Energy Audit

December 10, 2014

Wilton Town Hall & Theatre

BUILDING STRATEGIES FOR AN AFFORDABLE FUTURE
S.E.E.D.S.
SUSTAINABLE ENERGY EDUCATION DEMONSTRATION SERVICES
Margaret Dillon—603-532-8979—MDILLON@myfairpoint.net

Table of Contents

	Pages
A. Executive Summary	
Introduction	3
Building History and Site Description	4-5
Historic Energy Use	6-7
Summary of Recommendations	8-14
B. Overview of Energy Use in Buildings	15-19
C. Description of Existing Conditions	
A Thermodynamic "Snapshot"	20-21
Exterior Phots for Reference	22
Occupancy Patterns	23
Peak Heat Losses	24-25
Air Leakage and Building Tightness	26-27
Schematic Floor Plans	28-32
Thermographic Images	33-42
D. Heating and Cooling Equipment	43-46
December 12, 2014 Addendum:	
WEC's Proposed Project Scope for 2015	47

As an independent energy consultant doing business as Sustainable Energy Education & Demonstrations Services (S.E.E.D.S.), I have prepared this energy audit with the best of intentions to deliver a comprehensive and thoughtful document to assist the Town of Wilton in making informed decisions regarding energy improvements to their historic Town Hall. I do not make any warranty, express or implied, or assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed.

Sincere thanks to members of Wilton's Energy Committee, Town Staff, and Dennis Markaverich for their enthusiasm and assistance in completing this study. Special nod of thanks to John Shepardson for all his help and to Don LaTourette of Building Energy Technologies who ventured into the depths of crawlspaces under the building and attic corners at its top—places that I, regretfully, can no longer safely explore.

Respectfully, Margaret Dillon

A. Executive Summary

Introduction

The objective of an energy audit is to identify energy conservation measures that reduce the net energy consumption thereby reducing operating costs. In addition to energy conservation, the evaluations and recommendations in this assessment consider occupant comfort and holistic building performance consistent with its functions as offices, meeting space, and a community theatre. The information obtained as part of this audit has been used to develop Energy Saving Measures (ESM's). These ESM's provide the basis for future building improvements and modifying the manner in which the building is operated.

This assessment is in keeping with an ASHRAE Level 2 building audit. The energy audit identifies all appropriate energy efficiency measures for a facility, and a financial analysis based on implementation costs, operating costs, and estimated savings. In this case, some full project costs are beyond the scope of this study. The ultimate goal is to identify and estimate the amount to be saved from energy improvements, the amount the energy saving measure will cost, and the estimated payback period for each ESM. In addition, the audit discusses any recommended changes to operations and maintenance procedures.

The Wilton Town Hall received an in-depth field survey consisting of a site-visit that takes into consideration the following:

Building characteristics
Building use, function, and occupancy patterns
Moisture concerns
Envelope systems
Heating systems
Lighting
Other electric loads

The recommendations in this report are offered in the context of balancing up front costs with the range of benefits from improved performance, including a reduction of energy use and annual operating costs. They are also designed to complement existing funding opportunities as well as consider the energy saving advantages within other specific capital investments at this time or in the futures. All of these factors make for a fairly complex balancing act! Since there are many things the Town needs to consider beyond energy use, optional project scenarios have been developed for an informed conversation with the Energy Committee and Selectmen. For example, insulating the walls during a renovation project makes the most sense, so the cost and benefit of those envelope upgrades has been included, but not the entire cost of the wall construction which will inevitably included other project costs without impacts on energy use.

The other large capital expense involves converting from steam heating to forced hot water throughout the building. While the existing boiler(s) have not come to the end of their service lives, there are several compelling advantages to making the conversion sooner than later, and specific advantages to planning for a system and fuel conversion as part of a larger energy savings project.

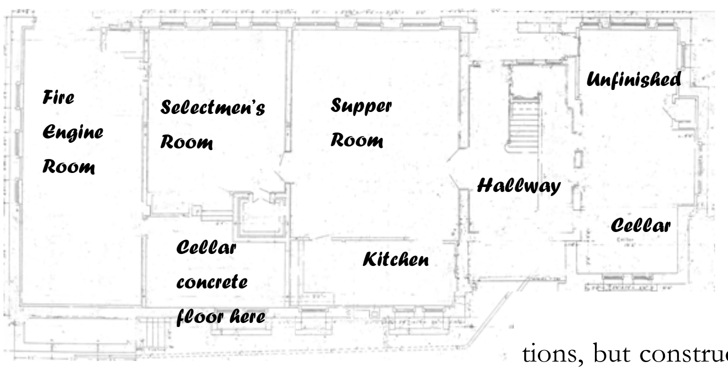
Estimates are based on existing and historical patterns, yet remain as estimates for there are many variables which cannot be predicted. The most accurate description of energy modeling I know is: "Energy models are always wrong, but some can be very useful." It is my sincere hope that this report will be helpful to the Town of Wilton in planning for the continued relevance of this grand building.

Brief Building History and Relevant Site Description

The history of the site and the building is nicely displayed in two plaques created and installed by the Wilton Heritage Commission. According to these signs, the Wilton Town Hall is built on the site of the

"Whiting House Hotel, destroyed in the Main Street fire of December, 1874. When the 2nd Meetinghouse in Wilton Center burned in 1859, a new Town House...was built in the Center. By 1869, the town voted to sell this building and hold Town Meeting at the old Depot Hall...until a suitable structure could be built here in the East Village. Designed by the noted firm of Merrill and Cutler, construction of the Town Hall began in 1883...and completed in 1885. In 2009, Wilton Town Hall was listed on the National Register of Historic Places."

Considering the number of buildings lost to fire in this Town as throughout New England, it is understandable why this Town Hall was constructed mostly of granite and brick. Built into a hill, the west (and slightly south) facing side of the building has its entrances just above Main Street level and banked into the hill with the upper floor entrance level with Maple Street. The lower level is constructed of 18" granite blocks with an interior wood post frame supporting the upper floor level (often referred to as the "First Floor"). The slated roof is structurally supported by 12" brick walls.



Original drawings from the office of Merrill and Cutler identify the intended uses for the lower level in the "Plan of Basement" drawing, noting that all areas except the Main Street entrance Hallway with stairs to the Main Hall will be "unfinished".

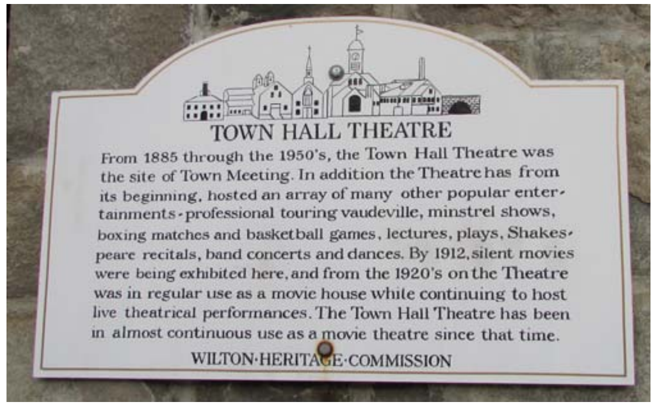
Original plans can sometimes offer insights into not only the architect's original intentions, but construction elements and details which can be helpful in understanding strategies for adapting a building over time as occupancy needs change and, as in the reason for this study, we face a national and global transition away from burning fossil fuels. Originally heated by coal, evidenced by the four remaining exterior chimneys, a large oil fired boiler (installed in the Cellar with the concrete floor) now makes the steam which still serves most of the building.

With a few exceptions, the wood framed floor is constructed over a dirt floor, with two small vent openings in the granite facing Main Street. Wire mesh has recently been installed to prevent the narrow crawl space becoming habitat for mid sized mammals.

At some point, the police station was located in the north side areas, and a concrete cell block constructed from the cellar in the northeast corner.

A 1998 renovation added fiberglass batt insulation to newly framed walls on the south side of the lower level creating more finished office space with a handicap accessible ramp entrance from Main Street. The steam distribution system was re-configured, and a smaller oil fired boiler and forced hot water baseboards were installed to serve the newly renovated offices and restrooms. Zone valves were added in an attempt to control heating what was the Supper Room, offices on the north side, and the Town Hall Theatre above.

The Wilton Town Hall Theatre served as the site for Town Meeting from 1885 to the 1950's, but has also served as a theatre from the beginning; offering a variety of entertainment venues for Wilton residents and the larger region.



The Theatre space is leased and operated by Dennis Markaverich, who continues to offer a variety of live events in addition to showing two movies every night of the year (and Sunday matinees) from black and white classics to new releases, making the Town Hall Theatre a destination place for movie lovers throughout the region.

Dennis also provides nighttime custodial services and his intimate knowledge of the building has been extremely helpful in developing this report. His enthusiasm for conserving energy in the building deserves acknowledgement and respect. At the same time, some of the most effective strategies for the transition to lower energy using buildings involves automated controls and advanced technologies. So, just as the old 35mm projector is being replaced by digital formats, so to are the manually adjusted dial thermostats being replaced by computerized, programmable, even remotely operated thermostats.

Fundamental to developing effective strategies to conserve energy in any building, most especially energy used for heating, is to identify sources of moisture and also develop management strategies to reduce or eliminate the risk of mold, rot, or deterioration of brick and mortar.

There was no evidence found of bulk water intrusion into the building. Past issues related to vapor condensation were somewhat abated by spraying closed cell foam on the some of the below grade granite foundation wall.

The dirt floor, connected to outside temperatures and remaining cold granite foundation walls in contact with ambient air and the earth will be addressed in this report.

With the exception of the missing downspout section, gravity driven bulk water appears to be effectively managed. However, continued diligence in patching pavement and keeping drains clear is critical for water to be directed away from the building.

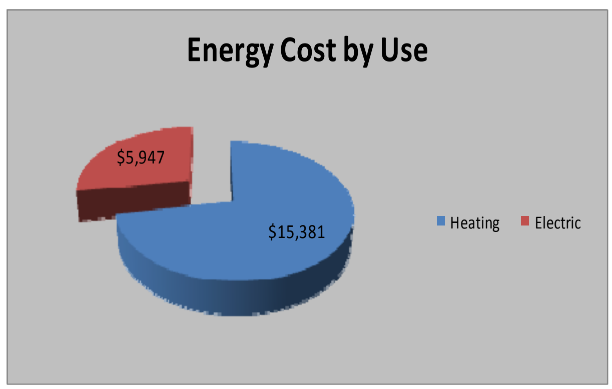
Historic Energy Use and Energy Utilization Index (EUI)

Energy and Units	Quantity	Site Btu	Source Btu	Costs
Electric kWh	35,300	120,443,600	401,043,300	$5,947
Oil Gallons	4,585	635,481,000	735,886,998	$15,381
Totals		**755,924,600**	**1,136,930,298**	**$21,328**
MMBtu's		**756**	**1,137**	
KBtu & $ /11628 sq ft		**65.0**	**97.8**	**$1.83**

The energy analysis above is based on the energy data provided during the site visit. Electric usage reflects 12 months from October 2013 through September 2014 and fuel oil deliveries from November 2013 through October 2014.

This offers a very simple snapshot analysis of a building's energy use by looking at the total amount of energy input (converted to Btu's) divided by the floor area of conditioned space. Based on the information provided and an estimated floor area of 11,628 sq ft, the Town Hall and Theatre's Energy Utilization Index (EUI) was 65KBtu/ft2 at a cost of $1.83 per ft2. This is a lower energy intensity than the average range for NH town offices suggesting that there may be fewer "low hanging fruit" opportunities than a building with a much higher energy EUI.

Site usage refers to the actual amount of electricity used on site in kWh. Source energy includes transmission losses and some allowance for off site generation. Source energy is used to equal the playing field when comparing electrical consumption with on site combustion fuel energy and to better reflect GHG emissions when considering off site generation.



Sixty five percent (65%) of the building's annual energy costs are attributed to space heating. While this report includes an assessment of electrical energy usage and recommendations to save electricity, the reducing fuel use and costs for space heating is a primary focus.

Fuel use is determined by several factors, each of which are described in greater detail in this report.

Factors include:

1) Outdoor temperature

2) Indoor thermostat settings

3) Heat losses to the outside through the shell or thermal envelope

4) Efficiency of the equipment and

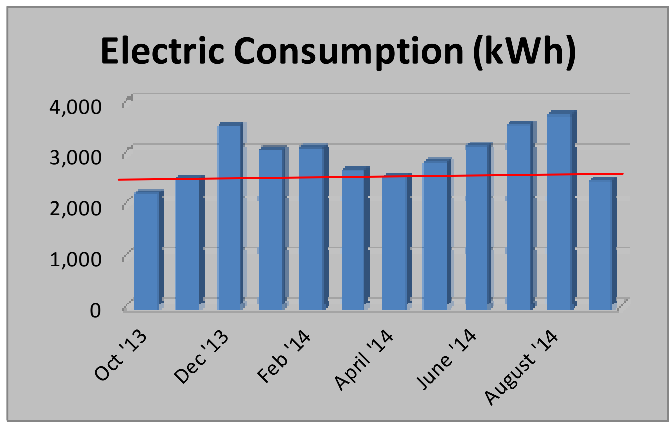
5) Efficiency of the distribution systems

6) Other occupant behavior.

The base monthly electric consumption is about 2500 kWh (red line). Base consumption refers to basic lights and equipment without seasonal loads such as air conditioning (cooling or heating). Usage increases in winter due primarily to distributing heat, as lighting requirements in the building is relatively constant throughout the year. Peak months in the summer is due to cooling, Note that readings are actually taken mid month, so the peak periods were from June through mid September.

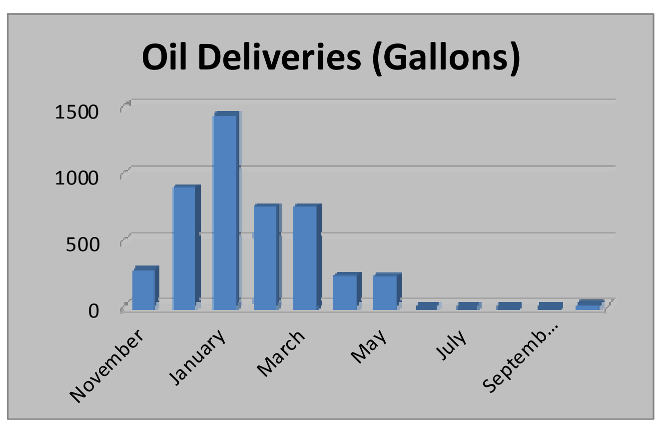
Month	Electric Usage (kWh)	Demand	Cost
Oct '13	2,220	29.0	$382.56
Nov '13	2,500	29.0	$402.69
Dec '13	3,540	34.0	$557.23
Jan '14	3,040	13.2	$522.65
Feb '14	3,080	12.2	$513.45
March '14	2,660	11.8	$462.41
April '14	2,540	8.6	$406.04
May '14	2,820	9.8	$452.72
June '14	3,120	16.2	$571.13
July '14	3,560	15.8	$612.65
August '14	3,760	16.8	$647.68
Sept '14	2,460	10.0	$416.03
Totals:	**35,300**		**$5,947**

Based on the annual baseline, it is estimated that cooling consumed about 3,000 kWh in the remarkably 'not hot' summer of 2014, for a cost of $507.



November 2013 thru October 2014	Oil Deliveries (gallons)	Cost
November	276	$882.92
December	892	$2,853.51
January	1434	$4,848.43
February	751	$2,549.98
March	751	$2,547.94
April	235	$798.42
May	231	$852.62
June	0	$0.00
July	0	$0.00
August	0	$0.00
September	0	$0.00
October	15	$47.35
Totals:	**4,585**	**$15,381**

Costs reflect Fuller's delivery costs without any discount if paid within ten days, which the Town did consistently. The Town has now contracted with Ciradelli Oil which does not offer a prompt payment discount. Contracted price for 2014-2015 is $3.199 per gallon.



Summary of Recommendations

Recommendations have been organized into several tracks: Recommended Immediate Actions relating to health and safety or relatively low cost measures for saving energy or managing moisture; Fuel Saving measures and Equipment Conversion Options; and electricity saving measures. Please note that project savings are estimates only and the actual numbers will vary due to a number of variables including contractor chosen, actual energy costs from year to year, occupancy patterns and behavior, thermostat settings and actual winter temperatures.

The summary chart of ESM's below are divided into Tier 'packages' and are specifically designed to reduce the heating load by improving the thermal envelope or shell, while also addressing air quality and moisture control. Each ESM is discussed in greater detail later in the report and the resulting heating loads for each Tier defined. The costs below reflect only the estimated costs for comprehensive air sealing and insulation. Tiers One and Two involve other construction and renovation costs which are beyond the scope of this study, though a cost benefit analysis was developed to provide *ball park*, order of magnitude, costs in order to inform the conversation about next steps.

In addition, after completing one or more Tiers described below, converting from steam to forced hot water throughout the building is strongly recommended, though system design and cost estimating is also beyond the scope of this study. In the interest of time, I have secured an estimate from Doug Waitt of Design Day Mechanicals for a heating and ventilation system design with construction documents. The goal of this report is to facilitate a decision on the scope and direction of a project for necessary bid packages to be developed in time for preparing your 2015 budget. To that end, great liberty (and some risk) has been taken to offer 'ball park' construction costs later in the report. There is far greater confidence in the cost estimates included in the chart below.

