Zero by Degrees LLC

Energy Independence in Affordable Steps

Building Energy Plan

May 3, 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 Teen Center- 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.

Summary of Analyzed Measures

Measure	Oil Saved (Gal)	Oil Saved ($)	Elec. Saved (kWh)	Elec. Saved ($)	Total Savings ($)	Approx. Cost of Measure ($)	Lifecycle (Years)	Simple Payback (Years)	SIR
O&M #1 - Thermostat Setback	197	$420	0	$0	$420	$250	15	0.6	25.2
ECM #1 - Attic Improvements	245	$521	0	$0	$521	$10,250	30	19.6	1.5
ECM #2 - Window Improvements	59	$125	0	$0	$125	$3,175	25	25.3	1.0
ECM #3 - Door Improvements	6	$13	0	$0	$13	$375	20	28.1	0.7
ECM #4 – Miscellaneous Air Leakage	11	$23	0	$0	$23	$1,000	20	43.4	0.5

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.

Note that we realize many of the simple paybacks listed for each scenario look less than ideal. We believe this is due in part to the fact that the building is a small and simple building without any complicated appliances or significantly abnormal occupant/building energy habits. Average annual energy consumptions are relatively low to begin with, as is the average cost per gallon of oil, and so the opportunity for vast savings is diminished by default. However, we're not sure if there are certain town energy goals at play, regardless of payback. All of this being said, we still believe we have identified the largest energy and durability opportunities within the building, and to some extent, believe that retrofit of these items could still make a lot of sense. We do not have a great sense of general occupant comfort, but suspect that many of these opportunities discussed below would generate significantly increased comfort, which cannot be valued in dollars. Each scenario outlined below discusses not only how that given scenario benefits the building from an energy standpoint but a comfort standpoint as well. Note that anticipated costs do not included any rebates which may be available through Efficiency Vermont.

Notes for Understanding this Report

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 are not 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 $2.13 per gallon of oil and $0.144 per 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.

287 Fairview Sq., Fairlee VT 05045
Phone: 802. 522. 9713
Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

Health and Safety Recommendations

All building systems interrelate and occasionally improvements to one building system can create problems in another. Measures to improve energy efficiency should be regarded in the context of the health and safety of occupants and in the long-term durability of a building. Careful consideration of the following and testing before and after efficiency improvements will help to prevent conditions that could have a negative impact on the building.

1. The exhaust fan of the bathroom contains flex ducting in the attic that exhausts to the outdoors via the soffit at the eave. Our first concern here is where the flex ducting is exhausting the air. The flex ducting leads to the soffit of the roof eave where it then forces the air straight down. The concern here is that the exhausted air is able to rise directly back up to the underside of the eave and even back into the attic, especially in the winter when the exhausted air is warmer than the outdoor air. If the warm, moist, exhausted air rises back up to the eave and back to the attic this leaves opportunity for moisture to condense on colder attic surfaces, particularly during the winter months, posing a risk for things such as mold, mildew, or wood rot. That being said, there doesn't appear to be any historical evidence of anything significant like this occurring, but it could still be contributing to any ice dam issues that may occur at this eave. The second concern with the flex duct is the irregular path it creates. Flex duct tends to dip and bend and can create low points, where moisture can condense and accumulate, especially if the duct is above the plane of the insulation, as it is in this case. We recommend that the flex ducting be replaced with a hard PVC pipe that runs straight up through the roof, rather than out through the soffit. The PVC is recommended for its durability and also for greater compatibility when air sealing as is described below. The PVC pipe should be fitted with an updraft cap so that warm air is not exhausted down onto the roof itself (to reduce snow melt and ice dam potential) and is also protected from rain entering the pipe.

287 Fairview Sq., Fairlee VT 05045
Phone: 802. 522. 9713
Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com


The flex duct is routed both above and below the plane of the insulation out to the soffit. We're not sure why there are two ducts, perhaps there is a second exhaust fan below the insulation that we could not observe from the attic.

2. The present natural ventilation is currently sufficient for the building and the occupants (see "Building ventilation" below) according to the Building Airflow Standard. Continuous mechanical ventilation equal to 85 CFM would be required for proper ventilation of the building if the building air tightness is improved beyond 1097 CFM50 as a result of the proposed recommendations.

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Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

R-Value Summary

Walls: 5/8” gypsum wall board, 6” fiberglass batts, 2x6 wood studs, 5/8” board and batten siding. Approximate R-value: 20.6

Existing Ceiling (Flat & Slopes: 5/8” gypsum wall board, 8” average of fiberglass batts between 2x4 truss chords. Approximate R-value: 23.0

Foundation: Poured concrete slab, 2” extruded polystyrene (XPS) insulation. Approximate R-value: 10.8

East Door: Insulated metal door with double pane glass. Approximate R-value: 5.2

Double Doors: Insulated metal doors, single pane glass. Approximate R-value: 6.3

Metal Doors: Insulated metal doors. Approximate R-value: 16

Wood Windows: Wood frame with double pane glass. Approximate R-value: 2.5

Vinyl Windows: Vinyl frame, double pane glass. Approximate R-value: 2.5

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Energy Plan - Energy Efficiency Measure Descriptions

The following measures with predicted savings, predicted costs, and implementation notes can be used as the foundation for a long-term energy plan for this building. The energy plan has the potential to save the most energy at the least cost if consulted at least once a year and before every renovation, addition, and equipment or building upgrade.

1. O&M#1 – New Thermostat and Setbacks

After inquiring about the building's general occupancy hours, we were informed about the buildings typical occupancy hours, temperature settings, and other general practices. Typically, the building remains unoccupied more than it is occupied during a normal day with the thermostat set at 69 degrees during all hours. The building is only occupied a small portion of the day, but the temperature settings for occupant comfort remain even when there are no occupants. This means the building is being heated to a desired comfort temperature when it doesn't need to be, thus using more energy than needed. To reduce unnecessary energy consumption instantaneously, temperature setbacks can be implemented while the building is unoccupied. For the Teen Center, we recommend a regular temperature setback of 60 degrees. This setback could be even lower for greater energy savings, although we wouldn't recommend anything lower than 50 degrees. Given the simple shape and small size of the building, the building's heating system should be able to recover from 60 degrees to an occupied temperature setting of 69 degrees quickly, especially after other recommended ECMs below are implemented.

The settings can be set manually on the current thermostats each day, or programmed, for when occupants come in for the day and leave for the night, but since there are often sporadic hours outside of the typical evening "open hours", we think a "smart" learning thermostat should be installed. A smart learning thermostat, like the NEST thermostat, can be set on a time schedule or even learn the buildings habits and adjust the desired temperature settings automatically. Over a short time, the thermostats "learn" your patterns and will make adjustments automatically. As it relates to some of the inconsistent occupancy of this building, the occupancy sensor within can tell the thermostat if it can setback to a lower temperature setting or not. Another important feature of these smart thermostats is their ability to store temperature and heating cycle data that can be analyzed later in correlation with weather data to see track heating patterns.

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O&M #1 - Thermostat Setback	197	$420	$250	15	0.6	25.2

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2. ECM#1 – Insulate & Air Seal Attic

Given our infrared findings and visual inspection of the attic, there are several improvements that can be made to improve the overall performance of the attic. The attic of the original construction is comprised of 5/8" gypsum wall board, about 8" average of fiberglass batting between 2x6 floor joists that are 16" o.c. for an estimated R-value of about 23. The short knee wall in the attic is of similar construction, but in a vertical orientation with 2x4s and 3.5" fiberglass batts. About R-10 when considering the missing insulation in some areas, shown below. There are a few factors that may further decrease the overall R-value of the attic floor. In many instances the fiberglass batts are not installed consistently and tightly but rather laid loosely between and over the floor joists creating holes and/or pockets in the insulation plane. There were also some areas that are missing insulation completely giving those sections little to no R-value. The ductwork that runs through the attic currently has insulation laid loosely over top with large breaks in the insulation, delivering cooler air to the conditioned portion of the building and significantly reducing the distribution efficiency of the heating system.

The current fiberglass batts insulating the attic are unevenly laid over top of joists and between the bays.

The ductwork is partly insulated with several gaps and voids.

