Energy Audit

January 15, 2019

Plaistow Library

85 Main Street
Plaistow, NH

Audit Prepared by

BUILDING STRATEGIES FOR AN AFFORDABLE FUTURE
S.E.E.D.S.
SUSTAINABLE ENERGY EDUCATION DEMONSTRATION SERVICES
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Introduction

The purpose of an energy audit is to identify energy saving measures (ESM) in a building. Computer simulated and other energy models were developed for this project using multiple strategies and software. The models estimate predicted future energy consumption based on the local climate conditions, physical dimensions and characteristics of a building, mechanical systems, presumed lighting, equipment, and occupancy patterns, in addition to a number of other variables.

With the building modeled in existing conditions, energy savings can be estimated for improvements to the thermal envelope. The cost of those measures can then be analyzed in terms of predicted energy saved. The primary objective is to evaluate the level of investment warranted by energy and dollars saved from those specific measures. In this case, improving the envelope is expected to have significant 'non-energy' benefits, such as improving occupant comfort and reducing, or eliminating ice dams.

This assessment has also included a study of the 1999 architectural drawings as well as previous engineering studies, a lighting retrofit spreadsheet, and energy audit by Paul Button. Engineering reports made available include those from: Advantage Engineering (2014); Castacna Consulting Group (2015?), and an HVAC retro-commissioning report in 2016.

This audit has been prepared with the best of intentions to assist the Town and Board of Trustees to make informed decisions regarding energy related improvements. It is also includes information to determine whether some measures might be eligible for weatherization rebates from Unitil.

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Executive Summary

The Plaistow Library (Library) was designed and constructed in 1999. The floor plan is remarkably well designed: providing lovely daylit areas which offer both a sense of openness and visibility as well as a sense of privacy. While it is the objective of this assessment to identify deficiencies in energy performance, the design of the floor plan is a primary feature in terms of making a public Library an inviting and pleasant place to be. Please accept the rest of this assessment within the context that, having visited dozens of NH Libraries, in my opinion, your Library is extraordinarily beautiful.

That said, occupant comfort is also a very important aspect of energy performance. Based on interviews with the Director and other staff members, the multiple engineering studies, and subsequent investments making changes to the mechanical systems, it appears that this 20 year old building still has unresolved comfort issues. It is the opinion of this assessment that a fundamental deficiency is the lack of an air barrier—or pressure plane—in contact with the thermal barrier; ie insulation. That is not to say that previous recommendations to improve the HVAC systems and controls were not warranted and that their implementation good investments! But, in our opinion, the missing piece of the puzzle has been the fact that you cannot effectively, or efficiently, control air flow and interior building pressures, without a continuous and effective air barrier between inside conditioned space and outside—which in this case includes all various unconditioned attics.

Installing sheetrock, plywood, or OSB at the ceiling, or attic floor, is now considered standard practice for code compliant, energy efficient buildings. But that has not been the case in the past. The architect's 1999 plans did specify a 'vapor barrier' stapled to the bottom of attic trusses, which in theory could be part of an air barrier system, but it has only been relatively recently that we understood the importance of specifying sealing all seams, penetrations, and the edges of the polyethylene liner to all perimeter framing. And plastic liners tend to get torn or poked over time—which is one reason that rigid materials, such as drywall, plywood, or OSB, with all seams and transitions air sealed, is now considered best practice. Another advantage of an actual OSB or plywood floor is that it can hold 16-24 inches of cellulose for a very effective insulation layer.

The vapor barrier, in the areas where it actually exists below the Library's attic trusses, is not continuous and so is not effectively stopping air flow. This results in warmed, conditioned air rising to the roof sheathing and—in some cases—melting snow which results in severe ice formations. To even greater impact, depending on whether the air handlers are creating a pressurized or depressurized building, inside air is either being 'pushed' into the attics and outside, or 'pulled' from the attics or outside into conditioned areas. During inspections above the ceiling planes in December, large volumes of blowing cold air were felt.

Because of the costs and complications involved to address this condition effectively, I asked Rich Burns of Shakes to Shingles to conduct his own site visit and develop a proposal with cost estimate. Rich confirmed my assessment and submitted a work scope (page 12) and costs (below). It should also be noted that several issues raised by previous engineering reports allude to the lack of an effective thermal barrier at the ceiling plane, though they were referred to as "insulation" issues.

Installing a rigid air barrier—to establish a pressure plane—is not inexpensive in the first costs of construction. And even in recent years in NH, it is often "value engineered" out of a project for budgetary purposes. But installing it later is considerably more costly. This is the reason for this long summary: the primary recommendation from this report is to construct a rigid barrier to establish a pressure plane in contact with improved insulation layers.

ESM with considerable 'non-energy' related benefits	Construct Pressure Barrier	Air Sealing and Insulation	Total Project
Lower Attic Package	$71,890	$29,898	$101,788.
Upper Attic Package	$12,096	$5,224	$17,320.
Break Room Package		$1,928	$1,928.
Perimeter Wall/Slab Seal		$2,346	$2,346.
Totals	$83,986	$39,398.	$123,384.

The cost for this barrier may not be easily justified by energy savings alone, but it is key to effecting a robust, durable, and continuous air barrier in contact with improved levels of insulation. And the result of all those improvements will be to save energy, operating costs, and—importantly—support the heating, ventilation and air conditioning systems to effectively provide indoor comfort.

	Cost of Measure	Annual Therms Saved	Annual kWh Saved	Energy Saved MMBtus	Dollars Saved
Envelope Upgrade	$123,384.	2,716	12,069	312.8	$5,579

The chart below attempts to break down the upgrade project into two parts: constructing the pressure boundary and additional air sealing and insulation upgrades. To be clear, these measures are recommended as a whole, single package. But it is possible that Unitil may be able to provide a weatherization rebate for the costs associated with air sealing (spray foam and other sealants) and insulation. Constructing a floor which doesn't exist falls into the 'new construction' category and rarely meets their energy savings threshold for rebates. The way the savings are calculated below may not either! But that's how important that rigid floor is.

	Cost of Measure	Savings in Therms	Savings in kWh	Energy Savings MMBtu	Annual Dollars Saved	Simple PayBack Years	Life of Measure Years	Invest-ment Gains	ROI	Annual ROI
Air Sealing and Insulation	$39,398	1494	4586	122.4	$2,679	14.71	25	$27,577	70.0%	2.2%
Install Pressure Boundary	$83,986	1222	7483	190.4	$2,900	28.96	50	$61,014	72.7%	1.1%
Totals	$123,384	2716	12069	312.8	$5,579	22.11	30	$88,591	71.8%	1.8%

The Return on Investment (ROI) is a common metric used to forecast 'profitability' on investments. The simple formula is ROI = Gain from Investment—Cost of Investment / Cost of Investment. This analysis includes Time (in years) since gains from energy savings occur every year for the life of the measure—ie the estimated number of years that the improvement remains functioning as intended. The annualized ROI is most helpful in that it offers a comparative metric, in this case—a 1.8% annual return on the $123,384 investment every year for approximately 30 years. The estimated savings is based on current energy prices. In reality, the cost of energy tends to increase over time, so the value of any improvement which conserves energy conserving will also increase in value. In other words, the annualized ROI could be expected to be higher than 1.8% every year.

But as stated before, this is not a typical Energy Saving Measure investment! Typically, 'simple payback' is within a 10 year time period. This is still the recommendation, however, to not only address comfort issues, but to enhance the value of the costs for improvements to the mechanical system over the past seven or eight years. Importantly, envelope improvements will continue to save energy after the intial investment is 'paid back.'

Other Recommendations & A Nod to Previous Assessments

It can be very frustrating for building owners to hear different opinions—sometimes conflicting—on resolving problems in a building. This report includes an attempt to identify and integrate the findings and opinions of this assessment with the most pertinent findings from previous assessments. Even if solutions may differ a little, or a lot, there is also some consensus. With respect for information from engineers, auditors, and consultants who have assessed the Library over the past 10 years, excerpts have been taken from their reports for each topic covered. In the spirit of 'not re-inventing the wheel' and 'multiple brains are better than one", information from these past efforts which are included below have either helped inform this assessment or highlight some of the strategies to improve energy performance which have consensus.

Topics include responses to specific questions asked during the site visit.

Historic Energy Use Analysis

The energy analysis below is based on average annual energy data provided for oil and electricity for the Library.