Fuel Energy Saving Measures	Est. Costs	Totals	1st Year Fuel Savings	20 Year Fuel Savings	Yr. Reduction GHG lbs
Tier One Envelope Improvements					
Weatherstrip all lower level windows	$540				
Weatherstrip all theatre windows	$1,195				
Weatherstrip all exterior doors	$1,205				
Crawlspaces: Lay poly and SPF perimeter	$12,000				
Air Seal and Re-Insulate Attic Floors	$24,300				
Total Estimated Costs for Tier One	***$39,240***	**$39,240**	**$1,927**	**$49,140**	**14,428**
Tier Two Envelope Improvements					
SPF Meeting Room	$925				
Selectmen's Office (3" for 8')	$2,450				
Planning and Building Inspector's Office	$4,200				
Thermax on Boiler Room	$1,848				
Add R10 air tight panels to theatre windows	$3,815				
Total Estimated Costs for Tier Two	***$13,238***	**$52,478**	**$4,108**	**$102,156**	**8,305**
Tier Three Envelope Improvements					
Spray 3" SPF on Clerk's Office Wall	$1,362				
Spray two (2) " SPF on all Theatre Walls	$15,000				
Total Estimated Costs for Tier Three	***$16,362***	**$68,840**	**$8,381**	**$175,415**	**10,843**

Summary Notes on Envelope Improvements

Tier One

The measures in this tier have two goals:

I. Reduce uncontrolled air infiltration through air sealing the foundation, windows, doors, and the ceiling plane. In order to accomplish this without increasing the risk of moisture and other air quality issues in the building, the dirt floor of the crawlspace needs to be sealed with a class one vapor barrier.

II. Bring the crawlspace into conditioned space by insulating the exterior foundation wall (as much as possible) and put the attic outside conditioned space by dramatically improving the insulation layer on the roof slopes and attic floors.

1. 2 and 3. Weatherstrip all windows and doors. The windows in the Town Hall were significantly improved by adding dual glazing and replacing the weight and pulley system with a contained spring mechanism. However, there remains considerable leakage at the edges of the lower sashes in particular, especially where the bottom sash meets the sill. At relatively low cost per unit, gasket weather-stripping can be installed to reduce this air leakage. While a fairly simple task, it is worth hiring a skilled professional to assure the window will still be able to opened and close tightly and for longer lasting results. The same advice is true for all exterior doors.

3. The recommendation is to create an access hatch under the stairwell of the Main Street entrance and lay a 6ml polyethylene liner across the entire dirt floor, sealing it to the granite foundation with a 2" cost of closed cell foam spray (SPF). The foam should cover the entire foundation wall to the floor deck above. This is a nasty and costly job and requires a motivated installer to do well.
4. Remove all existing insulation material from each attic floor (including decked attic) and slopes as possible. Construct a minimum R20 thermodome over the ceiling ventilation area, with removable or hinged tightly sealed top for summer operation. Spray 3" closed cell foam on all vertical or connecting walls between attics. Surgically air seal all penetrations and balloon framed perimeter walls. Inspect plaster and wiring and fix as necessary, then dense pack slopes and blow in 15 inches of cellulose. Cellulose should be of good quality and contain no aluminum sulfate. Construct thermodome at top of stairs.

Tier Two

The focus of these measures is to improve the thermal barrier of the lower floor by insulating the walls. These measures will disrupt daily operations and items #6 and #8 will require other construction costs.

6. 8. (and 11). Remove surfaces of the exterior wall and spray 3" SPF against the granite, from floor to ceiling, including behind the framing if possible. Re-surface with gypsum and plaster and wainscoting.
7. Spray 3" closed cell foam against granite from ceiling to *at least* four feet below top of framed wall. This will require access above suspended ceiling and temporarily removing some of the fiberglass batts, which can be (properly) re-installed afterwards.
9. Secure 2" Thermax (commercial grade foil faced polyisocyanurate) on exterior boiler room wall and spray SPF between joists.
10. Custom build R10 insulated, removable, panels with rigid foam board and luan or plywood to fit tightly into all drape covered theatre windows. All panels should have light exterior surfaces.

The analysis of the building's fuel use involved assessing the components of the building's thermal envelope (heating demand) as well as both heating systems (supply). Room by room heat loss calculations are included on schematic diagrams. This has allowed an estimation of how much fuel is used by the Smith boiler and hydronic baseboard to heat the offices on the south side of the building, as well as estimating the loads of meeting room, north offices and the theatre on the upper level, all served by the Steam system with three "zones".

Metric	2 Zoned FHW Base-board	Office "Zoned" Steam	Theatre "Zoned" Steam	Usage gallons & dollars
Design Load - Btu/hr	41,843	103,487	201,183	
Total Load - Btu's	81,200,000	227,220,000	441,700,000	
Annual Oil Use - Gallons	580	1,623	3,155	5,358
Load Fuel Cost - Dollars	$1,850	$5,177	$10,064	$17,091
W/ Thermostat Setbacks	505	1,385	2,695	**4,585**
Actual Costs @ $3.19/gal	$1,611	$4,418	$8,597	**$14,626**

It is important to note that buildings operate as whole, dynamic, systems and that occupant behavior and annual temperatures vary over time, even hour by hour. We can calculate heat losses and heating loads for a room or a zone and for different outside conditions; divide up the space in a building by ownership; management; different uses; and estimate occupancy schedules and thermostat adjustments. All of those types of information were used to develop the estimates above, and yet it is virtually impossible to know exactly how much oil was used to heat which space. We can only know with any certainty how many gallons of oil is delivered to a building each year. It is the goal of this assessment to estimate as closely as possible what happened to the btu's of heat which were released when the oil was burned. By 'modeling' the building's properties, we can then prioritize changes and improvements to reduce the amount of oil needed, at the same time providing greater comfort to the occupants. Importantly in this case, we can better estimate the impact of converting a steam system operating at less than 70% system efficiency with less than effective heat distribution for comfort.

Tier One	South Offices	North Offices	Theatre	TOTAL
Design Load Btu / Hr	36,392	86,455	179,243	
Estimated Annual Fuel Use	421	1,151	2,409	**3,981**
Fuel Costs @ $3.19 / gal	$1,343	$3,672	$7,685	**$12,699**
Tier Two				
Design Load Btu / Hr	36,392	57,425	158,909	
Estimated Annual Fuel Use	387	813	2,182	**3,382**
Fuel Costs @ $3.19 / gal	$1,235	$2,520	$6,764	**$10,519**
Tier Three				
Design Load Btu / Hr	34,006	57,425	58,412	
Estimated Annual Fuel Use	332	809	817	**1,958**
Fuel Costs @ $3.19 / gal	$1,059	$2,581	$2,606	**$6,246**

Reducing the demand not only reduces annual fuel costs and improves comfort, but reduces the size of any replacement heating equipment which can save on installation costs.

The (somewhat cumbersome) chart to the right attempts to illustrate three project scenarios:

1. Keep existing heating systems and make envelope upgrades only. From a simple cost benefit analysis, alone, without any funding incentives, reducing the demand through air sealing, insulating, and reducing moisture loads from the crawlspaces, this option has merit. Again note, the shaded cells indicate only roughly estimated associated costs. Tier Two's associated costs involve renovations of the North Offices. Tier Three's costs may be especially complicated, if the tiles on the wall of the large theatre contain asbestos. It is likely that a Tier Two upgrade is the most feasible at this time. A PSNH may rebate 35% of the total cost of energy saving measures.

2. Improve the envelope to reduce the demand and replace the existing steam boiler and pipes, converting to forced hot water hydronic heating and a new, properly sized, oil fired boiler with advanced controls and a ducted combustion air supply. This will provide far better zone control, comfort, efficiency, and reduce health and safety hazards. It will also reduce costs maintaining and fiddling with the existing distribution system. With very roughly estimated costs on associated construction and system install, this scenario doesn't appear to be as financially feasible.

3. Improve the envelope, convert to forced hot water from a pellet fired boiler. While this requires the largest investment, there is—at this time—a $50,000 rebate incentive for installing pellet boilers. When combined to the substantially lower costs per btu for pellets, a Tier Two upgrade, FHW conversion and fuel switching appears to have the greatest long term return.

Another chart on the following page summarizes these scenarios, including the potential rebates available.

Improvement Tier	Insulation / Air Sealing	Construction	System	Ventilation	Total Costs	1st Year Savings	Gals Oil Saved	Lbs GHG Reduced	20 Year Savings	20 Yr ROI
Tier I	$39,240			$7,500	$46,740	$2,023	634	14,428	$49,140	5.1%
Tier 11	$52,478	$12,000		$15,000	$79,478	$4,206	1,318	29,995	$102,156	38.4%
Tier 111	$68,840	$85,000		$25,000	$178,840	$8,479	2,658	60,471	$175,415	17.4%
Steam to FHW		**With Conversion**	**Oil**	**Ventilation**						
Tier I with FHW	$39,240	$65,000	$25,000	$7,500	$136,740	$4,048	1,269	28,870	$98,358	-28.1%
Tier II with FHW	$52,478	$72,000	$20,000	$15,000	$159,478	$5,860	1,837	41,792	$142,383	-7.4%
Tier III with FHW	$68,840	$150,000	$15,000	$25,000	$258,840	$9,379	2,940	66,885	$227,875	-10.8%
FHW w/ Pellets		**Conversion**	**Pellets**	**Ventilation**						
Tier I with Pellets	$39,240	$65,000	$98,000	$7,500	$209,740	$6,999	4,585	104,309	$170,960	-18.5%
Tier II with Pellets	$52,478	$72,000	$75,000	$15,000	$214,478	$8,305	4,585	104,309	$198,902	-4.7%
Tier III with Pellets	$68,840	$150,000	$60,000	$25,000	$303,840	$10,843	4,585	104,309	$265,963	-11.5%

Based on the estimates below, the best options are to apply for subsidies for Tier Two envelope upgrades and convert to a pellet fired boiler and replacing the steam distribution system with forced hot water.

As indicated on the previous page, associated project costs include installing an ERV (Energy Recovery Ventilation) in the small theatre and additional ventilation equipment for other areas as required by code or deemed necessary for air exchange without a significant energy penalty.

Note that the cost of the equipment should go down with more aggressive envelope improvements and lower demand. Again, these costs are only rough estimates, based on experience and the two option proposal submitted by Frolling Energy in 2013.

For another option, note that Wilder Plumbing and Heating—also out of Peterborough—has had successful experience installing Okofen pellet boilers in commercial, school, church, and residential buildings. Okofen boilers are manufactured in Austria and distributed by Maine Energy. For more info, go to:

http:www.maineenergysystems.com/gclid=CIS4w4GAucICFQ_l7AodjzAAbg

Both boilers are excellent products and both local installers have good experience.

Improvement Package	Estimated Total Costs	PSNH Rebate	PUC Rebate	Total Subsidy	Potential Town Costs
Tier I	$46,740	$13,734		**$13,734**	$33,006
Tier 11	$79,478	$18,367		**$18,367**	$61,111
Tier 111	$178,840	$24,094		**$24,094**	$154,746
Tier I with FHW	$136,740	$13,734		**$13,734**	$123,006
Tier II with FHW	$159,478	$18,367		**$18,367**	$141,111
Tier III with FHW	$258,840	$24,094		**$24,094**	$234,746
Tier I with Pellets	$209,740	$13,734	$50,000	**$63,734**	$146,006
Tier II with Pellets	$214,478	$18,367	$50,000	**$68,367**	$146,111
Tier III with Pellets	$303,840	$24,094	$50,000	**$74,094**	$229,746

Project Option	Estimated 20 Year Heating Costs	Estimated 20 year Savings	Ball Park Estimated Project Costs	ROI
Existing Envelope	$355,377			
Tier One	$306,237	$49,140	$46,740	5.1%
Tier Two	$253,221	$102,156	$79,478	38.4%
Tier Three	$149,359	$206,018	$178,840	17.4%
Existing Envelope	$294,843	$60,534		
Tier One FHW	$257,019	$98,358	$136,740	-28.1%
Tier Two FHW	$212,994	$142,383	$159,478	-7.4%
Tier Three FHW	$127,502	$227,875	$258,840	-10.8%
Tier One Pellets	$184,417	$170,960	$209,740	-18.5%
Tier Two Pellets	$156,475	$198,902	$214,478	-4.7%
Tier Three Pellets	$89,414	$265,963	$303,840	-11.5%
With subsidies				
Existing	$355,377			
Tier One	$306,237	$49,140	$33,006	48.9%
Tier Two	$253,221	$102,156	$61,111	73.9%
Tier Three	$149,359	$206,018	$154,746	34.1%
Existing Envelope	$294,843	$60,534		
Tier One FHW	$257,019	$98,358	$123,006	-20.0%
Tier Two FHW	$212,994	$142,383	$141,111	2.8%
Tier Three FHW	$127,502	$227,875	$234,746	-2.0%
Tier One Pellets	$184,417	$170,960	$146,006	17.1%
Tier Two Pellets	$156,475	$198,902	$146,411	39.6%
Tier Three Pellets	$89,414	$265,963	$229,746	16.9%

If you would like to proceed with any of the recommended scenarios, follow up steps include:

1. Contract for hydronic system design (oil or pellet). Doug Waitt from Design Day Mechanicals has offered system design services and construction documents for a fee of $4,600. CD's would be completed by the end of January, but budgets could be developed earlier if necessary. He also offered construction administration for an additional $1200. Depending on the extent of air sealing achieved, and code requirements, ventilation will likely be necessary in at least some areas of the building.
2. Contact Anne Karczmarczyk at 634-2760 for PSNH thermal improvement rebates. This report may suffice for the application. If they need further modeling, Steve Elliot said that PSNH would likely cover any additional expense. They are currently developing the guidelines for the 2015 program but will go out to bid for a contractor to implement energy saving projects. It is my intention that this report will help Town decision makers participate in developing a comprehensive scope of work, even if some recommendations herein are not approved measures for PSNH rebates.
3. Incentives for pellet boilers are being administered through the NH PUC Sustainable Energy Division http://www.puc.state.nh.us/Sustainable%20Energy/RenewableEnergyRebates-CI-BFWP.html . They are administering the funding that supports most renewable technologies, i.e. Solar and biomass. Last year's proposal from Froling Energy was used for estimating purposes in this study.

Recommendations for more immediate action steps:

4. Install Carbon Monoxide alarm monitors in the hallway outside the boiler room. Sealing the two basement windows was an excellent energy saving strategy and the 10" duct may well provide adequate combustion air. But under certain outdoor conditions and when both boilers are firing, it is still possible for back drafting of flue gasses to occur. Yet another advantage of replacing existing boilers is to install combustion appliances with their own ducted air supply.
5. Assuming the buried drain is not clogged, re-install a down spout on the west side of the building, connecting to the drain.
6. Replace the programmable thermostats in the Selectmen's and Clerk's office, as well as the dial thermostats in the Meeting Room, Assessor's Office and Theatre, with more advanced, easier to operate programmable thermostats. (Example shown to the right). Importantly, program each thermostat for aggressive nighttime and weekend setbacks and timed to return to comfort settings by the time people show up for work. Advanced thermostats can be easily programmed for seven days and can be manually overridden, then automatically return to programed scheduled after one or two hours.

Honeywell Vision Pro @ $125 each is one good option.

7. If not already done, hire an electrician to check and verify that there are no hot 'orphaned' knob and tube sections remaining in the building. No insulation project should commence without this verification.

Conserving Electricity

Use	Consumption kWh/yr	Annual Cost
Office Equipment	10,635	$1,787
Hot Water Heating	3,125	$525
Town Hall Ceiling Fans	2,298	$386
Town Hall Lighting	3,158	$531
Theatre Equipment	9,675	$1,625
Theatre Lighting	2,134	$359
Cooling	2,800	$470
Heating	1,475	$248
TOTALS	**35,300**	$5,947

Cost for electrical usage represents 31% of the Town Hall's total energy costs.

Based interviews and the three site visits, it appears that all occupants are conscious to turn lights off in unoccupied spaces and most turn off office equipment at the end of the day.

Any electrical device which has an LED light, internal timer, or 'sleep mode' draws electricity even when turned off. The only way to stop all "phantom loads" is to unplug or disconnect from power with the use of a power strip. To save electricity and money, turn off and unplug all office equipment at the end of each day, unless it serves a function overnight (fax machines and computer servers are two exceptions to the UPLUG IT rule).

All eight ceiling fans are intentionally left running 24/7/365. Ceiling fans may, at times, be an efficient and effective way to distribute heat to or away from occupants. However, in winter, they can also just move cool air and cause discomfort. There is little reason (if any) to run ceiling fans in this building when unoccupied, so turning fans only when they benefit occupant comfort is estimated to save $450 per year. The meeting room fan does not have an accessible on/off/switch, though it appears that the switch plate has been replaced with a solid cover - therefore inexpensive to change.

The only Town Hall lighting which has not been recently upgraded to more efficient fluorescents is in the Assessor's Office area, which has T12 lamps. Upgrading to more efficient lighting should be part of any renovation plans. If renovations are postponed for over a year, then installing T8 electronic fixtures is recommended at this time.

The three wall sconces in the entry are on the general hall circuit and yet are not necessary during daylight hours. The cost of adding a light sensor on its own circuit is not cost effective at this time, though something to consider for the future.

Theater equipment and lighting is old and inefficient to a large degree. Investing in new equipment in lighting is likely not a Town expense so has not been explored in this Study. That said, the digital projector is left on 24/7/365 and was measured to draw 500 watts per hour for a total annual cost of $708. Dennis said he would look into the consequences of turning it off when possible.

B. Overview of Building Energy Use

There are three general areas of energy use in most NH buildings:

1. Space heating (and cooling)
2. Lights, Appliances, and Electronic Devices
3. Hot Water Heating

In cold climates such as NH, energy used for space heating is often the 'dominant load' or the use that requires the most energy and dollar costs. To assess the space heating load, or energy used to heat a building in the winter, there are two primary factors: the demand, related to heat loss through the envelope and occupancy patterns, and the supply, related to equipment and distribution.

1. The Envelope or Enclosure—Demand Side

Demand for heating energy is largely based on the effective performance of the thermal envelope (also called shell or enclosure). The overall goal of the envelope is to effectively manage moisture while limiting air movement and heat transfer. This is done by specific materials or collection of materials to serve as control layers of the assembly. Pages 15-20 offer a more detailed introduction to thermodynamics and heat loss relevant to understanding the heating loads of the Town Hall and recommended strategies to reduce fuel use through shell improvements. Page 21 offers a schematic image of the ideal goal for the Town Hall.

2. Heating equipment—Supply Side

A boiler or furnace is used to generate enough heat (in Btu's) to replace what is lost to the outside through the enclosure as heat moves to cold via conduction, convection, and radiation. The effective performance of the envelope determines the size or capacity of the equipment. The more efficient the equipment, the less energy used. But the better the envelope, the less the efficiency of the equipment becomes a factor. Alternately, the poorer the envelope, the more important the efficiency of the equipment—because, in part, it runs more often.