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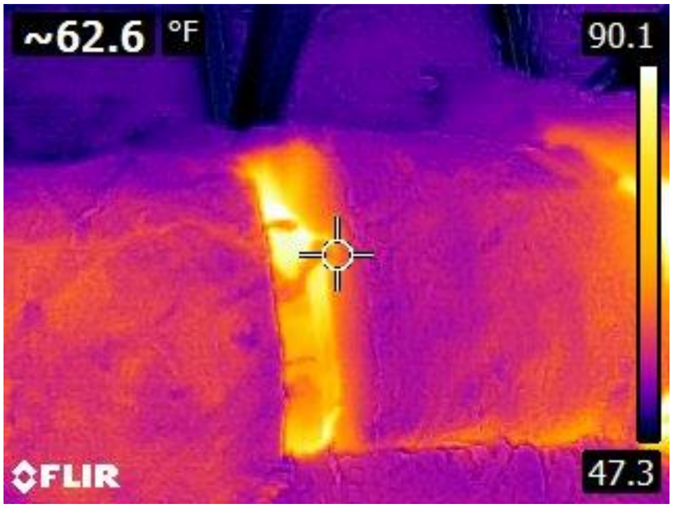
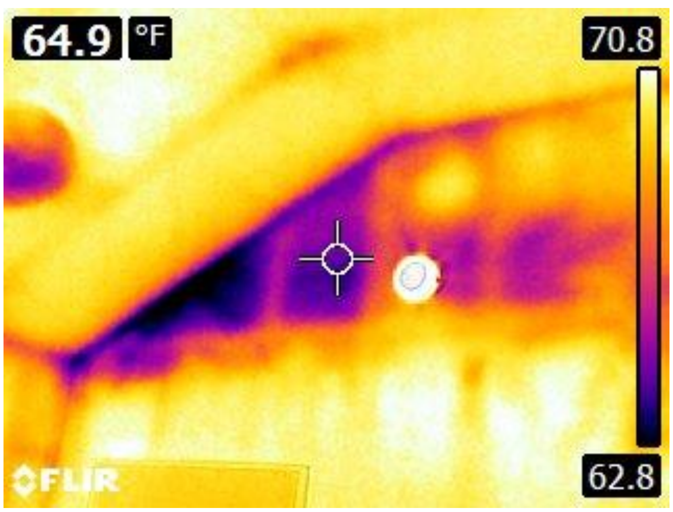
Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

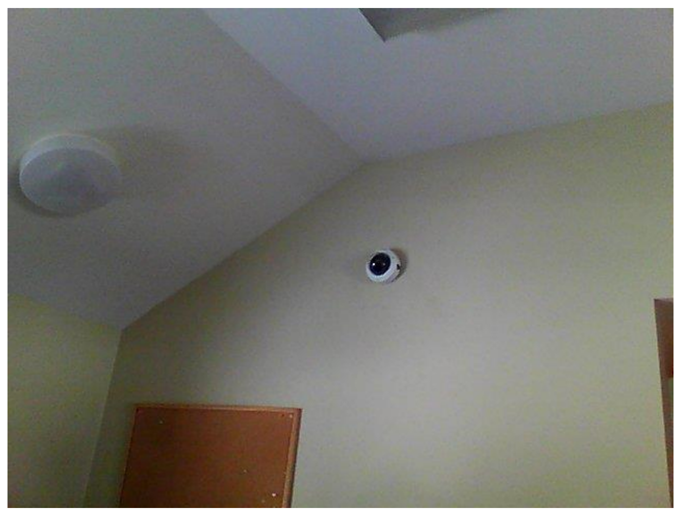


This image shows the heat loss from an uninsulated section of ductwork.

Visible light image



This image shows cold spots in the attic knee wall where it rises up to the cathedral ceiling. This indicates areas of missing insulation,



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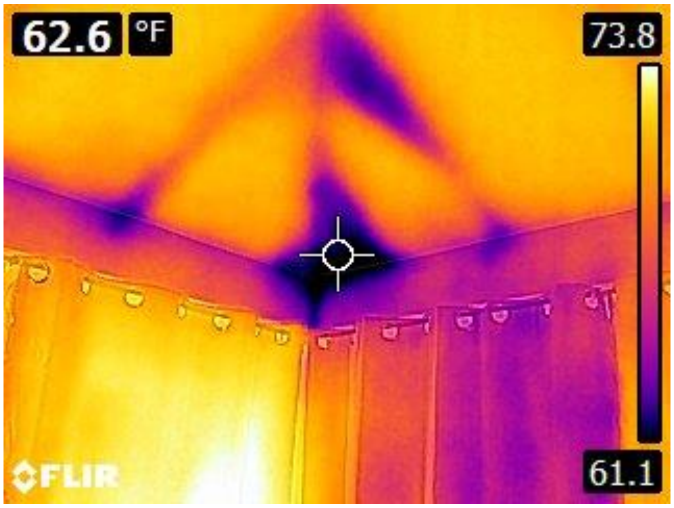
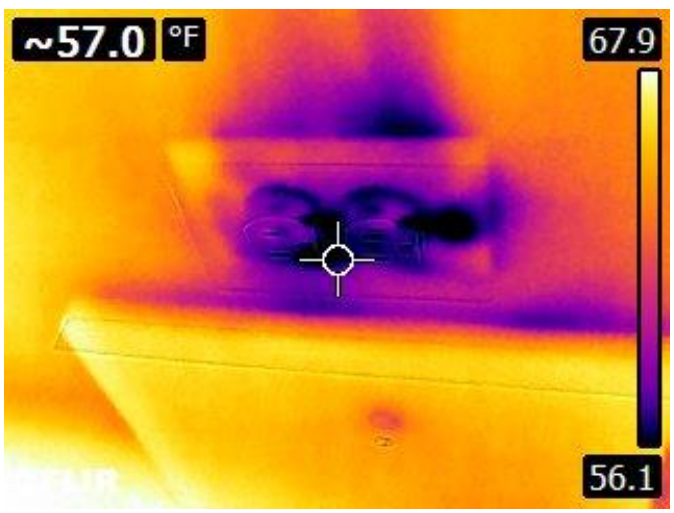


A cold spot indicating missing insulation in the south west corner of the cathedral ceiling.

Visible light image.

Regarding air leakage, infrared images indicate that there is warm air exfiltration potential at the tops of interior partitions and exterior walls, around recessed can lights, mechanical ductwork, boiler room wiring holes and penetrations, around the attic hatch, and through miscellaneous items in the "Open Space" room which include a hole directly through the ceiling, a ceiling outlet, and a wood board fastened to the ceiling.



Air leakage around the ceiling outlet and wood board in the open space room.

Visible light image.

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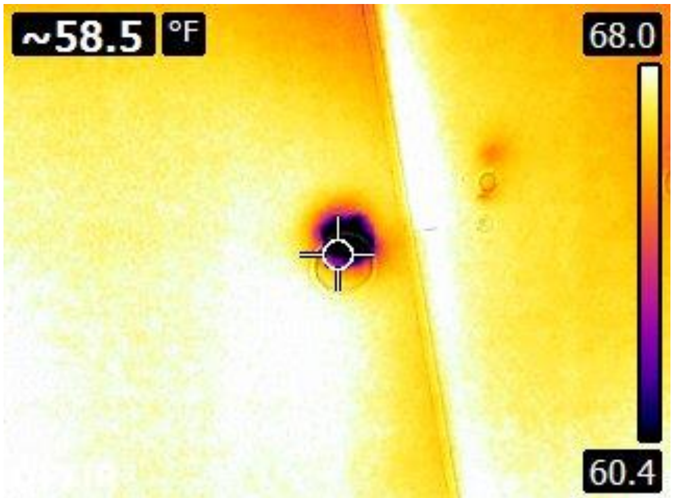
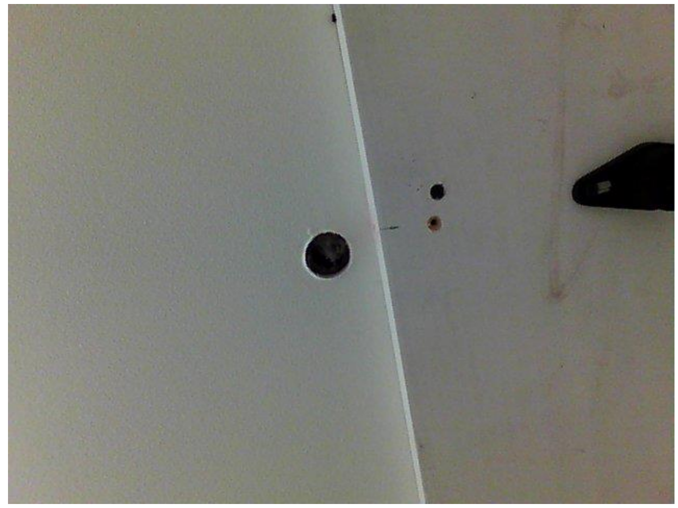


Air leakage through a hole in the ceiling drywall in the open space room.



