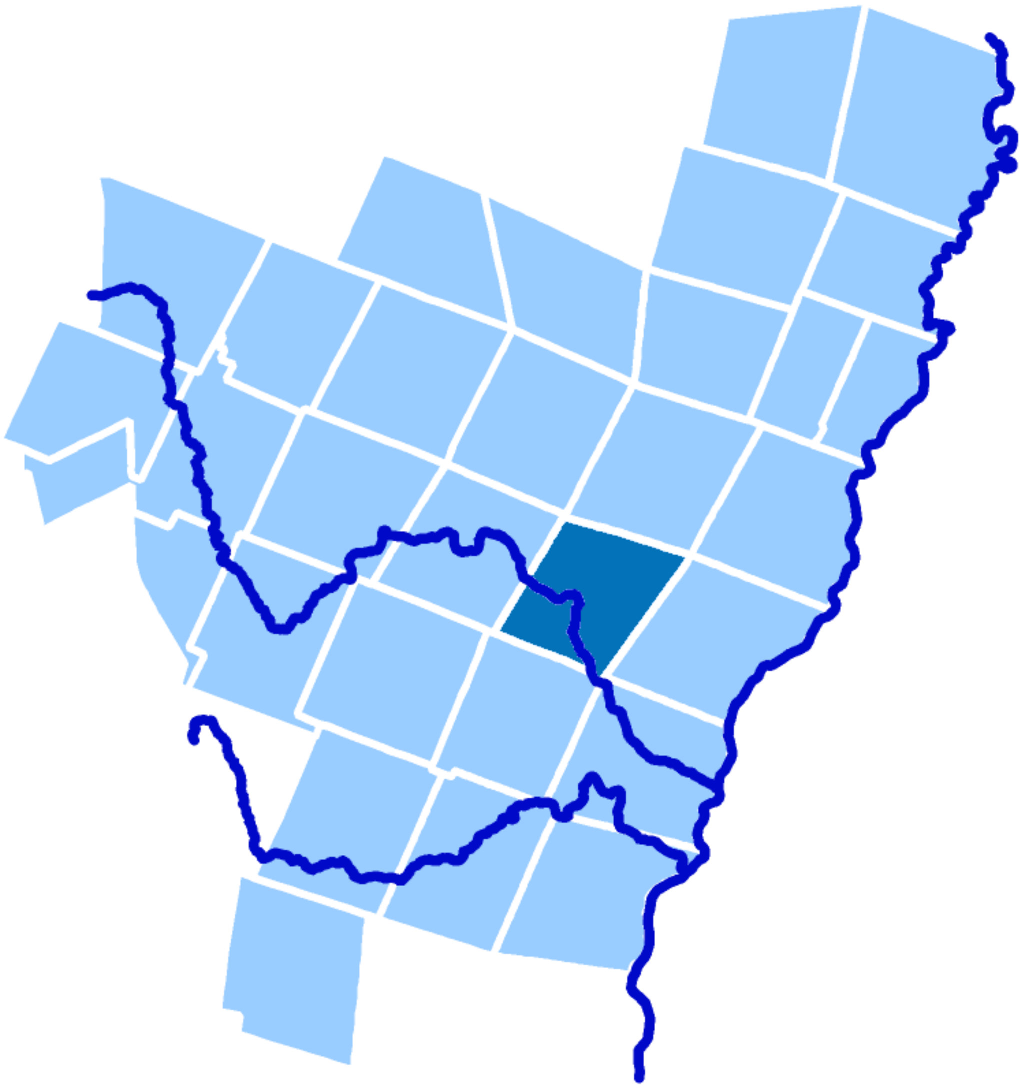
Two Rivers-Ottauquechee Regional Commission



Baxter Library

Building Energy Plan

Provided for the Town of Sharon by the Two Rivers-Ottauquechee Regional Commission's Energy Efficiency and Conservation Program.
Funded through a grant from the US Department of Energy.

This Building Energy Plan was provided for your community at no charge with help from an Energy Efficiency and Conservation Block Grant through the US Department of Energy.

For Questions about the Two Rivers Ottauquechee Energy Efficiency and Conservation Program, please contact:

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Building Energy Plan

December 20, 2012

To: Sharon Selectboard and Mr. Chris Sargent, TRORC
From: Jon Haehnel, Zero by Degrees LLC

RE: Energy Audit Conducted November 16&28, 2012 on the Baxter Library.

Thank you for inviting Zero by Degrees LLC to help with your building energy needs. The following report presents our findings and recommendations from our diagnostic visit(s). It is our hope that this report can be the basis for a long term energy plan for the building.

Purpose

To identify potential building retrofits and operational practices to reduce energy use.

Executive Summary

The library is used only a few hours each week and is being operated as efficiently as possible. The thermostat is set to 50 F or turned off when unoccupied. All lighting, computers, and printers are turned off when unoccupied and most lights have been replaced with CFL bulbs. Hot water is provided on demand so there are no standby losses. This is excellent news except that it makes finding additional energy saving opportunities harder to find, especially electricity savings. There are cost effective opportunities in the poorly insulated ceiling, leaky windows, and old furnace. The walls, though uninsulated, do not have much opportunity because there is not access to improve them. The most intriguing opportunity on the library is to consider switching heating systems to an air source heat pump which could save money today and could eventually be powered by a solar photovoltaic system.