Energy & Unit	Units	Site MMBTUS	Source MMBTUS	Cost
Natural Gas - Therms	8,008	800.8	920.9	$11,357
Electric -kWh	120,690	411.8	1,371.2	$20,921
		1,212.6	2,292.1	$32,278
EUI	13,890	87.30	165.0	$2.32

The Energy Utilization Index (EUI) offers a simple snapshot analysis of a building's energy use by looking at total amount of energy input (converted to Btu's) divided by the floor area of conditioned space. "Site Energy" refers to units of energy delivered to a site. Source energy includes transmission and total raw energy the building requires.

Based on the information provided, the Library's Source EUI is 87.3 KBtu/ft2; Source Energy EUI is 165.0 KBtu/FT2. This is reltively low for a NH Library with air conditioning, which are typically intense or large energy consumers, with EUI's routinely over 90-130KBtu/FT2.

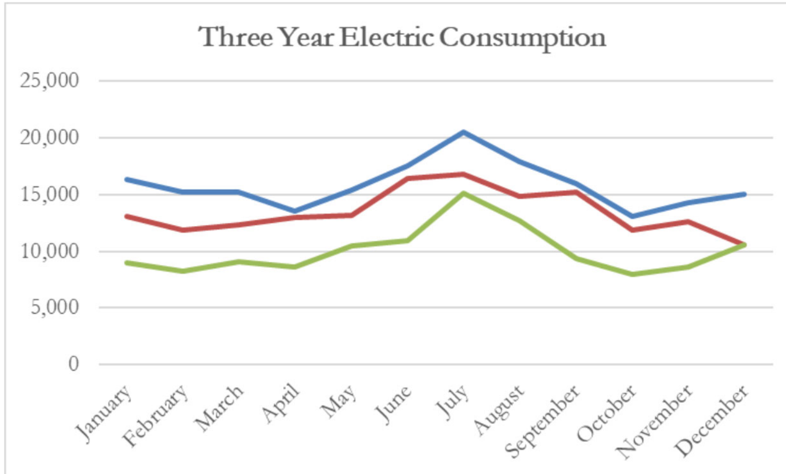
Annual energy costs could be expected to be $2.32 per sq ft in 2019 energy prices. This reflects the recent increase in gas supply costs as well as an increase in customer charges due to exceeding 8000 therms. The chart below reflects the anticipated annual energy analysis following the implementation of the envelope upgrade packages. The estimated costs reflect not only energy savings but returning to the lower customer charge for natural gas.

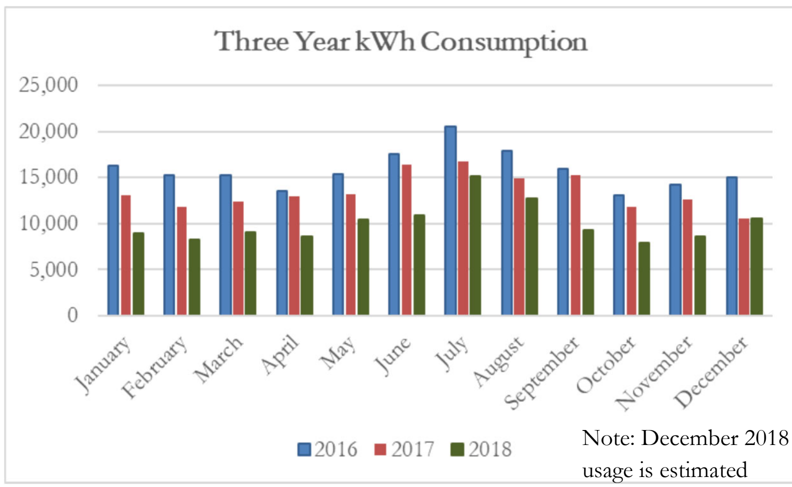
Estimated Future Analysis

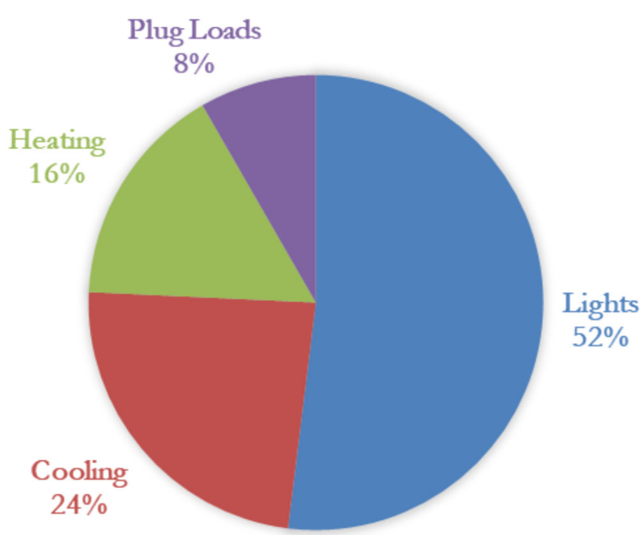
Energy & Unit	Units	Site MMBTUS	Source MMBTUS	Cost
Natural Gas - Therms	5,671	567.1	652.1	$8,912
Electric -kWh	113,070	385.8	1,284.6	$21,370
		952.9	1,936.7	$30,282
EUI	13890	68.60	139.4	$2.18

Month	2016	2017	2018
January	16,320	13,080	9,000
February	15,240	11,880	8,250
March	15,240	12,360	9,120
April	13,560	12,960	8,640
May	15,360	13,200	10,440
June	17,520	16,440	10,920
July	20,520	16,800	15,120
August	17,880	14,880	12,720
September	15,960	15,240	9,360
October	13,080	11,880	7,920
November	14,280	12,600	8,640
December	15,000	10,560	*10,560*
Totals	189,960	161,880	120,690

Reported electric consumption history reflects energy savings from improvements made to mechanical systems, controls, and a partial conversion to LED lighting.



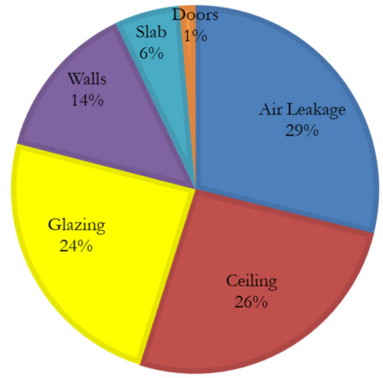




The pie chart estimates a general breakdown of kWh usage based on an inventory of electric devices and other loads.

Such an analysis helps inform potential savings from savings from specific energy saving measures.

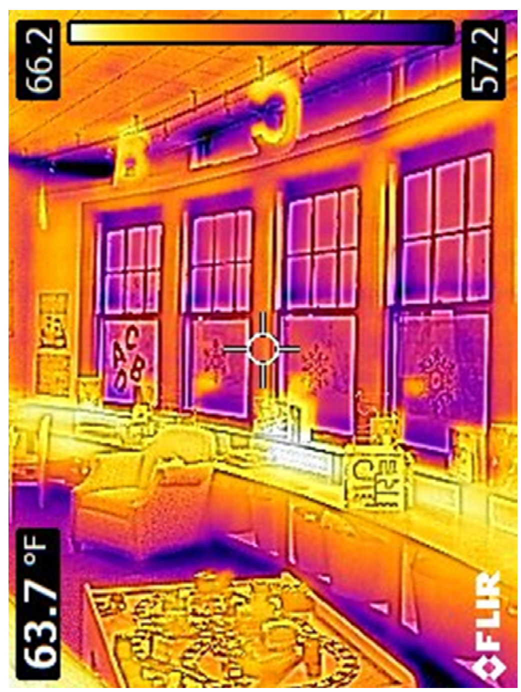
Thermal Envelope Losses



The thermal envelope represents the assembly of materials which separate inside conditioned space with outside and unconditioned areas. Layer(s) of insulation typically define the location of the 'thermal barrier' but other materials are included in the assembly often provide important air and vapor control. The presence, or absence, of a continuous air barrier has a significant impact on the thermal performance of the insulation—especially low density 'filter' materials like fiberglass. In reality, the air barrier is also the most important vapor control mechanism.

