Building Energy Plan

May 25, 2018

To: Kathleen Ramsay – Town of Middlebury
From: Peter Pesano & Mike LaCrosse - Zero by Degrees, LLC
RE: March 15th & 27th, 2018 Energy Audit at the Middlebury Police Department – Middlebury, VT

Thank you for inviting Zero by Degrees LLC to help with your home energy needs. The following report presents our findings and recommendations from our diagnostic visit. It is our hope that this report can be the basis for a long term energy plan for your building. Note that John F. Penney Consulting Services provided the HVAC analysis and documentation for this report.

Summary of Analyzed Measures

Measure	Propane Saved (Gal)	Propane Saved ($)	Elec. Saved (kWh)	Elec. Saved ($)	Total Savings ($)	Approx. Cost of Measure	Lifecycle (Years)	Simple Payback (Years)	SIR
ECM #1 – Wall to Roof Air Sealing	227	$415	234	$31	$446	$6,000	25	13.5	1.85
ECM #2 – Interior Window Storms	298	$546	469	$63	$609	$2,200	20	3.6	5.6
ECM #3 – Multi-Use 105 Infill	353	$647	498	$70	$717	$7,200	30	10.0	3.0
ECM #4 – Door Improvements	60	$110	(-29)	(-$4)	$106	$675	20	6.4	3.1
ECM #5 – Wall to Floor Air Sealing	26	$48	86	$12	$60	$375	20	6.3	3.2

O&M - Operation & Maintenance measure - low or no cost measures that involve changes in how the building is used or operated.
ECM - Energy Conservation Measure – measures that involve some expense to make a change to the building.
Simple Payback – The number of years the energy improvement will take to pay back the investment.
SIR - Savings to investment ratio, is the present value of savings divided by the cost. It is considered the most meaningful criteria for ranking measures. The higher the SIR the better the return on investment. Generally, an SIR less than 1 is considered a poor energy investment although there may be other reasons besides savings for going ahead with the measure.

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<u>Notes for Understanding this Report</u>

1. Cost estimates in this report typically include the cost for materials and labor to implement the energy efficiency measure. There can be many hidden costs associated with any building improvement that are beyond the scope of this energy audit report. The following costs may apply to the energy efficiency measures listed but have not been specifically accounted for in this report: design, demolition, temporary staging or masking beyond the normal measures of the installation crew, temporary storage or moving costs, increased maintenance costs, historic preservation review, permitting, state and federal regulations for lead, asbestos, radon, and the like. There may also be salvage value for old equipment or reduced maintenance that could reduce the cost of an energy improvement. Salvage values and reduced maintenance are not accounted for in the cost estimates in this report. Cost predictions in this report <u>are not</u> estimates or fixed quotes. They only indicate the approximate cost for the recommended upgrade assuming that you hire an outside contractor for the upgrade and are meant to aid in making preliminary decisions. Especially for complex and large projects, a detailed review of the costs and maintenance implications is recommended.
2. Predicted energy savings for each measure should be viewed as the savings that would be obtained if only that measure was implemented. Energy savings for individual measures are not necessarily cumulative. In other words, energy savings are interactive, and the implementation of one measure can reduce the potential savings of subsequent measures. This interactivity is very common between envelope improvements and HVAC system improvements.
3. There are several "wild cards" in predicting energy savings. Among them, the weather from year to year, occupant behavior, changes in levels of occupancy and environmental factors that are difficult to quantify. For these reasons, predicted savings are guidelines and not guarantees.
4. When viewing thermographs, lighter colors indicate higher surface temperatures than darker colors. What is considered "heat loss" is dependent upon the perspective from which it is viewed.
5. Some infrared images are taken under depressurization. Depressurization causes all outdoor air to flow inward and is not the normal operating state of the building. It is done to reveal conditions that would not normally be detected or to enhance thermographic images. Depressurization is also used to mimic the environment a building would be under in conditions of high wind or very cold temperatures. The building was depressurized to about –50 Pascals during the last part of the imaging.
6. Air leaks are detected by the infrared camera when cooler air "washes" across a surface. The pattern of air leakage is typically dark wispy lines emanating from the air leakage site.
7. I used a cost of $1.83 per gallon of propane and an average of $0.14/kWh of electricity to predict cost savings. These costs were generated based on a 3-year average of the energy data provided by the town of Middlebury.

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R-value Survey:

The R-value survey lists our findings of the wall, ceiling, and foundation assemblies gathered from plans and visual inspection. Their approximate R-values follow.

Foundation: 2" XPS insulation, 8" poured concrete. R-11.3

Walls:

CMU walls- 5/8" gyp. board, 2"x6" steel studs, 6" fiberglass batts, 1/2" Gyp. board, 2" XPS insulation, 4" concrete block. R-28

Steel Siding on Studs- 5/8" gyp. board, 2"x6" steel studs, 6" fiberglass batts, ½" gyp. board, 1 ½" XPS insulation, steel siding. R-26

Steel Siding on Block- 4" concrete block, 4" XPS insulation, steel siding. R-23

Roof: steel roof deck, 6" polyisocyanurate insulation. R-39

Doors:

Insulated Steel Doors. R-15.9
Glass Doors- aluminum frame, double pane. R-2.75

Windows and Storefronts: aluminum frame, double pane. R-2.0

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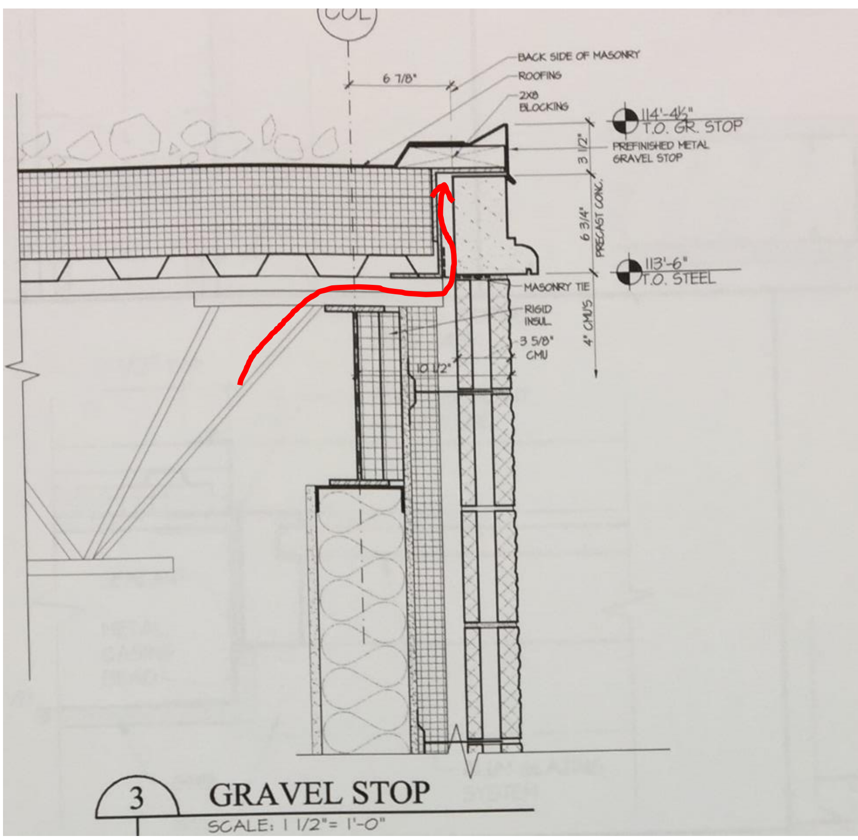
<u>Findings and Recommendations:</u>

Below are our findings and recommendations for the Police Department building. Infrared images shown below are taken with the building depressurized to -50 Pascals. Our findings reflect areas of energy loss and durability concerns.