⇒ There are several components to boiler energy efficiency including combustion, jacket losses, and heat exchanger effectiveness. Boilers are, by design or adaptation, set up to either always be "on" and ready to distribute heat when called for (similar to sleep mode in electronic devices) or a "cold start" which means it shuts itself off until heat is called for which reduces losses—just as unplugging electric devices.

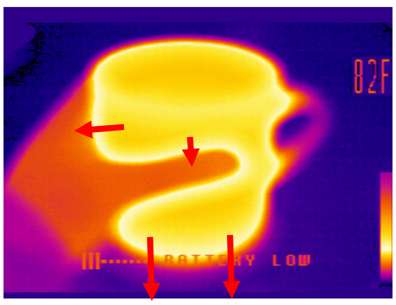
⇒ The distribution system—this is the system which moves heated air or water (in this case hot water or steam) through a building and can offer different opportunities for improvements. Most importantly, the distribution system should be inside the enclosure to limit losses to the outside.

⇒ Controls—thermostat controls and tying the temperature of the heated water to the temperature outside is a high priority for improving efficiency and reducing energy use. Outdoor reset controls are of no use to steam boilers, since the water has to reach at least 212°F to function as steam. While this is a considerable downside to steam in terms of energy efficiency, a steam system has considerably less water by volume to heat, which compensates somewhat for the necessary high temperatures throughout the season.

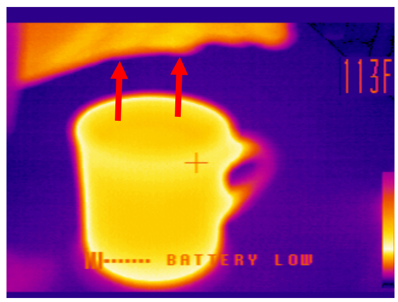
Thermodynamics Revisited

Thanks to several 19th century physicists, we can have an understanding of the principles of energy. These universal principles are known through the Four Laws of Thermodynamics which describe how energy is transformed or distributed through entropy. While complex in their entirety, understanding the basics of how energy—in the form of heat—transfers through space is important to our growing need and interest in energy conservation, most especially in buildings which use energy from fuels for space conditioning.

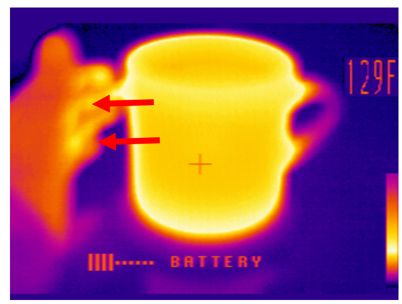
The infra red—or thermographic—images below of a ceramic mug containing hot water are offered as a way to illustrate the three basic methods of heat transfer: Conduction, convection, and radiation. Brighter indicates warmer surface temperatures. In spite of our commitment to the notion that "heat rises," so grab a cup of your favorite hot beverage and consider the dynamic world of heat transfer!



Conduction



Convection



Radiation

Conduction is the process by which heat transfers through direct contact from a warmer surface to a cooler surface. Above, the hot water heated the cup which then heated my hand—very rapidly, I might add! Note that heat will always move to cold, no matter the direction.

Convection is the process by which heat is carried in a fluid, such as air or water. In the above illustration, as is often the case in buildings, warmer air rises because it is lighter than surrounding cooler air.

Radiation refers to heat moving through space from a warmer surface to cooler surface. Above, the hot water conducted heat through the mug which warmed the exterior surface of the mug, which then radiated heat through space to my hand, one inch a way. Radiation needs visible contact—hence clouds or tree shade reduce the impact of a warming sun.

All three processes happen at the same time, but one usually dominates. Time is also a factor, and the dominating method may become secondary over time as material conditions change. A cup of hot liquid was used to illustrate methods of heat transfer because it is something about which everyone is familiar. Without thinking about it, we "drink it while its hot,", "wait for it to cool", accept a "warm up" by adding more hot liquid, "keep a lid on it" to prevent convective losses, and smartly hold mugs by their cooler handles.

Managing Heat Loss

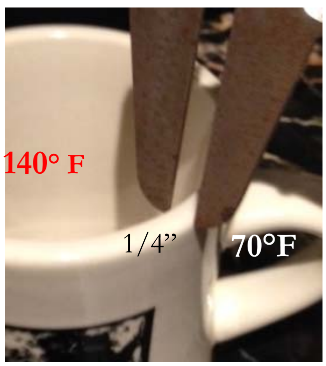
We are also familiar with a range of methods and materials to help manage heat transfer from our hot drinks. "Insulated" coffee cups, cups with lids, and cups with more than one material layer with an air space in between, are all ways to slow heat loss, addressing one or more of the three transfer mechanisms.

⇒ Conductivity—or thermal properties—of the materials;

⇒ Thickness of those materials;

⇒ Temperature difference of the materials;

⇒ ⇒ Total surface area of the contact.

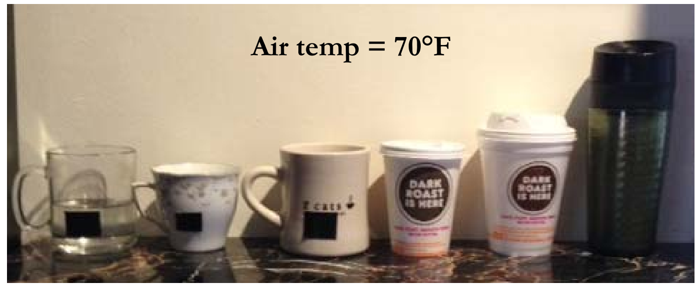


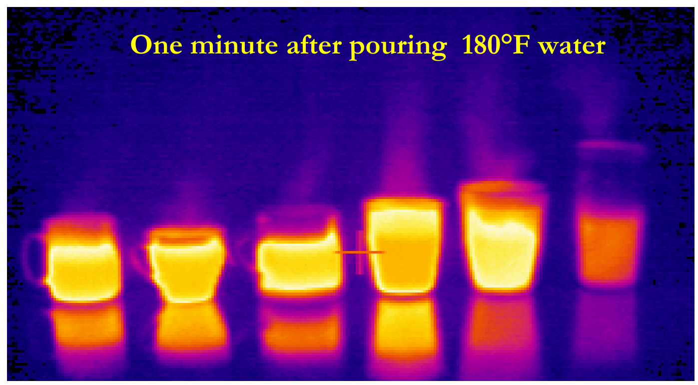
Ceramic conductivity translates mathematically to its "R-Value" or resistance to heat transfer. In this case, for example, R0.4 per inch or R0.1 for the cup—and a delta T of 70°F. (140-70=70). The greater the delta T, the more rapidly heat transfers.

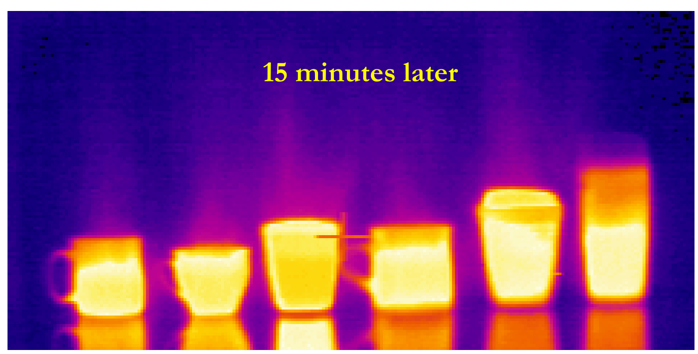
Convective losses will depend on the air above and around each container. The three lidded cups vary due to the lid 'tightness.'

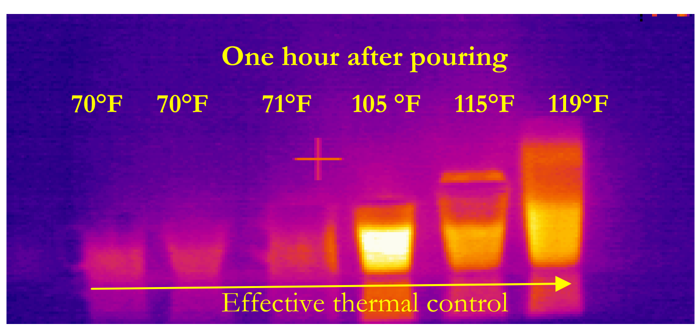
Radiation rates differ based on the geometry and mass of each cup and will vary over time as the cup's exterior surface changes due to conduction. Emissivity, or reflectivity, of a material also impacts radiation.

Heat loss is measured in Btu's and over time, usually one hour. In this example, the water temperature of all cups after one hour are indicated to the right.









Thermodynamics in Buildings

Summary points of the hot cup discussion to consider for buildings:

1. Heat will always move to cold.

2. Warm air rises, as air will always move from areas of greater pressure to lower pressure.

3. We can't stop the transfer of heat, but we can slow it down by stopping air and using insulation. The more continuous the air barrier and insulation, the slower the heat loss and the more fuel conserved.

4. All things have different material properties. Factors which impact thermal performance include conductivity and R-Value, density, air permeance, thickness of the material.

5. The temperature difference between inside and outside (delta T, or ΔT), also determine the rate of heat transfer. The greater the Delta T, the faster the rate of heat loss (or gain).

The principles of heat transfer in buildings are the same as in coffee cups. Conserving energy is considerably more complex, in part because buildings function as a system. To the above Key Points list we can add:

6. The Thermal Barrier (aka Enclosure and Envelope) of a building is the barrier between inside conditioned space and outside weather /climate. It is comprised of control layers designed to slow heat transfer through the foundation, walls, doors, windows, and ceiling or attic.

7. The effectiveness of the thermal barrier depends on the materials selected and how they are installed. The most effective thermal barrier will have continuous and effective levels of insulation in direct contact with a continuous air barrier on all six sides.

8. The more effective the thermal barrier, the lower the demand for heat, and to some extent, the lower the demand for cooling the in the summer.

9. Turning down a thermostat in winter (or up in summer) always saves energy because it reduces the temperature between inside and outside (ΔT). The more effective the thermal envelope and the slower the heat loss, the more one can lower the thermostat without risk of freezing pipes and the faster it will 'recover' to comfortable settings.

10. There are many more types of insulation materials and strategies for buildings than for hot beverages! How they are installed matters to their performance. *A lot.*

11. Besides cost, factors to consider when selecting insulation materials include R-value, thickness allowed in the space, density, air permeance, and skills and equipment needed by the installer.

12. Establishing an effective air barrier at the top of the building often yields the most dramatic reductions in heating energy. Air sealing other areas of the buildings, including windows and doors, can also yield cost effective results. Typically, replacing windows is the **least** cost and performance effective measure.

Managing Moisture in Buildings

Buildings—as a structure—don't typically need to be heated or cooled. And they do not need to breath; at least in the same way we animals need to breathe. They DO need to be able to dry out when they get wet. Water can be as much a mortal enemy to buildings as fire, so while developing strategies to manage heat and air flows in buildings, it is critical to also manage moisture; that is—liquid water and vapor.

People often say "buildings have to breath," which tends to perpetuate the myth that one can make a building too air tight, since we naturally associate breathing with air. While a lot of air leakage has helped keep buildings dry out in the past, effectively managing moisture is key when tightening a building to conserve energy.

Building surfaces can get wet a number of ways: Liquid water gets in as falling or wind driven rain gets in through cracks or gaps; ground water seeping in through basement gaps, or even leaking or burst pipes.

Water can also form when vapor makes contact with a cold surface and condenses into liquid water. As the warm, moisture ladened, air rising from the hot water in the photo, hits the surface of the cold glass plate, the vapor in the air cools below its dew point and then condenses to form droplets of liquid water. We see this often on bathroom windows or mirrors after taking a shower.

This is not a problem as long as those droplets can dry out before causing rot or mold. But if a wood window frame, for example, is always damp from condensation—or vapor condenses on the inside of exterior sheathing within a wall cavity and can't dry out—then mold and/or rot is bound to happen.

A conventional practice has been to install 'vapor barriers' on the warm side of a wall or ceiling to prevent vapor from migrating to the colder exterior surfaces. These barriers or 'retarders' slow or prevent vapor diffusion which means they can also slow or prevent drying back to the interior if the assembly gets wet. And it turns out that far more vapor migrates through the air than by through diffusion. So a vapor barrier that is also not an "air barrier" can allow significant amounts of vapor into a wall assembly, while then reducing or preventing its ability to dry back out again.

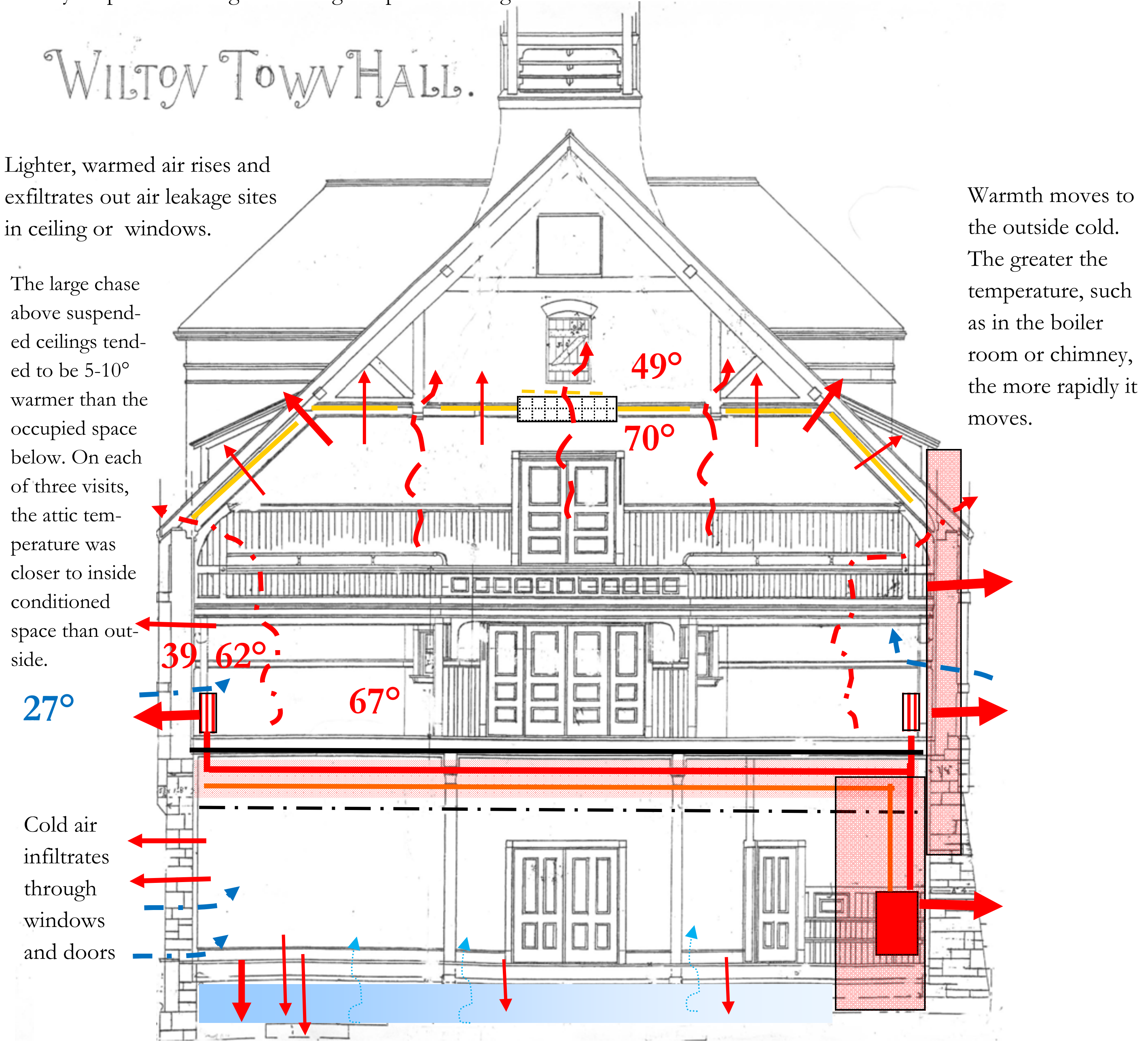
Understanding thermodynamics in buildings and building materials has been the primary focus of the building science field over the last thirty or forty years. It is an emerging science, in terms of influencing or integrating with ever changing technologies in building materials and products. As with the rest of our culture, products which are designed to sell may or may not be based on sound building science principles, nor are contractors or conventional building practices always informed about material properties and the realties of thermodynamic processes.

In other words, making buildings which will dry if they get wet, while also optimizing heating energy, can be complicated. This is especially true when retrofitting existing buildings, and most especially true for historic brick buildings where preserving the exterior brick is valued above all else.

C. Descriptions of Existing Conditions

A Thermodynamic "Snapshot"

The intention behind this busy graphic is to illustrate some of the more dominant thermodynamic activity in a middle cross section of the building. The crawlspace is connected to outside at the street level and so is cold, meaning that inside heat moves to it through the floor. At the same time, the earth is always at least dampish, so moisture often migrates to dryer conditions above. Cool outside air infiltrates through cracks and gaps at lower parts of the building, then warm and rise to help heat the building but also to exfiltrate to the cold outside. Meanwhile, distributed heat from the steam pipes is most concentrated between the air leaky suspended ceiling and the tighter plaster ceiling under the floor.