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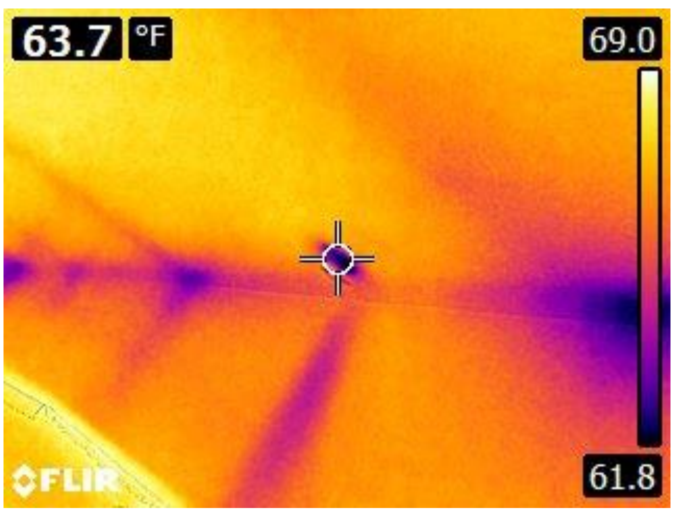

Air leakage through a hole in the drywall ceiling in the open space room near the east exterior door.

Visible light image.

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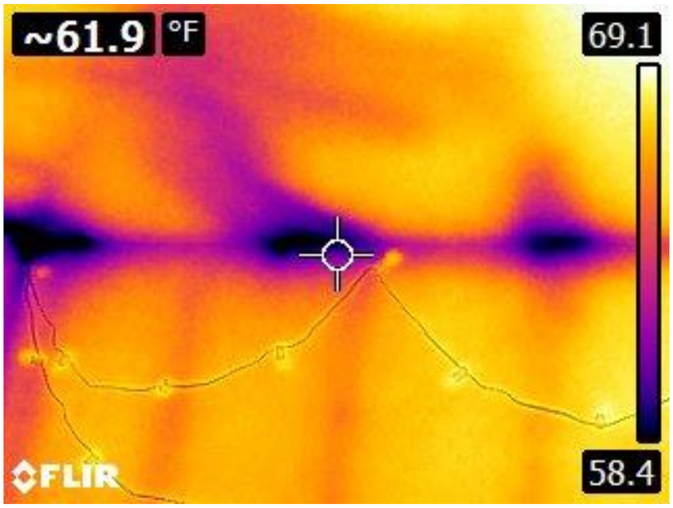
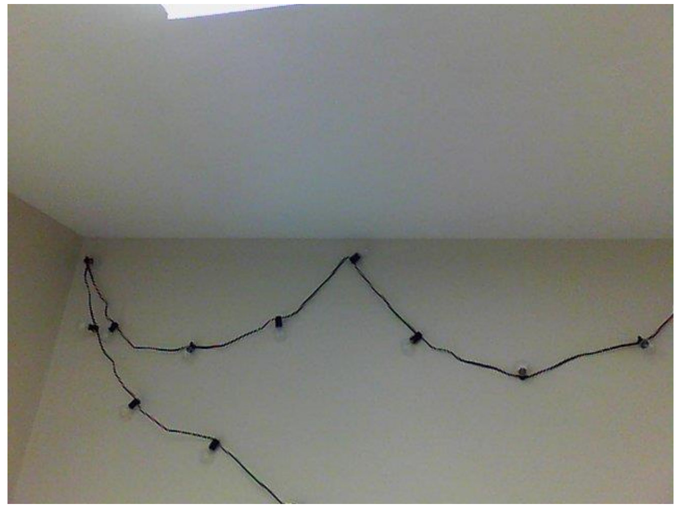


Air leakage at the wall to ceiling connection in the open space room.



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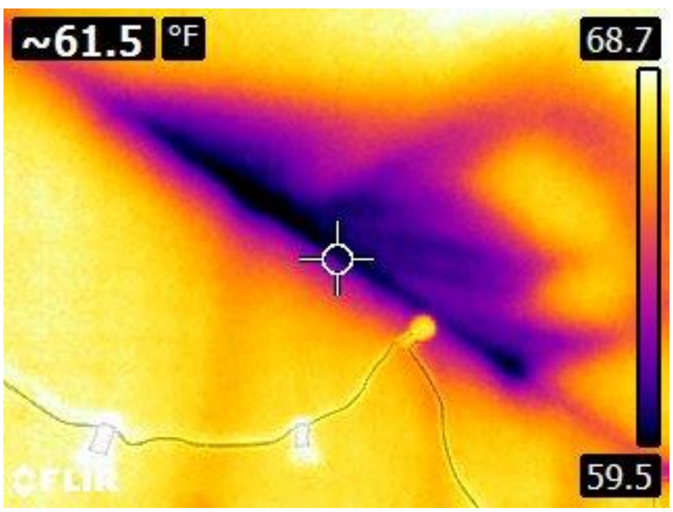
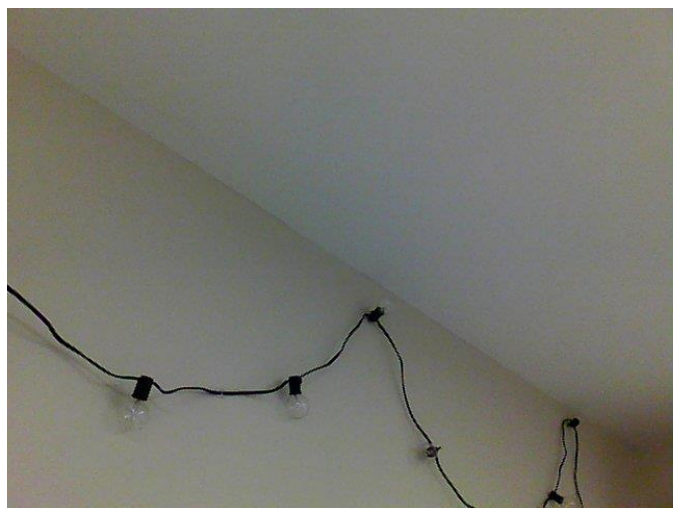


Air leakage at the wall to ceiling connection in the open space room.



Visible light image.

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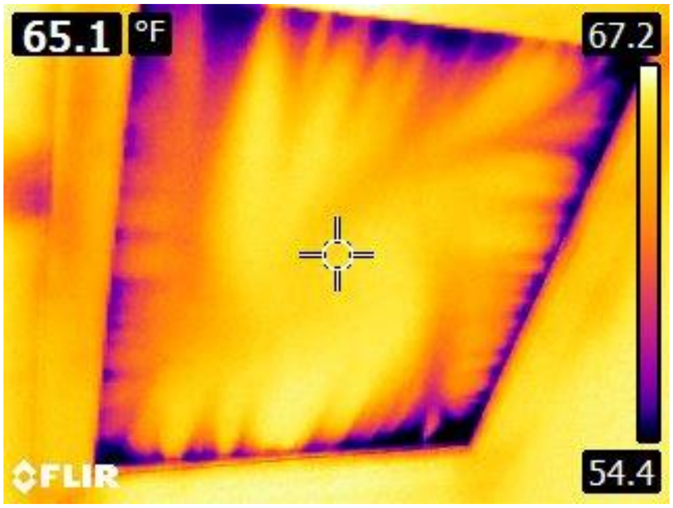
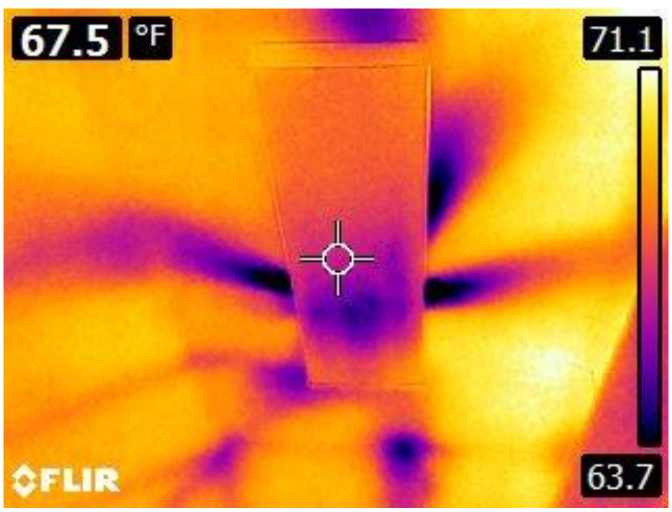
Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com



Air leakage around the attic hatch door.

Visible light image.



This image shows the air leakage around a typical ceiling light fixture in the lounge area.