ECM #1 - Wall to Roof Air Sealing

When investigating above the drop ceiling plane in the Multi-Use/Training Room 105 and Patrol 128, we noticed a significant temperature difference and could feel air movement in those spaces. What we found was cold, outdoor air infiltrating the conditioned space where the exterior walls meet the roof. This means that under normal conditions, warm air is able to escape the building at these locations, via the space between the metal deck and the steel I-beam which appears to be directly connected to the outdoor masonry air space or b according to the drawings.



Warm air is easily able to migrate between the metal roof deck and the top of the steel beam via the pathway show, beyond any air barrier materials. Depending on the wall configuration, interior drywall or interior CMU are typically the materials acting the most like an air barrier.

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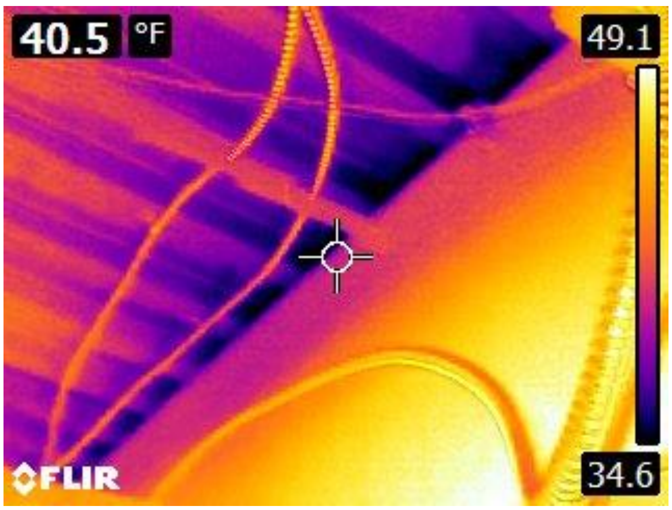
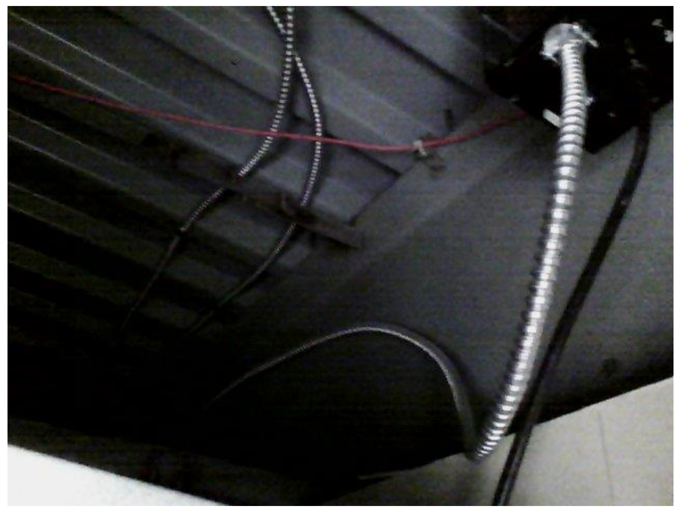
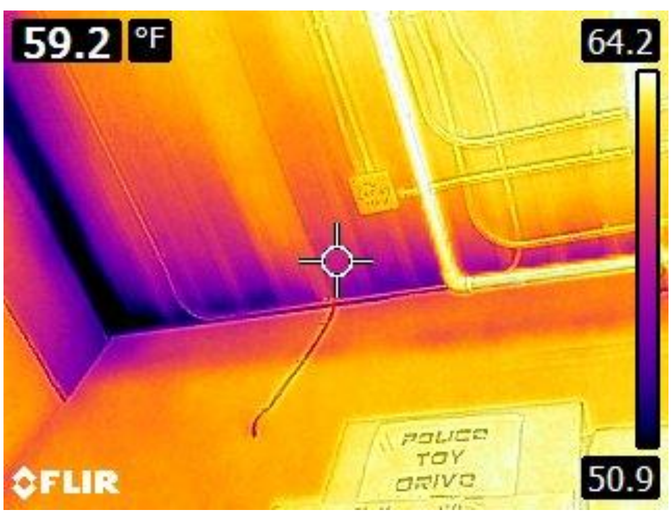
The air leakage is occurring in both direction of the roof deck flutes where it meets the exterior walls, not only in these rooms, but around the entire perimeter of the building. We recommend air sealing the wall to roof connections from the inside to help eliminate the air leakage in these areas. The air seal should be made with closed cell spray foam between the metal roof deck and the steel I-beam the deck rests on. Where bar joists interrupt this detail intermittently, the foam will need to be sprayed continuously onto either side of the bar joist and foam should be introduced between the two pieces of angle iron at the center of the bar joists' terminal end over the I-beam. The foam will need to be covered with a 15-minute thermal barrier. See Appendix 'A' at the end of this report. This air seal detailing should be made around the entire perimeter of the building at the wall to roof connection.



Air leakage at the wall to roof connection in the multi-use 105 room at the east exterior wall.


Visible light image.



Air leakage at the wall to roof in the storage room 116.

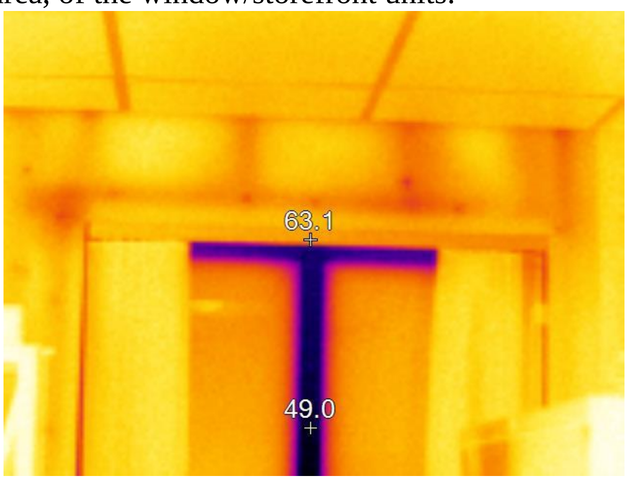
Visible light image.

