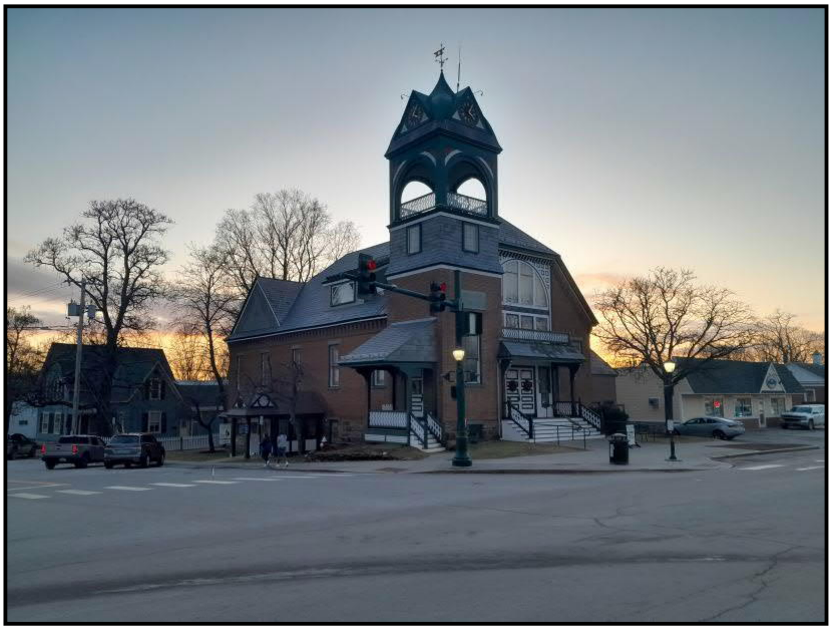
# MUNICIPAL ENERGY RESILIENCE PROGRAM
# LEVEL II ENERGY ASSESSMENT

*prepared for*

**Town of Bristol, VT**
1 South St.
Bristol, VT 05443



Holley Hall
1 South St.
Bristol, VT 05443

**June 18, 2024**


**Mechanical, Electrical, Plumbing**
6 Green Tree Dr.
S. Burlington, VT 05403

**Building Enclosure**
206 W. Newberry Rd.
Bloomfield, CT 06002

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# 1. Executive Summary

The purpose of this Level II Energy Assessment is to provide the building Owner (Town/City) and the State of Vermont - Building and General Services with specific recommendations for building Energy Conservation Measures (ECMs) and Renewable and Resilient Energy Measures (RREMs). These measures will reduce electric and fossil fuel consumption and associated costs, and potentially provide resilience against cost fluctuations and interruptions in the supply of purchased energy. The assessment includes a review of the building's historical energy consumption and costs, exterior enclosure, mechanical and plumbing systems, and lighting.

The costs and savings for each measure are calculated using industry standard engineering methods. ECMs with a payback period greater than the Expected Useful Life (EUL) of the equipment are not typically recommended, as the cost of the measure will not be recovered during the lifespan of the equipment. These ECMs may be recommended for implementation at the time of future system replacement, where it would be appropriate to evaluate based on the premium cost of installing energy efficient equipment rather than the full cost of the measure.

## 1.1. Building General Data

| General Building Data | | | |
|---|---|---|---|
| Type | Story Quantity | Year Built / Renovated | Floor Area (sq. ft.) |
| Town Office / Hall | 2 | Renovated 2010 | 7,800 |

| Building Occupancy | |
|---|---|
| Occupancy | |
| Occupied Hours/Week | 30 |
| Occupied Weeks/Year | 52 |
| Occupant Quantity | 5 Avg. |

| Building Conditioning | |
|---|---|
| Conditioning Type | Percent of Floor Area |
| Heated | 100% |
| Cooled | 50% |
| Unconditioned | 0% |

| Facility Contact | | |
|---|---|---|
| Name | Title | Phone Number |
| Richard Butz | Building Contact | (716) 536-9912 |

## 1.2. Basis of Assessment

This Assessment is completed based on information obtained from the following sources.

| Building Information Sources | | | | |
|---|---|---|---|---|
| Site Visit | Utility Data Summary from Owner | Utility Bills | Construction / As-Built Drawings | Other |
| ✓<br>12/20/2023 | ✓ | | ✓<br>03/01/2010 | |

## 1.3. Energy Conservation Measures

The following table summarizes the recommended ECMs in terms of investment cost, energy, cost savings, and payback.