Summary of Analyzed Measures

Measure	Total Savings	Approx. Cost of Measure	Possible Rebate	Cost with Rebate	Lifecycle (Years)	Simple Payback (Years)	SIR
O&M #1 - Close basement duct	$71	$1	$0	$1	30	0.0	2129.9
ECM #1 - Insulate Attic	$217	$2,718	$263	$2,455	30	11.3	2.7
ECM #2 - Improve Windows	$198	$3,071	$500	$2,571	15	13.0	1.2
ECM #3 - Electrical Upgrades	$17	$307	$0	$307	15	18.5	0.8
ECM #4 - Improve doors	$35	$700	$0	$700	20	19.9	1.0
ECM #5a - Upgrade Heating System*	$443	$8,500	$338	$8,162	25	18.4	1.4
ECM #5b - Change Heating System*	$1,130	$7,000	$320	$6,680	15	5.9	2.5

O&M - Operation & Maintenance measure
ECM - Energy Conservation Measure
Simple Payback – The number of years the energy improvement will take to pay back the investment.

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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.

** ECM# 5a and 5b are not cumulative savings they are mutually exclusive choices, explained further below.*

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. 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.
3. 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.
4. 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 this part of the imaging.
5. 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.
6. I used $0.145/kWh peak and $3.88/gallon of oil to predict cost savings. Energy prices are volatile and difficult to predict year to year but the long term trend is that energy prices will continue to rise.
7. Rebates, incentives, and tax credits may change or have termination dates. Verify that the suggested rebates/credits in this report are still in effect and look for additional programs that may have come into effect at http://www.dsireusa.org/ and http://www.efficiencyvermont.org/pages/

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when you are ready to implement your energy conservation measures. Lighting, motors, heating, cooling, and ventilation system rebates may be applied for directly through Efficiency Vermont's website http://www.efficiencyvermont.com/pages/. Insulation and air sealing rebates through Efficiency Vermont may require that the work be done through a Certified Home Performance with Energy Star contractor and that all health and safety recommendations be completed in order to qualify for the rebate.

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. There are no carbon monoxide (CO) detectors in the building. At least 1 should be installed on the main floor and in the basement.
2. Have the furnace tuned to reduce CO levels (See "Combustion Testing" below).
3. The present natural ventilation is sufficient for the building and the occupants (see "Building Ventilation" below). Continuous mechanical ventilation of 61 CFM may be required for proper ventilation of the building if the building air tightness is significantly improved. While developing the work scope for envelope improvements consult with a home performance contractor to determine the best way to get the required ventilation.
4. The return air duct in the basement is rusted out and the hole needs to be fixed.

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 – Close Basement Duct

This duct is providing warm air to the unused basement and it could easily be dampered shut.

There is one duct dedicated to the basement that probably does not need to be. Given that the foundation walls are mostly below grade this basement probably stays around 55 degrees even on the coldest winter days. In addition, the basement gains radiant heat energy from the furnace and ductwork itself. This duct has an in line damper that can be closed and it should be done immediately. Over time you may find that duct is not needed so it can be removed and capped permanently. The only reason to keep it long term is to provide heat to the basement in the unlikely event that the fallout shelter has to be used. Even then, with many people down there heating will not be the prime concern.

Oil Saved (Gal)	Oil Saved ($)	Elec. Saved (kWh)	Elec. Saved ($)	Total Savings	Approx. Cost of Measure	Possible Rebate	Cost with Rebate	Lifecycle (Years)	Simple Payback (Years)	SIR
17	$65	39	$6	$71	$1	$0	$1	30	0.0	2129.9

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2. ECM#1 - Insulate Attic

a.

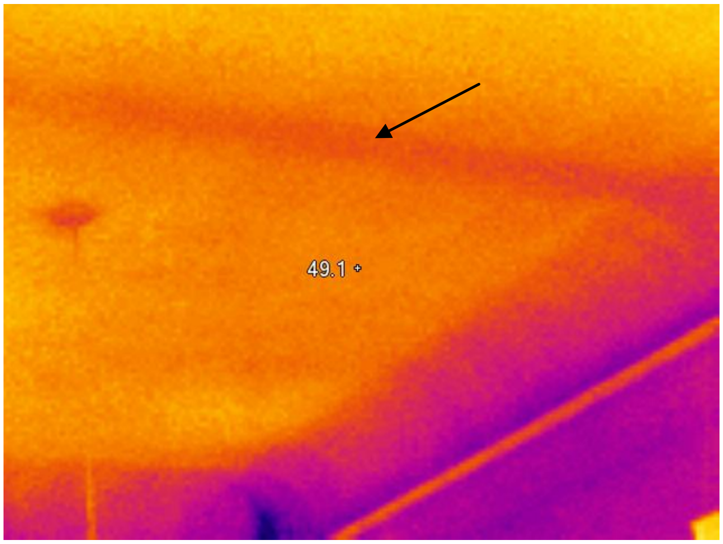
The attic has a single layer of R19 fiberglass that is probalay performing at a level of R15 or less because it has been packed down.

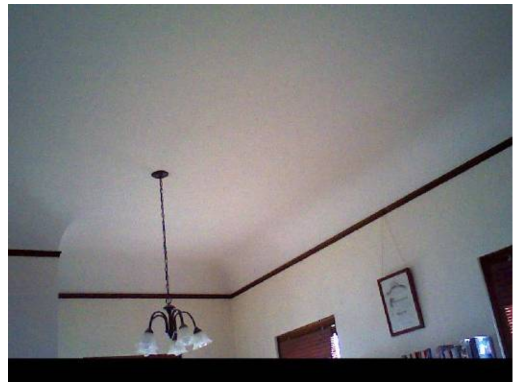
Looking under the fiberglass there is “step” wall that needs rigid insulation attached to it.

b.