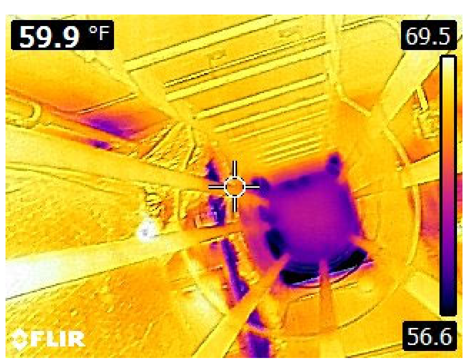
Mechanical systems play a large role in energy consumption in the Library, as in many commercial buildings. This is due to significant cooling loads—where internal gains may rival or even exceed losses; outdoor air ventilation requirements; and energy required to move large volumes of air.

Even so, deficiencies in the thermal envelope do matter in terms of conserving heat in the winter, limiting gains in the summer while also preserving coolth.



The pie chart above shows estimated 'responsibility' for envelope heat losses. Note that air leakage isn't a single component but represents the transitions or cracks and gaps, between materials in each of the other components.

Dark areas in infra red indicate colder surfaces areas. "Wind washing" (arrow) indicates cold air movement.



Windows, doors, and roof access hatches, are all important in order to access the outside (even if only visually). But they are also 'big holes' in the thermal envelope, which when not effectively air sealed around the edges, increase energy usage and discomfort. "Holes" (cracks and gaps) at higher parts of the building pull air through choles at lower places. This is why establishing a pressure plane is key.

Ceilings, Attics, and Pressure Planes

Copied Issue #7 from 2014 Advantage Engineering's Report

Description: Significant air movement in Periodicals section ceiling space.

Remarks: Air temperature...appears to be near that of outside air temperature. Significant cold air movement in the ceiling space could cause water piping to freeze, poor space temperature control, and excessive energy consumption….1/28/2014—source of cold air appears to be coming from mechanical space above where insulation and vapor barrier have been compromised for heating hot water piping penetrations.

The entire field of Building Science has evolved largely over the issue of water and vapor control and addressing the confusion between air and vapor barriers. I agree completely with the above remark, but would clarify that the problem is a lack of an air barrier. The poly liner is vapor impermeable so can slow vapor migration via diffusion—ie eliminates drying capacity in either direction—but it is its role as a barrier impermeable to air which is critical here. To be effective, insulation layers need to stop air. So low density materials, like fiberglass in particular, need to be in direct contact with an air barrier on all six sides in order to perform anywhere near their rated "R-Value". In fact, "R-Value" only tells part of the story as it only pertains to conductive heat transfer. Convective heat transfer—ie heat transfer via air– functions under different mechanisms. In other words, without an air barrier—air can easily move through fiberglass taking heat or coolth with it. This is why Paul Button stated that "the insulation disheveled and of little value" (see below).

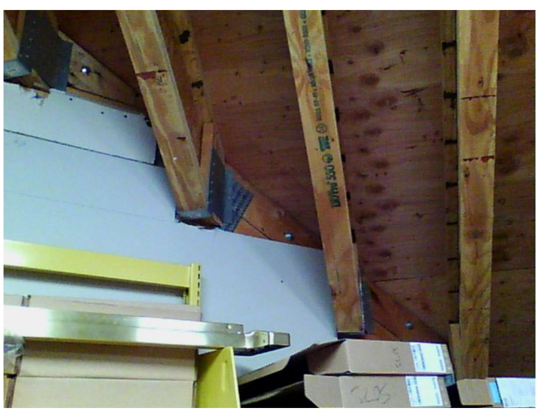
From 2015 Paul Button energy audit

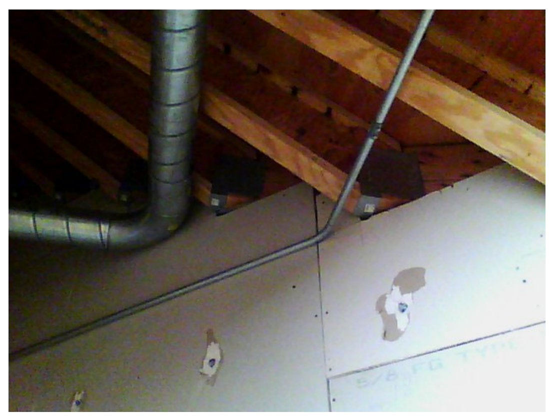
The rooflines in the upstairs storage rooms should be spray foamed. The insulation is disheveled and of little value. Severe ice dams occurred this past (2014-2015) heating season. The (probably) uninsulated interior wall of the vaulted atrium wall is likely losing heat through conductance, heating the underside of the roof sheathing and resulting in those ice dams.

I concur with Paul's assessment of the existing insulation and that heat loss is the primary cause of ice dams and specifically in the attic storage room over the Director's office. Spraying closed cell foam on the underside of the roof—Ie bringing the attic area into conditioned space—is an accepted approach and would likely succeed in reducing heat loss and preventing ice dams.

However, it would be very costly to do properly, ie manage vapor and assure cold, dry roof sheathing. This would include a minimum of 7" thickness in the rafter bays and at least 3" coverage over LVL beams and at least 1" over I-joist rafter surfaces for monolithic coverage. In my opinion, the preferred strategy would be to maintain roof venting and create an effective thermal and air barrier at the floor plane as in the Shakes to Shingles proposed work scope. I also suggest removing the fiberglass batts sporadically placed in between rafters.

Reported Ice Dams

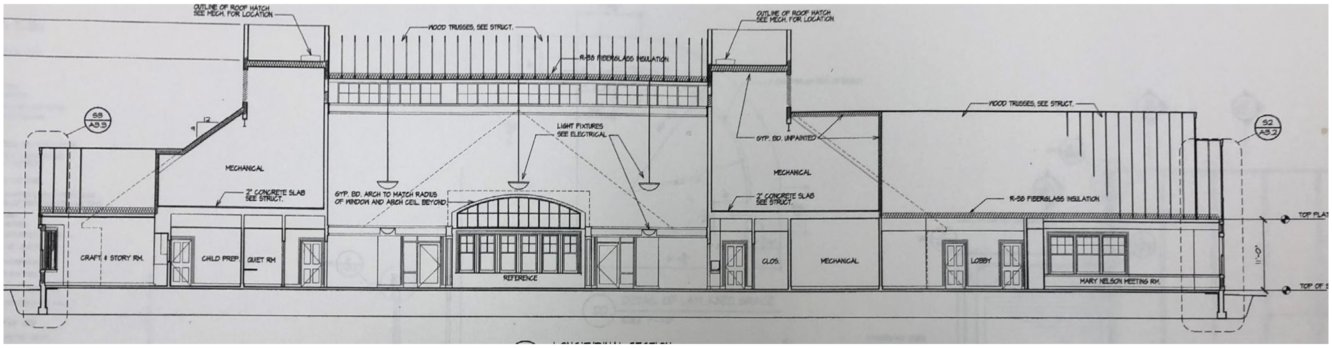


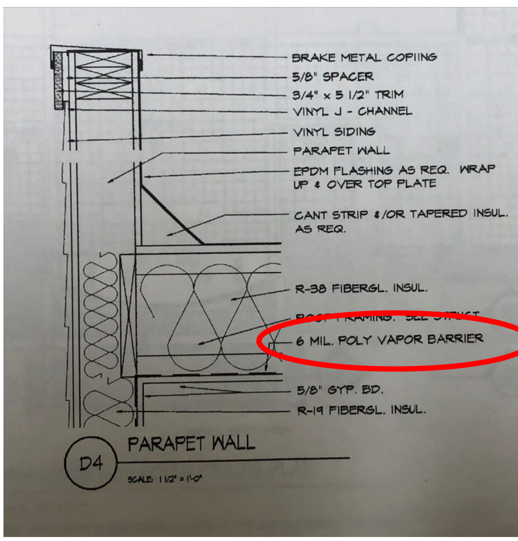


The attic areas on both sides of the break room—particularly over the Director's office (#1) was found to be 65 degrees on the 25 degree day of the site visit. Ice dams form when roof sheathing is heated from below causing snow to melt, then drain to the roof's edge where it freezes when exposed to cold air. As this continues to happen, layers of ice form larger and large icicles and dam.