| # | Description | Initial Investment ($) | Annual Energy Savings | | Annual Cost Savings | Simple Payback (Years) |
|---|---|---|---|---|---|---|
| | | | Fuel (Gal Oil) | Electricity (kWh) | | |
| 1 | Walls | $55,100 | 700 | 0 | $2,100 | 26.3 |
| 2 | Windows | $8,200 | 150 | 0 | $425 | 18.7 |
| 3 | Doors | $300 | 20 | 0 | $60 | 4.8 |
| 4 | Air Sealing | $50 | 10 | 0 | $35 | 1.4 |
| 5 | Programmable Thermostats | $1,200 | 100 | 3,100 | $300 | 4.0 |
| 6 | Integrated Heating Controls | $1,200 | 300 | 0 | $300 | 4.0 |
| 7 | Lighting Retrofit | $2,800 | 0 | 3,100 | $600 | 4.7 |
| | **TOTAL** | **$68,850** | **1,280** | **3,100** | **$3,820** | **18.0** |
| | | | **65.6%** | **13.0%** | **36.8%** | |

## 1.4. Renewable & Resilient Energy Measures

The following tables summarize the recommended RREMs in terms of investment cost and benefits provided.

| Battery Electric Storage Summary | |
|---|---|
| Equipment Quantity / Capacity | 5 / 13.5 kWh Each |
| Investment Cost After Incentives | $44,000 |

*Note: Information on this measure is provided for informational purposes only; The Owner needs to consider if the value of backup power to the building, and the value of electric storage vs. a fuel-fired electric generator is worth the investment.*

| Electric Vehicle Charger Summary | |
|---|---|
| Charger Quantity / Type | 1 / Level I |
| Investment Cost After Incentives | $125 |

| Renewable Heating Summary | |
|---|---|
| Type | Heat Pump,<br>Air-to-Air / Oil Hybrid |
| Annual $CO_2$e Emissions Eliminated (%) | 65% |
| Investment Cost After Incentives | $19,550 |
| Annual Cost Savings | $825 |
| Simple Payback | 23.7 Years |

*Note: The heat pump / oil hybrid option is not cost effective from a financial perspective alone. Only when considering the additional benefits of reduced energy cost volatility, positive impact on the local economy, and reduced environmental impact, is this a worthwhile investment and recommended.*

## 1.5. Occupant Health & Comfort Measures

The following table summarizes the recommended occupant health and comfort measures.

| Occupant Health & Comfort Summary | |
|---|---|
| Measure | Benefit |
| Replace Existing Thermostats with Programmable Ones | Improve occupant comfort |

## 2. Introduction

The purpose of this Energy Assessment is to provide the building Owner (Town/City) and the State of Vermont - Building and General Services (VT BGS) with a baseline of energy usage, the relative energy efficiency of the facility, and specific recommendations for Energy Conservation and Renewable and Resilient Energy Measures. Information obtained from these analyses may be used to support a future application for a Municipal Energy Resilience Implementation Grant, any other State or Federal Energy Conservation Program, as well as support performance contracting, justify a municipal bond-funded improvement program, or as a basis for replacement of equipment or systems.

The energy assessment consisted of an onsite visual assessment to determine current conditions, itemize the energy consuming equipment (mechanical, electrical, plumbing); The study also included interviews and consultation with operational and maintenance personnel. The following is a summary of the tasks and reporting that make up the Energy Assessment report.

**Utilities**

A review of the existing energy types supplied to the building, historical consumption, and associates costs and required on-site storage.

**Building Enclosure**

A survey and assessment of the characteristics and conditions of the building enclosure including walls, windows, doors, and roofs.

Whole building air leakage testing utilizing a blower door tool.

**Energy Consuming Equipment & Systems**

A survey of building spaces to document and assess utility-related equipment, including heating, cooling, ventilation, domestic hot water and lighting systems.

Measurement of illumination levels in each space and comparison to recommended levels.

**Recommendations for Energy Savings Opportunities**

Based on the information gathered during the on-site assessment, the utility rates, as well as recent consumption data and engineering analysis, identification of opportunities to save energy and associated probable construction costs, projected energy/utility savings and resulting simple payback analysis.

### Clarifications

This Assessment has been completed in accordance with the State of Vermont ACT 172.

This report has been prepared for and is exclusively for the use and benefit of the Town / City and VT BGS (“Client”). The purpose for which this report shall be used shall be limited to the use as stated in the contract between the Client and Salas O’Brien’s / DuBois & King (“Assessor”). This report, or any of the information contained therein, is not for the use or benefit of, nor may it be relied upon by any other person or entity, for any purpose without the advance written consent of the Assessor. Any reuse or distribution without such consent shall be at the Client’s sole risk, without liability to the Assessor.

The Assessor has no control over the cost of labor, material, and equipment, or over competitive bidding or market conditions. Therefore, the accuracy of project construction cost estimates included in this Assessment as compared to actual contractor bids or the actual cost to the Client are not guaranteed. Construction costs estimates are understood to be an opinion of a probable budget for construction costs. If a more accurate budget is required, we recommend enlisting the services of a professional estimating agency.

This Assessment is not intended to be or should be construed as any type of design for construction which a licensed Architect or Engineer is required for.