Under the fiberglass there is a layer of fiberboard that covers the framing space over the plaster ceiling. Ideally the insulation would be in contact with the plaster ceiling.

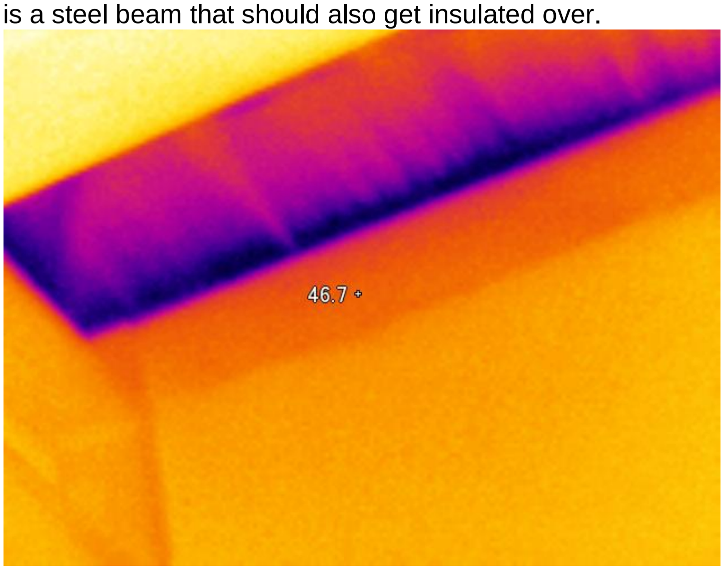
Looking at the attic hatch it needs a layer of insulation affixed to it. Note also another step wall, this one has no insulation.





Visible Light Image

c. IR014172.IS2
11/28/2012 12:01:31 PM
The plaster ceiling gets cooler as it curves down to meet the wall. Cellulose should be blown in from above at the ceiling perimeter so it will fill that curved space. The line indicated is a steel beam that should also get insulated over.



Visible Light Image

d. IR014198.IS2
11/28/2012 12:05:37 PM
The attic hatch from below with cold air streaming by it.

The images detail the state of the attic insulation, in a phase, it needs more. The existing fiberglass is in decent shape and most of it can remain in place as long as it remains flat. Below the fiberboard there is a framing space for the plaster ceiling. Ideally the fiberboard would be removed so new insulation could

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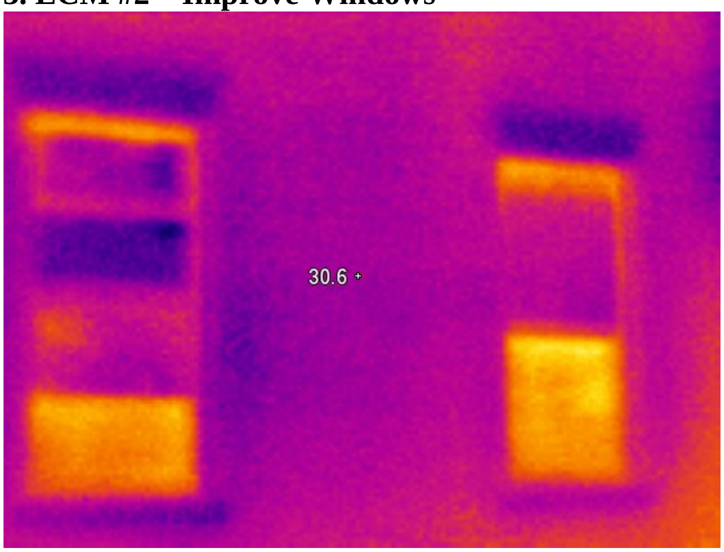
be in direct contact with the whole plaster ceiling but this would make the project cost more for a minimal gain in performance. As a compromise, the fiberboard should be removed at the ceiling perimeter so new cellulose insulation can be blown all the way down to the plaster ceiling at the perimeter of the attic. After that, blow another 10" to 12" layer of cellulose over the top of the existing fiberglass making sure the fiberglass is completely flat at the time.

Before installing cellulose glue 2" rigid polyisocyanurate foam board (Dow Tuff-R) to the masonry step walls in the attic.

Finally, Weather-strip the hatch so it seals tightly to the trim when closed. The attic hatch needs 6" of rigid polyisocyanurate insulation glued to it. Use wide foil tape to cover and protect the edges of the insulation.

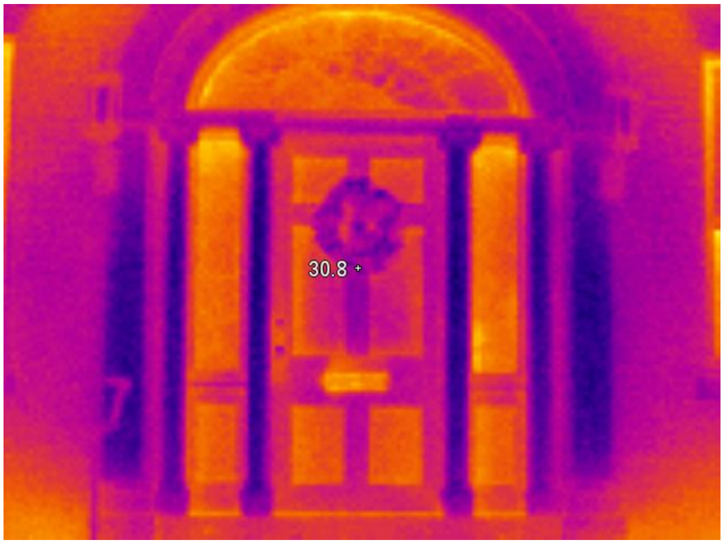
Oil Saved (Gal)	Oil Saved ($)	Elec. Saved (kWh)	Elec. Saved ($)	Total Savings	Approx. Cost of Measure	Possible Rebate	Cost with Rebate	Lifecycle (Years)	Simple Payback (Years)	SIR
52	$200	112	$17	$217	$2,718	$263	$2,455	30	11.3	2.7