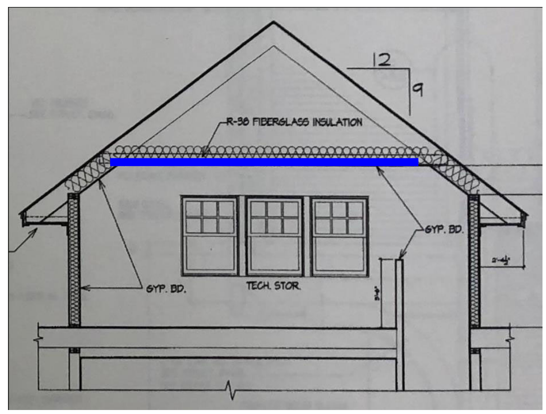
1999 Drawings from Sheer McCrystal Palson

"Gypsum Board unpainted" -

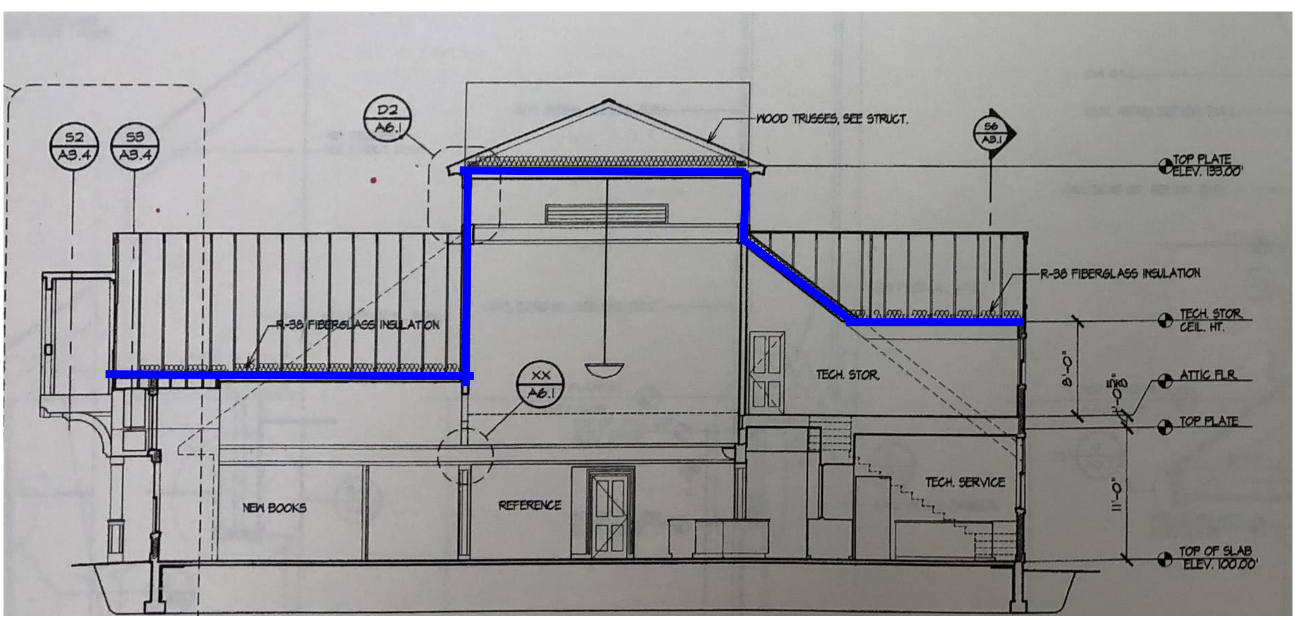




Barrier found in some places—not all—and typically not sealed.



Added pressure plane



Shakes to Shingles Work Scope: Establishing a Pressure Boundary, Air Sealing and Insulation Upgrade

The fiberglass insulation directly above the suspended ceiling is sagging down and does not have an adequate air barrier. The air leaving the building is filtering through the fiberglass and cellulose insulation. The effectiveness of the insulation is greatly reduced when it is installed in this manner. Below is a list of what needs to be done for this attic to be air sealed.

1. Lower attics:

a. The floor and all of the books will be covered with plastic before the work begins.

b. Portions of the suspended ceiling will be removed to get materials into the outer sections.

c. Accesses will be cut through the drywall in the 2nd floor utility rooms to gain access to the front and right.

d. Blocking will be installed below the utility room knee walls and rear walls where the attics meet the 1st floor conditioned space.

e. A new ceiling will be installed above the existing insulation made out of 7/16 OSB.

f. All of the seams will be sealed with spray foam to completely seal the new pressure boundary.

g. Vents/air chutes will be installed to preserve the ventilation.

h. R-60 cellulose will be installed across the entire attic space above the new pressure boundary.

i. The top of the exterior walls is open above the suspended ceiling. 3-inches of spray foam will be installed around the perimeter of the entire building.

2. Upper attic:

a. This attic will need to be accessed with a lift.

b. A portion of the roof will be opened to install all of the materials.

c. Because of the height, all of the workers will need to be tied off with harnesses and follow conceal space protocol while working in this attic.

d. A new ceiling will be installed above the existing insulation made out of 7/16 OSB.

e. All of the seams will be sealed with spray foam to completely seal the new pressure boundary.

f. Propa vents/air chutes will be installed to preserve the ventilation.

g. R-60 cellulose will be installed across the entire attic space above the new pressure boundary.

3. Break room attic:

a. This attic will be access from the open attic/storage area on the left side.

b. The poorly installed fiberglass will be straightened out.

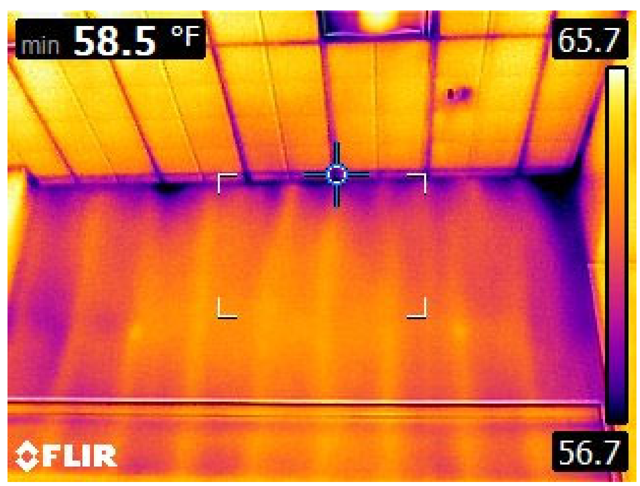
c. All of the interior walls, wiring, and plumbing penetrations will be sealed with one-part foam.

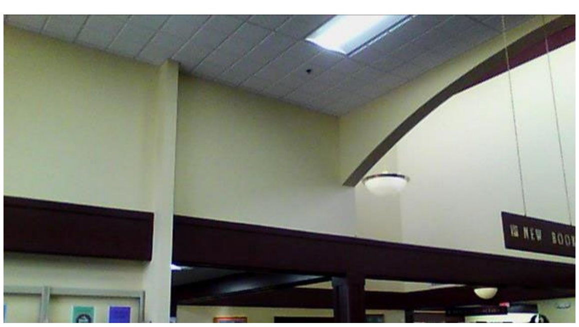
d. A barrier will be installed at the entrance to the attic to keep the insulation in place.

e. Propa vents/air chutes will be installed to preserve the ventilation.

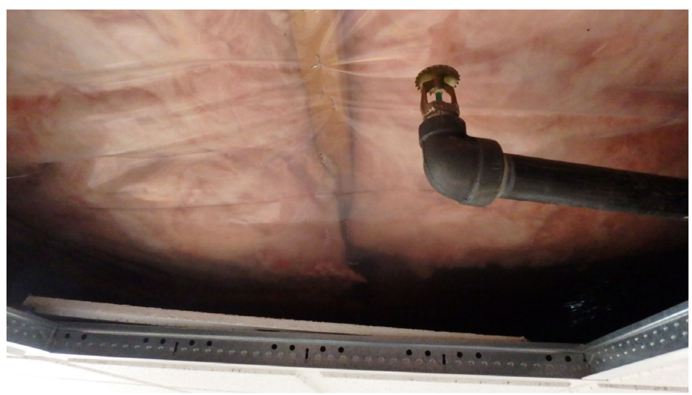
f. R-38 cellulose will be installed over the existing insulation.

Thermographic (infra red) depicts differences in surface temperatures: darker indicates cooler. Dark areas demonstrate deficiencies in the thermal envelope. Either from air leakage or missing/compromised insulation.