# 3. Utilities

## 3.1. Historical Energy Consumption & Cost by Type

Energy can be calculated and reported in multiple different ways, each with their advantages and disadvantages. Generally, this report uses Site Energy and Energy Cost, but also reports on Emissions.

- **Site Energy** – Amount of energy consumed by a building as measured by site utility meters. Typically, electricity and one or multiple fuels.
- **Source Energy** – Accounts for the additional energy consumed in the extraction, processing, and transport of primary fuels such as coal, oil, gas, the energy losses in thermal combustion in power generation plants, and the energy losses in transmission and distribution to a building. Site/source conversions are typically national averages.
- **Energy Cost** – The monetary value for energy which serves a building.
- **Energy Emissions** – Amount of $CO_{2e}$ source emissions. Rates are from regional grid annual averages for electric and national averages for fuel.

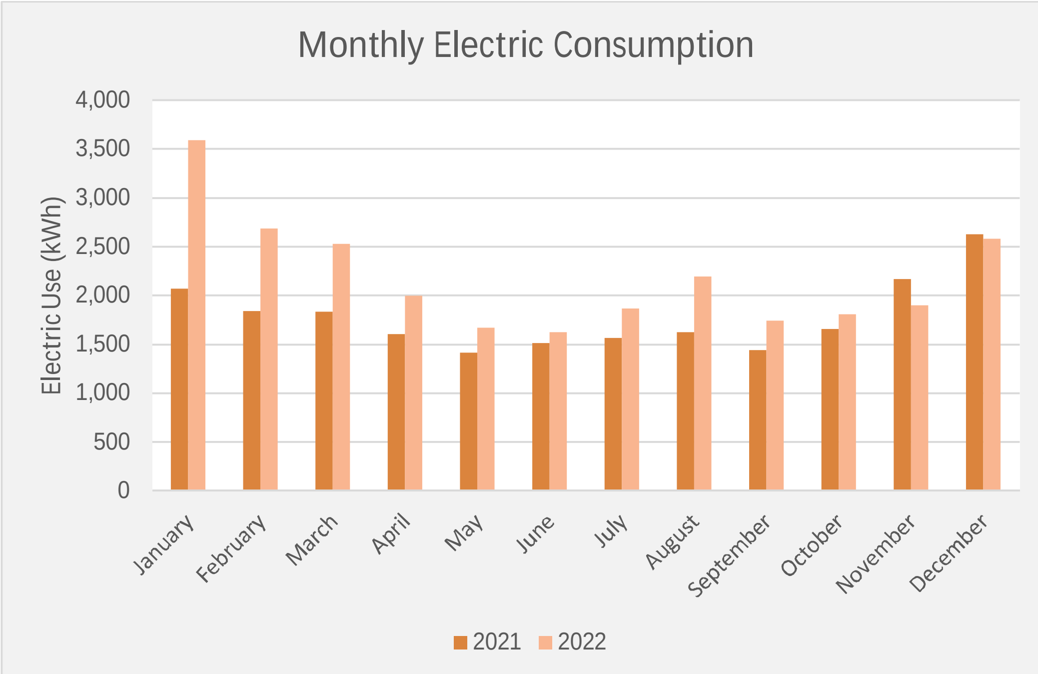
| Energy Summary | | | | |
|---|---|---|---|---|
| Energy Type | Energy Provider | Meter Quantity | Energy Uses | Usage Data Time Period |
| Electric | Green Mountain Power | 1 | Space cooling, lighting, plug-in equipment, fans, pumps | 01/2021 – 12/2022 |
| Propane | Unable to Verify | - | Generator | Not Provided |
| No. 2 Oil | Unable to Verify | - | Space heating and domestic hot water | 09/2022 – 05/2023 |