Measure	Propane Saved (Gal)	Propane Saved ($)	Elec. Saved (kWh)	Elec. Saved ($)	Total Savings ($)	Approx. Cost of Measure	Lifecycle (Years)	Simple Payback (Years)	SIR
ECM #1 – Wall to Roof Air Sealing	227	$415	234	$31	$446	$6,000	25	13.5	1.85

ECM #2 & #3 - Window/Storefront Improvements

Window Units

The issues found with the windows throughout the building were low R-value and air leakage. With the windows having a very low R-value, it allows heat to move through the frame much easier resulting in the aluminum frame being cold on the interior side. When the window is cold, our body heat will radiate towards the window at a faster rate, giving the feeling that there is cold air coming in. Generally, the air leakage that was found wasn't major, and so we believe that most comfort concerns derived from the high conductivity, and in some areas high surface area, of the window/storefront units.



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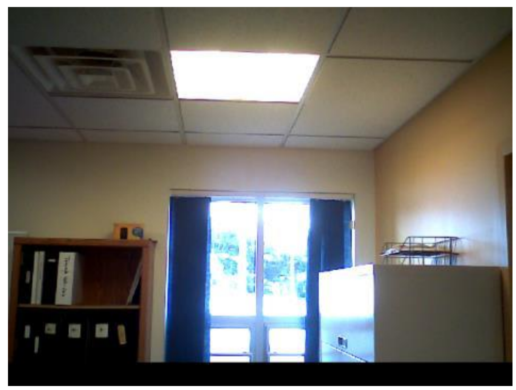
3/27/2018 8:30:17 AM
On a 35F morning the inside of the window frames measured around 49F, closer to outdoor temperatures than indoor temperatures. Indicative of their high conductivity.



Visible Light Image

From an air leakage standpoint, both the operable sections and the rough openings of the units appeared to perform fine. Any air leakage seen/felt was where the window frame connects to the window sill receiver plate.

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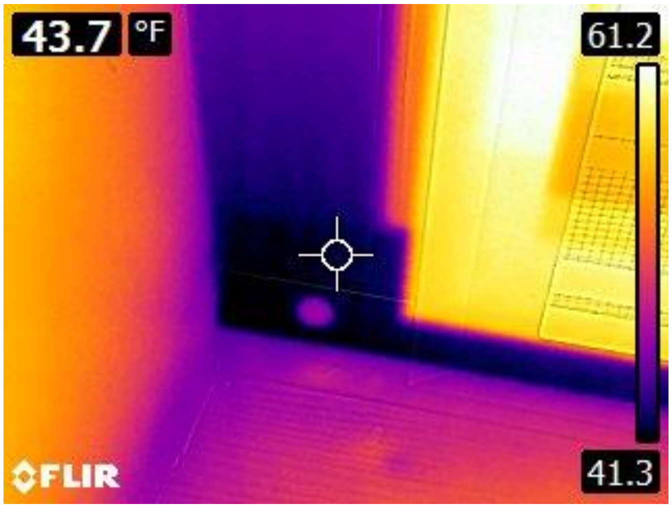

The air leakage between the window frame and sill receiver plate is not seen clearly, but these images are more intended to show the locations where the air leakage was found in most of the windows throughout the building.

Visible light image. The red arrow indicates the joint where air was felt coming in and where we recommend installing the bead of caulk.

To directly eliminate the air leakage between the frame and sill receiver plate we recommend installing a bead of caulk at the joints shown above at each window. Regarding general R-value and air leakage improvement, we also suggest adding compression fit interior storms to all window units. Compression fit storms are custom fit to each window and come with a perimeter gasket to install tightly so that air movement to the interior of the building through the window units is minimized. The additional pane also increases R-value. In rooms with many and/or large windows they do double duty to reduce energy costs. 1- In many cases they double the R-value of the window and, 2- they decrease radiant losses from the human body to the windows. People feel warmer when in the room so they leave the thermostat at a lower setting.

There are currently blinds installed in the window returns that would need to be moved further out to the edge of the wall so that there is enough room to install the storms. An alternative option would be to replace the current blinds with automated insulated blinds similar to the ones installed in the multi-use room. These would also help increase the R-value of the window units, although they wouldn't address air leakage unless the head and jambs could be installed in a track which creates a sealed blind system when closed. To get the best insulating results of the automated insulated blinds and reduce solar gain, we recommend that they remain down at all times when the room is not in use and also when the room is being used but the natural light isn't desired or needed.

At one window in the conference room (110), we found air leakage under the wood sill of the window return. There is a gap located where the drywall meets the wood sill where the air is

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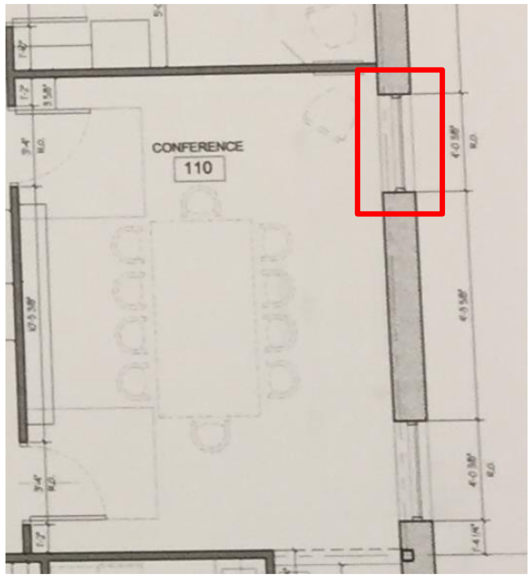
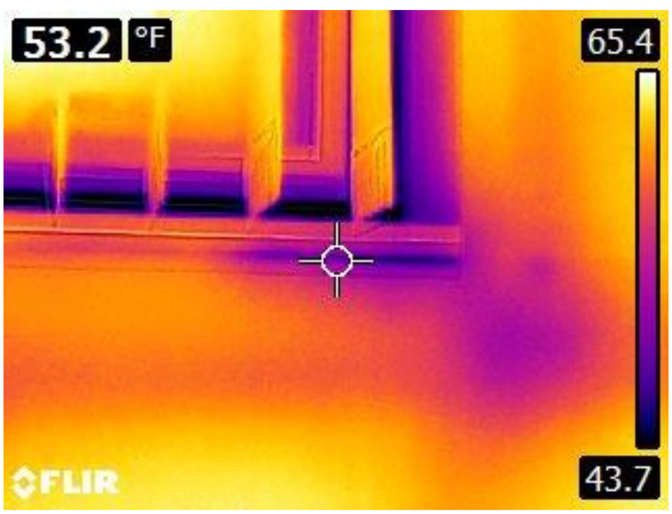
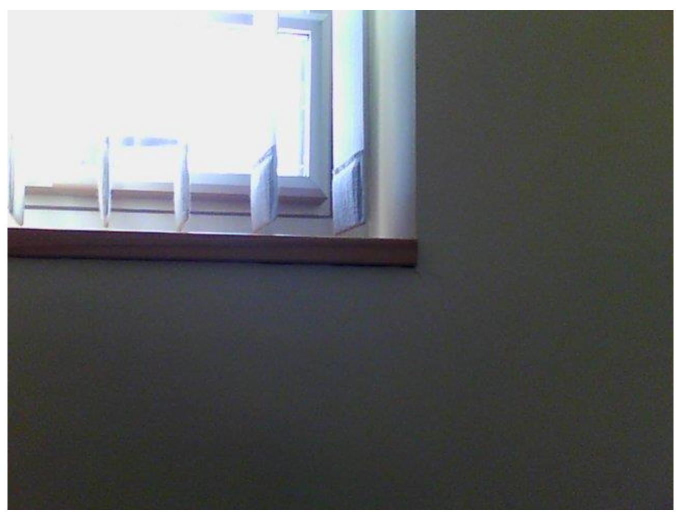
seen and felt coming in at. We recommend caulking this gap the entire length of the sill to eliminate the air leakage here. The window and leak location are indicated below.