Visible light image.

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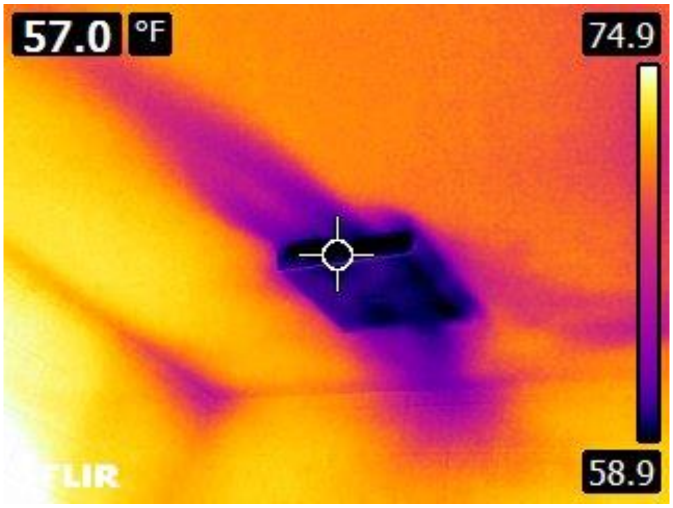

Air leakage through the bathroom exhaust fan.

Visible light image.

These leaks were found throughout the building but for the most part can all be addressed in a similar manner. Depending on the specific source of air leakage, different air sealing measures may need to be made.

The best attic improvements can be made by first removing all of the current insulation from the attic flat, the cathedral slopes around the perimeter, out of the knee wall, and out from around the duct work. Once the attic insulation has been completely removed, air sealing measures can begin. The following details should be air sealed with spray foam.

a) Recessed lights: Cover the lights with boxes made out of foil faced polyisocyanurate board (Dow Tuff R) that maintain at least a 3" air space on all sides of the light (including above). The boxes should be taped together with aluminum tape and foamed to the back of the sheetrock from inside the attic. CFL or LED bulbs should be used in these lights from then on to prevent the light from overheating which at best would cause the light to shut off at random times and at worst cause a fire .
b) Bathroom vent fan: replace any bathroom vent flexible ducts with hard PVC pipe that runs through the roof with updraft caps. Then install an insulated box over the bathroom fans similar to the boxes over the recessed lights, sealing in the PVC penetration as well.
c) Perimeter wall top plates: cover top plates completely with spray foam. Note, that not all perimeter wall top plates will be accessible due to the cathedral slopes which limit access
d) Electrical boxes in the ceiling. Follow the same procedure as outlined in ECM #4.
e) Seal over the top of all interior walls. Seal the accessible wall top plate over the gap to the ceiling drywall. Seal any wiring penetrations through the top plate. Kit foam can be used to bury the whole top plate or can foam can be used to seal each joint individually.

287 Fairview Sq., Fairlee VT 05045
Phone: 802. 522. 9713
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Email: zerobydegrees@gmail.com

f) The attic hatch: The current hatch is insulated well but should be weather-stripped around the down facing perimeter. 2 layers of ¾" plywood should be added to the hatch to add weight to create a tighter seal.
g) Outlets: kill power to the switch/outlet, remove the cover and pull the switch/outlet (leave wiring attached), caulk the box to the sheetrock, foam seal the location where the wiring enters the box, and then install a foam insert before you put the cover back on.
h) Holes through drywall: Holes can be sealed either from below by filling and mudding over the hole, or from above with can-foam if the hole contains a penetrating object like wiring or pipe.
i) Wood board: depending on the condition above, spray foaming where it connects through the drywall on the attic side or caulking around its perimeter from below will prevent air from being able to move around it.

Boiler Room Air Sealing

There are a few point sources of significant air leakage that were found in the boiler room and are worth mentioning specifically because they may require different handling. The first source is at the wall to ceiling connection along the north wall. This is above the gray plywood board that has the electrical boxes and timers fastened to it. In this area, there are holes drilled through the drywall of the ceiling for wiring. These holes lead up into the attic and are unsealed, allowing air to easily move around the wiring. There was also a significant amount of air being pulled directly through what appeared to be the wall to ceiling joint. The plywood panel that is fastened to the wall butts up to the ceiling so the drywall connection is not visible, so we are unable to determine what the seal there is, if there is any. Lastly, air leakage was also seen coming in around the perimeters of some of the ductwork, specifially the exhaust flue, and miscellaneous piping that penetrates the ceiling.

Air leakage at these locations can be remedied relatively easily. For the holes through the ceiling, ideally we'd like to see conduits installed for the wire to be fed through. The conduit should be sealed to the drywall it is penetrating, and the remaining void conduit should be filled with spray foam. If conduit isn't installed, spray foam can be used to fill in the open space of the holes around the wiring. Just spray foaming around the wiring may not be as relieable but would help in decreasing or eliminating air leakage ther completely if done suffieciently. As for the drywall wall to ceiling connection, a closer examination, which may require partial removal of the plywood panel, should be made to ensure that is in fact the source of the air leakage. If it is as simple as an unsealed drywall joint, is installing a bead of caulk in the wall to ceiling corner to fill the gap between the drywall that is allowing air to move through. For the flue pipe and duct work penetrations, use fire rated sealant to seal around the edges of where the flue pipe meets the metal pan at the ceiling, and also around the perimeter of the metal pan where it meets the drywall. The other leaking ductwork should be sealed around the perimeter where the metal meets the drywall. For the leaking pipes, use caulk to seal around the entire perimeters, ensureing there is no gaps or voids.

287 Fairview Sq., Fairlee VT 05045
Phone: 802. 522. 9713
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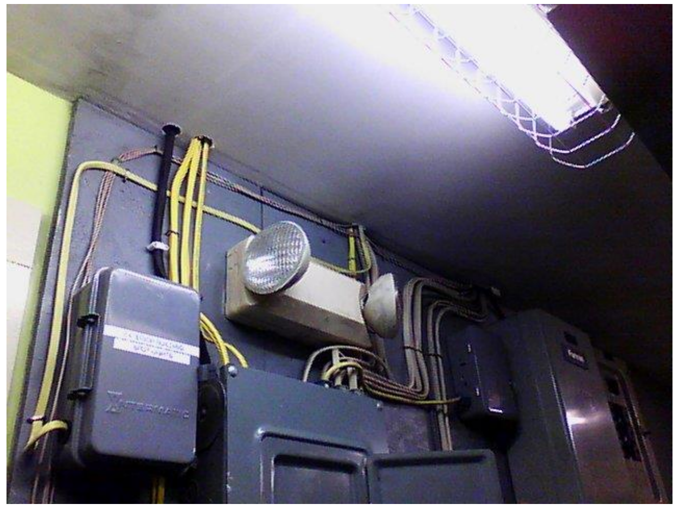
Email: zerobydegrees@gmail.com

Air leakage through the wall to ceiling connection on the north wall of the boiler room and through holes in the drywall ceiling where wiring is being fed through.



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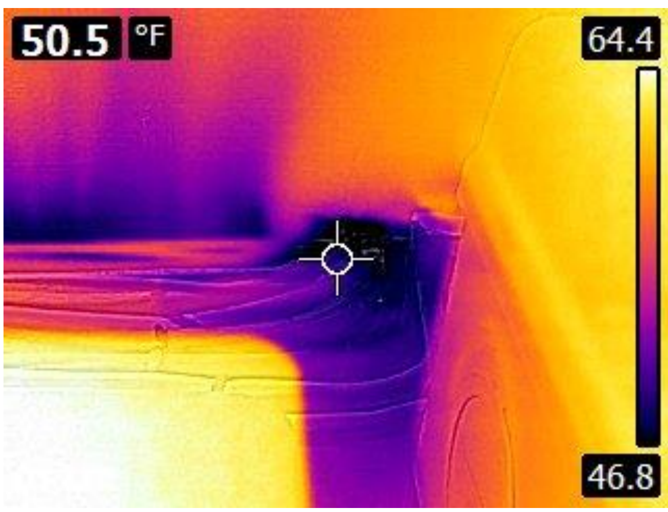

Air leakage through a hole made for wiring in the drywall ceiling of the boiler room and through the wall to ceiling connection.

Visible light image.