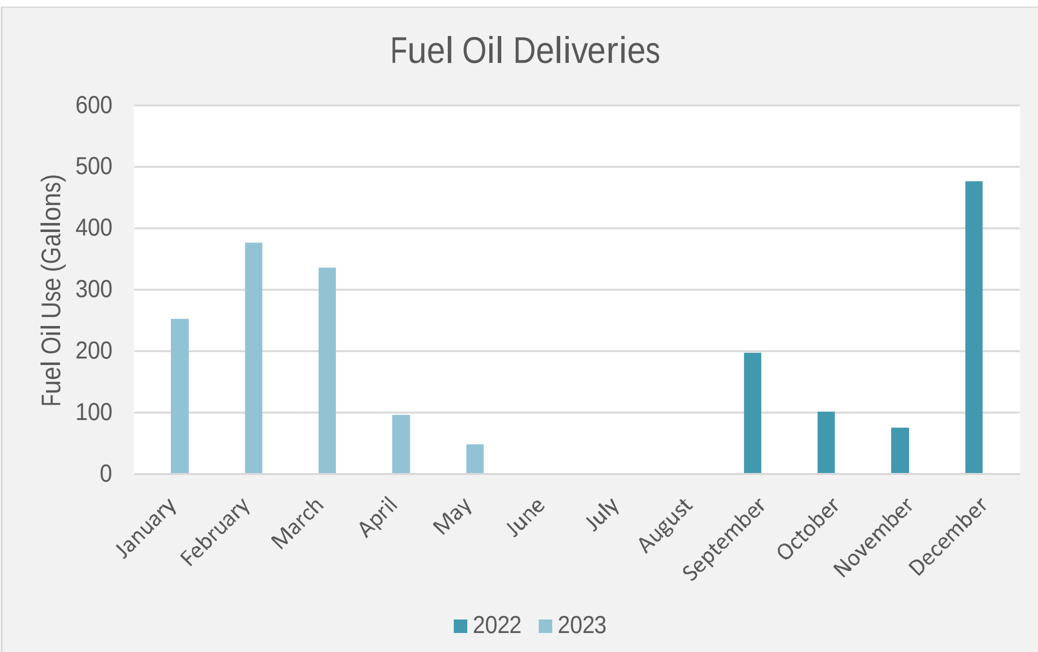
| Energy Analysis | | | | | | |
|---|---|---|---|---|---|---|
| Energy Type | Annual Energy Use | Annual Energy Cost | Energy Cost Rate | Annual Site Energy Use (MBtu) | Annual Source Energy Use (MBtu) | Annual Energy Emissions (Mt $CO_2e$) |
| Electric | 23,800 kWh | $4,525 | $0.20/kWh | 80 | 235 | 10 |
| No. 2 Oil | 1,950 Gal | $6,950 | $3.55/gal | 270 | 325 | 25 |
| TOTAL | - | $11,475 | - | 350 | 560 | 35 |

**Values presented here for electric do not account for the impact of solar net metering.*

***Assessment/Recommendations:***

- Electric use is similar from month-to-month, somewhat correlated with seasonal building space heating demand.
- Fuel use is strongly correlated with seasonal building space heating demand.
- Fuel use represents roughly 60% of total energy cost and 70% of total energy emissions vs. electric use.




The following utility rates were used for the purposes of savings analysis. The electrical savings rate is lower than the blended electrical rate ($0.20/kWh) as only variable usage costs are able to be offset; fixed costs are not.

| Average Utility Rates | | | |
|---|---|---|---|
| Electricity | No.2 Oil | Propane | Wood Pellets |
| $0.190 /kWh | $3.00/Gal | $2.50/Gal | $300/Ton |

## 3.2. Fuel Storage

| Fuel Storage - Existing | | |
|---|---|---|
| Type | No.2 Oil | Propane |
| Quantity / Capacity | 1 / 275 Gal | 3 / 120 Gal each |
| Location | Interior | Above Grade Exterior |

Figure 2 – Existing Oil Storage Tank

Figure 1 – Existing Propane Storage Tanks

## 3.3. Electric Service

| Electrical Service - Existing | |
|---|---|
| Capacity | 400A, 120/240V, 1Ø, 60 Hz |

***Assessment/Recommendations:***

The existing electrical service does appear to have the capacity to support the addition of electric vehicles chargers and electric heat pumps. A licensed electrical engineer should be consulted to verify what spepcific modifications are required.

## 3.4. Electric Storage

The existing building/site has no battery electric storage.

***Assessment/Recommendations:***

An electric lithium battery storage system could be added to increase building resiliency. The value of this system is primarily the ability to continue to utilize the building in the case of a loss of electrical power from the utility, similar to that provided by a traditional fuel-fired electric generator. The benefit is it does not consume fuel or produce the associated on-site emissions. The battery system may provide additional utility cost savings; however, these are relatively minor or nonexistent based on current rates. The system proposed is selected to provide the capacity to power the building for approximately one average 24-hour period based on historical consumption data. There appears to be some value of resiliency for this building, demonstrated by the fact that a back-up electric system currently exists (fossil fuel powered).

| Battery Electric Storage - Proposed | |
|---|---|
| Quantity / Capacity | 5 / 13.5 kWh Each |
| Location | Interior Electrical Room |
| Space Served | Entire Building |
| Investment Cost | $75,000 |
| Potential Incentives | $8,500 (GMP) + $22,500 (Federal IRS) |

## 3.5. Electric Generation

The existing building/site has a fuel fired generator and is part of an off-site community solar PV arrangement.

| Emergency Generators - Existing | |
|---|---|
| Quantity / Capacity | 1 / Unable to verify |
| Make / Model | Kohler / Unable to verify |
| Fuel | Propane |
| Year Installed / Age | Unable to verify |
| Location Installed | Exterior Ground Mounted |
| Space Served | Entire Building |


Figure 3 – Existing Propane-Fired Generator

***Assessment/Recommendations:***

No additional solar PV system is recommended, as the existing community solar array is reported to offset the full possible cost of electrical use annually; an additional system would provide no benefit.