3. ECM #2 – Improve Windows



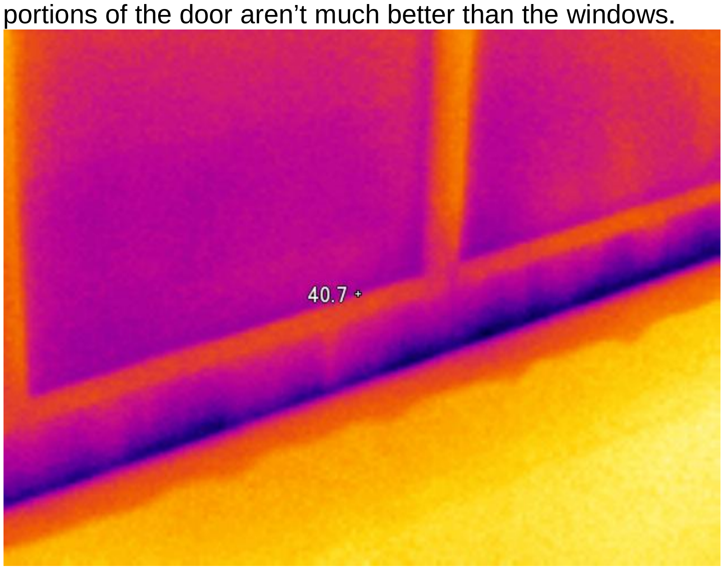
a. IR014152.IS2
11/28/2012 11:52:48 AM
Most of the storm windows have not been closed for winter yet. Note the difference in heat loss where the storm is partially closed.

Visible Light Image



Visible Light Image

b. IR014159.IS2
11/28/2012 11:53:42 AM
The windows above and to the sides of this door are single pane windows with no storms. Note also that the wood portions of the door aren't much better than the windows.



Visible Light Image

c. IR014193.IS2
11/28/2012 12:04:35 PM
The air sweeping up under this window sash is typical of all the windows even with the storms closed.

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d.
This window needs to have the broken pane replaced.

The windows are single pane wood framed windows with exterior aluminum framed storm windows. The exterior storms do not add much in terms of air tightness but when closed they double the R-value of the window. Close all the storm windows every fall.

All of the windows, with and without storm windows down, are air leaky at all sides of each sash. Make the upper sash a fixed sash and caulk it in place with clear silicone caulk. Weather strip the lower sash and the storm windows based on the recommendations below*:

1. Window sashes can be sealed at top, bottom and edges by installing v-shaped weather-strip. Top and bottom weather-strip can be installed on the window casing where the top and bottom sash close, with sash in place. To install side weather-strip, remove the window stops from one side of the sash, remove the sash, install v-shaped weather-strip on the window jamb with point of weather-strip pointing in and replace the sash. If sash is too tight to fit with new weather-strip, you will need to trim off a very small amount from one of the sash edges, leaving sash wide enough that they press out against and compress the weather-strip. Vinyl v-weather-strip is available from most building supply warehouses. Much longer lasting bronze v-strip is available from Architectural Resource Center: http://www.aresource.com/cushion.html#start
2. If you can shake the sashes and they rattle, you can tighten the window latches that pull the sashes together by removing the inner portion of the closing mechanism, filling old screw holes with wooden match sticks or slivers of wood, replace the latch, drilling new holes further away from the outer part of the latch so it pulls the two sashes tightly together.
3. If you have an old sash with ropes, pulleys and counterweights, remove the inside trim piece covering the counterweight cavity on each side of window. Cut the counterweight cord and remove the counterweights (make sure sashes are latched so they do not drop when removing counterweights). Remove window stops from one side and remove the sash. (This is a good time

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to install v-shaped weather-strip at sides – see above.) Remove cording attached to the sash and remove pulleys from window jambs. If you do not need to retain opening capability of outer/upper sash, reinstall it, temporarily screwing the sash in place and caulk at edges. If you want to keep the sash operable, replace old counterweigh pulleys with "Pullman Window Counterbalance" (available at: 585-334-1350, http://pullmanbalances.com/) and attach counterweight spring to the sash and replace. Then fill the counterweight cavity with polyisocyanurate foam insulation board, slightly undercut around the outside and air seal edges of foam board with minimal-expanding spray foam.

4. Caulk the edges of exterior storm windows to the trim with high quality exterior grade acrylic latex caulk with silicone – make sure not to caulk over the round weep holes at the bottom of the storm panel that drain out condensation.
5. If any of the storm windows do not close tightly, leaving a gap in opposing corners when closed, you will need to loosen three sides of the storm window frame from the trim outside, square it up so it closes properly and reattach with caulk and screws.

* Source: Green Energy Times - Fall 2010

The instructions above for improving the windows are extensive but they could be done by reasonably skilled volunteers especially with guidance from a carpenter. I allowed $800 to set and caulk the upper sash and improve the lower sash and storm windows of all the windows. This will easily cover materials but would be too low to have it professionally done.

Either before or after the windows have been tightened I further recommend installing interior storm windows on all windows including the top and side windows at the front entrance. Interior storm windows cost much less than a replacement window and will not harm the historical natural of the original window. 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.

