES Code Minimum (C402.4.1.1)		<0.30
2021 International Energy Conservation Code (C402.5.3)		0.40
Leaky Construction (approx.)	>0.45	>0.50

These results indicate that the building's air barrier is very leaky when compared to today's code standards. Drastic improvements would be needed to reach 2020 VT CBES Code Minimum of 0.30 CFM75/SF of shell. This would require a reduction of 5,972 CFM of air leakage, approximately 74

VIII. Appendix B: Foam Notes

Polyurethane foam or foam plastic is an extremely useful tool in air sealing when used correctly. In this report, we may refer to various types of foam as part of an insulation or air sealing strategy. The following brief guide will help the reader understand, and anticipate requirements, for foam. Please contact BVH Integrated Services, P.C. if you would like assistance writing foam or air barrier specifications.

1. Foam and fire protection: The foam system or foam coating must be an approved 15-minute thermal barrier or ignition barrier. Occupied spaces require a 15-minute thermal barrier, which has to be shown through one of the following tests: NFPA 286, FM4880, UL1040, or UL1715, to be an approved equal to ½" thick gypsum board. The less stringent ignition barrier is only allowed for unoccupied attics or crawlspaces "where entry is made only for the service of utilities". An ignition barrier is one of six permissible materials (per IRC 314.5.3 and IRC 314.5.4) 1½ " mineral fiber insulation, ¼"thick hardboard, 3/8" particle board, ¼" thick wood structural panels, 3/8" thick gypsum board, or corrosion resistant steel having a base metal thickness of 0.016 inch. Other materials may qualify as ignition barriers but they must be shown to meet the criteria for an ignition barrier as described in IRC 314.6 through one of the following tests: NFPA 286, FM4880, UL1040, or UL1715. Often, the installer can recommend an appropriate thermal barrier.

2. Types of Foam:
   - Open-cell: Good air barrier, crushable, about R3.5/inch, NOT a vapor barrier
   - Closed-cell: Good air and vapor barrier, dense, about R6/inch
   - Kit foam: Closed-cell foam in small propane-like cylinders for "do-it-yourself" applications. Prone to misuse because it is not intuitive. READ ALL instructions and cautions if using kit foam and practice with it before starting. Installing bad kit foam makes an sticky impossible mess.
   - Can foam: Also called one-part foam, hardware store foam and gun foam. Closed-cell foam that is very intuitive to use especially if one buys the reusable gun.

   Can-foam is great for sealing and filling gaps larger than 1/8" and up to about 1-1/2" wide but not for filling voids or cavities or for bulk insulation. Can-foam does not apply well in multiple layers. For gaps 1/8" and smaller silicone or urethane caulk is recommended, foam will not seal a gap 1/8" or less, it will just cover and hide the gap.

   Kit foam is good for voids and cavities but not for narrow gaps. Kit foam can be used as bulk spray insulation for small areas (< 100 sf) and to fill a small number if closed cavity wall or roof bays if done by a professional. Kit foam is also good for sealing joints on a surface like sheetrock or plywood seams and for making "fillet" type seals around a large pipe or duct.

   Open-cell foam can be sprayed but is not a good fit when tolerances are tight because it expands 100X its wet volume. Open cell foam can be applied in thick layers. It can be injected and is a good option for air sealing closed cavities. Open-cell foam is vapor permeable so it may be the better choice when applied to old masonry but consult a building scientist for any foam over existing masonry applications. Open-cell foam is not a good choice in locations that are likely to be damp with no drying potential - i.e. basements and crawlspaces - closed cell foam is the better choice.

Closed-cell foam is good for bulk insulation where tight tolerances are required, it only expands 30-40X its wet volume. Closed-cell foam can be injected into closed wall bays but requires an *experienced* professional for application and there are not many that do closed-cell injection any more. For optimal foam stability, we recommend that closed-cell foam be applied in layers (or lifts) 3" or less in optimal conditions and even thinner in suboptimal conditions. Allow the first lift to cool to room temperature before installing the next lift. We are aware that foam manufacturers allow for greater pass thicknesses and that our recommendations can make the install process slower and labor costs higher but it does lead to a better finished product. It should be noted that most foam manufacturers also have broad disclaimers at the bottom of their technical data sheets. Closed-cell foam is more technical and less forgiving to the installer than open-cell foam.

3. <u>Cautions with foam:</u>
   - Properly installed closed-cell foam does not shrink or crack but improperly installed foam may, the cracking will typically show the first winter after installation. Installing the foam with a ratio monitor, checking substrate temperatures frequently, and installing in multiple lifts is the best way to ensure quality foam. However, installing foam in thick lifts is a labor and cost savings so there is always pressure in the industry to allow for thicker and thicker lifts. How thick the foam can be installed in one pass varies by manufacturer and by substrate temperature. Foam applied to a hot roof on a warm August day or to a foundation on a cold November morning has to be applied in thinner lifts than in other more ideal conditions. It is up to the foam installer to understand these conditions and the limits of the product they are installing. <u>The importance of this for a quality product cannot be overstated.</u> We recommend requiring a written guarantee from the installer and the manufacturer that the foam will not crack or delaminate for at least 2 years after installation.
   - Temperature and humidity: Foam arrives at the site as unmixed chemicals. Making foam is a chemical reaction that is sensitive to temperature and humidity. Optimal air and substrate temperatures are around 70 F. Although the foam industry has adapted its machines and chemicals to work at higher and lower temperatures, the further the conditions are from optimal the more experience is required of the installer to know when it is still appropriate to install the foam.
   - Experienced installers: Experience matters. Knowing how the foam will react under all conditions is critical to a good installation. Experienced foamers often cost more because it really does take longer to do the job correctly, the new guys think they can cut this corner until they get called back.
   - Building Science: A new branch of science has emerged to help us understand how parts of a building interact. As a building gets air and vapor tight, understanding those interactions becomes more critical. Consider hiring a building science expert when contemplating the extensive use of foam, the use of foam over surfaces like brick and stone that are vapor permeable or in the use of foam on rubble foundations.
   - Each type of foam listed above has its advantages and limitations. Consider carefully what you are trying to do and pick the appropriate foam.
   - Foam also does not span large holes or gaps (wider than about 2") on its own, it usually needs a dam to be sprayed against.
   - Because foam expands, fills, and adheres to surfaces people tend to think it will fill and seal everywhere we want it to on its own. It will not. Foam will not make up for poor installation technique. Pockets, corner bays, or blind cavities are properly filled by putting the gun deep into the pocket and "backing out" while spraying. Cavities over 10" deep may be too deep for

traditional spray foam, injection foam may be needed. Blind pockets should be pointed out to the installer before they start.

- Overspray: spray applied foam insulations are prone to overspray. Therefore, appropriate measures should be taken to ensure that any finishes and furniture are protected so as not to cause permanent damage. This is particularly important in existing buildings.

Closed-cell foam has a greater tendency to expand and contract when exposed to hot and humid spaces. Higher densities of foam (2.5 pcf and up) and/or vapor closed surface coatings may be required for foam exposed to high humidity environments like indoor pools, hot tubs, greenhouses, industrial processes, and the like.

IX. Appendix C: Project Stakeholder Information

Table C1: Contact Information for Project Stakeholders

Name	Affiliation	Role	E-mail	Phone
Brian Sewell	State of Vermont Buildings and General Services	State Energy Program Manager	brian.sewell@vermont.gov	(802) 622-4291
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Mike LaCrosse	Cx Associates	Energy Assessor	mike.lacrosse@cx-assoc.com	(603)-545-1438
Zachary Brown	Town of Canaan		clerktreas@canaan-vt.org	(802) 266-3370