## 3.6. Electric Vehicle Chargers

No EV chargers currently exist at the building/site.

***Assessment/Recommendations:***

The addition of a new Level 1 or Level 2 charger appears to be technically feasible for the building and could be valuable for the employees who commute to and work at the building. Level 1 chargers operate on a standard 120V/20A circuit, provide around 5 miles of charge per hour, and are relatively inexpensive, while Level 2 chargers operate on a 240V/40A circuit, provide around 20 miles of charge per hour, and are more expensive. A Level 1 charger is expected to provide sufficient charging during the relatively long period of time employee's vehicles are parked on-site, and is recommended versus a Level 2 charger.

| Electric Vehicle Chargers - Options | | |
|---|---|---|
| Type | Level 1 | Level 2 |
| Quantity / Capacity | 1 – 20A / 120V | 1 – 40A / 240V |
| Location | Parking Lot | Parking Lot |
| Electric Metering / Payment | Through Building / Electric Utility | Through Building / Electric Utility |
| Investment Cost | $2,500 - Pedestal-mounted | $4,000 - Pedestal-mounted |
| Potential Incentives | $2,375 (Charge VT) | $750 GMP + $3,090 (Charge VT) |

Figure 4 – Example Leviton brand pedestal-mounted outlet for Level 1 EV charger.


Figure 5 - Example Enphase brand pedestal-mounted Level 2 EV charger.

# 4. Building Enclosure

The building envelope consists of the exterior shell, made up of the walls, windows, roof, and floor. The envelope provides building integrity and separates the exterior from the interior conditioned space.

Notes for Understanding the Building Envelope:

1. All building systems interrelate and occasionally improvements to one building system can create problems in another. This is particularly true of envelope and HVAC improvements. Measures to improve energy efficiency should be regarded in the context of the health and safety of occupants and in the long-term durability of the building. Careful consideration of the following and testing before and after efficiency improvements will help to prevent conditions that could have a negative impact on the building.
2. When viewing thermographs, lighter colors indicate higher surface temperatures than darker colors. What is considered "heat loss" is dependent upon the perspective from which it is viewed, inside or outside.
3. Some infrared images are taken under depressurization. Depressurization causes all outdoor air to flow inward and is not the normal operating state of the building. It is done to reveal conditions that would not normally be detected or to enhance thermographic images. Depressurization is also used to mimic the environment a building would be under in conditions of high wind or very cold temperatures. The building was depressurized to about –16 Pascals during the last part of the imaging.
4. Air leaks are detected by the infrared camera when cooler air "washes" across a surface. The pattern of air leakage is typically wispy lines emanating from the air leakage site.
5. One measure used to determine if an improvement is warranted is comparison to the current 2020 Vermont Commercial Building Energy Standards (CBES). Though code minimum might be considered a low bar it is important to understand that the code minimums have progressed significantly in recent years. They are far more stringent than they were even 20 years ago. Today, a code minimum envelope is quite robust from an energy perspective. In addition, the energy savings from increased insulation thickness (R-value) is not linear, it is geometric. So, the energy savings for doubling the insulation thickness is high for areas with low or missing insulation but low for areas with code minimum insulation. While the CBES is used as a reference, the requirements are applicable only to new buildings and to existing buildings when renovation occur; existing buildings which are not modified are not required to comply with the requirements.
6. Estimated costs include only the costs that relate to energy improvements. For example, if the recommendation is to add more insulation when the roof membrane is replaced, only the cost of the additional insulation is included in the simple payback calculation since the roof membrane replacement would have to be done regardless.

## 4.1. Foundation

| Building Foundation - Existing | |
|---|---|
| Foundation (main) | Mortared stone |
| Foundation (addition) | Concrete foundation walls |
| Basement Wall Insulation Type | Closed-cell spray foam |
| Basement Wall R-value | R-22 |

***Assessment/Recommendations:***

The foundation is in good condition and performing above a code compliant (R-15 continuous insulation) foundation. The 2010 renovation of the lower level included 2x4" framing with closed-cell spray foam insulation on the existing foundation. Adding additional insulation would not be cost effective and is not recommended.

## 4.2. Roof

| Original Building Roof - Existing | | | |
|---|---|---|---|
| Finish | Slate | Main Ventilation Source | Unvented |
| Type / Geometry | Gable | Roof Drains | Edge drainage to ground |
| Insulation | Spray foam and cellulose | Roof / Attic Insulation | R-49 |

***Assessment/Recommendations:***

The roof and attic are in good condition and performing the same as a code compliant (R-49) attic. It was improved with a 4" spray foam air seal and 6" of cellulose in the 2010 renovation. Adding additional insulation would not be cost effective and is not recommended.

| Building Addition Roof - Existing | | | |
|---|---|---|---|
| Finish | Slate | Main Ventilation Source | Soffit vents |
| Type / Geometry | Gable | Roof Drains | Edge drainage to ground |
| Insulation | Cellulose blown | Roof / Attic Insulation | R-46 |

***Assessment/Recommendations:***

The roof and attic are in good condition and performing about the same as a code compliant (R-49) attic. It was built with 13" of cellulose in the attic in the 2010 renovation. Adding additional insulation would not be cost effective and is not recommended.