I carried the cost for Advanced Energy Panels, an interior storm window made in Orford, NH. These windows are reasonably priced and have good compression fit weather-stripping. It may be more cost effective to *make* carefully fit wooden window frames sheathed in low cost window film on both sides (both types of windows shown below).

Please note that the $500 rebate attributed to this measure depends on a minimum 10% reduction in air leakage as measured by a blower door. Most of the leakage is in the windows but attic improvements and door improvements will also be necessary to meet this goal.

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An example of a homemade interior storm window.

The white frame is an Advanced Energy Panel.

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I did not run pricing for this but insulated shades would further increase the R-value of the windows during unoccupied times and serve double duty on hot summer days. Insulated shades are expensive and must get closed every winter night in order to be effective but they can add another R4 to a window.

Oil Saved (Gal)	Oil Saved ($)	Elec. Saved (kWh)	Elec. Saved ($)	Total Savings	Approx. Cost of Measure	Possible Rebate	Cost with Rebate	Lifecycle (Years)	Simple Payback (Years)	SIR
47	$183	94	$14	$198	$3,071	$500	$2,571	15	13.0	1.2

4. ECM #3 – Electrical Upgrades

This back light needs to be isolated on a separate switch.

The outside light on at 11am.

There are still a few incandescent bulbs in the library although most have been switched to CFLs. Replace immediately all incandescent bulbs that are on for several hours a day with comparable light quality CFLs or LED bulbs. CFL bulbs come in many sizes now to fit nearly any application. LED bulbs are available to replace incandescent lights up to 60 watts, respond instantaneously, and have excellent light quality. Unfortunately, LED bulbs are still expensive so I would check specific rebates on LED bulbs before purchasing. Both CFL and LED bulbs promise longer life than incandescent bulbs although quality seems to matter a great deal on this issue; I have had many CFL bulbs expire long before they were supposed to. Replace the incandescent bulbs that are rarely used when the old bulbs burn out since they not used often enough to warrant immediate replacement. Although there are no additional incentives for switching to CFL bulbs Efficiency VT has been working with retailers to provide rebates at the point of sale so the cost of the CFL bulbs is very reasonable.

There is good reason to be both excited and cautious about the LED products on the market. Many of the durability claims around CFL lights have been over stated and may also be true for the expensive LED

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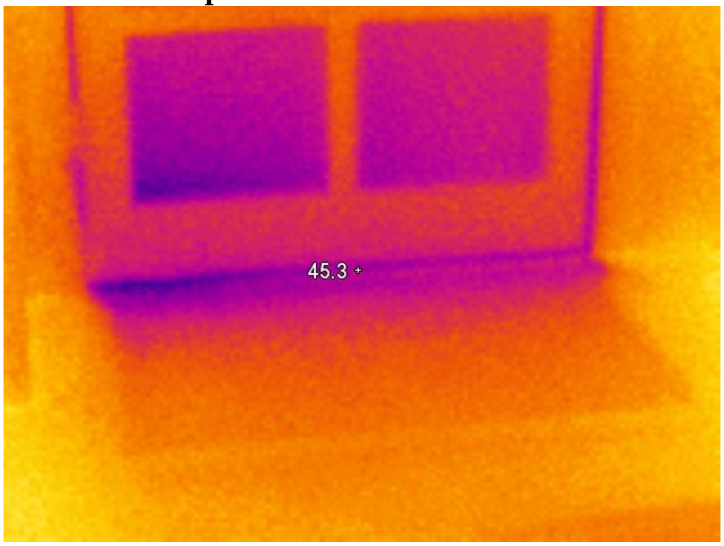
lights. Also, screw in type LED lights tend to be more focused than diffuse and may work better for task lighting then general lighting. While there are still relatively few A- type bulbs on the market (shaped like traditional light bulbs) there are more screw in PAR (flood light shaped bulbs) lights that can be used in recessed light fixtures and track lighting.

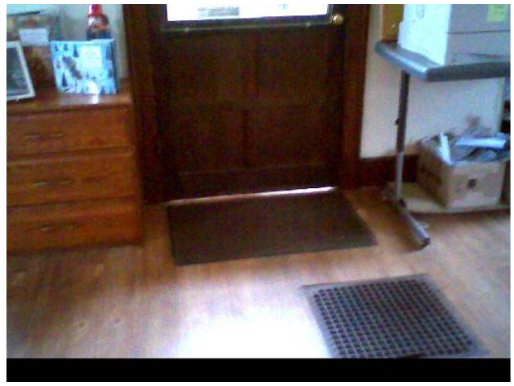
The back entrance photo sensor appears not to be working and should be easy to replace. At the same time have an electrician rewire the chandeliers in the library so the back chandelier can be switched independently from the rest. With the high number of windows the room often has enough light without the lights being on except for the back of the library. As a result the lights are all on so the back can be properly lit. A separate switch for the back light would solve this problem. Access in the attic is very good for rewiring (make this change before the insulation measure above). Unfortunately the cost of an electrician makes this relatively simple task have a long payback.

The basement lights are old T12 technology that should be replaced with Super T8 lights and low ballast factor ballasts when possible. There is very little energy savings for this action, the lights are not on very often however, T12 lights are being phased out of production so it would be good to replace them.