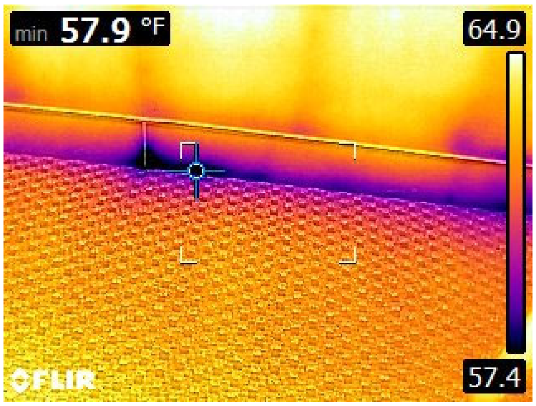
Looking up at the insulation (thermal layer), there are a variety of conditions—with or without a plastic liner which can serve as a 'partial' air barrier.

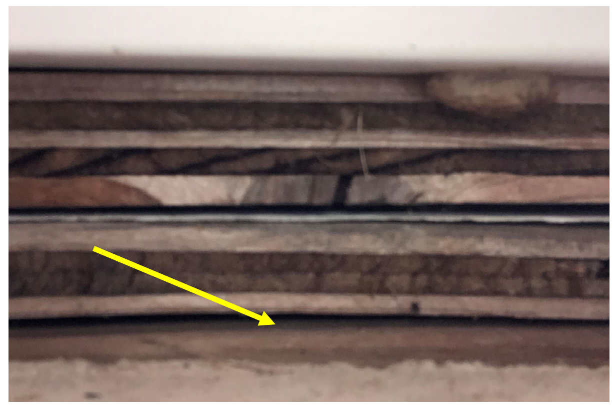


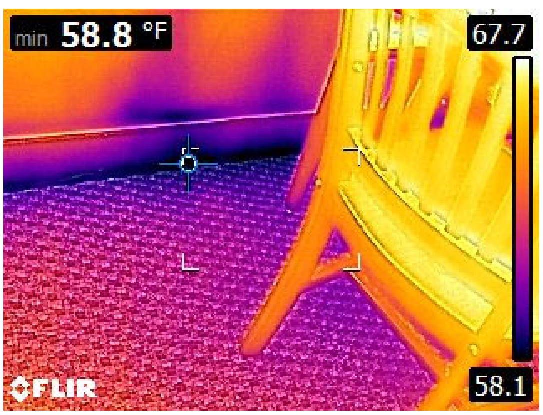
From inside the attics.

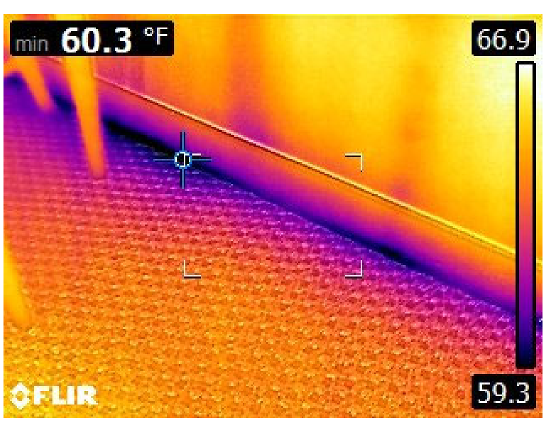
Perimeter Wall/Slab

The digital images on the right were taken 'looking up' at the edge of the wall sheathing as it met the sill and slab. Though regretfully a little out of focus, they show two layers multiple layers of plywood, what is likely some sort of building wrap, and—importantly, space gaps in between. Part of the envelope upgrade includes carefully spraying a low expansion foam around the entire perimeter to seal the inside plywood to the sill/slab edge. When cured, carefully trim any foam from to the outside.









Window Glazing

Copied from Castacna Consulting Group

> Page 8: It appears that a majority of the windows...have lose the insulating glass seal (and) condensation has formed between the insulated glass units. The sash of the windows can be replaced without having to remove the entire unit thus not having to disturb trim, siding, and drywall.
>
> Page 11: We are recommending that a certified repair with a 10 year warranty be used at a much lower cost than a complete glass replacement. We have estimated that approximately 80% of the exterior glazing (130+ windows) has failed at an average unit cost of $200 per window with a total cost of $15,000.

I had not heard of a 'certified repair' for aluminum clad wood windows before but concur that such a measure could be cost effective. Unfortunately, the Glass Guru is a large franchise and the Barre location is no longer in business. The closest location is Albany, New York.

Replacing these windows with similar original performance and sashes typically costs between $50-$70 per square foot, or well over $100,000 for a total replacement. While there would be energy savings—both during the heating and cooling seasons—and improved comfort in the children's Craft Room which is prone to overheating—the primary benefit would be visual, which is outside the scope of this assessment. (See next page)

The existing window units do appear to have a low e coating on the interior of the inside pane (photo right) which indicates high solar heat gain as well as reducing heat loss to the outside. So even without the original air seal, these windows still have value. In fact, replacing them with low solar heat gain windows would reduce their contributions to space heating, offsetting some improvements in reducing losses. The more significant impact on replacing south and west facing glass with lower solar gains would be to reduce cooling loads. But again, a very long 'payback' with mostly visual 'non energy' benefits.

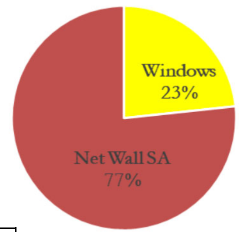
More significant energy benefits around window glazing come from installing tracked window quilts from https://www.windowquilt.com/ in Brattleboro, Vt. At a cost of about $15 per sq ft, they would have been recommended for the Children's Craft room for nighttime use and to help reduce overheating. Total cost less than $2,000.

Another option to consider would be to replace selected glazing areas with translucent Kalwall insulated panels (see pages 13 and 14). For example the inoperable glass lites over the reception area and above operable windows covers about 500 square feet, or 25% of all glazing. This would change looks on both the exterior and interior, but also reduce glare without reducing daylight. More, it would provide a more significant reduction in heating and cooling loads at similar ft2 installed costs. If this is something the Trustees would like to explore further, contact https://www.kalwall.com/.

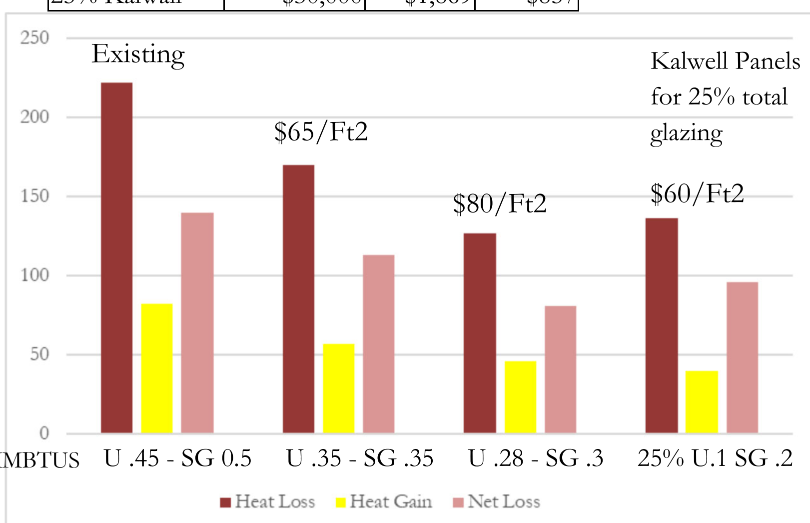
Window Glazing

These charts offer sample scenarios for replacing windows with varying performance values. Or replacing inoperable lites (25% of glazing) with translucent panels. This latter option doesn't address 'fogging' but does offer lower upfront costs for saving electricity and gas.