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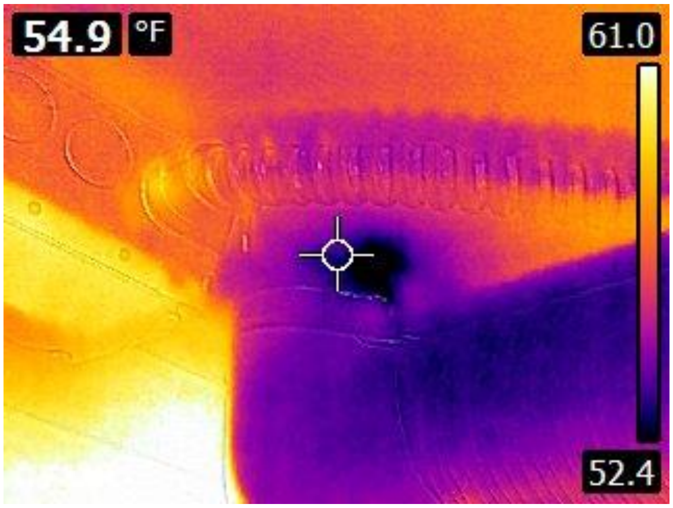
Email: zerobydegrees@gmail.com



Air leakage around a pipe penetration through the ceiling in the boiler room.

Visible light image.

Air leakage around the exhaust flue pipe and around the perimeter of the metal pan.

Visible light image.

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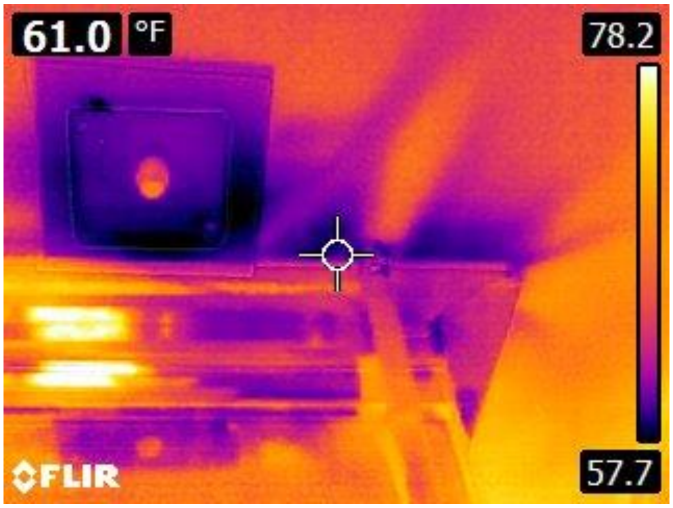

Air leakage around ductwork where it penetrates the ceiling in the boiler room.

Visible light image.

After all areas have been air sealed, the ductwork which runs through the unconditioned attic should be improved while it is accessible in order to improve distribution efficiency. Improved distribution efficiency not only reduces total energy consumption, but also delivers warmer air at supply grills which can feel more comfortable to the occupant as that air circulates through the building.

Seal the ductwork that runs through the attic with duct mastic. Be generous on the mastic, we've tested it when applied in the typical amounts and the joints still leak. A common guideline is to make it "as thick as a nickel". After sealing the ducts they should be carefully wrapped in R11 insulation to form a continuous jacket around all the ducts. Alternatively the ductwork can be wrapped completely with 2 inches of closed cell spray foam which would address both air seal and insulate.

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Ducts with typical mastic still leak but a thick coat of mastic performs well. Using either insulated jackets to wrap the ductwork or spray foaming them completely will provide increased and consistent R-value around them.

There are some flexible supply ducts which run through the attic that likely suffer from reduced air flow because of increased air friction, but we do not think that the improvement in distribution efficiency will warrant the added cost. After air sealing and improving the duct work, insulate the 2x4 attic knee wall from top to bottom, end to end, with 6 inches of closed cell spray foam, insulating over the studs to eliminate thermal bridging. Then, assess the condition and length of the ventilation baffles in the cathedral slopes around the perimeter of the building. If necessary, replace baffles and extend them at least 2 feet above the plane of the attic floor. This will ensure continuous ventilation beyond the plane of the proposed insulation. Then fill each cathedral slope bay full with loose fill cellulose. Do not overfill so as to crush the baffle and block ventilation. Then across the attic flat, blow an even 16" of loose fill cellulose insulation. This will generate an improved R-value of about 50 in the flat. Take care to ensure that all areas are filled evenly without any low or missing areas. Some areas will be a bit difficult to access but it should be doable to insulate everywhere.

Alternatively, rather than air sealing select areas, the entire attic plane can be air sealed and insulated with 2" of spray foam with cellulose installed over top. Doing this would help seal all of the smaller, one-off points of leakage that may be otherwise over looked. At the same time, this is likely a more expensive alternative, and the payback for the primary recommendation is already less than ideal.

Between the improved air tightness and gain in R-value, there are still appreciable savings to be realized, and we suspect that occupants might notice and improved sense of comfort between warm supply air and higher surface temperatures of the ceiling.

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Email: zerobydegrees@gmail.com

3. ECM #2 – Windows

Significant air leakage was found through most of the window units throughout the whole building. Under depressurization, air could be seen infiltrating around the perimeter of the lower operable sashes, at the meeting rail, and the top corners of the top sashes. With the air leakage occuring through the units themselves and not their rough openings, it is telling us that the issues lie within the window units themselves, not their surrounding installation. Because these windows have ample space on the interior, we recommend installing compression fit interior storms to aid in the air leakage through them. 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. The billiards and lounge rooms on the east end of the building are areas we could imagine occupant comfort being a concern because of the relatively high ratio of glass to insulated wall on three sides of the building.

These wood windows appear to be original to the building as they show signs of aging and wear. It is worth noting that a few of the window unit frames contain noticeable rot at the exterior, which is discussed in greater detail under "Durability Concerns". As mentioned in that section, where rot is present, replacement of window units in their entirety makes more sense from a durability standpoint. An extra investment for a tighter, higher R-value, window could then eliminate the need for the compression fit storm on the interior. A mix of interior storms and window replacements may be the most realistic scenario. However, since total window replacement is a recommendation derived from the perspective of durability, the costs of replacement are not reflected below as it would exacerbate the payback. The savings reflected assume the scenario which favors energy savings at the lowest cost which is to add interior storms to *all* window units.

287 Fairview Sq., Fairlee VT 05045
Phone: 802. 522. 9713
Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

This image shows air leakage through the jambs and sills of two window units. This is an example of what was found at most units.

Visible light image.

This image shows air leakage through the meeting rail of a window unit on the west elevation. This is an example of what was found at most units.

Visible light image.

This image shows air leakage through the top corner of the upper sash of a window unit on the west elevation. This is an example of what was found at most units.

Visible light image.

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Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

This image shows air leakage through the jambs and sills of two window units at the north and west elevation corner.

Visible light image.

Measure	Oil Saved (Gal)	Oil Saved ($)	Approx. Cost of Measure	Lifecycle (Years)	Simple Payback (Years)	SIR
ECM #2 - Window Improvements	59	$125	$3,164	25	25.3	1.0

4. ECM #3 – Doors

Under depressurization, air could be seen and felt coming in around the two sets of double doors at the heads, jambs, and thresholds. The leakage that was found wasn't consistent around the entire perimeters of the doors but was spotty due to areas where the current weather stripping is missing or not making full contact with the door. For the most part, the doors' weather stripping appeared to be in good condition, so completely replacing it may not be necessary at the moment. What we recommend be done instead is an inspection of each door, adjusting the weather stripping as necessary so that it is making full contact with the door when it is shut. In spots where the weather stripping is cut short, often in corners, replace as needed so that a weather-stripping runs the full length of the jamb or head. You will know you have it tight when the doors are closed and you cannot see daylight at the weather-stripping. 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. Replacement parts from the original manufacturer are ideal if still available. Even old doors can serve very well if the weather stripping and sweeps are in good shape.