Oil Saved (Gal)	Oil Saved ($)	Elec. Saved (kWh)	Elec. Saved ($)	Total Savings	Approx. Cost of Measure	Possible Rebate	Cost with Rebate	Lifecycle (Years)	Simple Payback (Years)	SIR
-1	($4)	133	$20	$17	$307	$0	$307	15	18.5	0.8

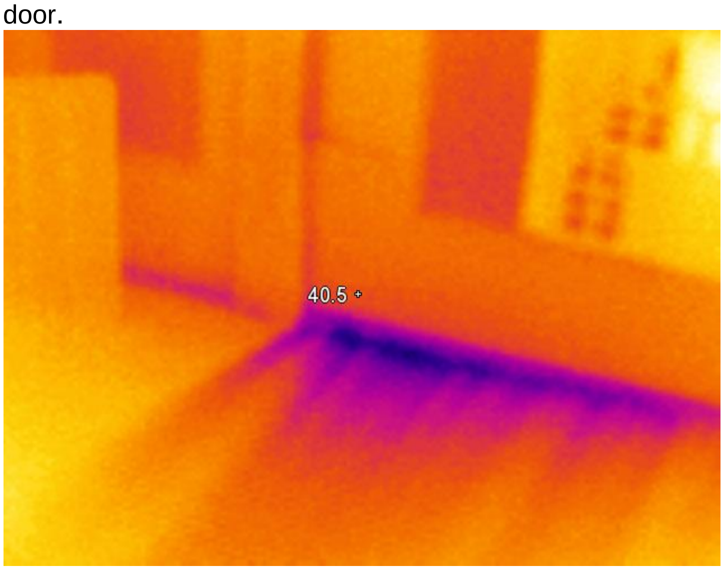
5.ECM#4 – Improve doors





Visible Light Image

a. IR014173.IS2
11/28/2012 12:01:37 PM
The interior vestibule door is a thin interior door that borders an unheated space. There is no weather-stripping on the door.



Visible Light Image

b. IR014178.IS2
11/28/2012 12:02:11 PM
The front door needs new sweeps.

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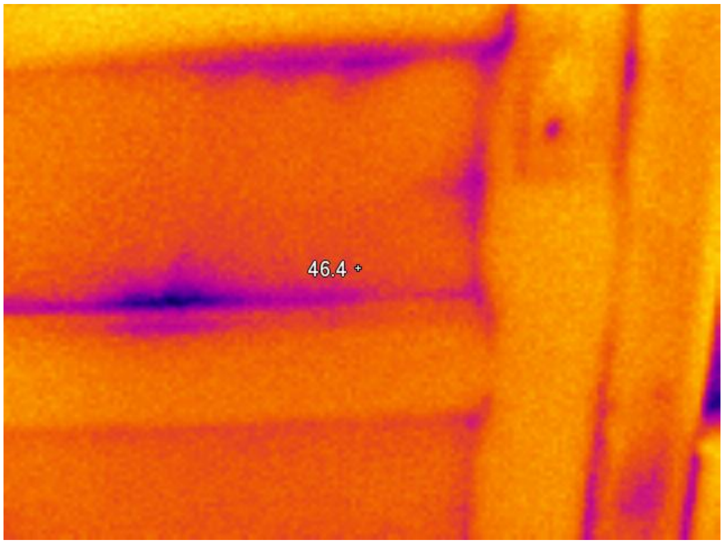

c. IR014202.IS2
11/28/2012 12:06:38 PM
The back basement door is very leaky with daylight visible in many places.

Visible Light Image

The back door is in pretty good shape but the other 2 doors need attention. Weather-strip the exterior doors at the head, jambs, and especially at the threshold with commercial grade weather-stripping (www.draftseal.com or Q-lon available through The Energy Federation (www.efi.org). When the door is closed you should not be able to see daylight light 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 on doors that are used rarely like the back basement door since it has to perform more like a wall most of the time. Consider also weather-stripping the interior door that goes to the basement that is consistently at a lower set temperature.

If the back basement door is not used most of the winter install a 2” thick sheet of rigid foam insulation between the door and the storm door. The rigid insulation should be covered with ¼” plywood painted white (or decorated in any way) to protect the foam from sunlight. This is low cost way to make the door triple in R-value.

The interior vestibule should be replaced with an insulated exterior door to separate the heated room from the cold vestibule.

Oil Saved (Gal)	Oil Saved ($)	Elec. Saved (kWh)	Elec. Saved ($)	Total Savings	Approx. Cost of Measure	Possible Rebate	Cost with Rebate	Lifecycle (Years)	Simple Payback (Years)	SIR
8	$33	16	$2	$35	$700	$0	$700	20	19.9	1.0

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6. ECM #5 – Change Heating Systems

This energy savings measure represents the largest opportunity at the library. A relatively straightforward option would be to replace the current furnace which is operating at less than its 74% measured efficiency because it runs in very short cycles. I believe it is short cycling because it is double the size it needs to be for this building so it can satisfy the thermostat with a very short run time. It has the smallest nozzle size that it is designed for so the logical step is to replace it with a modern condensing furnace. Condensing oil furnaces are rare but they have efficiencies in the 95% range. Replacing the furnace with a *smaller* condensing furnace that can run longer cycles is one way to save energy but the payback would be long because the building runs at such low temperatures.

This building has 2 characteristics that make another option possible: it is small and it has an open floor plan. The other option is an air source heat pump (ASHP). A heat pump uses electricity to extract heat content from the outside air. In this way it is able to provide more thermal energy to the building than it receives in electricity. In other words you can get 2 to 3 kWh out for every 1 kWh in. The option is to stop using the oil furnace entirely and switch to a heat pump instead. I have to emphasize that I have investigated this possibility enough to establish that a heat pump could feasibly heat this building but there is more engineering to be done that is beyond the scope of this audit to make sure this is a real fit.