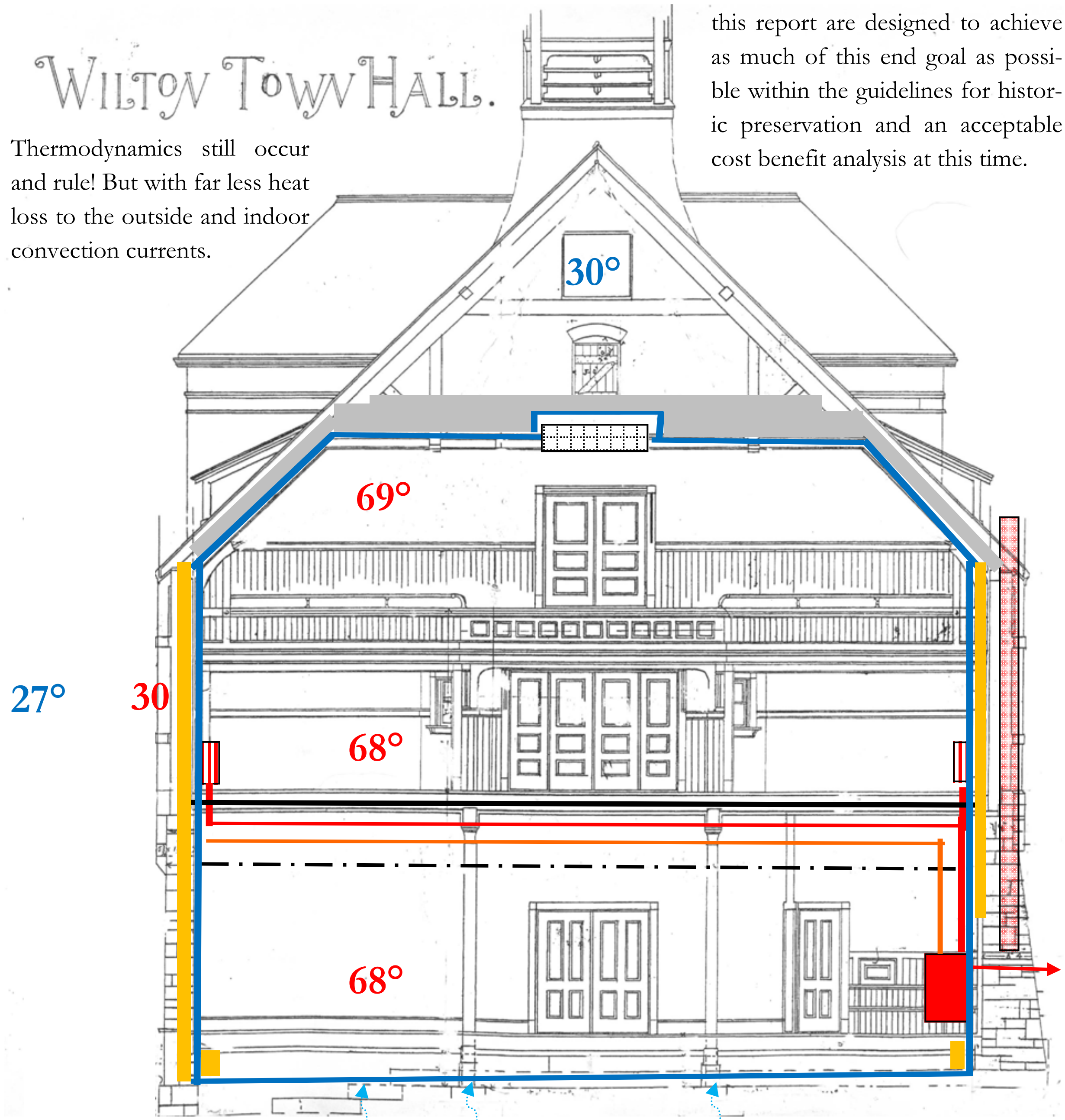
The sum result is considerable heat loss to the outside and inefficient distribution and possible discomfort.

The Ideal Goal

The goal is to effect a continuous air barrier (blue) all around the exterior surface of the shell and in direct contact with continuous insulation in effective levels of thickness. Based on the Town Hall's building materials, closed cell foam on the granite and brick walls and cellulose in the slope and attic floors may be most appropriate. Replacing the steam boiler and system with more efficient equipment and distribution system, properly sized for the improved envelope (reduced demand) and connected to an outdoor reset to supply the heat that is needed for the outside conditions (no more, no less) will provide optimum heating supply for the lowered building's demand .

The recommendations included in this report are designed to achieve as much of this end goal as possible within the guidelines for historic preservation and an acceptable cost benefit analysis at this time.

Thermodynamics still occur and rule! But with far less heat loss to the outside and indoor convection currents.



The net result would be a building with dramatically reduced demand for heat, reduced moisture drive through the floor the and responsive zone control for efficient generation and even distribution of supply heat.

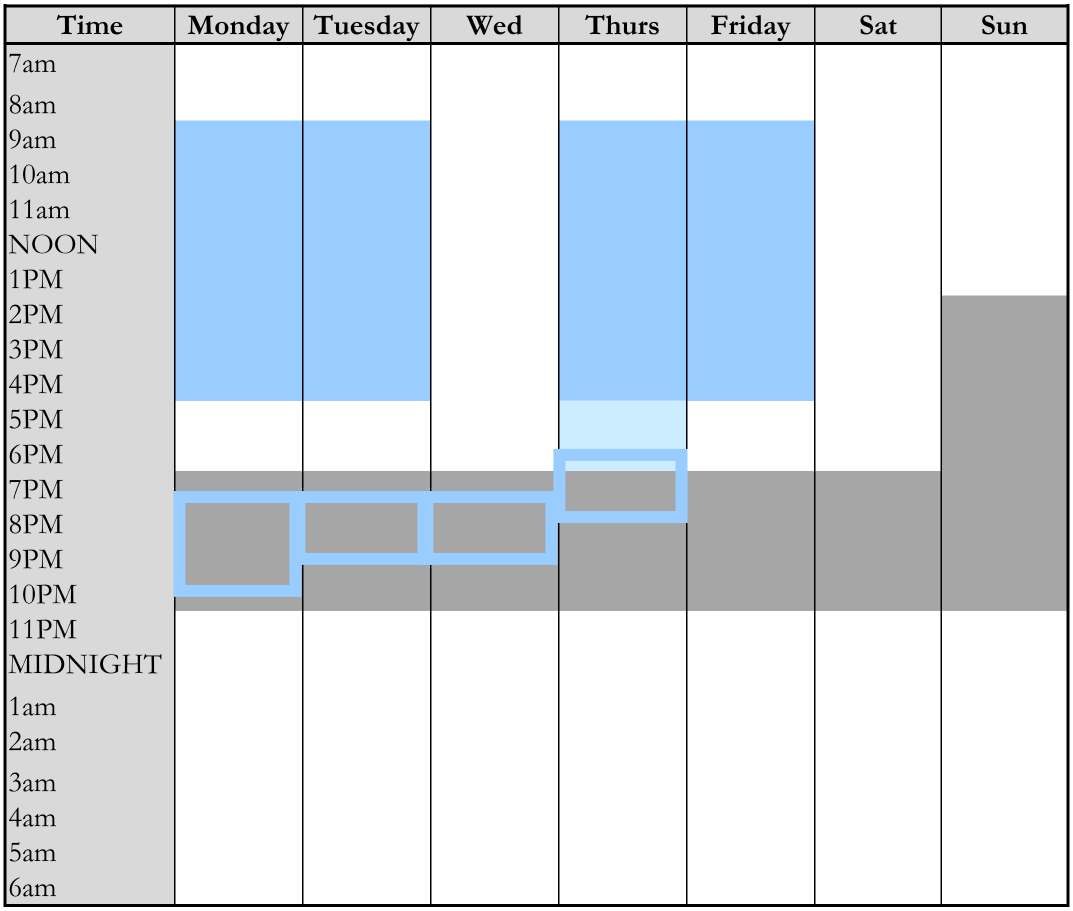
East facing

North facing

South facing

West facing

Occupancy Patterns



Occupancy schedules can vary week to week and season to season. The chart above reflects what is believed to be a fairly consistent pattern for the Town Hall, even if missing specific events or meetings.

The Theatre (shaded in gray) shows movies every night starting at 7:30 and Sunday matiness start at 2:00 for an occupancy of approximately 26 mostly evening hours a week, or 15% of the number total hours in a week.

The Town Offices (shaded or highlighted in blue and purple for building inspector) are occupied approximately 54 hours each week, based on office hours and sporadic meeting schedules, or about 2800 hours per year and about 32% of the year.

One reason for the graphic is to depict the number of hours the building is effectively unoccupied. One exception is that Dennis provides janitorial services each night, though it is his habit to turn thermostats down or off as if the building is unoccupied.

Therefore of the 8760 hours in each year, the building is effectively unoccupied 53% of the time, including during the coldest, nighttime, temperatures. Aggressive set backs on easily programmable thermostats is the best way to save fuel when the building is unoccupied and still provide a comfortable indoor environment when occupied.

The other reason is to help illustrate the advantage of proper zone control over each of the building areas: Selectmen's Office, Clerk's Office, Meeting Room, Planning and Assessors, and Theatre.

Peak Heat Loss Calculation for Existing Conditions

A room by room peak heat loss calculation is used to determine the size of the heating equipment and distribution needed in a building. It assesses each component of the thermal envelopment and calculates how much heat would be lost during one of the coldest hours of a winter in a particular region. Conductive heat loss is determined by surface area, conductivity of the material (or assembly), and the difference in temperature between inside and outside. In this case, the "design temperature" is based on a minus three degree outdoor temperature with an indoor temperature of 70 degrees—therefore a delta T (ΔT) of 73 degrees F. Based on these calculations, the total heat lost to the outside during one hour when its minus three degrees outside is just under an estimated 350,000 Btu's. The last column reflects the relative heat loss proportioned for each room or area. The bottom lines reflect heat loss by envelope component.

Based on this calculation, walls account for 50% of the building's conductive heat loss, followed by air leakage, windows and the floor. Ceiling values are misleading as performance is greatly influenced by thermodynamics as depicted in the previous diagrams. Therefore the continuity of an air barrier at the ceiling plane will have a far greater impact on heat loss to the outside than suggested in the chart on the next page. Its also important to note that windows and doors are large contributors to air leakage and can have a significant impact on comfort—which then impacts the thermostat setting. This is especially true in the Town Hall because the overall structure of the building is very tight. Older (and new conventional framing) wood framed buildings tend to be very 'air leaky' because air easily moves through gaps between wood framing unless intentionally sealed—as is the direction of the built environment in the 21st century.

In fact, air leakage per se is not as significant a factor in heat loss as uninsulated walls and general stack effect (warm air rising in tall buildings), but does play a role in air quality when rooms are fully occupied and moisture control.

This is a very simple approach to energy analysis but valuable in terms of presenting a general snap shot for prioritizing primary improvement opportunities which are:

⇒ Establish a moisture barrier on the dirt floor of the crawlspace under the building.

⇒ Air sealing window, doors, and the ceiling plane

⇒ Upgrading insulation levels the ceiling/roof plane

⇒ Install R10 insulated, air tight, winter panels in the Theatre windows which are effectively left darkened by drapes anyway. Fixed windows can have fairly permanent panels, while panels should be easily removable for operable windows.

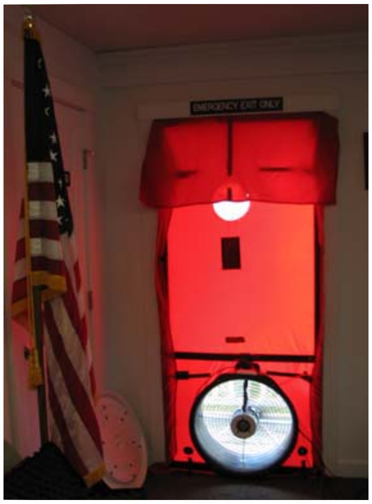
⇒ Insulate walls as practical to do so (inspiring or as part of planned renovations)

These estimates are presumed reasonable because when modeled through an analysis of estimated heating system, efficiencies and a bin analysis of Wilton's heating degree days for the past two years, the predicted fuel use came within 4% of actual fuel use. Therefore, it is estimated that completing the envelope upgrades, which will also allow more aggressive thermostat setbacks at night, will yield the predicted fuel savings. Please understand these are still estimates and results can also vary in response thermostat settings and winter temperatures as well as other variables.

Peak Heat Loss Calculation for Existing Conditions

Zone & Envelope	Walls	Windows	Doors	Ceiling	Floor	Infiltration	TOTALS
TOWN HALL							
Entry	1,128	2,503	568		1,260	1,971	**7,430**
Selectmen's Office	1,506	2,090			2,900	1,971	**8,467**
storage closet	1,195				720	114	**2,029**
Public WC	796				180	284	**1,260**
Staff WC	796				180	284	**1,260**
Hall					2,050	1,277	**3,327**
Clerk's Office	5,645	3,407			5,520	3,173	**17,745**
Vault					286	39	**325**
Total Office -FHW	***11,066***	***8,000***	***568***		***13,096***	***9,113***	***41,843***
	26.4%	*19.1%*	*1.4%*	*0.0%*	*31.3%*	*21.8%*	*100.0%*
Meeting Room	8,906	1,877			11,100	4,376	**26,259**
File Room	1,095				2,000	788	**3,883**
Kitchen	608				1,100	434	**2,142**
1st Floor Entry	6,692	521	6,205		4,000	4,730	**22,148**
Womens's WC	1,217				1,450	714	**3,381**
Men's WC					1,500	591	**2,091**
Cell Block	10,780				2,000	394	**13,174**
Tax Assessors/CE	8,541	2,746			3,429	4,730	**19,446**
Planning	3,139	3,337			686	473	**7,635**
Closet	2,920				400	8	**3,328**
Total Office - Steam	***43,898***	***8,481***	***6,205***	*-*	***27,665***	***17,238***	***103,487***
	42.4%	*8.2%*	*6.0%*		*26.7%*	*16.7%*	*100.0%*
THEATRE							
Theatre Lobby	18,226	3,754	6,643			9,313	**37,936**
Large Theatre	54,409	8,627		9,758		16,453	**89,247**
Stage	25,501	3,618		1,841		2,034	**32,994**
storage	3,115	1,270				993	**5,378**
Small Theatre	15,452	4,285		1,565		2,796	**24,098**
Projection Room	2,433	1,564				1,143	**5,140**
Mezzanine				1,250			**1,250**
Server Room	2,433	1,564				1,143	**5,140**
Total Theatre - Steam	***121,569***	***24,682***	***6,643***	***14,414***		***33,875***	***201,183***
	60.4%	*12.3%*	*3.3%*	*7.2%*		*16.8%*	*100.0%*
Total Steam	***165,467***	***33,163***	***12,848***	***14,414***	***27,665***	***51,113***	***304,670***
	54.3%	*10.9%*	*4.2%*	*4.7%*	*9.1%*	*16.8%*	*100%*
Whole Building	**176,533**	**41,163**	**13,416**	**14,414**	**40,761**	**60,226**	**346,513**
	50.9%	11.9%	3.9%	4.2%	11.8%	17.4%	100%

Air Leakage and Blower Door Tests



Uncontrolled air infiltration—and exfiltration—can account for up to 35% of a building's heat loss and heating bill and is often the cause of discomfort. (Think drafty old buildings or new windows!) Since air can carry a lot of water vapor with it, air leakage through the exterior of a building can also contribute to moisture problems such as mold and rot in walls and roofs or ceilings. Conversely, it is winter air infiltration which is most responsible for excessive dryness in the winter. Finally, icicles and ice dams are most often the result of warm, conditioned air rising up though gaps in the ceiling and warming the under side of a roof and melting the snow from below. Melt water then runs down to the edge of the roof where it freezes when exposed to air. For all these reasons, limiting air infiltration is often at the top of the list to conserve energy, improve comfort, and reduce roof damage and other moisture problems.

The 'blower door' is used to help locate and estimate the amount of air leakage in a building. It consists of an adjustable frame which mounts in an exterior doorway, a nylon "skirt" that is stretched over the frame to stop air except for a hole at the bottom in which a fan is placed. The fan is capable of moving up to about 6,000 cubic feet of air per minute. Plastic tubes are used as "pressure taps" and are attached to the pressure gauge (left) to measure both the amount of air pulled through the fan and the pressure difference between inside and outside.

This equipment can be used for several different diagnostic tests but the most common is for measuring the amount of air which can be pulled through cracks and gaps in the envelope at a standardized pressure (-50 pascals). With the fan running, one can also use a smoke gun or an infra red scanner to locate those cracks and gaps.

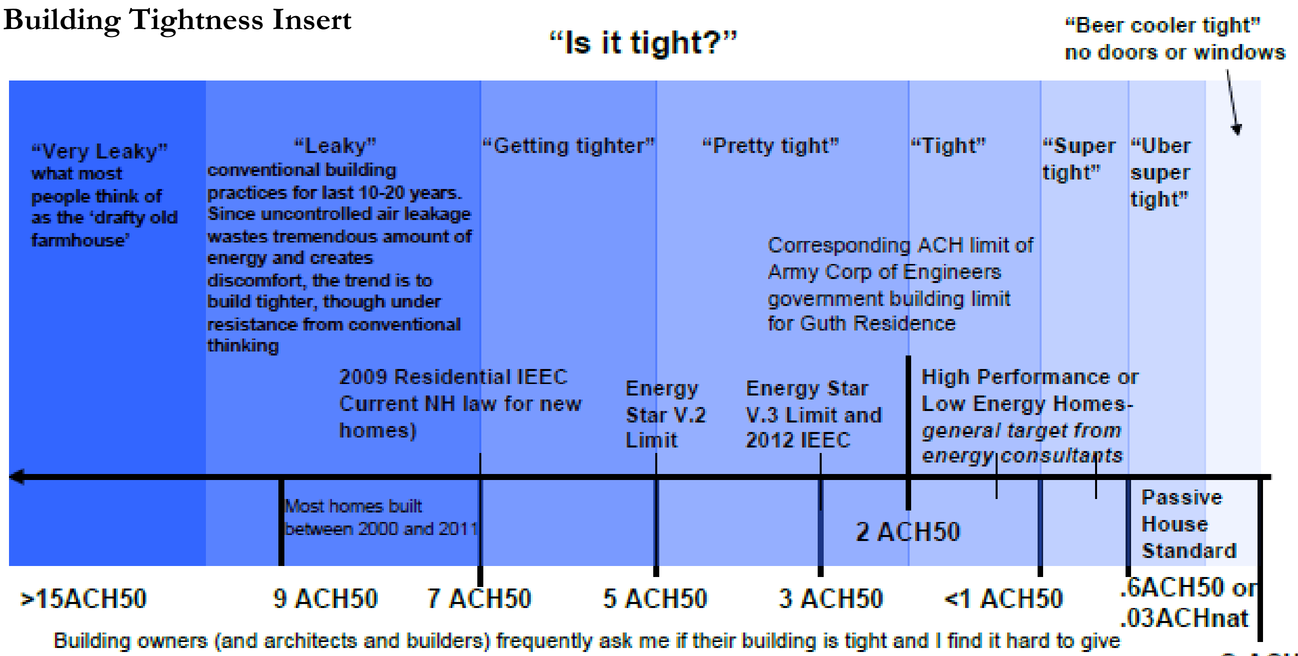
As interesting a test as that can be, a blower door test was not conducted at the Town for a number of reasons, mostly logistical and a concern for drawing up contaminants from the dirt floor. (One of the staff members commented about allergic reactions in the building and I didn't want to risk stirring anything up). But as mentioned elsewhere, masonry buildings like this tend to be very tight, with leakage sites limited to window and door openings and gaps in the ceiling plane which are easier to quantify and qualify with thermographic imaging and a measuring tape.