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Phone: 802. 522. 9713
Web: www.zerobydegrees.com
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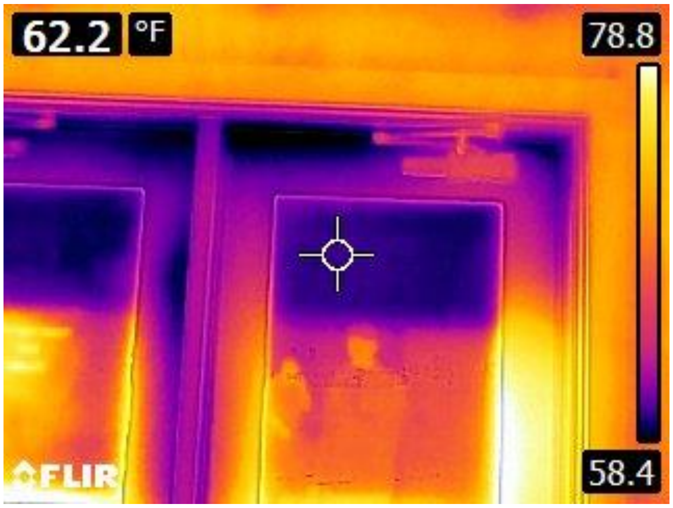
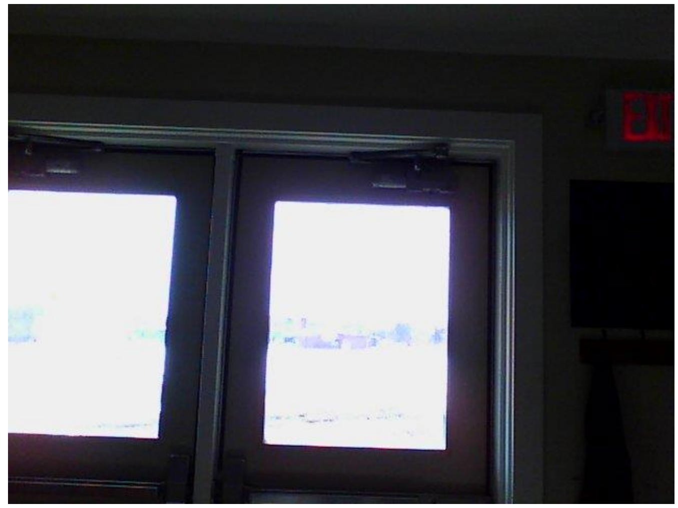
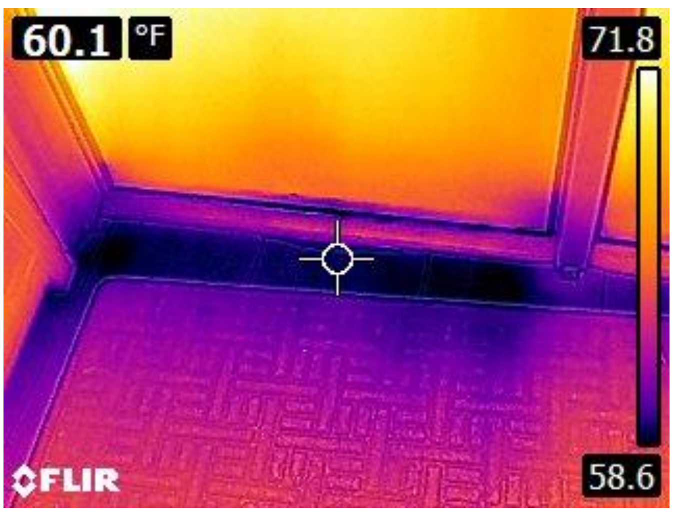


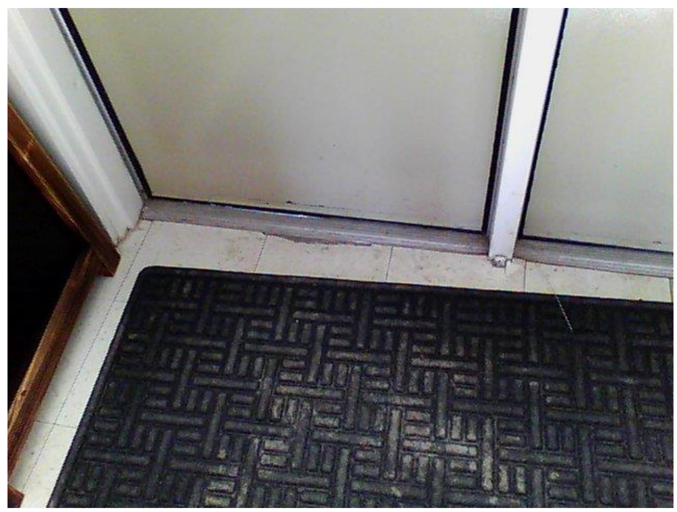
Air leakage at the head and jambs of the double doors on the south wall. Similar results were found at the double doors on the north wall.



Visible light image.



Air leakage at the threshold of the double doors on the south wall. Similar results were found at the double doors on the north wall.



Visible light image.

Measure	Oil Saved (Gal)	Oil Saved ($)	Approx. Cost of Measure	Lifecycle (Years)	Simple Payback (Years)	SIR
ECM #3 - Door Improvements	6	$13	$375	20	28.1	0.7

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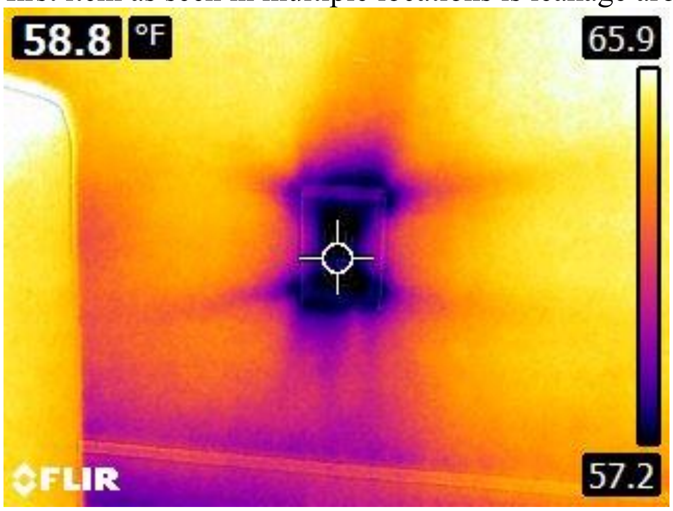
Phone: 802. 522. 9713
Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

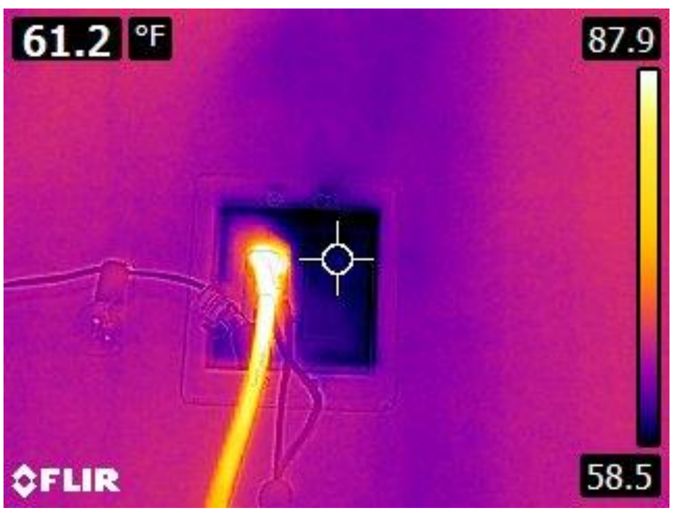
5. ECM#4 – Miscellaneous Air Leakage

While the bulk of the air leakage found has been identified between a few large sources, there were also some smaller items that, cumulatively, can have a positive impact on the buildings total air leakage. The first item as seen in multiple locations is leakage around electrical outlets on exterior walls.

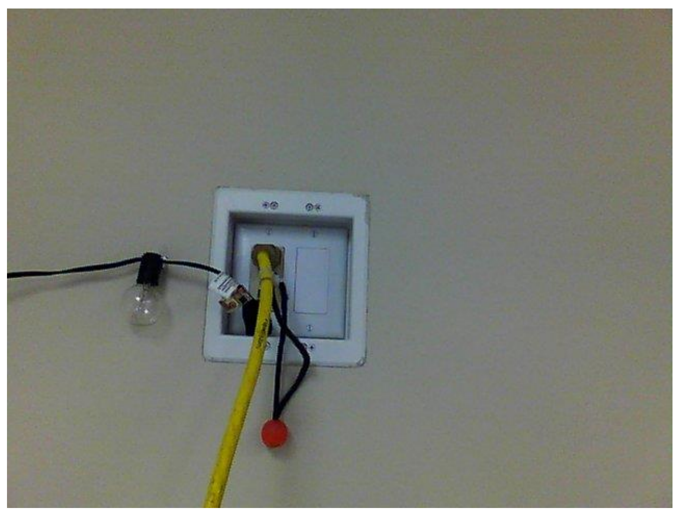


Air leakage through an electrical outlet on the west exterior wall.

Visible light image.



Air leakage through an electrical outlet on the south exterior wall of the open space room.



Visible light image.

The wall outlets can be addressed the same way as sealing the ceiling outlets were instructed;

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1. Kill power to the switch/outlet
2. Remove the escutcheon cover and pull the switch/outlet (leave wiring attached)
3. Caulk the electrical box to the sheetrock
4. Caulk seal open punch outs in the box
5. Seal the location(s) where the wiring enters the box with wiring compatible duct putty or caulk
6. Replace the escutcheon cover.