Points that deserve further consideration:

1. What kind of heat pump system? A mini-split system could be installed and the furnace system could be reserved as a backup system. The small open room is a good fit for a wall mounted mini-split. Alternatively an air to water heat pump could be used with a fan coil installed in the existing ductwork but the power consumption would be slightly higher because the fan motor would be used.
2. The above listed envelope improvements should be done first to reduce the overall heat load especially for a mini-split system that would not have the advantage of ductwork to distribute heat.
3. Consider the long term potential for this site to have solar PV panels. The heat pump will consume a significant amount of electricity but at a much lower cost than and equivalent amount of heating oil so it will begin saving money from day one. However, if there were solar panels on site producing energy and “banking” it in the grid on days the library is not used or in the summer when heat is not needed the heat pump could run for almost nothing in the winter. This building could run at near zero energy!
4. One of the advantages of heat pumps is that they can both heat *and* cool a building. While this is good thing, the building presently is not cooled in the summer. Expect people to use it in cooling mode and increase the total electric bill unless that mode is specifically locked out.
5. Air source heat pumps have been around for long time but have typically been used in more temperate climates. Advancements in the technology have allowed them to work in our part of the

country and rebate structures are being discussed that I have not included in this report. I included only the standard Efficiency VT rebate for ASHPs.

6. A more typical fit for an air source heat pump is a superinsulated building which this is not nor will it be even with the above listed measures. Still, it is small so I think the option is feasible.

Note that the savings predictions below are mutually exclusive, the savings will be realized if one or the other option is chosen, not both.

Switching to condensing furnace

Oil Saved (Gal)	Oil Saved ($)	Elec. Saved (kWh)	Elec. Saved ($)	Total Savings	Approx. Cost of Measure	Possible Rebate	Cost with Rebate	Lifecycle (Years)	Simple Payback (Years)	SIR
107	$416	178	$27	$443	$8,500	$338	$8,162	25	18.4	1.4

Switching to Air source heat pump

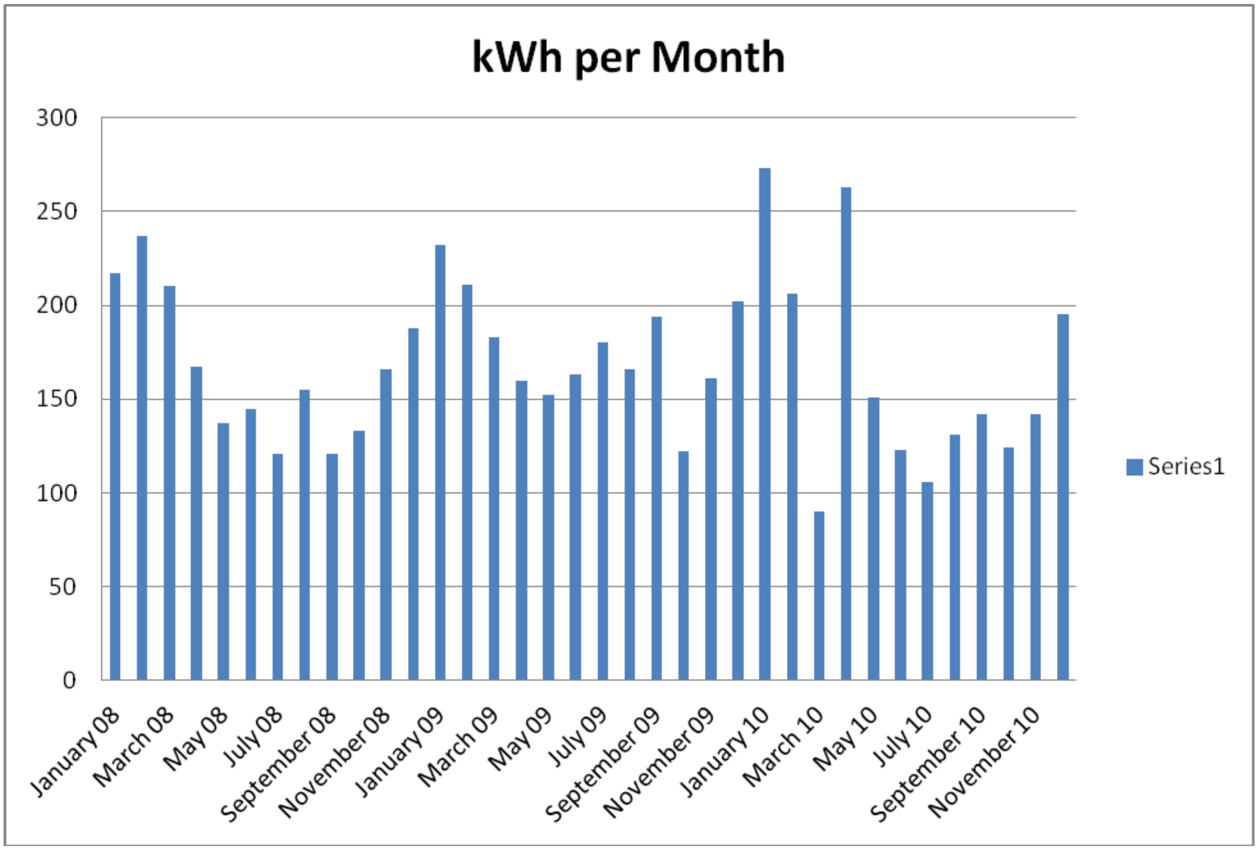
Oil Saved (Gal)	Oil Saved ($)	Elec. Saved (kWh)	Elec. Saved ($)	Total Savings	Approx. Cost of Measure	Possible Rebate	Cost with Rebate	Lifecycle (Years)	Simple Payback (Years)	SIR
479	$1,859	-4,744	($729)	$1,130	$7,000	$320	$6,680	15	5.9	2.5

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 spike seasonally). The designation “NA” indicates data that was not made available for this study.