## 4.3. Walls

| Upper Level Exterior Walls - Existing | |
|---|---|
| Primary Finish | Brick |
| Wall Insulation Type | None |
| Wall Framing Type | Wood framed |
| Wall Thickness | Total wall thickness is 12" (on level 1) |
| Wall R-value | R-6 |

***Assessment/Recommendations:***

The walls are in good condition but performing below a code compliant (R-19 c.i.) mass wall. Adding additional insulation would be cost effective and is recommended.

Most of the walls in the recreation director's office and the walls of the main theater are not insulated. The wood to wood trim joints leak on all the walls that have no insulation. There are particularly large air leaks at the balcony and balcony stairs.

The exterior walls that are below the stage are accessible to add insulation. There is a significant amount of cold air under the stage and much of it is attributable to this uninsulated wall. These walls can be insulated with closed-cell spray foam at 3 to 4 inches thick depending on hygrothermal modeling which is recommended.

We recommend insulating the walls of the recreation office, under the stage, and in the main theater from inside. The existing brick appears to be 2 wythes thick with an air space behind the wood lathe and plaster of about 5.75 inches that could be filled with blown cellulose, mineral wool, or closed-cell spray foam.

Given that these walls have no insulation represents a significant opportunity to save energy. However, this opportunity is not without its risks. The existing brick wall remains in good condition in part because heat and water vapor are able to flow in and out of the brick easily. Adding an insulation layer of any type will change the heat and vapor movement in the wall and runs the risk of causing long-term damage to the brick in the form of spalling, efflorescence, and/or mortar deterioration. These risks can be managed by hygrothermal computer modeling each of the insulation alternatives and thicknesses to see which poses the least risk. This is an expensive analysis, but it is recommended before embarking on any retrofit insulation strategy. Optimizing roof drip edges and window flashings to reduce water on the brick will also reduce the risk after insulating.

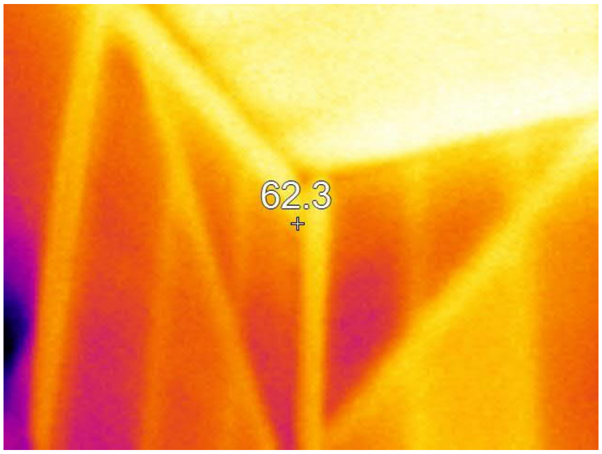



Figure 6 – Uninsulated walls in the rec. office

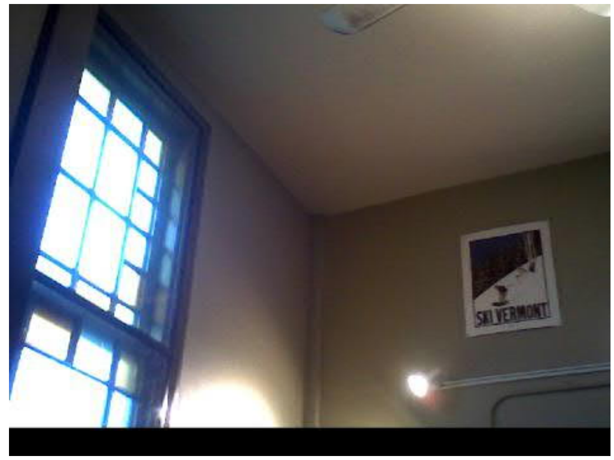



Figure 7 - Visible Light Image

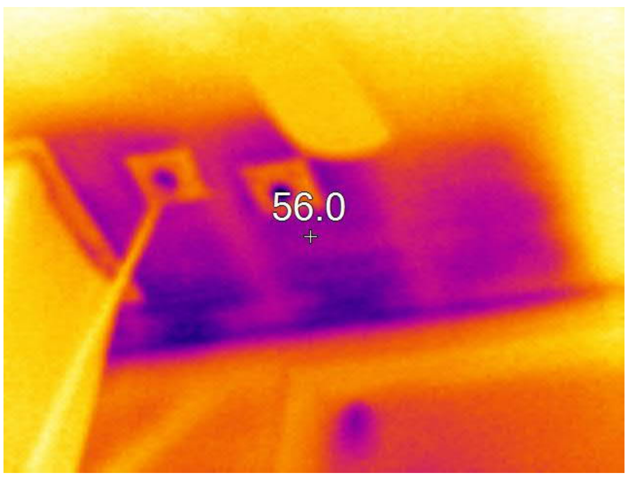



Figure 8 -Small area of uninsulated ceiling in the rec. office adjacent to the exterior wall.