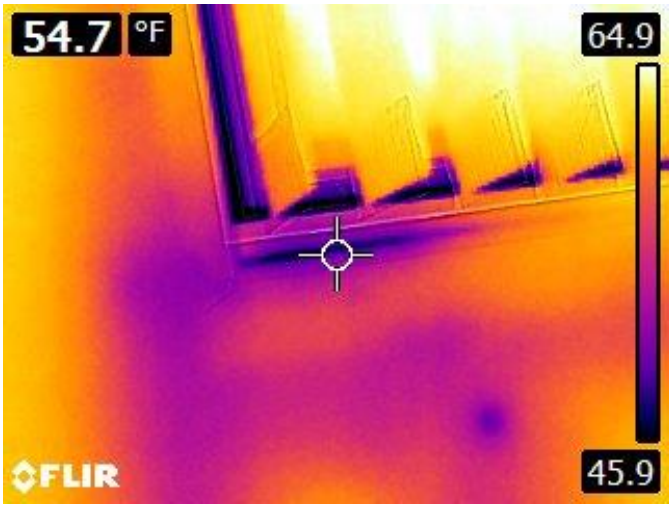
Location of the window described above.



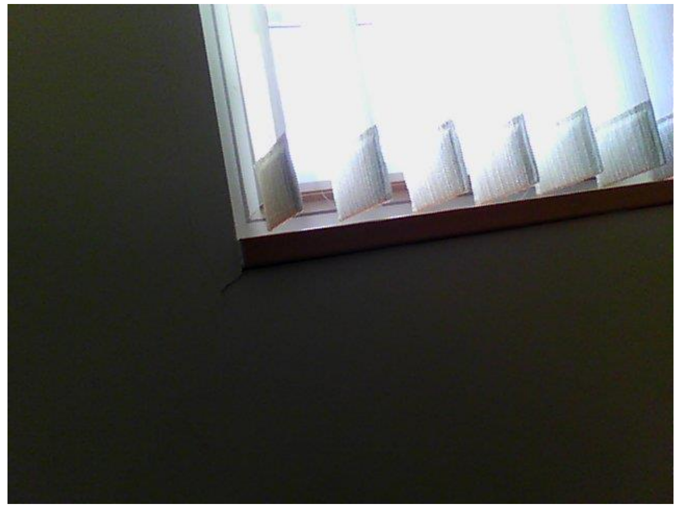
Air leakage through a gap between the drywall and wood sill on the window return.



Visible light image.



Air leakage through a gap between the drywall and wood sill on the window return. Same window as above but opposite corner.



Visible light image.

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ECM #2 – Interior Window Storms	298	$546	469	$63	$609	$2,200	20	3.6	5.6

Storefronts

During our initial site visit, Chief Hanley expressed significant comfort concerns in the Multi-Use/Training 105 room which he suspected are attributed to the storefront units. For the reasons aforementioned about windows in the subsection above, as well as a high ratio of glass to insulated wall, we agree that the storefront systems in this room are a major factor of the building envelope playing into overall comfort of this space, especially since this space is a corner room with two exterior walls. The oversized nature of the HVAC systems in this space also appear to play a significant role as well. This is discussed in the "Mechanical Systems" portion of the report, provided by JFPCS. Some measures have been taken to reduce comfort/energy concerns in the form of air sealing the operable portions of the storefront entrance on the east elevation. The doors in this storefront system do not get utilized and have been caulk-sealed shut to reduce air leakage. During our second visit on 3/27/18, we noted that the insulated blinds installed over the storefronts in the room were not being utilized. Not only do we recommend they be utilized while the room is occupied, primarily for reasons of comfort, but also when the room is unoccupied as this will help maintain the room at a higher temperature around the clock and make it more comfortable to begin with when the room is ready to be used. Not to mention, reduced energy load. While this is a good short-term strategy, we think a more intensive long-term strategy for handling these comfort issues should be considered. Chief Hanley had mentioned some of his thoughts about replacing a portion of the storefront units with infilled/insulated wall assembly, in the long-term. We agree completely with this line of thinking. We think that a small portion of the surface area that the storefronts occupy could be "saved" to allow for some natural day lighting, but that otherwise, the openings get replaced with an insulated wall system. First, remove the existing storefronts in room 105 in their entirety. Then, in the existing openings frame out 2x6 wall, 16" on center. with fiberglass mat-faced gypsum sheathing, a building wrap over the sheathing to act as a drainage plane, and 1x3 strapping to stand-off a cladding system. The estimated cost assumes fiber-cement clapboards, but finishes can be much more or less expensive. Before framing, note that a portion of the openings at the top should be framed out for new transom window units, to salvage some natural daylight. Then on the inside, insulated between the studs with 5.5" of closed cell spray foam, filling each bay. See appendix A at the end of the report regarding the application of spray foam. Then finish with 5/8" drywall, mudded and taped. This kind of long-term solution will significantly raise the average R-value of the exterior surface area in the room, reducing its overall heat load and increasing overall occupant comfort.

We believe that the storefronts can be removed and infilled with a wall assembly similar to that of the existing insulated walls. A small portion of the opening may be salvaged for a natural daylighting, but the overall average R-value of the exterior surface area will be greatly improved.

Measure	Propane Saved (Gal)	Propane Saved ($)	Elec. Saved (kWh)	Elec. Saved ($)	Total Savings ($)	Approx. Cost of Measure	Lifecycle (Years)	Simple Payback (Years)	SIR

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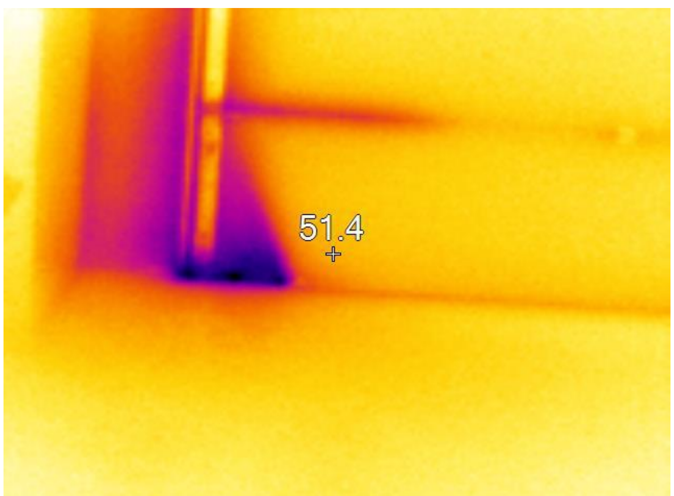
ECM #3 – Multi-Use 105 Infill	353	$647	(-471)	(-$66)	$581	$7,200	30	12.4	2.4