Another miscellaneous source of air leakage was identified in the boiler room. A short line of ductwork that appears to be the combustion make-up air for the furnace, penetrates through the north exterior wall of the boiler room and is open ended on the interior side. When the building was depressurized, large amounts of cold outdoor air was pulled through this ductwork into the open space of the boiler room. This indicates that the ductwork is in fact connected to the outdoors and that it also does not have a working damper, if one at all. If combustion make-up air is not necessary for the furnace and serves no other purpose, we recommend removing the ductwork and sealing the off the hole left from the penetration. If this ductwork is being used to draw in necessary combustion make-up air, then it is important that it remains, but some modifications may be possible. One possible solution to eliminating the unwanted air infiltration and leakage through the ductwork when the combustion air is not needed is to run the ductwork directly to the burner. Ask the boiler service company if an outside combustion air boot can be retrofit directly to the burner. This significantly reduces the possibility of back draft and would allow for a rather significant hole in the wall, namely the combustion air intake, to be generally closed off from the rest of the building. An alternative option may be to install a damper in the ductwork that would close off the "hole" through the exterior wall when the burner doesn't immediately need the make-up air. An HVAC specialist should be consulted before implementing any of these possible retrofits to ensure that they won't conflict with the operation and safety of the furnace system.

Air leakage through what is believed to be the combustion make up air ductwork in the boiler room.

Visible light image.

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Phone: 802. 522. 9713

Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

Measure	Oil Saved (Gal)	Oil Saved ($)	Approx. Cost of Measure	Lifecycle (Years)	Simple Payback (Years)	SIR
ECM #4 – Miscellaneous Air Leakage	11	$23	$1,000	20	43.4	0.5

Additional Envelope Comments

The following items are things we identified on site as having opportunity for improvement, but have not been incorporated into any specific energy modeling scenario.

Durability Concerns

Aside from energy savings opportunities, we also look for general durability concerns as it relates to the building envelope. A durability concern applies to either an isolated or broad part of the building that is currently prone to damage or prone to potential future damage. Through visual inspection, we have found a couple of durability concerns with the Teen Center that we believe are worth addressing at some point in the future. Both of these issues were found on the exterior of the building.

1. The first concern is the window units which are rotting at the wood frame, as briefly mentioned above in ECM #2. These wood framed windows have been exposed to considerable amounts of water and moisture over time resulting in areas of rot and deterioration. The areas of rot seem to be at the sill and other horizontal members that may be acting as a shelf for water to sit on for extended periods of time.

287 Fairview Sq., Fairlee VT 05045
Phone: 802. 522. 9713
Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

Seen here is a section of rotten wood and damaged EIFS at the north west corner of the building.

Wood rot at the frame of a window sill.

Horizontal surfaces which are not rotted are at risk for future rot where paint is peeling or missing.

These areas that have already started to experience varying degrees of rot will only get worse and could potentially lead to new moisture related problems in the surrounding wall assembly if not

287 Fairview Sq., Fairlee VT 05045
Phone: 802. 522. 9713
Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

addressed. Where window frames are already comprised by rot, we recommend consideration be given to total window replacement. This is being recommended primarily for durability reasons rather than energy, but considering both, keep the following things in mind:

1. Consider installing single hung units so the top sash is sealed in place. This reduces air leakage overall and makes them easier to close and latch.
2. Specify that new windows are to be foam sealed into the rough opening or to the original frame to make an airtight connection to the wall.
3. Buy windows with low conduction frames like fiberglass and warm edge spacers between the glazing. Fiberglass frames are also much more durable and water-resistant. Vinyl frames are water-resistant as well but are less durable long term and of a lesser quality. Aluminum is also an option, but they have a lower R-value, even with thermally broken frames which we recommend.
4. Get as high an R-value and as low a U-value as possible. New windows with suspended films can perform on par with triple pane windows at a much lower weight. Target R4 (U=0.25) or better. Where windows are being completely replaced, we recommend investing in these higher R-value windows, but in lieu of putting an interior storms behind it as recommended in ECM#2.
5. Finally, identify any windows that are no longer in use or aren't necessary and infill them with insulated wall. We suspect there aren't any, but like to mention this as a consideration.

2. The second durability concern is around the exterior of the foundation at the XPS insulation and stucco finish. In areas where this system is present, damage to both the stucco and insulation is present in varying degrees. Some areas look ok while others have chunks of insulation exposed or missing. We suspect much of this damage is from surrounding outdoor work and typical wear and tear that public buildings suffer from. These areas where the XPS is damaged and/or missing decrease the foundations R-value. We recommend replacing the sections of the damaged stucco and insulation. You can also get protective coated XPS that can be attached with masonry anchors for a higher price but a faster install. Of course, this may not match with the rest of the existing insulation.

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Phone: 802. 522. 9713
Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

This image shows the damaged EIFS at the foundation on the north elevation. Seen here is exposed, damaged, and missing XPS (blue material.)

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Web: www.zerobydegrees.com
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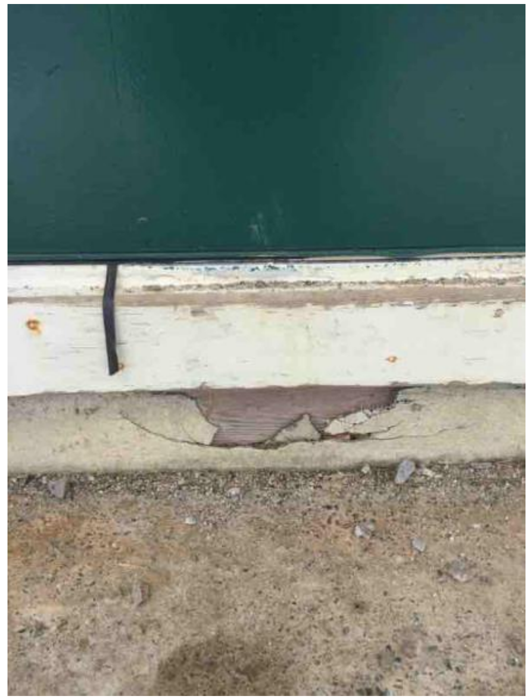

Damage to the stucco under the door on the east elevation.

3. There are several areas where the bottom of the board and batten siding and other wood sections are rotted as a result of over exposure to water and lack of drying. This rot is primarily on the south side. Despite large overhangs, we suspect the cladding is subject to some degree of back splash on this south end, especially where pavement exists. The surrounding land is generally flat, but with snow on the ground it was difficult to assess how well graded the land is around the building to divert water away from it. If snow build up, or rain/melt run-off is diverted toward the building, then the water level could rise just high enough to make some prolonged contact with the cladding, which extends quite low to the ground on some elevations. The south is one example, where there is also less ability for water to drain due to the paved walkway. While elevations other than the south are not without some cladding concerns, the cladding overall *is* in better condition, which we believe is largely due to the ¾" drainage stone reducing splashback and facilitating drainage. The one exception is locations where the cladding comes in contact directly with the stone, such as near the southwest building corner. Lastly, we noted that there was no evidence that any of the boards had been primed before they were painted, which increases risk of water absorption and premature rot.

   First we suggest installing a gutter system on the south facing roof that spans the length of the eave and diverts drain water in the downspout well away from the building. This should reduce splashback that is otherwise currently occurring on the pavement. Then, identify all warped or

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Phone: 802. 522. 9713
Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

rotted cladding around the building, and replace it. You can use the photos below as a benchmark for determining what should be replaced. It is important that the cladding be primed on all sides, especially the bottom edge at the end-grain. This is the end of the wood which is most absorbent and also most subjected to the most moisture.

This is the section of the board and batten siding on the south elevation that has experienced rot damage due to how close it its to the pavement walkway.

287 Fairview Sq., Fairlee VT 05045
Phone: 802. 522. 9713
Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

Moisture damage at the bottom of the siding on the south elevation. Note that even though there is drainage stone here, because the siding is touching the stone it is able to absorb the water.

Moisture damage at the bottom of the siding on the south elevation over the pavement.

4. Lastly, the building is simply in need of scraping and painting. Aside from where rot is already occurring. Much of the paint is starting to peel. Spot priming and repainting will add longevity to the finishes of the building which are still in decent condition.

Lighting

Because the occupancy and overall lighting load for the building is relatively low, we do not have any major lighting overhaul recommendations. Most of the building's lighting is already either fluorescent, CFL, or LED bulbs. There were very few incandescent bulbs. Any fluorescent or CFL bulbs which operate, say, more than 6 or 7 hours per day may warrant immediate conversion to LED, but otherwise simply convert non-LED bulbs and ballasts (if applicable) to LED as bulbs burn out.