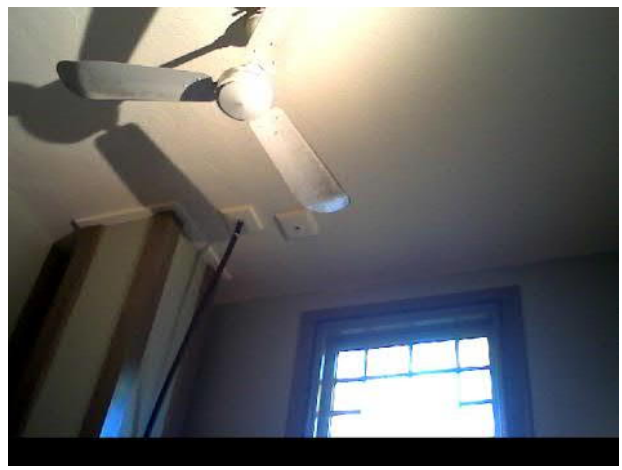


Figure 9 - Visible Light Image

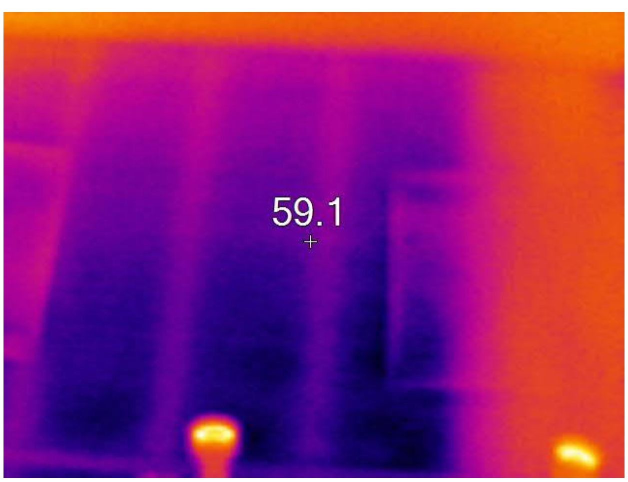



Figure 10 - Uninsulated walls in the rec. office


Figure 11 - Visible Light Image

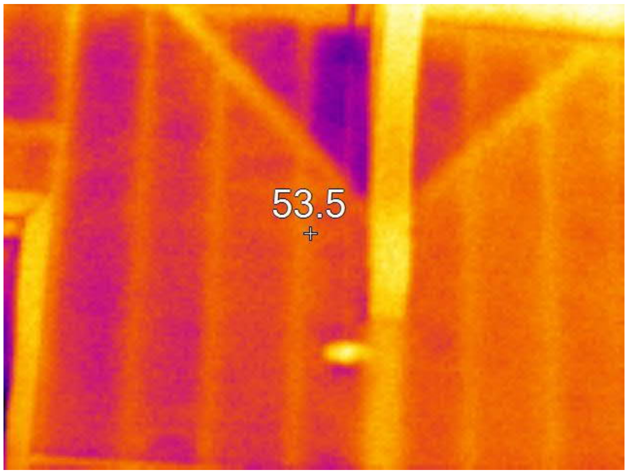



Figure 12 - Uninsulated walls in the main hall

Figure 13 - Visible Light Image

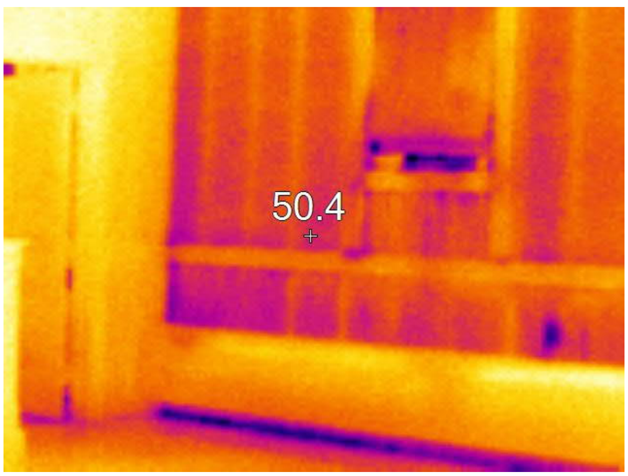



Figure 14 - Uninsulated walls in the main hall

Figure 15 - Visible Light Image

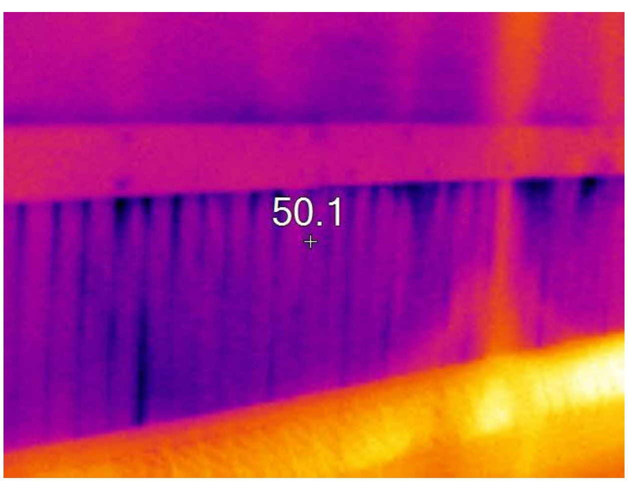



Figure 16 - Air leaks at the wood trim

Figure 17 - Visible Light Image

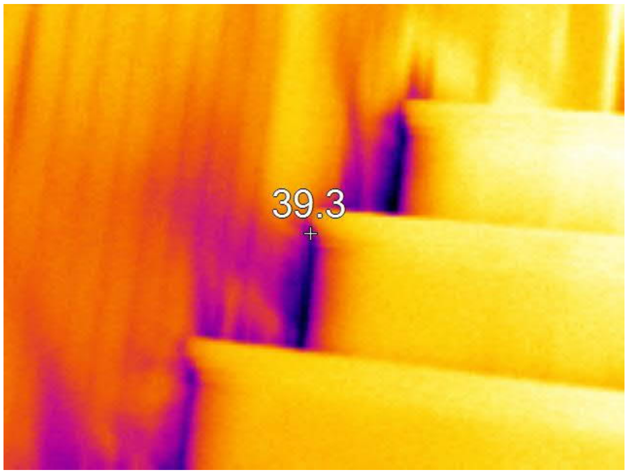
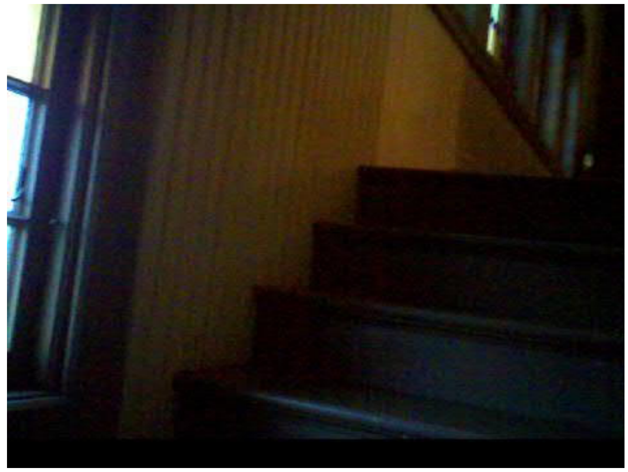