ECM #4 - Door Improvements

Sally Port Overhead Door

Air leakage was found at a few different locations of the sally port overhead door. Because the door was hit by a car, it is now slightly displaced. The bottom section of the door is caved in and bottom corners do not make contact with the ground when in the closed position. Because the corners of the door and the weather stripping don't make contact with the ground, air is able to slip under the door in and out of the conditioned space. Because this lower section is damaged, we recommend replacing just that lower damaged section so that it aligns evenly with the slab below and can create a tight seal when the door is in a closed position. Air leakage was also seen at the head of the overhead door. We recommend adding and adjusting weather stripping here so the door head fits tightly, so no air is able to move past it. When all improvements are made, verify that when the door is closed it closes to its full vertical position, and still makes continuous contact with the gasket at the head and jambs, and that the bottom gasket contacts the floor continuously.



Air leakage at the bottom left corner of the overhead door.

Visible Light Image

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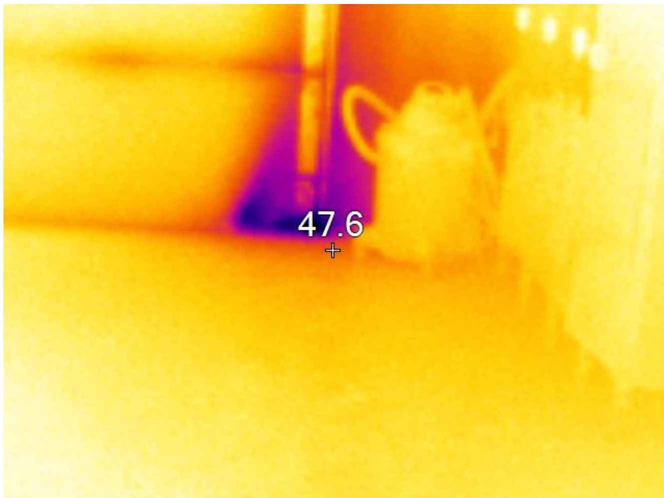
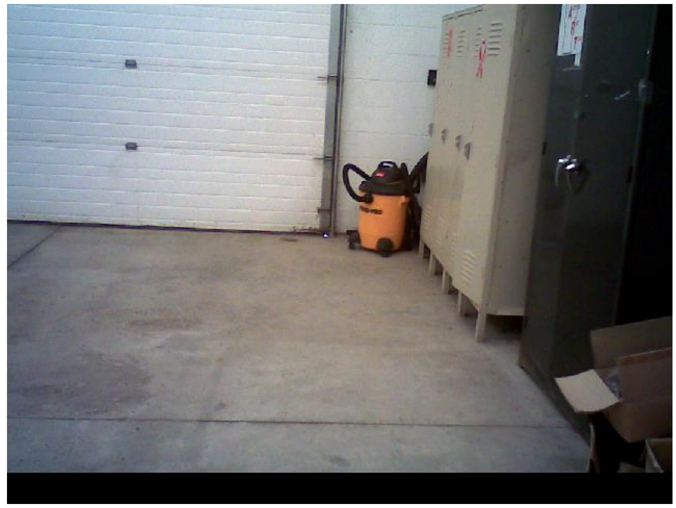
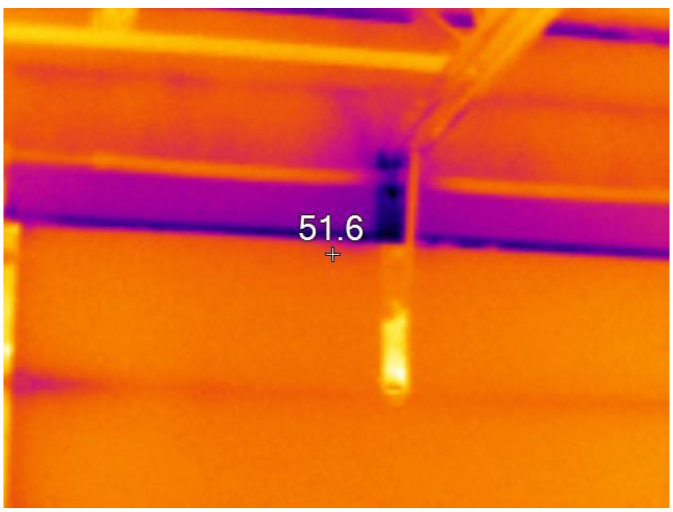
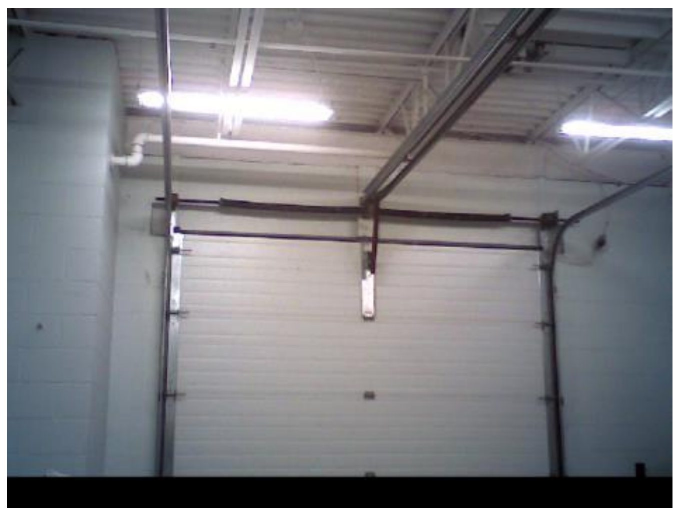


Air leakage at the bottom right corner of the overhead door.


Visible Light Image



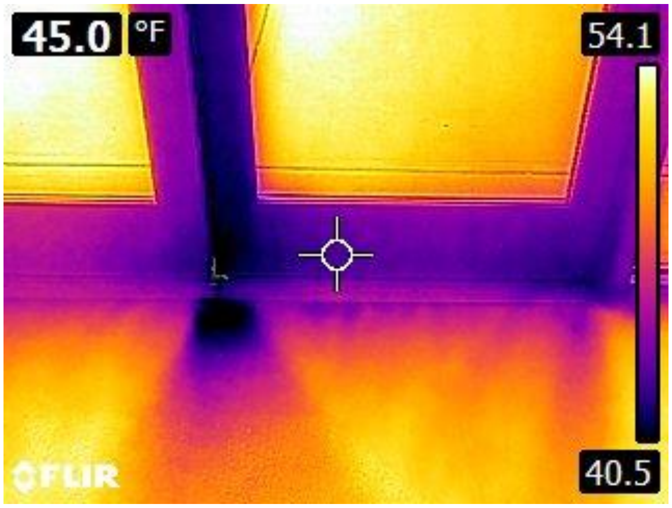
Air leakage at the overhead door head.