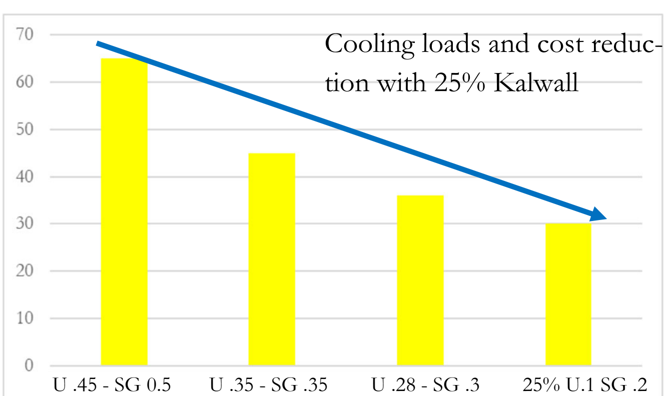
Window to Wall Surface Area Ratio



	Replacement Costs	Heating Only Costs	Annual Savings
Existing		$2,726	
U .35 SHGC .35	$125,040	$2,200	$526
U .28 SHGC .3	$166,720	$1,577	$1,149
25% Kalwall	$30,000	$1,869	$857



Estimated Comparison of Window Performance Values with Ball Park Replacement Costs per FT2



MMBTUS

	ΔT °F	Btu/Hr	Heat Loss Per Bin HR
	12	10,308	6,854,820
	17	14,603	11,229,707
	22	18,898	12,718,354
	27	23,193	15,771,240
	32	27,488	18,774,304
	37	31,783	25,267,485
	42	36,078	27,238,890
	47	40,373	30,037,512
	52	44,668	21,842,652
	57	48,963	18,459,051
	62	53,258	13,421,016
	67	57,553	9,784,010
	72	61,848	6,184,800
	77	66,143	3,241,007
	82	70,438	1,197,446
		Heat Loss	222,022,294
		Solar Gains	82,375,895
Existing		Net Loss	139,646,399

These two charts (above and below) refer to Temperature Bin Tables, explained on page 22.

	ΔT °F	Btu/Hr	Heat Loss Per Bin HR
	12	7,908	5,258,820
	17	11,203	8,615,107
	22	14,498	9,757,154
	27	17,793	12,099,240
	32	21,088	14,403,104
	37	24,383	19,384,485
	42	27,678	20,896,890
	47	30,973	23,043,912
	52	34,268	16,757,052
	57	37,563	14,161,251
	62	40,858	10,296,216
	67	44,153	7,506,010
	72	47,448	4,744,800
	77	50,743	2,486,407
	82	54,038	918,646
		Heat Loss	170,329,094
		Solar Gains	57,663,126
Case #2		Net Loss	112,665,968

Window Replacments

Retrofits and Energy Upgrades with Kalwall Window Replacements result in dramatic savings by stopping heat loss and reducing electric light usage by offering glare free-usable diffuse daylight, eliminating the need for shades, and decreasing solar heat gain. Our high performance systems are very competitively priced, virtually maintenance free, and offer increased security compared to typical glass retrofits, for both increased impact resistance and vandalism.

Window Replacement Systems

Kalwall Window Replacements offer budget-friendly fenestration options that deliver glare-free daylighting while simultaneously increasing energy performance and decreasing maintenance requirements. Delivered in unitized formats, specifiers can combine translucent and vision glazing to provide diffuse daylight, views and ventilation. Perfect for deep energy retrofit (DER) & renovations, these systems can be installed in existing rough openings rapidly, minimizing disruption to building occupants.

Graffiti and vandal resistant face sheets including high impact options
Highly insulated to reduce heating+cooling costs from HVAC systems
Various head, sill & jamb detail options for retrofits in existing R.O.s
Much lower maintenance requirements compared to conventional glazing
Windborne debris protection - tested and certified up to large missile D

HC-2000 Windows

Kalwall manufactures its HC-2000 Windows for commercial and industrial applications where both budget and performance are primary drivers. HC-2000 windows have been engineered and tested to ensure reliability.

HC-2000 available: fixed, project-in, project-out (max sizes vary)
HC-2000: AAMA/ANSI Performance Class: PI-AW50, PO-HC55, F-AW80

E-Series Windows

Kalwall manufactures its E-Series Windows for architectural applications where performance and craftsmanship are paramount. E-Series windows are engineered and tested for the most demanding applications.

E-Series available: fixed, project-in, project-out (max sizes vary)
E-Series: AAMA/ANSI Performance Class: PI-AW60, PO-AW70, F-AW80
E-Series Large Missile Impact: Design pressure 80 PSF (3.83kPa) tested and certified to TAS 201, TAS 202, TAS 203, ASTM E1886 & ASTM E1996

STANDARD SYSTEM | THERMAL BREAK+STRUT SYSTEM | CONCEALED FASTENERS

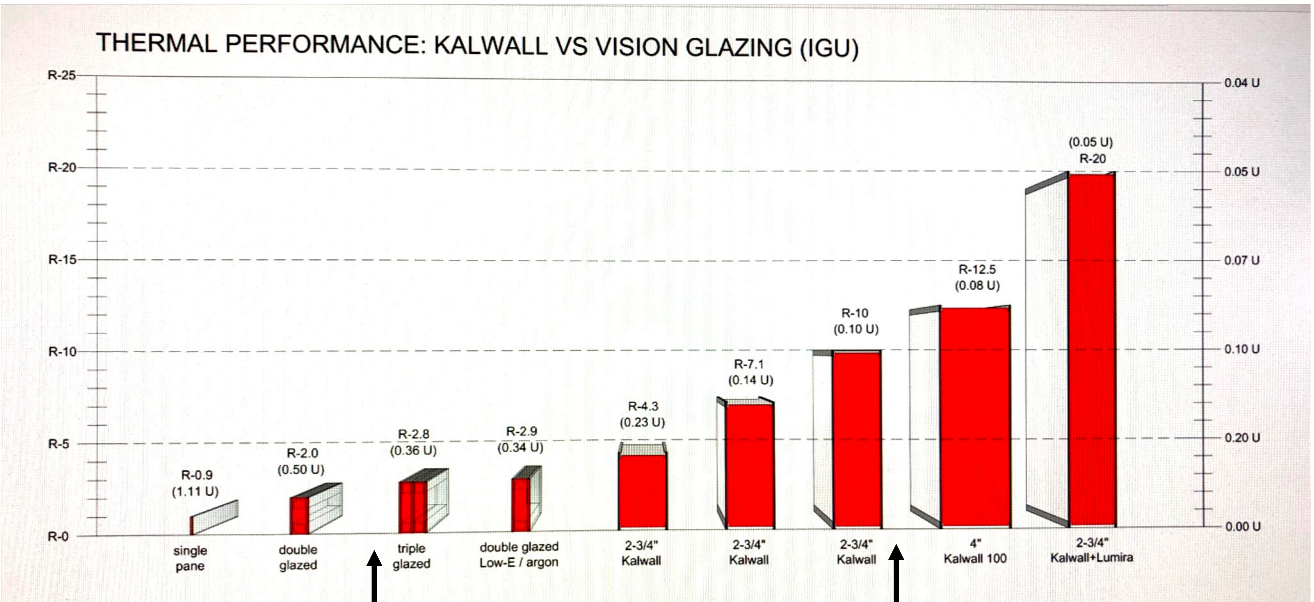
Before Window Replacement
Old, energy-inefficient single-pane glazing

During Window Replacement
Replacement system installed in existing R.O.s

After Window Replacement
New, energy-efficient Kalwall system in service.

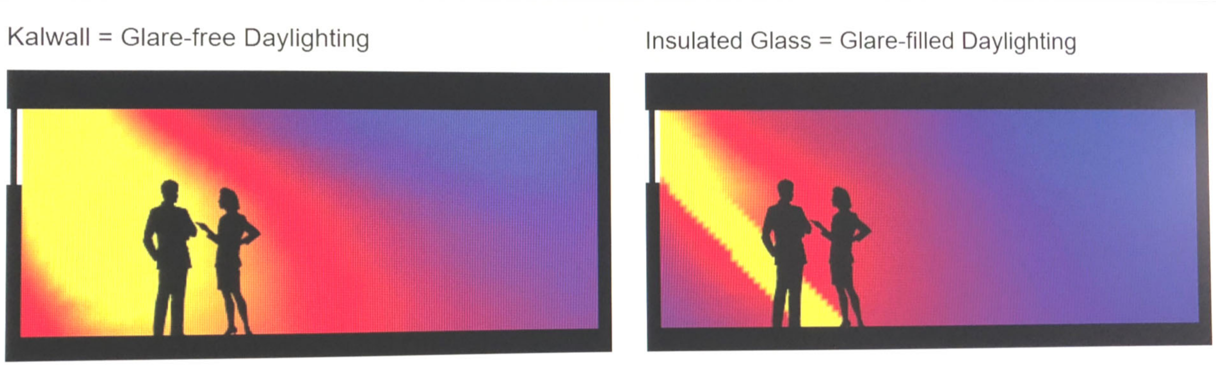
Please visit KALWALL.COM for all window replacement specifications, CAD details, BIM families & performance charts

For more information, visit https://www.kalwall.com/



R-value of existing glazing

For approximately the same per square foot cost, Kalwall panel units offers far greater thermal performance and a stronger, more resilient surface area. Units can combine translucent panels with an operable glass window.