287 Fairview Sq., Fairlee VT 05045
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Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

Existing Energy Use

Below is a summary of the energy use for the building in recent years. When possible, the total loads are divided into base load (energy loads that are consistent month to month) and seasonal load (energy loads that vary seasonally). The designation "N/A" indicates data that was not made available for this study.

Energy Use Summary for Dent Home							
Energy type	Unit	Total 2015	Total 2016	Total 2017	Average	Annual Base load	Annual Seasonal load
Electricity	kWh	7,331	7,261	5,467	6,686.3	3,296	3,390
Heating Oil	Gallons	622.7	572.2	696.8	630.6	N/A	N/A

Energy Intensity Benchmarks				
Building Name	Floor Area sq. ft.	Electricity kWh/sf	Heat Energy kBTU/sf	Total Energy kBTU/sf
Middlebury Teen Center	1,615	4.1	0.4	54.2
Similar TYPE Buildings in NE		14.1	0.11	15.3
Similar SIZE buildings in NE		15	0.27	37.5

This chart is showing that heating and electrical consumption is better than average compared to other buildings in the Northeast of similar type and size. This is partly attributable to the building being on the small side and the infrequent use of the building. The building has some regular "open" hours, but of the total hours in a week it isn't very many. That being said, there are still a couple of significant opportunities available, of which are outlined in the report above.

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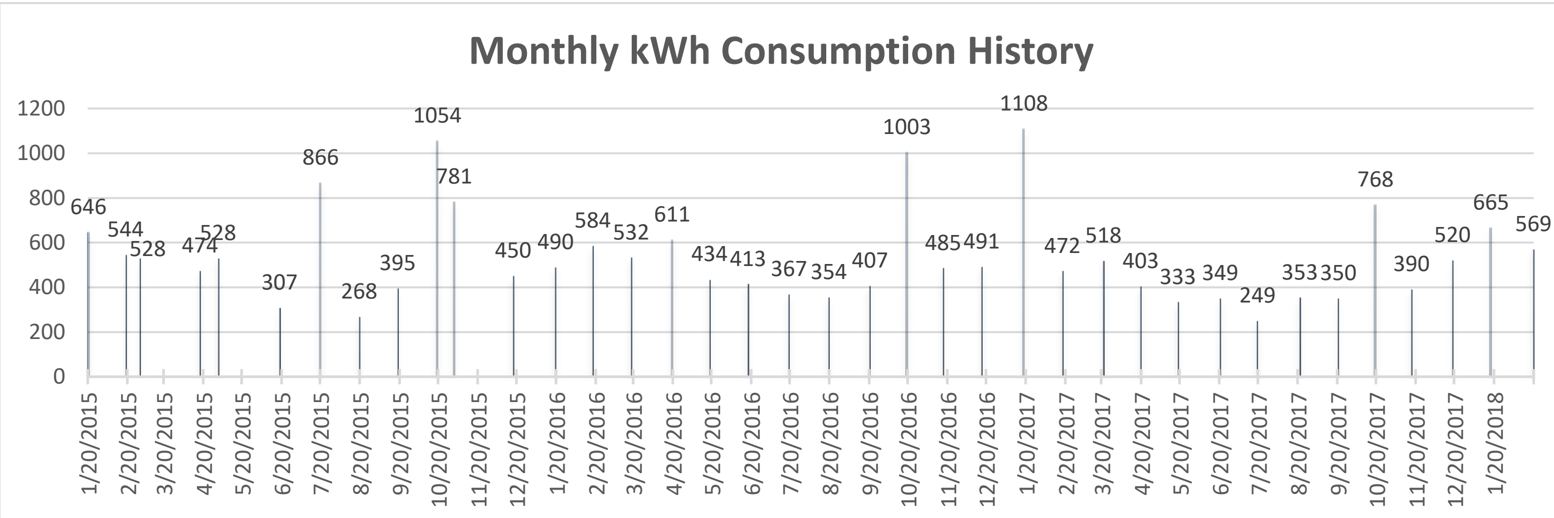
Electricity Consumption



The table above summarizes the building's electrical consumption by month over the past 3 years, given the consumption data provided to us. Generally speaking, there is a smooth pattern of usage with most months repeating consistently the next year. We've noted that the months of October tend to have consistent high spikes in usage. We understand that the ball field lights are connected to the same meter as the Teen Center and that they are used only in the fall months. Typical flood lights often contain high wattage lamps and so we suspect these consistent October spikes correlate with the usage of those ball field lights. The only other two anomalies fall on January of 2017 and July of 2015. Without further information it is difficult to say what may have caused these unique spikes, but it could simply be a matter of an appliance or high wattage lighting system that was left on for long periods of time, either intentionally or accidentally.

287 Fairview Sq., Fairlee VT 05045
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Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

Combustion Testing

The table below summarizes the testing on the boiler appliance. Cells in red indicate carbon monoxide (CO) levels above BPI limits for that appliance which is an indicator of incomplete combustion and a possible health risk if the flue is not properly drafting.
CAZ- *combustion appliance zone, the area where a combustion appliance is and where pressure readings are taken to determine if conditions for back drafting may occur.*
Worst case – *turning on all fans and appliances that can make the building negatively pressurized to see if the potential for back drafting exists.*
ppm*- parts per million, the unit of measurement for gases like carbon monoxide.*
Pascals*- the SI unit for pressure.*

Combustion Testing- Furnace #1, Oil		
Baseline CAZ pressure	2.0	Pascals
Worst case CAZ pressure	2.0	Pascals
Worst Case Spillage	Pass	
Steady State Stack Temperature	399	˚ F
Steady State Efficiency	84.7	%
Flue CO	18	ppm
Outside temp	48	˚ F
Minimum Acceptable draft	-1.55	Pascals
Draft	N/A	Pascals
Ambient CO	0	ppm

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Phone: 802. 522. 9713
Web: www.zerobydegrees.com
Email: zerobydegrees@gmail.com

Building Ventilation

The table below is a summary of the calculations to determine the minimum ventilation required for the building compared to the ventilation rate determined by blower door testing. Based on our testing, the Teen Center is sufficiently ventilated at present but may need mechanical ventilation if air tightening measures are employed on the building. According to BPI protocols air tightening beyond 1097 CFM50 will require 85 CFM continuous mechanical ventilation. Given the above scope of recommendations, reaching this level of air tightness may be attainable.

Minimum Building Airflow Standard (ASHRAE 62-89)		
Conditioned space floor area	1,614	square feet
Excluded areas	none	
Total conditioned volume	14,526	cubic feet
# of regular occupants	4	people*
# of stories above grade	1	stories
Zone and Location	2	Middlebury, VT
N- factor and Adj. N- factor	18.5	18.5
Required Building ventilation	85	CFM
Required Occupant ventilation	60	CFM
Minimum airflow standard	1568	CFM50
Blower door test result	2212	CFM50
Minimum airflow standard met?		Yes

**Realistically the building sees a fluctuation in the number of occupants within it. We assumed an average of 4 people at any given time.*

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Web: www.zerobydegrees.com
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Blower Door Test Results

Ambient conditions 3-27-18:
Outside temperature: 42 °F
Inside temperature: 69°F
Wind conditions: 10-15 mph gusts
Time of day: 11:00 am

Notes:

1. All interior doors were open.
2. All exterior doors and windows were closed and latched.
3. All HVAC systems where shut down.

Results:

The house had an air leakage rate of 0.68 cubic feet per minute per square foot of above grade surface area (CFM) at 50 Pascals. Most buildings in the United States are tested at 50 Pascals (0.2" w.c. or 1.04 lbs./sq. ft) pressure as a means of comparison. 50 Pascals is about 5 times the pressure a building might experience on a cold winter day.

CFM @ 50Pa.	Square Feet of Building Shell	CFM50/sf of shell	Cubic Feet of Volume	Air Changes per Hour @50
2,212	3,251	0.68	14,526	9.14

Air Leakage Comparison to Other Buildings:

Building	Air Leakage Rate (CFM50/sf of exposed shell)
Middlebury Teen Center	**0.68**
Ultra tight construction	<0.10
High performance construction	<0.25
Typical modern construction	0.60 to 0.90
Leaky construction	> 0.60

These air leakage numbers indicate that, compared to most buildings, the Teen Center falls into what is considered typical modern leaky construction. With the measures described above we believe we can reduce the overall air leakage by about 40% or to 1,327 CFM50.

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Web: www.zerobydegrees.com
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