In addition, CO2 levels were measured throughout the buildings and at various occupancy levels to determine if mechanical ventilation is advisable (in addition to being a code requirement). It is also important to understand that the lower level needs mechanical air exchange. I believe that the air handler in the back storage room runs 24/7 to circulate air to which consumes considerable electricity but does not add outside fresh air to the mix.

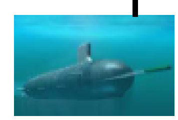
While a very limited study, installing mechanical ventilation with energy recovery (ERV) in the small theatre is recommended at this time. More CO2 monitoring could be useful, as would a blower door test following the installation of a liner over the dirt floor and other air sealing efforts.

Building Tightness Insert

"Is it tight?"



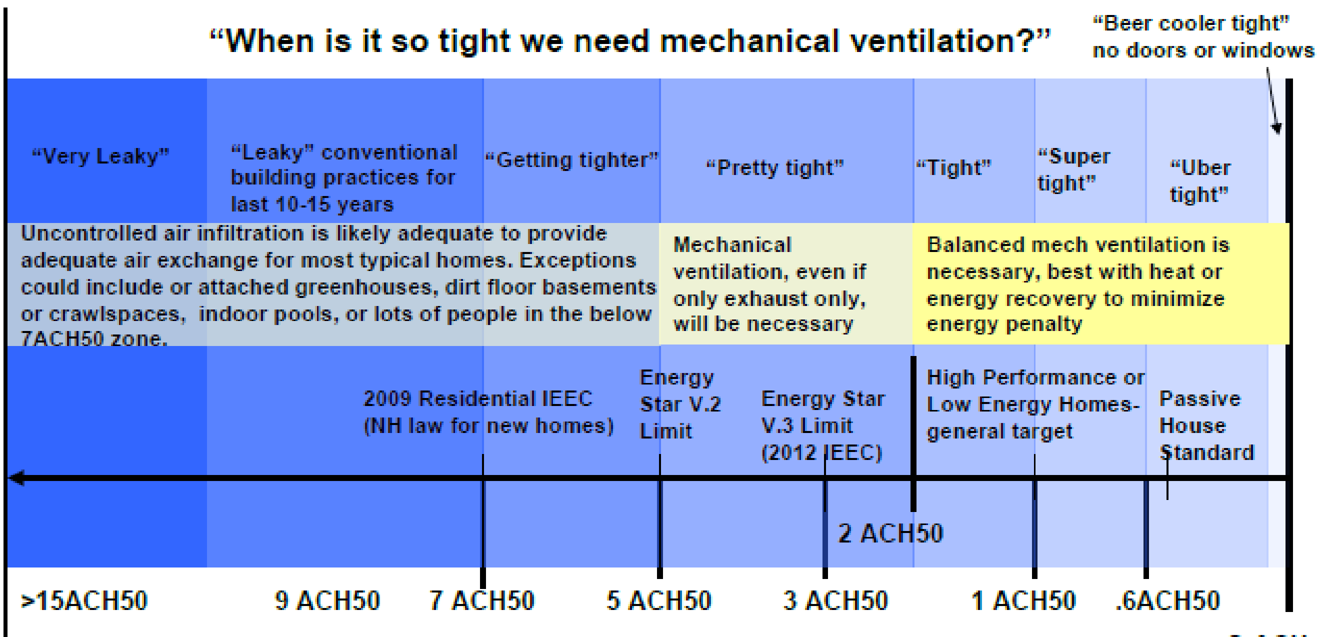
Building owners (and architects and builders) frequently ask me if their building is tight and I find it hard to give them a satisfying answer. In truth, air tightness is relative and the mathematical description of a building's air barrier or level of tightness has little meaning at best – and can be incredibly boring at worst. I once attempted humor with "well, if it were a submarine, everyone would drown" but, while accurate, proved less than helpful. So this graphic has been developed in an attempt to explain the spectrum of tightness in terms of existing buildings and the direction we're headed in terms of codes and standards. The tighter the building, the less air infiltration, and therefore heat loss, in the winter – which means less energy needed to run your equipment.



"ACH50" or Air Changes per Hour at -50 pascals, means the number of times the indoor conditioned air will exchange with outdoor air within one hour when the building is under -50 pascals of pressure. This is a standardized testing condition, using a blower door fan assembly. One can *estimate* the air exchange rate under natural conditions by dividing by 15. Colored boxes above are generalized zones for this discussion only.

1

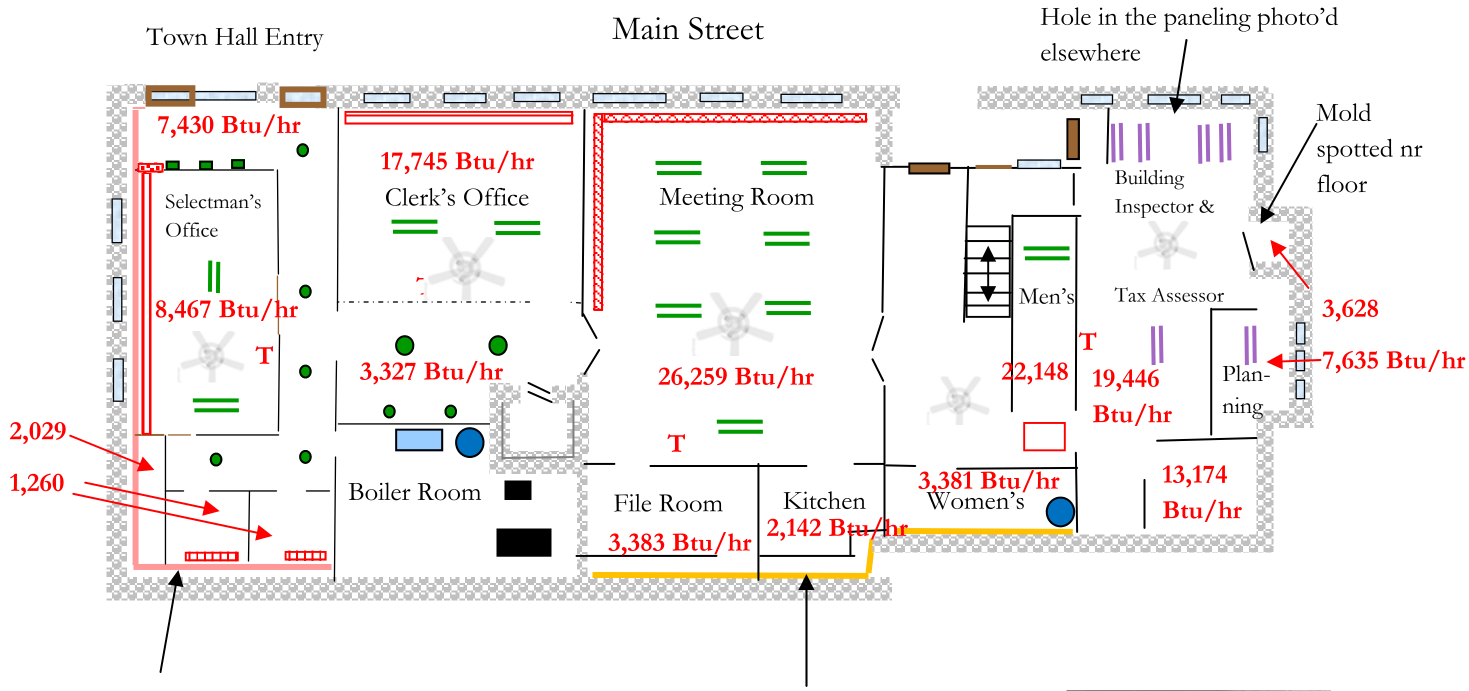
"When is it so tight we need mechanical ventilation?"



A common response to the 'tightness' discussion is that "buildings can be too tight: they need to breathe". The truth is that people need to breathe – buildings just need to be able to dry. Very high air leakage allowed buildings (wall and roof assemblies, etc.) to dry out if they got wet. But it takes tremendous amounts of energy to maintain comfortable indoor temperatures with so much air leakage. So the answer is: buildings *cannot be too tight*, and in fact must become as tight as we can make them, as long as they are designed to be able to dry out and as long as we provide mechanical ventilation when necessary so that people have enough fresh (or filtered) air to breathe. The various yellow shaded boxes above categorizes, in very general terms, when mechanical ventilation might be needed. There are a number of factors to consider when determining specific ventilation requirements – either by code or specific occupancy realties.

Town Hall—Schematic Diagram

Rough schematic diagrams with notes are included as a visual reference. These may (or may not) also be helpful when talking with various contractors about work scopes and estimates.



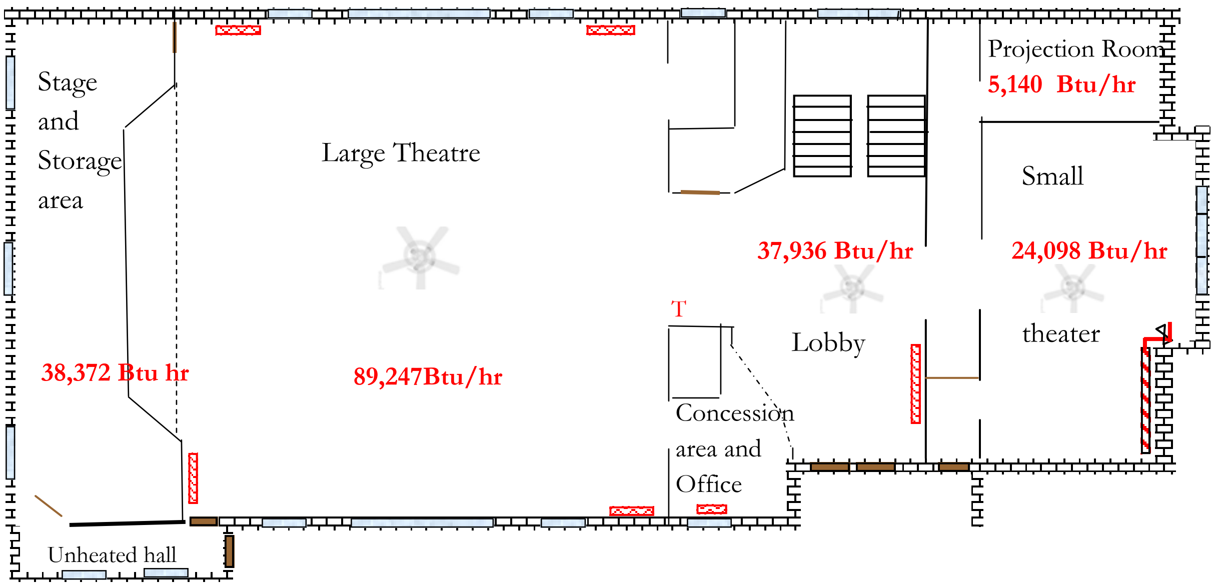
The walls of the Selectman's Office and restrooms have been framed in with 2x4's at 16" OC and offset from the granite foundation wall about 7". Three and a half inch faced (Class II vapor retarder) fiberglass batts (pink) are stapled into the cavities. Note the "R11" stamped on the facing indicates the resistance to heat flow when installed in a chamber in direct contact with an air barrier on all six sides and perfectly lofted. This is rarely accomplished in real life conditions and in this case, the batt is entirely open to the air space before the foundation wall, as well as open to the interior above the suspended ceiling, and not lofted in the cavity—resulting in a greatly reduced thermal performance: effectively between R4 and R6. (photo right)

The only other wall insulation in the building is on the foundation wall behind the file room, kitchen, and women's WC. Two to three inches of SPF (yellow) directly on the granite from slab to floor decking above - approx. 14 feet. Evidently, this was done as a moisture control strategy with positive results. All other walls in the building appear un-insulated.

Key

- Windows
- Wood Ext Door
- Glass Door
- Hot Water Baseboard
- Steam Radiator
- T Thermostat
- Boiler
- Elec Hot Water Heater
- 4' T12 fluorescent lamps
- T5 electronic fluorescent

The Theatre (s)



Maple Street Level

The one foot square wall tiles which line cover the walls are presumed to contain asbestos which, if true,

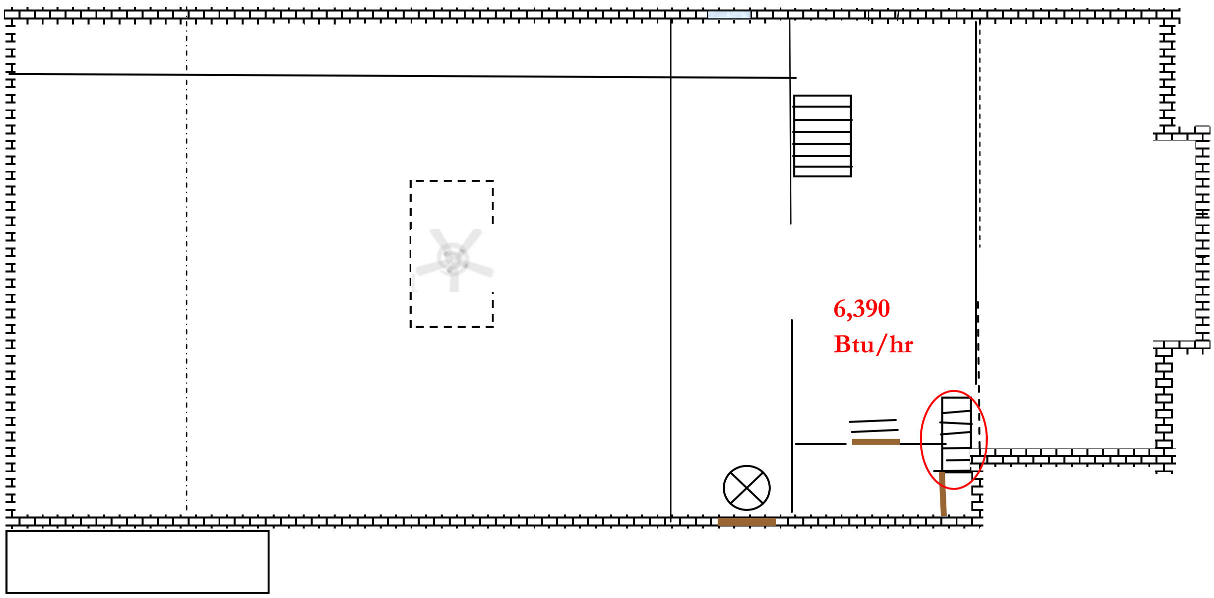
A) Adds slightly to insulation value and sound buffering

B) Greatly increases the cost of removing them to insulate and resurface these walls

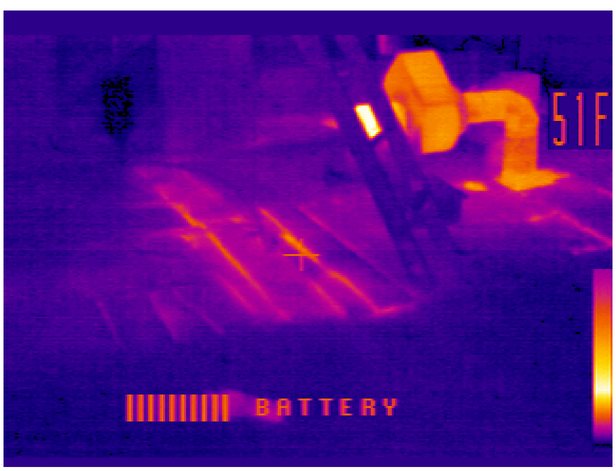
C) Adds another reason to remove and properly dispose them

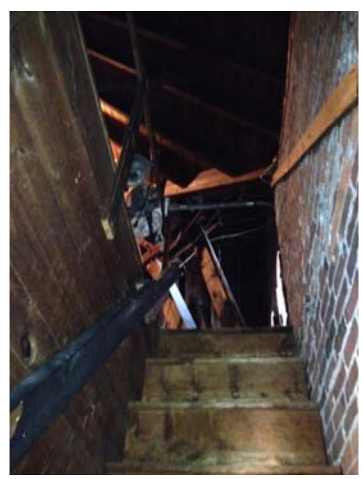
The slopes do have some insulation in them, but removing it with the material on the flat ceiling is recommended.

Mezzanine



Two of the few "low hanging fruit" opportunities involves creating an easily opened thermodome (R20 insulated box with tight fitting, weighted seal) for the top of the steps leading to the attic and air sealing around the exhaust fan assembly near the belfry. In fact, this warm air in winter could possibly be ducted back into the ceiling of the large theatre. In the summer, an alternate duct (Y connection with damper) should vent this warm, humid, air to the outside.