Visible Light Image

Entrances & Man Doors

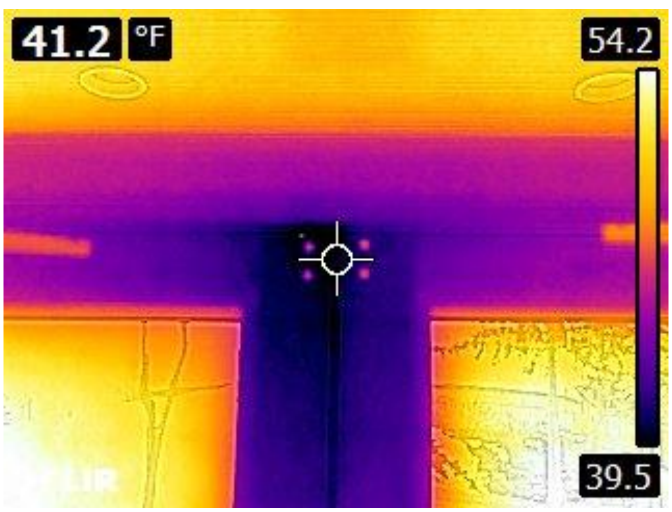
Air leakage was found through most doors due to insufficient weather stripping. Some doors are worse than others, but we recommend inspecting each exterior door and the roof access hatch and its weather stripping and adjust or replace as necessary. Weather-stripping should be on all of the exterior doors at the head, jambs, and especially at the threshold. When the door is closed the weather stripping should made continuous contact with the door and you should not be able to see daylight at the perimeter. Door thresholds also need to be added/replaced if they can be, if not, door sweeps should be added. Focus weather stripping efforts first on doors that are used rarely and emergency exits since they have to perform more like walls most of the time.

Commercial grade weather-stripping can be found at www.draftseal.com or Q-lon available through The Energy Federation www.efi.org or replacement parts from the original manufacturer if available. On doors that are still in good shape the most cost effective measure is to check the thresholds, sweeps, and weather-stripping of all the exterior doors and hatches once a year and replace as needed.



Air leakage at the astragal and threshold of the exterior double at the main entrance.

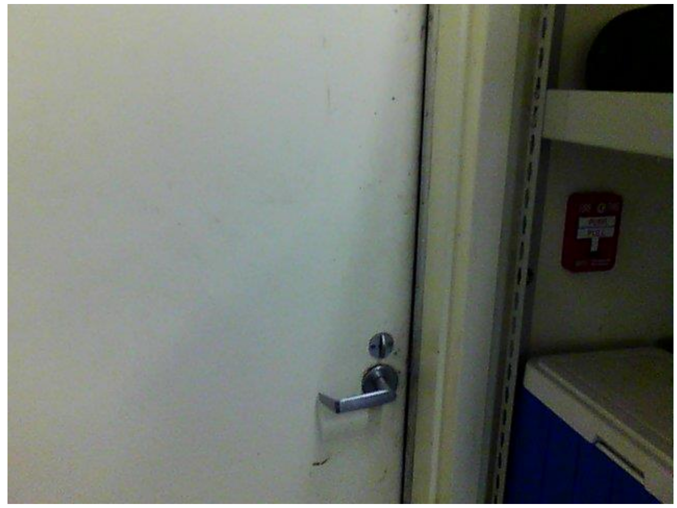
Visible Light Image



Air leakage at the astragal and head of the exterior double doors of the main entrance.

Visible Light Image

Air leakage through the jamb of the north exterior door located in the storage room 116.



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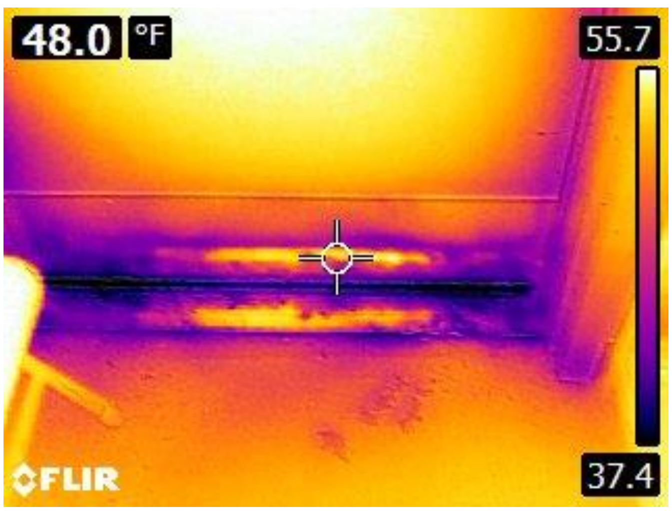
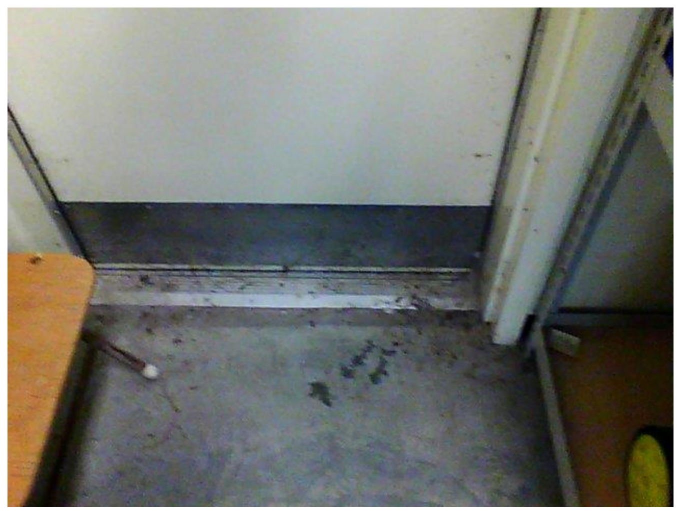


Air leakage at the threshold of the north exterior door in the storage room 116.



Visible Light Image

Note that the payback for this ECM looks less than desirable primarily due to the factored cost for the door section replacement, which we expect will be relatively expensive without offering much for the envelope. In other words it is a necessary provision to the actual envelope improvement.