Energy Use Summary for Baxter Memorial Library							
Energy type	Unit	Total 2008	Total 2009	Total 2010	Average	Annual Base load	Annual Seasonal load
Electricity	kWh	1997	2126	1946	2023	1456	567
Heating Oil	Gallons	626.7	NA	NA	626.7	NA	626.7

Below is the monthly electrical consumption in kWh for each month.



Power consumption follows a roughly seasonal pattern with use being highest in the winter months mostly because if the furnace. The spikes in summer are probably due to the use of a window fan for ventilation. Overall the library uses very little electricity because of the building size and schedule, about 5 kWh per day compared to the typical home which uses 20 to 25 kWh per day. This makes relatively small appliances like a window fan stand out in the monthly consumption. This also means that the opportunities to save electricity are small.

Energy intensity is energy consumption per square foot of floor area. The table below compares the energy intensity of this building with buildings of similar size and type in the North East (NE). Energy intensity per square foot of floor area does not account for differences in building volume or shell surface area so comparisons between buildings are not precise but are still useful.

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Energy Intensity Benchmarks					
Building Name	Floor Area sq. ft.	Electricity kWh/sf	Heating Oil gallons/sf	Heat Energy kBTU/sf	Total Energy kBTU/sf
Baxter Memorial Library	1750	1.2	0.36	49.7	53.7
Similar TYPE Buildings in NE		2.8	0.24	33.3	52.1
Similar SIZE buildings in NE		13.4	0.50	69.4	115.1

This table is showing that electrical consumption for this building is below average and fuel consumption is about average compared to buildings of similar type and similar size in the NE. Similar sized buildings are more like houses and see much more use than this building does. There is a conundrum with this building that shows up here and when trying to benchmark building's required ventilation. If I count only the main floor square footage the energy intensity would make the building look much worse than other buildings but if I count both floors it looks average to good. The fact is that the basement is not actively used but it *is* actively heated so it becomes hard to decide whether or not to include it.

Combustion Testing

The table below summarizes the testing on the boiler and furnaces. Cells in red indicate failure to draft, flue carbon monoxide (CO) levels above 25ppm, or ambient CO levels above normal levels. High CO levels are an indicator of incomplete combustion and a health risk. The N/A designation indicates that the test was not applicable to this combustion appliance either because the test data could not be obtained in a safe manner or testing could not be done in accordance with Building Performance Institute (BPI) protocols. The tests show that the furnace should be serviced to insure it is burning safely.

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.

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Combustion Testing- Furnace #1, Fuel #2 Oil		
Baseline CAZ pressure	-1.8	Pascals
Worst case CAZ pressure	0	Pascals
Worst Case Spillage	Passed	
Steady State Stack Temperature	597	˚ F
Steady State Efficiency	73.8	%
Flue CO	31	ppm
Outside temp	38	˚ F
Minimum Acceptable draft	-1.8	Pascals
Draft	-10	Pascals
Ambiant CO	0	ppm

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 building is sufficiently ventilated by natural ventilation now but may need more ventilation with improved air sealing. In this case the basement volume was excluded because it is not actively used. However, at the present time the basement is conditioned by one furnace supply duct which we recommend dampering off. Also, the basement is fallout shelter which may have ventilation requirements. Depending on whether the basement is included or not changes the amount of required ventilation per the BPI protocols.

Minimum Building Airflow Standard (ASHRAE 62-89)		
Conditioned space floor area	875	square feet
Excluded areas	basement	
Total conditioned volume	10500	cubic feet
# of regular occupants	4	people
# of stories above grade	1	stories
Zone and Location	2	Sharon, VT
N- factor and Adj. N- factor	19	19.0
Required Building ventilation	61	CFM
Required Occupant ventilation	60	CFM
Minimum airflow standard	1164	CFM50
Blower door test result	1451	CFM50
Minimum airflow standard met?		Yes

Blower Door Test Results

Ambient conditions 11-28-12:
Outside temperature: 37 °F
Inside temperature: 55 °F
Wind conditions: calm
Time of day: 11:30 am

Notes:

1. All interior doors were open including the door to the boiler room.
2. All exterior doors and windows were closed and latched.
3. All HVAC was turned off.

Results:
Most buildings in the United States are tested at 50 Pascals (0.2" w.c. or 1.04 lbs./sq. ft) as a means of comparison. 50 Pascals is about 5 times the pressure a building might experience on a cold winter day. Temperature adjusted CFM50 accounts for the change in air density as it is drawn in through gaps and cracks from outside and is a more accurate measure of air flow under test conditions.

Temperature adjusted CFM @ 50Pa.	Cubic feet of Building Volume	Air changes per hour @ 50Pa.	Square Feet of Building Shell	CFM50/sf of shell
1,451	17,500	4.97	2,745	0.53

Air Leakage Comparison to Other Buildings:

Building	**Air Leakage Rate (CFM50/sf of exposed shell)**
Ultra tight construction	<0.10
High performance construction	<0.25
Typical existing construction	0.60 to 0.90
Typical new construction	0.40 to 0.80
Baxter Library	**0.53**
Leaky construction	> 0.60

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