Consider re-placing glass with R10 transluscent panels

West facing

East facing

North facing

South facing

Heating, Cooling, and Ventilation Issues

Condensing VS Conventional Boiler

Pertinent Comment Copied from 2016 Environmental Health & Engineering's Report

> Page 2: The hot water supply temperature set point follows a reset schedule; it ranges between 140 degrees F and 190°F when outdoor temperature varies between 50°F and above, to 10°F and below.

This information is important when considering converting to a condensing boiler. Condensing boilers are significantly more efficient because they can recover some of the heat from waste gasses that goes up the flue in non condensing boilers. Gasses are sent through a heat exchanger which, as they cool, condense into a liquid–which is then used to pre-heat cooled return water. But for a boiler to operate in 'condensing mode' the temperature of the return water needs to be below around 140°. Systems which are designed with high supply water temperatures—as required for ducted air systems— often cannot operate in condensing mode. A condensing boiler will still "work' but at the lower efficiencies of a non-condensing boiler (like the one which is already installed).

Charts on the next page attempt to estimate how many hours each winter that a boiler might be able to operate in condensing mode. It is likely that the savings from those hours would not justify the cost to replace the existing boilers at this time. If (as) the cost of gas goes up or its time to replace existing boilers, re-visiting condensing boilers would be prudent.

Thermostat Setbacks for the Nelson Room

> 9. It is recommended that AHU-2 be left in an unoccupied (off) state unless called to be on for a function in the Nelson Room. (On the previous page): The control system is programmed with an optimal start/stop (OSS) algorithm that will determine exactly when to start the units so that the space temperature set point is satisfied when the building is occupied.

.In response to Cab Vinton's email question this week, about set back temperatures for the rarely occupied Nelson Room: Presuming that the control system is functioning properly, I concur with the recommendation to keep AHU-2 OFF with night setbacks of 60°-80° and day setback control of 65°-75° and to allow "occupants to utilize the occupancy override button on the thermostat to turn the unit on" provided the 2-hour reset function is operating.

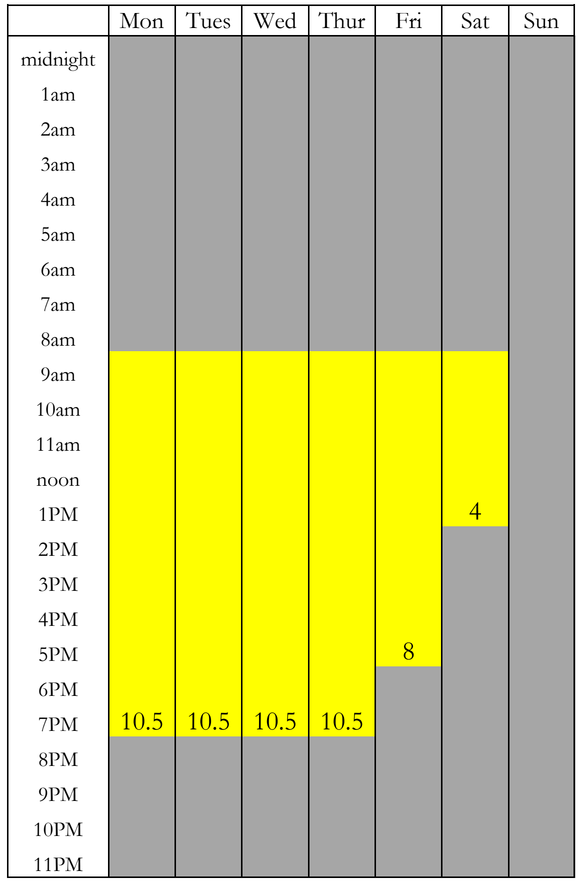
However, if the room will be unoccupied for more than 36 hours —for example from Friday to Monday—then deeper setbacks—even to 50 degrees—would be reasonable for most of the winter. As temperatures drop below 15 degrees, I would advise returning to the 60/65 program. It could become a hassle to keep monitoring and adjusting—and yet thermostat setbacks always save energy and money. The issues are a) the time it takes to come back up to occupied settings and b) in extreme cold, there may be a risk of freezing pipes.

Bin Data and Other Considerations for Converting to a Condensing Boiler

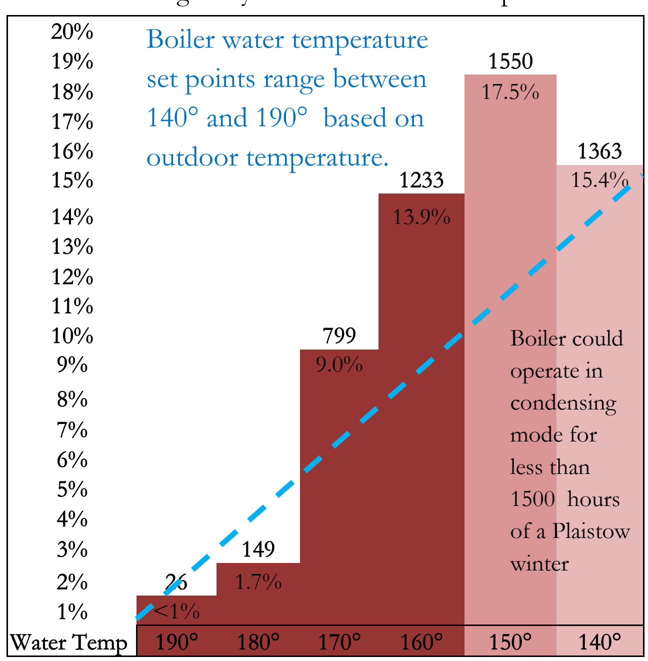
The Library (served by AHU-1) is open to the public 54 hours a week, or 32% of a week's 168 hours. 50 of those hours occur between the hours of 9am-6PM, which correspond to a Temperature Bin tracked by engineering data. Bin data groups temperatures or temperature ranges for a particular climate location. This is used to help predict energy consumption for a particular building's heating and cooling load and other useful formulas. The chart below reflects temperature bins for Manchester, NH (closest to Plaistow available). Based on the boiler set points, it is likely that they could only operate in condensing mode for less than 20% of the winter's heating hours.

Temp BIN	9am-6PM	Total 24 hrs	% Hours
100 to 104	0	0	0.00%
95 to 99	9	11	0.12%
90 to 94	54	72	0.81%
85 to 89	116	166	1.87%
80 to 84	200	317	3.57%
75 to 79	220	438	4.94%
70 to 74	239	638	7.19%
65 to 69	215	665	7.50%
60 to 64	232	769	8.67%
55 to 59	200	673	7.59%
50 to 54	212	680	7.67%
45 to 49	212	683	7.70%
40 to 44	237	795	8.96%
35 to 39	210	755	8.51%
30 to 34	194	744	8.39%
25 to 29	140	489	5.51%
20 to 24	106	377	4.25%
15 to 19	58	252	2.84%
10 to 14	38	170	1.92%
5 to 9	18	100	1.13%
0 to4	7	49	0.55%
-5 to -1	2	17	0.19%
-10 to -6	1	8	0.09%
-15 to -11	0	1	0.01%
-20 to -16	0	0	0.00%
-25 to -21	0	0	0.00%
-30 to -26	0	0	0.00%

Hours of Occupancy



The above chart is colored to highlight the number of hours that the building is unoccupied. They are mostly daytime hours with the highest year round outdoor temperatures.



Ventilation

Environmental Health & Engineering's Report

> Page 2: The (AHU-1) unit is designed to provide a minimum of 2,800 cfm of ventilation air to the building to meet indoor air quality requirements.

This information was entered in the energy model used in this analysis. Ventilation air is a significant factor in both heating and cooling loads. Adding an energy recovery unit was explored but—at current prices for natural gas—deemed not cost effective. As energy prices increase over time, this should be reconsidered.