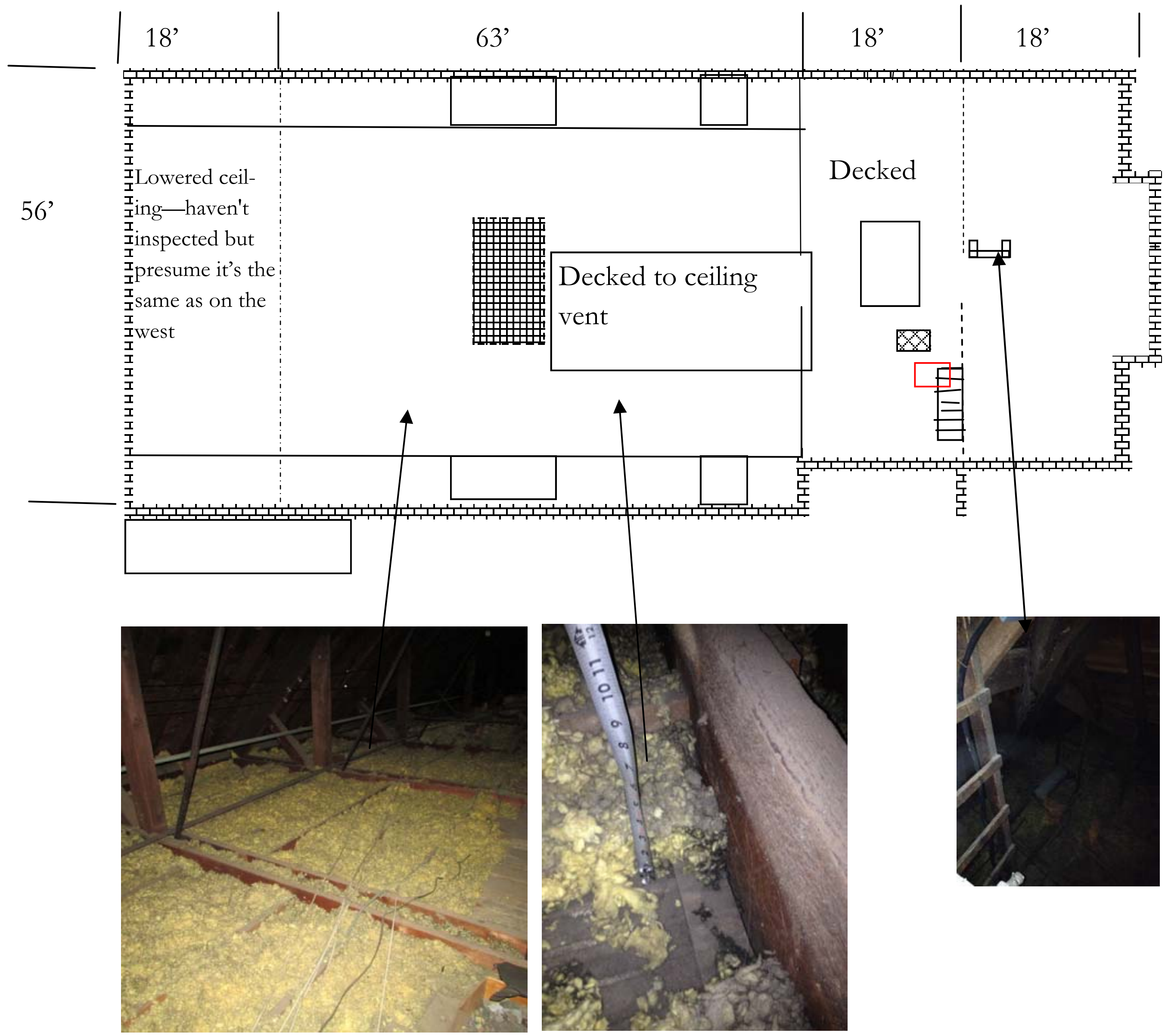


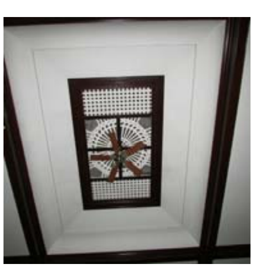


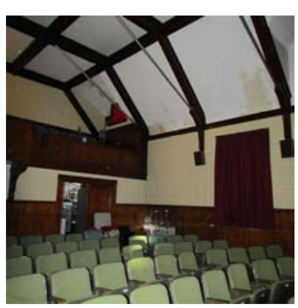
Bright areas indicate heat loss from the projection room into the attic. The warm duct and fan helped keep this cold attic a comfortable 50° one cold, clear, night when it was 27° outside. As does this charming staircase with unsealed and un-insulated door.

Attics

This page, and the following page 'under the floor' were developed in part for Don LaTourette for his exploration of the building's hinterland areas.

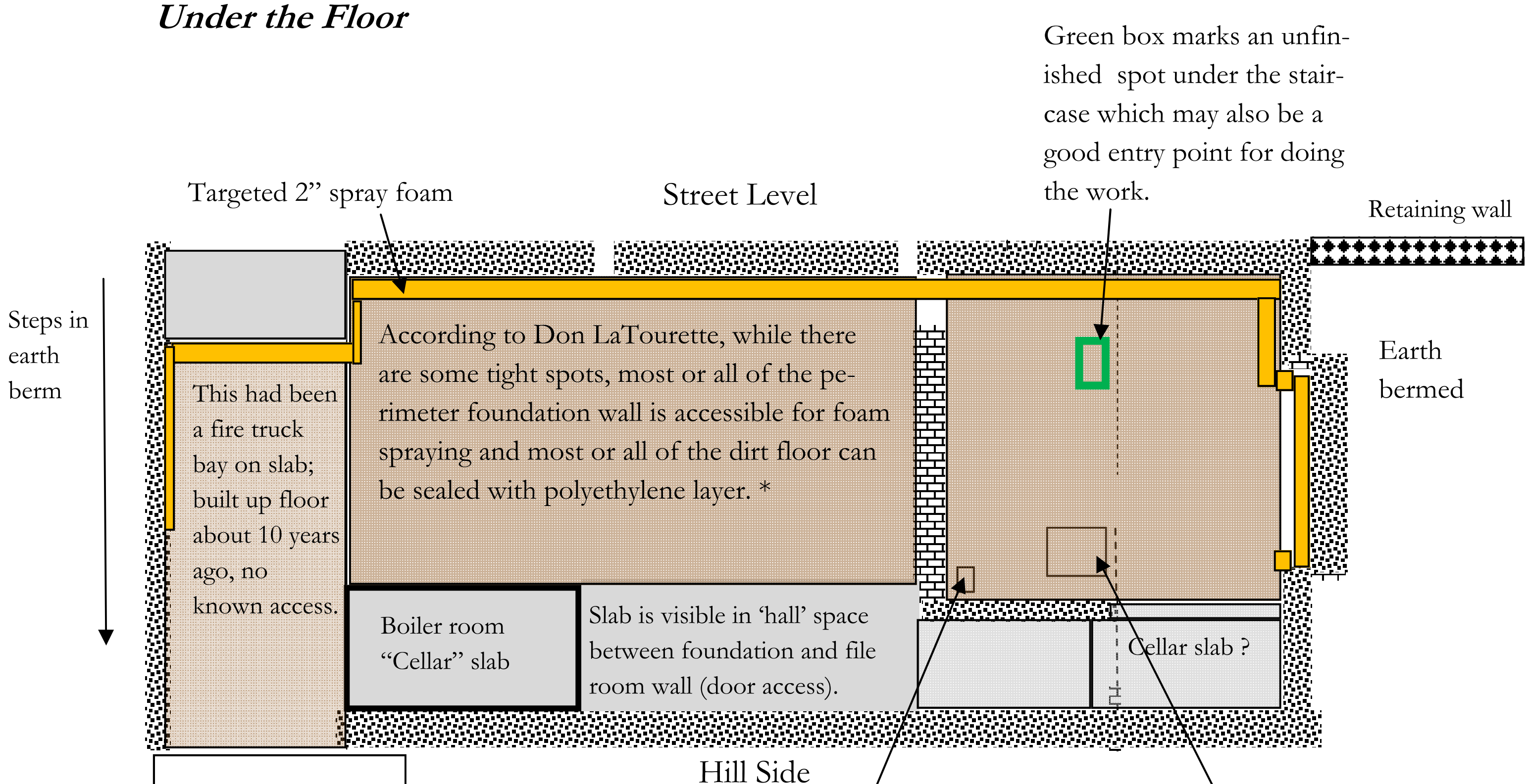




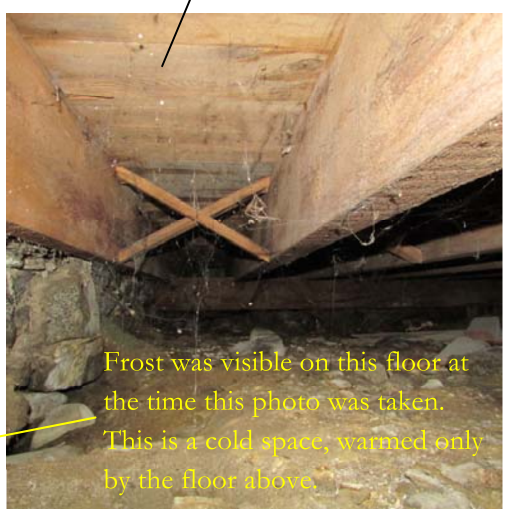


Slopes and glables MOSTLY void of insulation - 6" or less on flats

Under the Floor



This the view below the floor from the corner opening to the left of the woman's' restroom door.



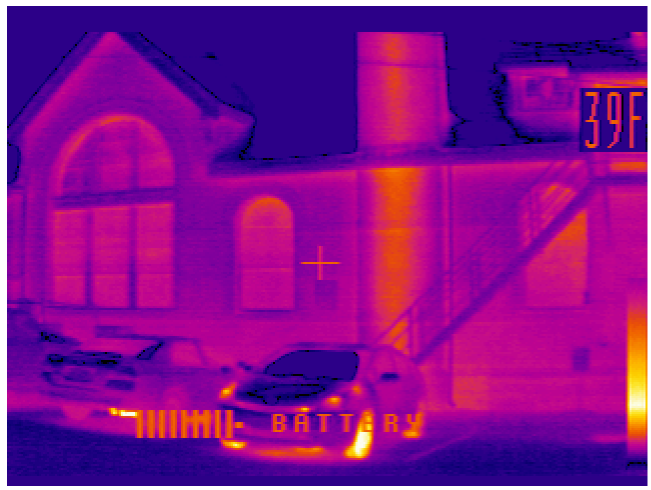
Larger access hatch in a 4' hallway, under a carpet, in front of the door to the Planning offices. John says its much better viewing and along the sewer pipe trench.

* Laying a poly liner and spraying foam against the foundation wall in a tight crawlspace is nasty, nasty work and requires someone of not only appropriate size and skill, but who cares enough to complete a comprehensive job. Further, there are fewer direct energy savings than other areas in a building, so such investment is often missing from utility managed rebate programs. What is important to remember that this measure improves air quality; reduces allergy producing contaminants in a building, and allows for more aggressive air sealing "upstairs" without risking problems such as mold or rot. I recommend Building Energy Technologies for all air sealing and insulation work, but especially for areas such as this crawlspace and attic which require a level of passionate intention to do well.

Interpreting Thermographic (Infra Red) Images

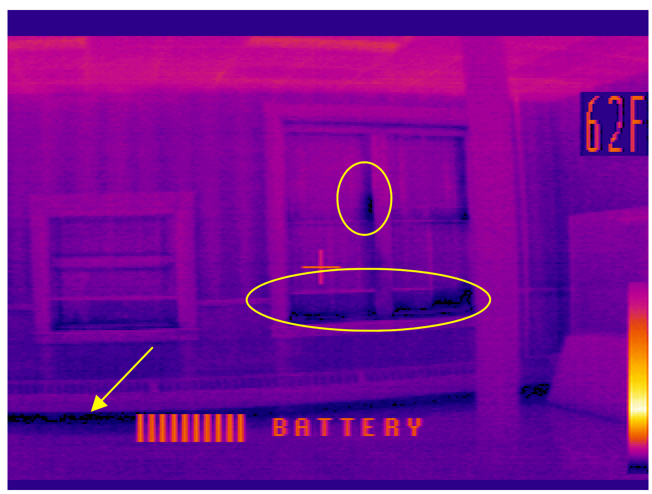
Thermographic, or infra red images depict differences in surface temperatures only. Recognizable shapes, such as chairs or windows, are visible only because surface areas emit different temperatures that surrounding areas. The camera used is a high resolution (240x360) Monroe HR, black and white scanner and images were colorized without any adjustments using IR DAQ software. Areas which are brighter depict warmer surface temperatures than darker areas. The camera is extremely sensitive so temperature differences of 1 degree can appear with contrast tones. Thermography can be a very helpful tool in building diagnostics, especially in assessing the performance of the thermal envelope, as its used for this report.

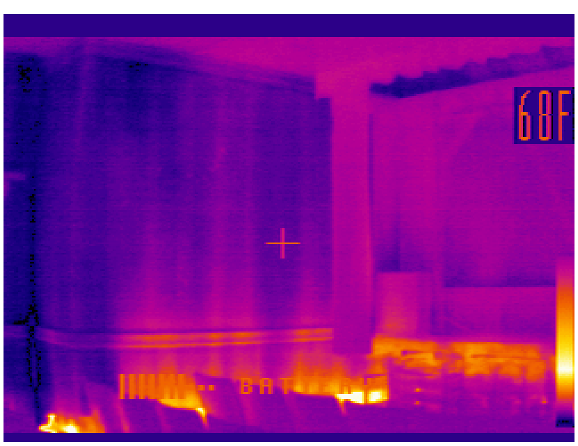
From the outside on a cold night, warmer (brighter) colors indicate heat loss from the inside. Outside air temperature was 27° while the brick wall (center hatch) was measured at 39° thanks to heat inside conditioned space—and the chimney and boiler room below—conducting to the outside.



When taken from the inside, areas of greater heat loss are seen as darker colors as heat conducts more rapidly to the outside. In the wall below right, the warmer vertical lines likely indicate stud framing on either side of cavities void of insulating material. Note the cold floor and darker areas at edges of windows where the sashes meet—signs of cold air infiltration and thermal bridging at the granite foundation.

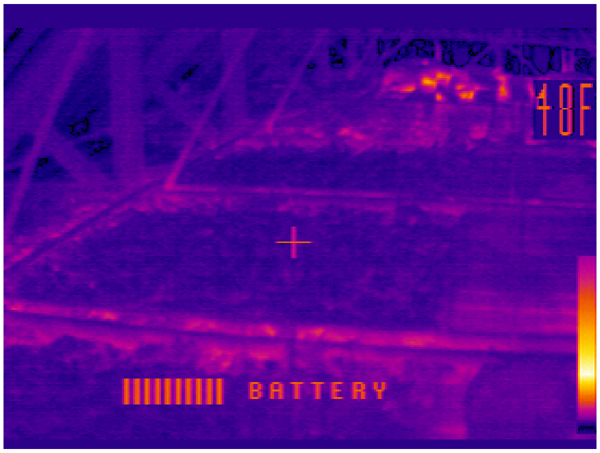
Circled areas indicate air infiltration or 'wind washing' causing discomfort and responsible for considerable fuel usage.

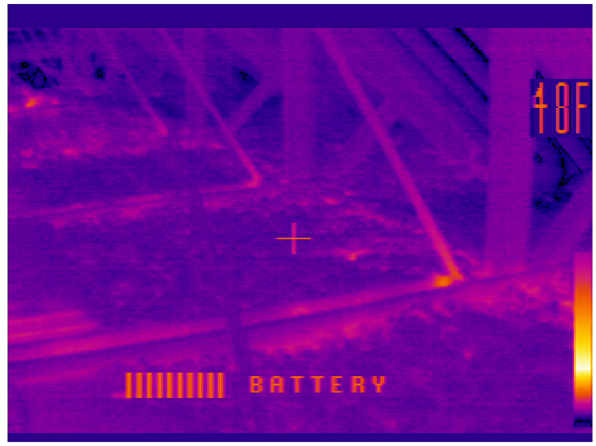




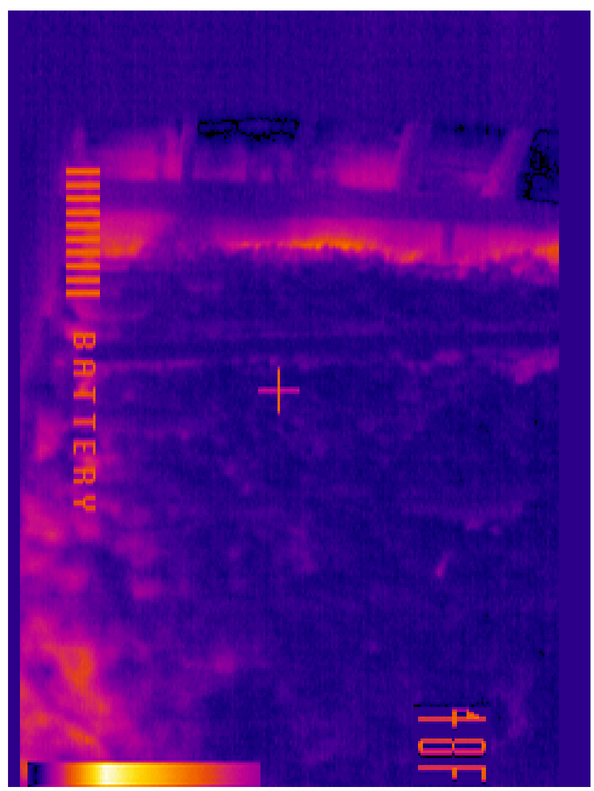
Steam pipe along the wall near the floor radiate Btu's as well as via convection as cooler air from the floor is warmed then rises because it is lighter, and warms the air while warming things and people in visual contact with the source.