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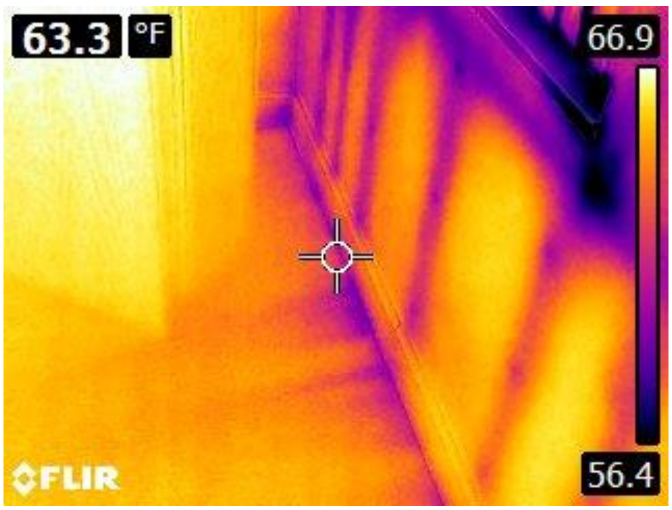
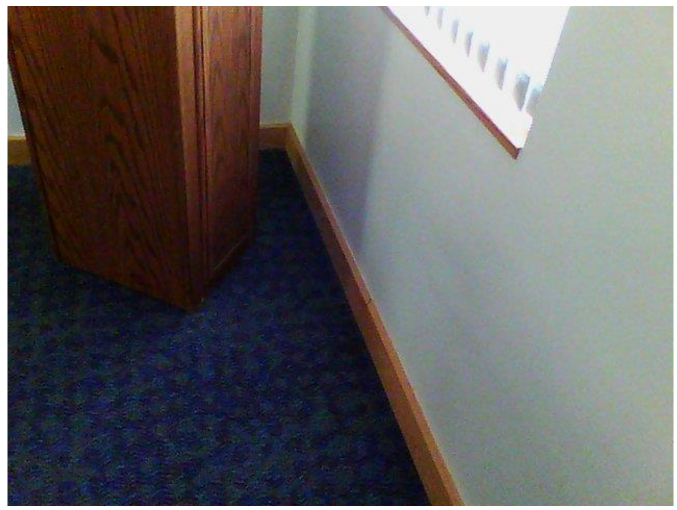
ECM #4 – Door Improvements	60	$110	(-29)	(-$4)	$106	$675	20	6.4	3.1

ECM #5 - Wall to Floor Air Sealing

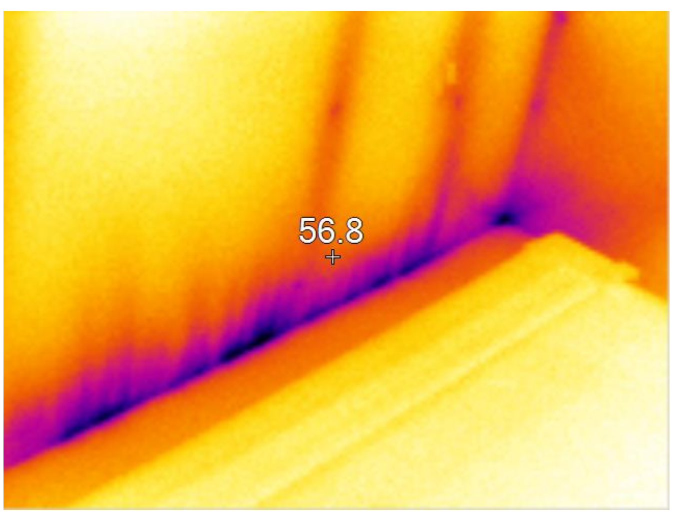
Though not a major source of air leakage, we did find evidence of air leakage at a few different sections of the wall to floor connection in the exercise room and conference room. Since this type of leak occurrence was only in a few locations, making repairs won't result in significant energy savings opportunities, but may improve comfort in the rooms. To repair these leakage areas, we recommend removing the baseboard trim to expose where the drywall meets the floor and caulking that joint.



Air leakage at the wall to floor connection in the conference room.



Visible light image.



Air leakage at the wall to floor connection in the exercise room.

Visible light image.

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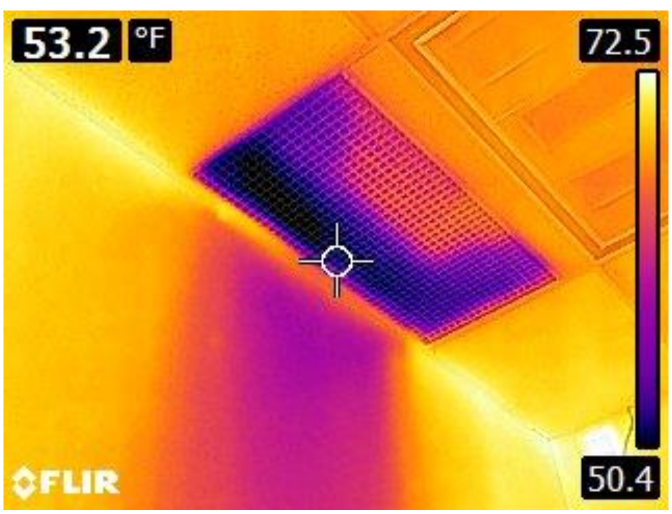
Measure	Propane Saved (Gal)	Propane Saved ($)	Elec. Saved (kWh)	Elec. Saved ($)	Total Savings ($)	Approx. Cost of Measure	Lifecycle (Years)	Simple Payback (Years)	SIR
ECM #5 – Wall to Floor Air Sealing	26	$48	86	$12	$60	$375	20	6.3	3.2

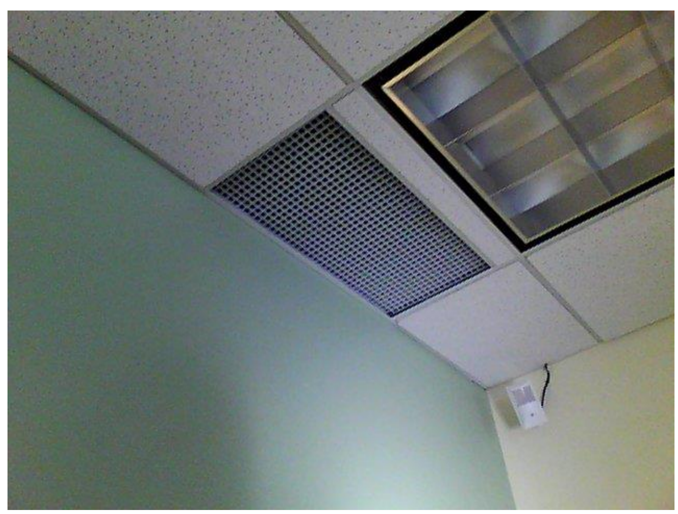
Additional Comments

Ventilation Supply, Returns and Exhaust

Seen consistently throughout the building was cold air being drawn in through all of the ventilation supply and return registers as well as the exhaust openings. The ventilation system should have mechanical dampers in them to significantly reduce the amount of uncontrolled air moving in or out of the building, but this evidence suggests the dampers may not be functioning properly. This may not be an issue if the ventilation system runs at all times, but if the system runs intermittently, then these dampers should be further inspected and tuned to open and close properly to prevent unwanted air leakage. Any improvements made regarding dampers should be considered carefully as it relates to other mechanical improvements suggested by JFPCS so as not to implement redundant or conflicting improvements.