Comment Copied from Castacna Consulting Group

> Pages 5-6: 2.a CO2 control for the meeting rooms and the general library open space on the first floor level. This will assist in air flow management from the existing air handlers…(and) manage outdoor ventilation air, thus reducing energy costs. This is highly recommended… In addition, we recommend additional air flow stations be added to the air handling...to achieve accurate CO2 control and provide additional assistance in energy conservation.

It is not clear to me if this has been implemented already, but if not, it is strongly recommended here as well. Ventilation air is important for an occupied building, but over ventilation—or ventilating an unoccupied building—may represent the single greatest waste of energy. Said another way: *not* conditioning outside air and running fans when unnecessary is the single most cost effective way to save energy. (Air cooled condensing units as discussed on page 7 of their report is also relevant). I do not know whether installing additional air flow stations—into a functioning demand control ventilation sequence- is advisable or not.

Balancing Air Flows

Environmental Health & Engineering's Report

> Recommendations:
>
> 4. Rebalance the airside of the building to ensure proper airflow to all VAV's while maintaining a neutral to slightly positive pressurization of the building.

Ideally, ducted air systems are balanced to maintain a neutral pressure in the building. If not balanced, then slightly pressurized would be better than depressurized. Either way, an intact pressure plane—ie air barrier—supports air flow balancing and increases efficiency and effectiveness.

Castacna Consulting Group:

> Page 4: Once the new control system gas been balanced, some of the issues of uneven room temperatures, cold spots, and general inefficiency of the systems as well as high utility costs should be rectified.

The above was a reasonable prediction, though without considering what this assessment considers: ie that 'missing piece of the puzzle'. In other words, it is believed that by establishing an effective pressure plane, the remaining issues should be rectified—and the existing air handling units and functioning DDC controls should be able to offer improved efficiency and comfortable indoor conditions.

Timer for Parking Lot Lights

While Lighting improvements was not to be part of this energy audit, the spreadsheet analysis from Sylvania was reviewed for insights into the general breakdown of electric consumption and cooling loads. Converting parking light fixtures to LED is typically recommended, especially if there are rebates available from Unitil.

Castacna Consulting Group had estimated the cost of $18,000 to convert all exterior lighting fixtures to LED. Slyvania calculated an annual savings of $3,202, which would suggest a simple payback of 5.6 years. Their inventory described exterior lighting below.

		#	watts	total watts
SIDES AND REAR OF BUILDING	100W MH Recessed 8" I.D. 8.5" O.D. Can, 4000K	10	128	1,280
EXTERIOR FRONT STREET SIGN	100W Quartz Knuckle Mount W ide Flood, 4000K	2	100	200
FRONT ENTRY	150W Quartz Knuckle Mount W ide Flood, 4000K	2	150	300
CENTER TALL AREA	250W MH Pendant Mount W ide Flood, 4000K	3	295	885
CENTER TALL AREA	250W MH W all Mount Round - Horizontal Sconce, 4000K	5	295	1,475
	400W MH Direct Arm W ide Flood, 4000K	10	458	4,580

Those savings include converting the (10) 400 watt floods on exterior light poles with 150 watt LED shoe box type for an anticipated savings of $733—based on being on for 1400 hours a year. If the hourly usage is correct, that would suggest the lights are on an average of 4 hours per night, which would suggest they are already on a timer. If the hours are incorrect, then the savings maybe higher than anticipated.

Exterior lighting is typically worth converting to LED, as long as the hours "on" justify the installed cost. So the recommendation here is to install a timer if not already installed. But also to determine how many hours the 10 lamps are on during a year, and revisit the cost for an LED conversion.

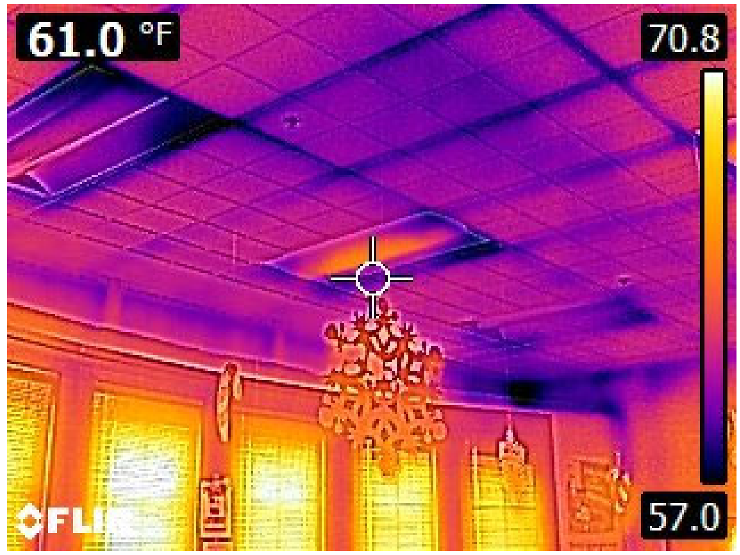
Specific Comfort Issues

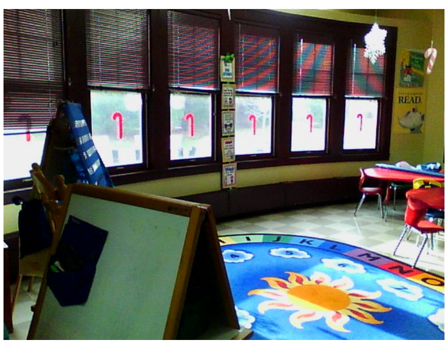
Children's Craft Room

Anecdotally, the Craft Room may experience the most significant temperature swings and discomfort. It is reported to be very cold in the morning, then heat up quickly when the sun is out and overheat during the day (in part due to many active bodies), then quickly become cold again in the afternoon.

1. This room has greater glazing to wall and floor surface area than any other space in the Library, hence its immediate change in temperature in response to the sun.
2. The thermostat is located near the desk in the large adjoining room, so the hydronic baseboard is not responsive to heat gains from people or the sun.
3. Addressing the ceiling plane is expected to make a significant reduction in 'drafts' and cold air infiltration from the ceiling.
4. Exterior shading devices will be the most effective solution to the comfort issue, though designing them is outside the scope of this audit.

Craft Room





Replace Refrigerator

While understanding Cab's interest in focusing on major savings, its important not to overlook the smaller measures—which can add up!

Replacing this single door unit with a simple $400-$500, 12 to 15 cubic foot, two door, Energy Star model could save $80-$100 per year.

Unitil Gas Rates as of January 1, 2019

Rate	Customer Charge	Distribution Charge per therm <75 therms	Distribution Charge per therm >75 therms	Local Deliver Adj per therm	Supply per therm	Low Use: <8000 therms per year Medium: >8000 and <80,000 High winter use is >67% of annual usage
G40	$72.26	$0.1795	$0.1795	$0.0396	$0.8771	Low Annual - High Winter
G41	$214.26	$0.2334	$0.2334	$0.0396	$0.8771	Medium Annual - High Winter
G42	$1,285.55	$0.1909	$0.1909	$0.0396	$0.8771	High Annual - High Winter
G50	$72.26	$0.1795	$0.1795	$0.0396	$0.7601	Low Annual - Low Winter
		first 1300	>1300			
G51	$214.26	$0.1648	$0.1346	$0.0396	$0.7601	Medium Annual - Low Winter
G52	$1,285.55	$0.1655	$0.1655	$0.0396	$0.7601	High Annual - Low Winter

The Library's usage has been close to the threshold for "low use" 8,000 therms per year and exceeded it in 2018, which meant a $142 increase in monthly Customer Charges. (Based on 2019 rates).

Following the Envelope Improvement packages, annual consumption will be reduced well below the thresh-old—while winter use will still be over 67% of annual consumption—securing the G40 rate regardless of individual winter temperatures.

Unitil Electric Rates as of January 1, 2019

Large General Service Rate: At least 100,000 kWh per month and 200 kVA of demand

Rate	Customer Charge	Demand per kVA	Delivery per kWh	Systems Benefit per kWh	Stranded Cost Charge per kWh	Stranded Cost Charge per kVA	Supply per kWh
G1	$85.99	$7.55	$0.02522	$0.00576	$0.00025	$0.25000	0.09539