Main Attic Floor

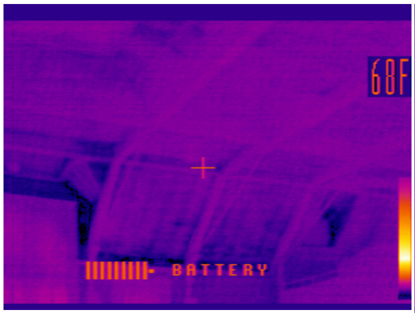


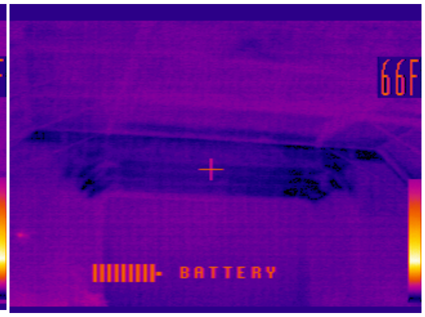


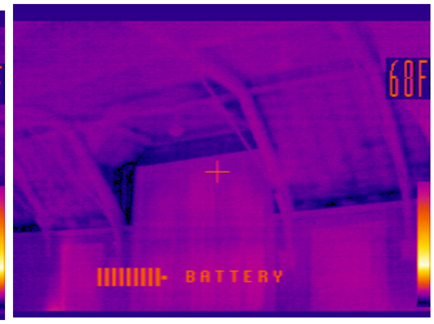
Four to six inches loose fill insulation material including rock wool and older fiberglass rest on the lathe and plaster ceiling but do not cover framing nor stop air from rising through framing gaps. Fiberglass batts over center vent, which is opened in summer, allow considerable heat loss in winter.



Theatre





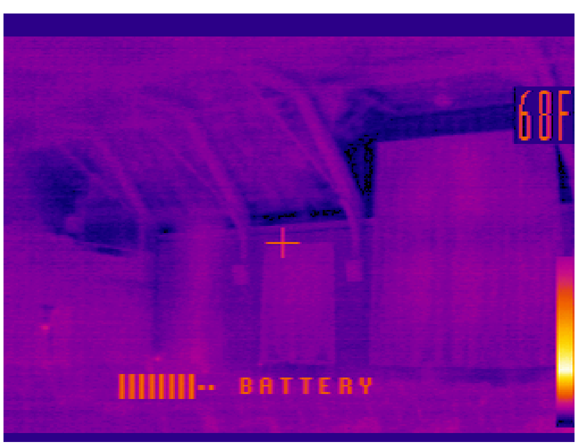


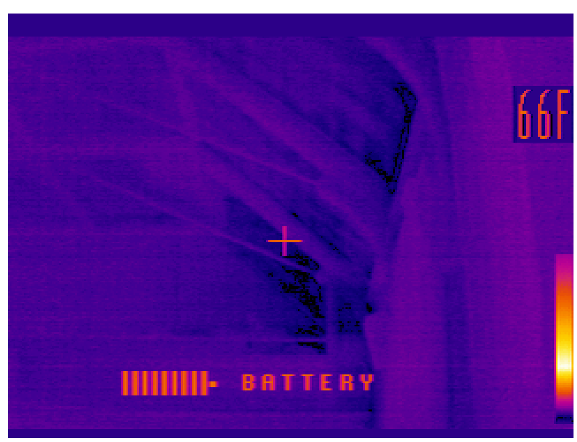
The digital images don't depict the same view as the IR images, mostly because the flash on my digital camera wasn't enough to illuminate the dark room, however hopefully the areas of ceiling coolth (ie compromised or missing insulation) is clear.

The best way to insulate effectively improve the thermal performance of this large theatre is to

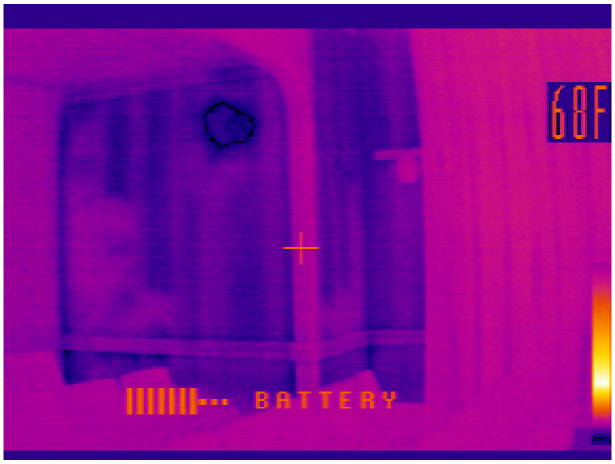
A) Remove the existing insulation above the ceiling, air seal, at all balloon framing openings, and blow in 14" cellulose.

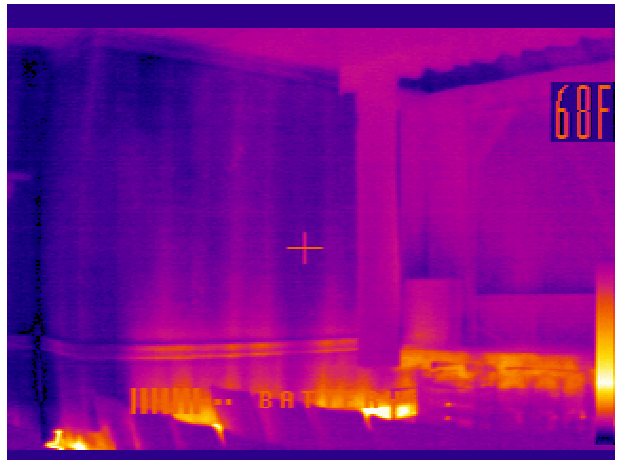
B) Remove slope insulation and re-dense pack with cellulose OR, access and foam seal the ceiling / wall connection from inside as part of a larger renovation project.





Small Theatre

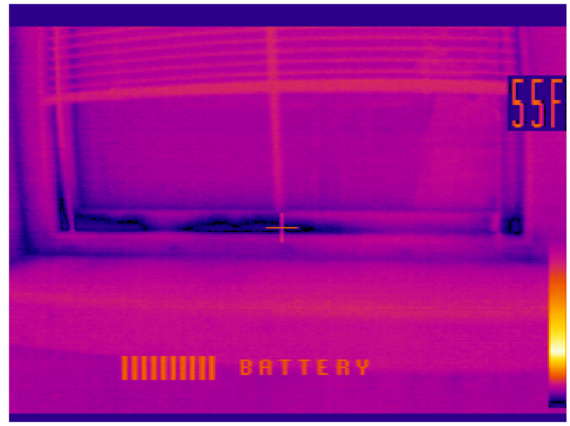




The small theatre has a large glazing to wall ratio, meaning that a high percentage of its wall surface area is in window glazing, though none of it useful for daylight, view, or air in the winter time. Insulated window panels would be the most cost effective way to improve a large surface area—especially on the windows behind the screen which I suspect haven't been seen in years!

This room is also one of the first which warrants mechanical ventilation based on a CO2 reading of 2150ppm after 20-25 people watched a three hour (albeit suspenseful) movie. Over twice the CO2 threshold for adding ventilation. It was also 78 degrees in the room by the end of the film as the room's temperature is controlled by the thermostat in the unoccupied, highly glazed and exposed Assessor's corner office stairs.

Windows and Doors



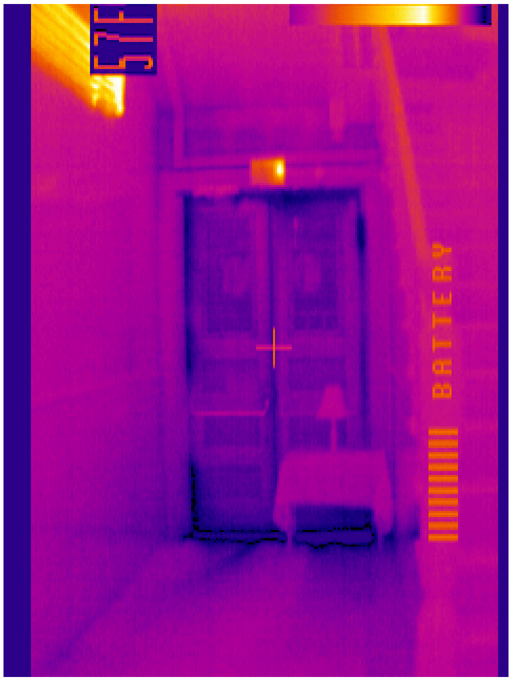
The two IR images above are classic examples of air leakage through both window sashes and rough openings. Professional weather-stripping can reduce the amount of air infiltration where the sash meets the sill.


All the window sashes in the Town Hall have been lovingly restored by Window Master and a double "bi-glass" pane routed into the lites. All pulleys and weights have been removed and replaced with spring tape mechanisms and the weight chases sealed. This is a good way to improve the performance of a single pane window while retaining its historic character. The total window performance is still limited by the wood creating the divided lites and remaining air leakage.

A successful further treatment is to install interior window glazing units for the winter, and sealing tightly to prevent warm moist air from condensing on the window sash. This is mentioned because there may be a time in the future when energy costs warrant additional measures, but at this time, the cost cannot be justified for the Town Hall windows.

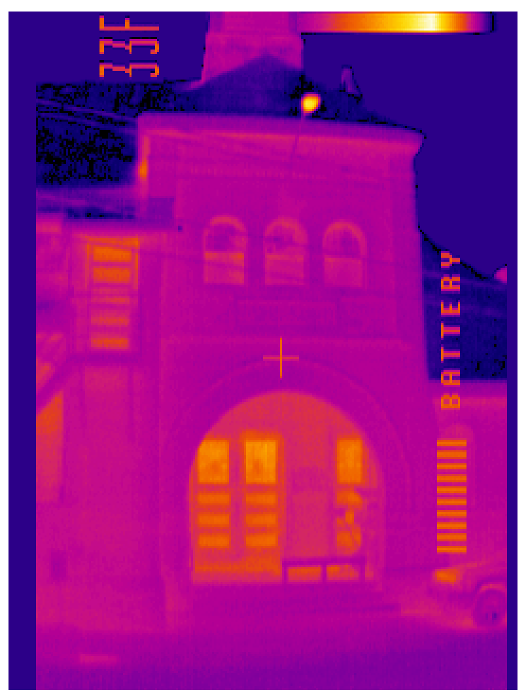
For the Theatre windows, which are always kept covered for darkness, however, custom building insulated winter panels with 2" XPS foam board and luan or 1/8" CDZ plywood to be installed and tightly sealed on the inside of all drape covered windows is recommended. Exterior surfaces maybe painted for looks, but only a light colored paint should be used on west facing glazing to prevent overheating the window. Panels over fixed windows do not have to be removed for summer.

Windows and Doors

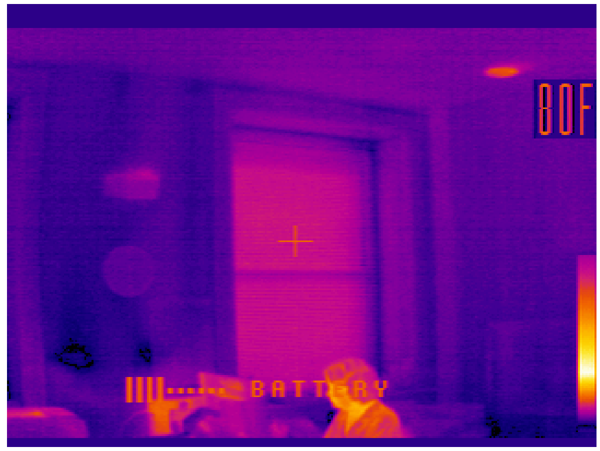


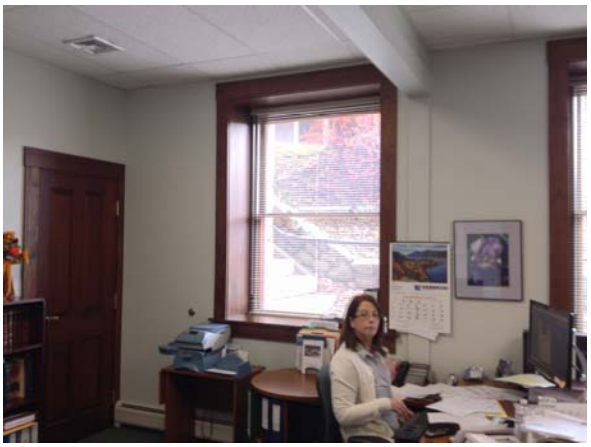
The Theatre doors have particularly large air gaps, but ALL exterior doors in the Town Hall would benefit from professional weather-stripping which should last many years and effectively stop air leakage while allowing the door to still open and close!

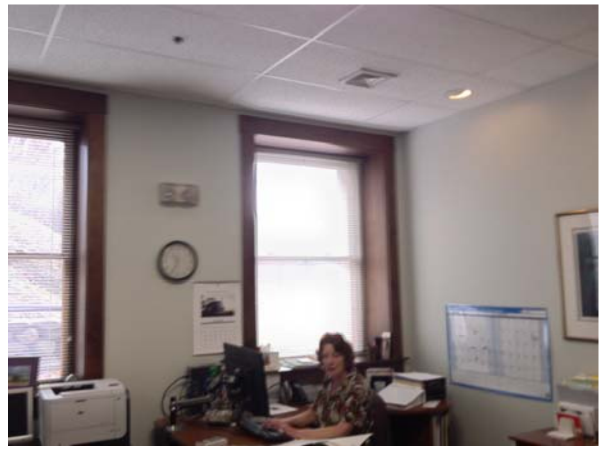
Mentioned and budgeted separately, but the door to the attic and the 'hatch' over the Large Theatre Ceiling Vent are technically also considered exterior door openings.



Selectmen's Office

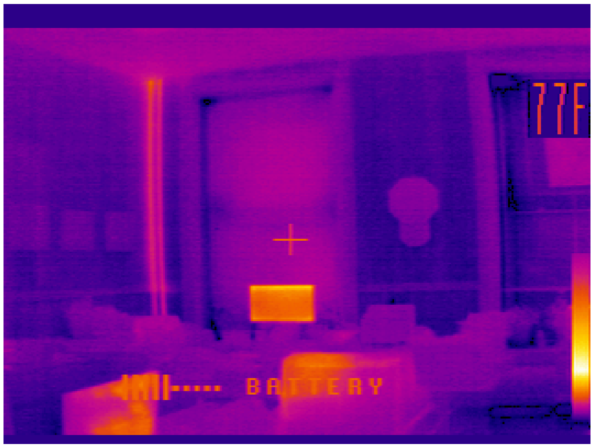






The renovations completed from the 1998 design included 2x4 framing, offset from the wall about 7", as shown in the images below, all taken from above the suspended ceiling in the restrooms. The IR images above suggest that the thermal performance is relatively poor, as would be expected from 3.5" batts without an air barrier on all six sides and not installed according to the manufacturer's recommendations. Better than nothing, true—but a better thermal barrier would yield far better results. In addition, any warm moist air that migrated through the air gaps to the cold foundation wall will at some point condense. Removing the batts above the suspended ceiling and spraying 3" SPF from the ceiling (or floor framing above) down the wall as far as possible is recommended to effect a continuous air, moisture, and thermal barrier.

Clerk's Office

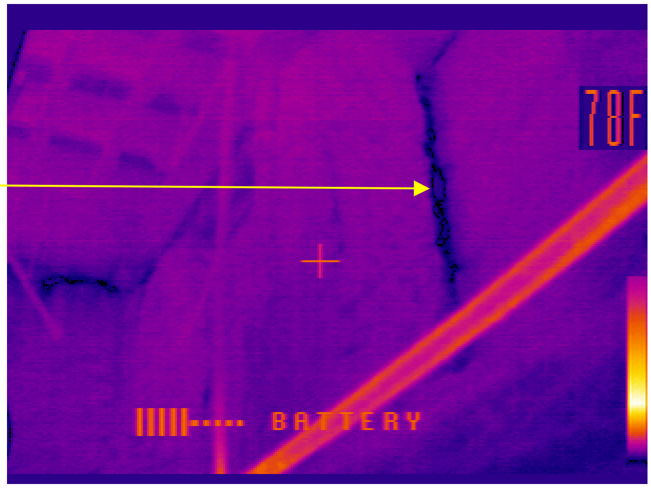



The walls of the Clerk's Office appear to be uninsulated and remain an opportunity for reducing heat loss and improving comfort in winter and summer to a lesser degree. The same insulation strategy recommended for the Selectmen's Office is recommended here, though in this case, removing the wall surface and wainscoting for a comprehensive wall insulation project is preferred.

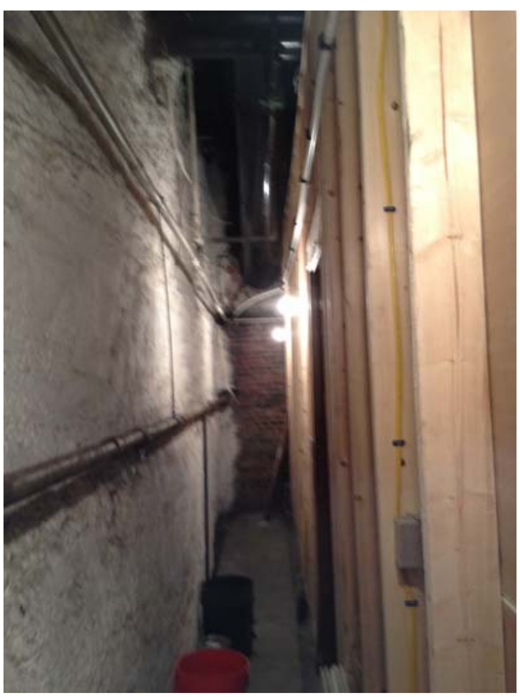
This project was included in Tier III upgrades because 1) the cost and disruption of the project and 2) the relatively lower wall to window ratio means insulating these walls has a relatively lower benefit, (In other words, this exterior walls' high glazing ratio has a significantly higher impact on heat loss for the room), and 3) it is assumed that no changes would be necessary to the baseboard in this room during the heating system conversion.

That said, my advice would be to get an estimate on insulating this wall along with other Tier II improvements as a 'line add' if its cost is more reasonable as part of a larger project. That way, if it could be logistically arranged, Tier II would have addressed the entire floor.