Cool air being drawn in through the supply/return register into the conference room.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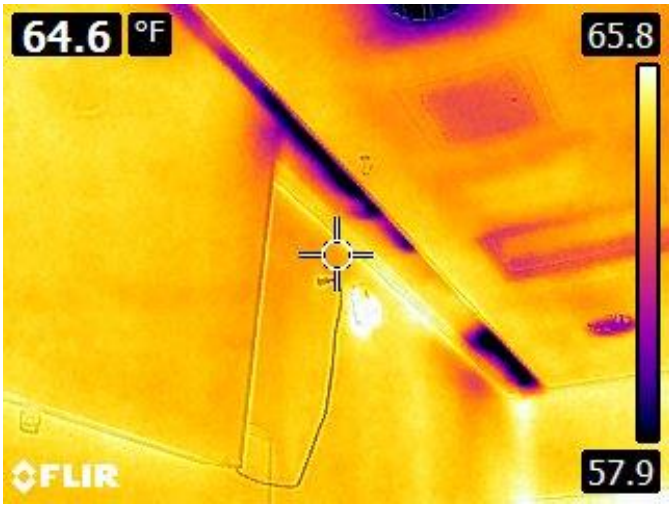

Air leakage through the ceiling registers in the multi-use/training room.

Visible light image.

Mechanical Systems

The mechanical heat, ventilation and air conditioning systems consist of six Carrier packaged rooftop units (RTUs). The following table lists the area served and the general performance of each RTU:

Tag	Carrier Model	Area Served	Nom. CFM	Heating	Cooling
RTU-1	48HJF006	Multi-Use/Training	1885	120/150	64.5
RTU-2	48HJE004	Chief/Conference/Storage	1220	50/72	37.4
RTU-3	48HJE005	Dispatcher/Super/Entry	1515	82/115	47.1
RTU-4	48HJE006	EVD/ARC/Admin	1990	82/115	61.8
RTU-5	48HJE005	Patrol/Quart/Arm/Book	1620	82/115	47.3
RTU-6	48GX024060	Locker Rooms	706	60	22.9

There is a Greenheck model MINIV-750 energy recovery ventilator (ERV) serving the locker rooms and several exhaust fans. The performance and service is scheduled as follows:

Tag	Make/Model	Service	CFM	Control
EF-1	Greenheck GB-091-4	Sally Port	500	CO
EF-2	Greenheck csp-a110	Toilet Room	75	Wall SW
EF-3	Broan L100MG	Janitors Closet	75	Wall SW
EF-4	Broan L100MG	Toilet Room	75	Wall SW

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EF-5	Broan L100MG	Toilet Room	75	Wall SW
EF-6	Greenheck CSP-A250	EVD Lab	200	Continuous
EF-7	Greenheck CSP-A251	EVD Lab	200	Continuous
EF-8	Greenheck CSP-A252	EVD Storage	200	Continuous
EF-9	Broan L100MG	Toilet Room	75	Wall SW
EF-10	Greenheck CSP-A251	Conference Room	200	Wall SW
CAF-1	Field CAS-4	Mechanical Room	Makeup	With appliance

A Modine gas-fired unit heater provides heat for the sally port.

The project was completed in the spring of 2004. Since occupancy, there have been several issues to resolve. Temperature control within some of the zones has been difficult. Some of the thermostats have been moved and equipment has been short cycling. The occupants have made adjustments to the space by adding space heaters and adjusting the thermostats. The original gas-fired domestic water heater has been replaced with a heat pump/electric water heater. The CAF-1 fan was removed.

Generally, the equipment should be in good condition. Rooftop equipment has a useful life expectancy of 20 to 25 years with good maintenance. Exhaust fans have a similar life expectancy. This equipment should be expected to operate for another 10 to 15 years. Annual inspections, belt and filter replacement, and a run-through of the original startup requirements every few years should keep the equipment operating efficiently. The efficiency rate of the equipment currently meets the minimum requirements of the Vermont Commercial Building Energy Standard.

Benchmarking the building gives an idea as to how efficient the building is using energy. This is calculated to an Energy Use Index or Intensity (EUI). EUI is calculated in terms of Btu/SF/year. The EUI for this building is 124. The median property EUI for a police station is 84. A score of 124 indicates that the building is using more energy than most other police stations in the data base. This score also tells us that improvements can reduce the building energy use.

There are two areas that stand out on the mechanicals systems. The first is zone control. When the building is occupied, the RTU fan should be on. This will help balance the temperature through the zone and should improve comfort. The amount of ventilation air entering the building through the RTUs is unknown. Some air is required as makeup air for the exhaust systems that are run continuously. Some makeup air may be more than the amount necessary to meet indoor air quality standards. Control of outdoor air is important to managing energy. Heating or cooling excess amounts of outdoor air for ventilation will increase energy consumption.

The second concern is that some of the RTUs appear to be oversized for the zones served. Oversizing heating and cooling equipment can increase energy use by short cycling the equipment. Short cycling causes inefficient combustion when heating reducing the overall efficiency of the unit. During cooling, oversized equipment never properly dehumidifies the space. The thermostats are lowered to keep the equipment running longer, subcooling the space. Short cycling will reduce the life of the equipment. When it is time to replace the RTUs the systems should be reevaluated and resized to properly address the heating and cooling load.

Even though the existing HVAC equipment is oversized, because it is not that old it may make sense to wait until it needs replacement. Then the systems can be reevaluated.

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Ambient Conditions 3-27-18:
Outside Temperature: 35 °F
Inside Temperature: 68 °F
Wind Conditions: Calm
Time of Day: 8:30 a.m.

Test Conditions:
1. All exterior doors and windows were closed and latched.
2. Interior doors were left open.
3. Active blower door equipment was setup in the south entrance of the Foyer 129.
4. HVAC equipment was shut off.

Blower Door Test Results:

The leakage rate of the building was 0.40 cubic feet per minute (CFM) at 50 Pascals of pressure (1.57 lbs. /sq. ft) per unit area of exterior above grade shell.

Field Measured CFM @50 Pascals	Temperature Adjusted CFM @ 50 Pascals	Square Feet of Building Shell	CFM50/SF
5,295	5,216	12,914	0.40

Referencing the comparison chart below, this result indicates that the building's air barrier performs better than typical modern construction, but is not considered to be high performance. Our physical findings corroborate with this quantitative data. Given the envelope recommendations outlined below, we think the air tightness of the building can be reduced to bring the building much closer to the level of high performance.

	CFM50/sf of shell
Middlebury Police Department	**0.40**
Ultra-Tight Air Barriers	<0.15
High Performance Air barriers	<0.25
Typical Modern Construction	0.60 to 0.90
Leaky Construction	>0.60

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Appendix A - Foam Notes

Polyurethane foam or foam plastic is an extremely useful tool in air sealing when used correctly. In this report I 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 Zero by Degrees LLC 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.

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.

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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 cavities but requires an *experienced* professional for application. Closed cell foam has to be applied in layers or lifts 2” or less. Closed-cell foam is more technical and less forgiving to the installer than open-cell foam.

3. Cautions with foam:
    - Temperature and humidity: Foam arrives at the site as unmixed chemicals. Making foam is a chemical reaction that is sensitive to temperature and humidity.
    - 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.

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