File Room, Kitchen, and Women's Restroom

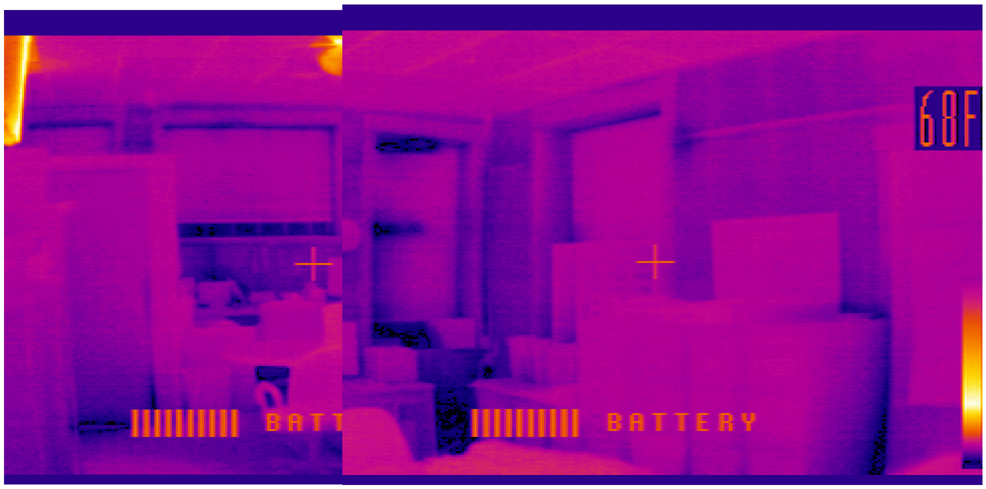


Overall an excellent improvement to this below grade foundation wall—and recommended for the rest of the foundation wall as possible. There does appear to be air leakage in through a crack at the window opening, hence the adage: "Eye tight is not necessarily air tight."



Tax Assessor, Planning, and Building Inspector's Office

The coldest and least comfortable area in the building, this area suffers from more doors, windows, and exposed exterior walls than any other office—compounded by the radiators and pipes located at the ceiling which offers less benefit—especially as high infiltration rates force the warmer air to the ceiling.



These office areas constitute the bulk of the Tier II improvements but only make sense during a compre-hensive renovation project—the design of which is outside my expertise and scope of this study.

A peak behind the paneling at John's desk shows a 4" cavity to granite down to the granite footing with a blast of cold air.

Not shy to offer my opinion, however, I suggest that temporarily relocating the office functions to the meeting room would allow the gutting of all wall: exterior, planning room divider, and concrete blocks of the old cell, and a fairly straightforward framing and re-wiring project. It would be the ideal time to insulate and install a new hydronic distribution piping for its own zone.

I would also suggest that adding a ductless air source, VRF, mini split heat pump would provide extremely efficient cooling and some heating and an residential ERV unit would provide balanced ventilation with energy recovery. These suggestions would be part of the HVAC design but offered here to reflect the appropriateness of these 21st century technologies for this office area.

With all due respect to conventional 20th century approaches from regional heating contractors, my advice is to explore beyond 'old school' strategies. To recap *some* of the key, relevant, current best practices: 1) Use closed cell foam (rigid board or spray) on below grade foundation walls and on above grade masonry walls, offsetting any wood framing from contact with the wall. 2) Build it tight, ventilate right. 3) All insulation should be continuous and in direct contact with an air barrier on all six sides. 4) Ventilation system should have their own duct work (as opposed to dumping fresh air into the ducts for cooling or heating air handler 5) Consider inverter driven, variable refrigerant flow (VRF), air source heat pumps for cooling and heating where appropriate. (Not as efficient in buildings or area with limited or sporadic occupancy.)

D. HVAC Equipment

Heating

These two boilers and distribution systems are operating about as efficiently as is possible. If anyone could squeeze greater efficiency or tweak the system to perform better, it would be Adrian Pinney our of Keene.

Completing even Tier Two envelope upgrades will reduce fuel costs and improve comfort, and could buy more time with the existing equipment—and would not an unreasonable decision.

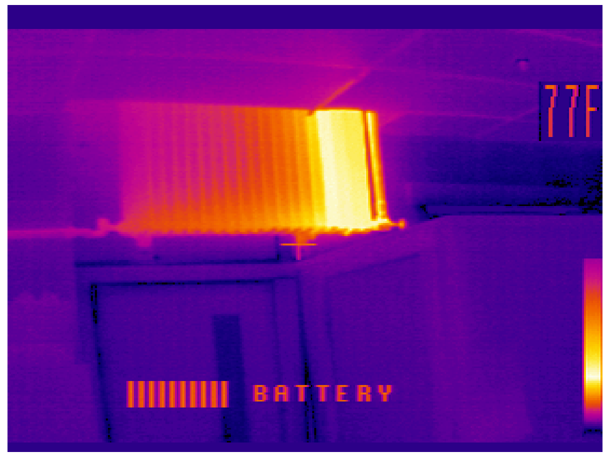
However, if there is local support to convert to pellet boilers, taking advantage of the $50K RGGI funds and the lower cost per Btu/value of pellets, makes this a great time to convert to invest in the conversion to forced hot water system. Benefits include: Greater efficiency, cleaner, better air quality and lower risk of dangerous air quality, better controls, improved comfort, and lower maintenance costs. Proper sizing, especially after Tier Two Improvements, will also yield better energy savings as well as lower upfront costs.

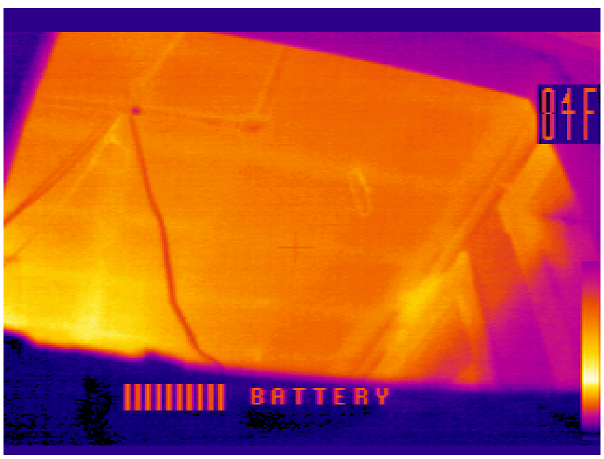
If you ask six contractors and engineers about what and how, you will receive at least seven ideas—each of which are deemed absolutely the best, most practical design.

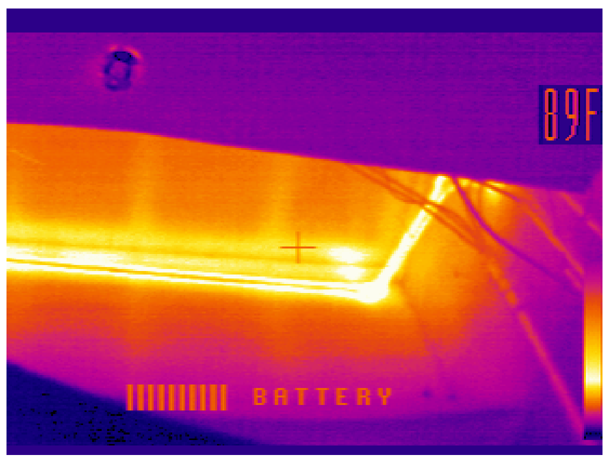
My advice is to hire Doug Wait to design a forced hot water system, possibly using the existing radiators, and include one or more ERV's for ventilation.

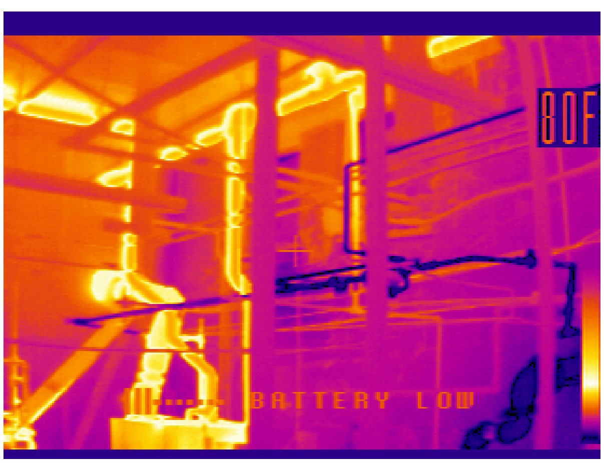
An open duct in the boiler room is intended to supply combustion make up air as needed. With building tightening to conserve energy, the combustion zone should be re-tested for adequate combustion air under worst case scenarios and the location of the intake determined.

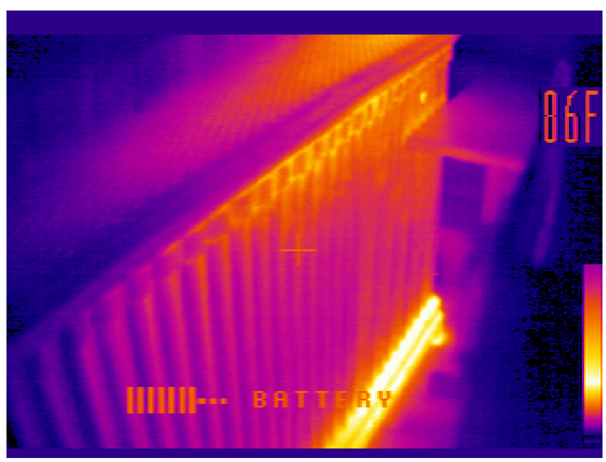
Comfort will likely always be an issue with the way the existing distribution is set up. Envelope improvements will certainly help prevent the need for wearing a coat in the office, but a lack of thermostatic control and uneven heating is a condition of many steam systems.











Comparison of Heating Fuel Costs

The chart below is from an excel calculator worksheet found at www.eia.gov/tools/faqs/heatcalc.xls

The worksheet allows one to enter in current fuel prices and estimated heating system efficiency (both cells highlighted in yellow) to determine the price per million Btu for each fuel and when used in varying system efficiencies (cells highlighted in green).

NH's current fuel costs are updated regularly and can be found at http://www.nh.gov/oep/energy/energy-nh/fuel-prices/index.htm

The unit cost of each energy source changes over time, of course, and sometimes radically. Some fuels have been historically more volatile than others and we have no reason to expect the future will be more stable—in fact the opposite may well be true. One might also expect that the dollar cost of burning fossil fuels will rise if the associated costs of climate change and other 'externalities' are factored into economic forecasting. Conversely, as the demand for oil declines (hopefully), the cost per gallon might go down, as it has recently.

In truth, non one has a crystal ball. The chart below provides a snapshot in time which can and will change. But since we make financial investment decisions based on current prices and historic trends and the rules of energy auditing are to use current costs and anticipate annual increases based on current models...worksheets like this are helpful.

Fuel Type	Fuel Unit	Fuel Price Per Unit (dollars)	Fuel Heat Content Per Unit (Btu)	Fuel Price Per Million Btu (dollars)	Heating Appliance Type	Type of Efficiency Rating [4]	Effiency Rating or Estimate [5]	Approx. Efficiency (%)	Per Million Btu (dollars)
Fuel Oil (#2)	Gallon	3.19	138,690	$22.99	Furnace or Boiler	AFUE	72.0	72%	$31.93
		3.19	138,690	$23.00	Furnace or Boiler	AFUE	85.0	85%	$27.06
Electricity	Kilowatthour	0.197	3,412	$57.62	Furnace or Boiler	Estimate	98.0	98%	$58.80
					ASHP	HSPF [6]	8.5	249%	$23.13
					GSHP	COP	3.3	330%	$17.46
					Baseboard	Estimate	100.0	100%	$57.62
Natural Gas [1]	Therm [2]	$1.47	100,000	$14.69	Furnace or Boiler	AFUE	92.0	92%	$15.97
					Room Heater (Vented)	AFUE	65.0	65%	$22.60
					Room Heater (Unvented)	Estimate	100.0	100%	$14.69
Propane	Gallon	$3.33	91,333	$36.43	Furnace or Boiler	AFUE	92.0	92%	$39.59
					Room Heater (Vented)	AFUE	65.0	65%	$56.04
Wood [3]	Cord	$325.00	22,000,000	$14.77	Non-Catalytic,	EPA	63.0	63%	$23.45
					Catalytic,	EPA	72.0	72%	$20.52
Pellets	Ton	$230.00	16,500,000	$13.94	Room Heater	EPA	82.0	82%	$17.00

The cost per fuel unit varies due to how many btu's are in each unit of fuel. For example, oil has 34% more heating capacity per gallon than propane, so while condensing propane systems may be far more efficient (approaching 98% in some cases), the total heating output per gallon is less. And the boiler has to be operating in condensing mode—ie return water temperatures less than about 135°- in order to achieve those high efficiencies. This is why converting to high efficiency propane systems is sometimes disappointing.

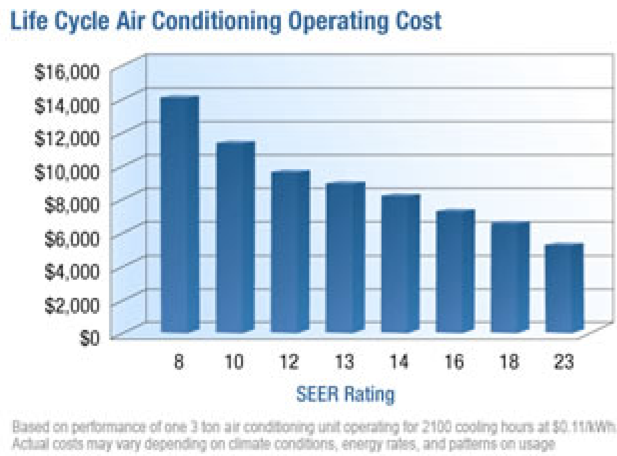
Note that pellets and ground source heat pumps (GSHP, aka 'geothermal') appear to have similar and lowest per unit costs at this time.

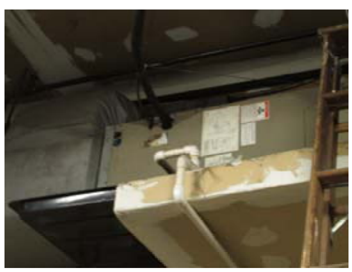
This consultant's editorial opinion is that energy sources which are non polluting, renewable and can be harnessed on site or in the local region are the only truly affordable and sustainable options over time. For NH at this time, that means solar powered heat pumps, pellet boilers, wood or wood chip boilers.

Cooling

Two outdoor split system, Thermal Zone, air compressors installed in 2009 provide ducted cooling to the offices on the south side of the building. The SEER ratings are not known. SEER ratings refer to Seasonal Energy Efficiency Ratio and is somewhat comparable to miles per gallon ratings for one's car. Code now requires minimum SEER 13 equipment be installed, though up to SEER 24 is available in advanced heat pump technology. These units are likely rated below SEER 12. The chart below provides an example of operating cost reductions based on higher SEER ratings—and electricity costs of $0.11/kWh.

Based on current usage estimates, cooling the Town offices may costs between $300-$400 a year so replacement for more efficient units is not recommended at this time. However, when these units have outlived there service life, replacing them with high efficiency heat pumps (SEER 18 or better) is strongly recommended.



Of greater concern is the fact that the duct are not sealed and draw air from the boiler room which could become an air quality issue. Mastic sealing the ducts is a short term improvement, though this is another reason for replacing the existing boilers.

The cooling strategy for the Theatres include three window units (2) four year old two ton units and (1) 2 year old 1.5 ton unit) SEER ratings unknown but likely 8 or 9, an army of floor fans and the large vent opening in the Theatre ceiling with ceiling fan. Total summer cooling costs are estimated at $500 a year.



12.12.14 Addendum: Subsequent to the competition of this report, The Wilton Energy Committee met to review and discuss the findings and recommendations. At that time, they decided to propose to the Selectmen on December 15th, that a Warrant Article be submitted in 2015 to complete all Tier Two envelope upgrades which did not involve construction, with the intention to pursue conversion to a pellet fired hydronic system in 2016. A revised summary was compiled to reflect the proposed project.

Summary of Town Hall Energy Audit Reccomendations

	Reccomended Immediate Measures	**Est. Costs**
	Health and Saftey; Indoor Air Quality	
HS 1	Install CO monitors with alarm in hallway by SO door	$50
HS 2	Mastic seal (air tight) A/C duct work	$2,200
	HS Total	*$2,250*
	Maintenance - Building Durability	
D 1	If drain is open, re-connect downspout on west	$50
D 2	Duct south restroom fans to boiler room	$300
	D Total	*$350*
	Planning and Funding	
P 1	Contact Anne Karczmarczyk for project funding	$0
	P Total	*$0*
	Electricity Saving Measures	
E 1	Turn off and unplug all office equipment at night as appropriate	$0
E 2	Install switch to ceiling fan in MR; turn on fans only when spaces are occupied & as necessary	$25
E 3	Replace T12 fixtures with T8 electronic in north offices	$595
E 4	Replace appliances with Energy Star models when needed; Freezer in stage at top of list	n/a
E 5	Place digital projector on timer if won't harm service life	$75
	E Total	*$695*
	Total measures for 2014 (as soon as possible)	**$3,295**

	For Warrant Article	**Est. Costs**
	Planning and Funding	
P 2	Design for conversion to hydronic heating and ventilation	$4,800
P 3	Electrician to verify no active knob and tube circuits	$500
	P Total	*$5,300*
	Fuel Energy Saving Measures	**Est Costs**
FS 1	Weatherstrip all lower level windows	$540
FS 2	Install (5) programmable thermostats with auto reset	$625
FS 3	Weatherstrip all theatre windows	$1,195
FS 4	Weatherstrip all exterior doors	$1,205
FS 5	Thermax on Boiler Room	$1,848
FS 6	3" SPF on west wall of Assessor's Office a.p.	$2,200
FS 7	Selectmen's Office (3" for 8')	$2,450
FS 8	Add R10 air tight panels to theatre windows	$3,815
FS 9	Crawlspaces: Lay poly and SPF perimeter	$12,000
FS 10	Air Seal and Re-Insulate Attic Floors	$24,300
	F Total	***$50,178***
	Less Anticipated Utility Rebate	$17,000
	Total Project Costs to Town	**$33,178**
	Estimated first year fuel savings	$2,975
	Projected 20 year savings at 2% annual fuel cost increase	$71,705
	Total Project ROI	43%