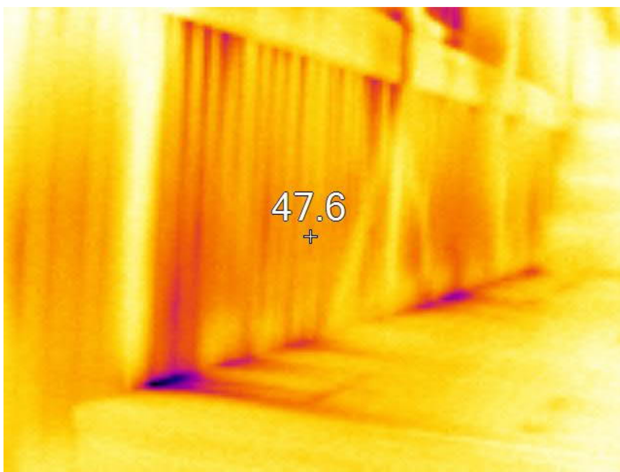
| | |
|---|---|
|  Figure 18 - Air leaks at the wood trim |  Figure 19 - Visible Light Image |
|  Figure 20 - Air leaks at the wood trim |  Figure 21 - Visible Light Image |

Figure 22 – Looking at the back wall under the stage we could see the open framed wall with no insulation.

The bell tower is exterior space that connects to cold attic, but it is not truly separate from the interior conditioned space of the main hall. The interior walls between the bell tower and the balcony are not insulated or air sealed. The floor of the bell tower has some insulation, but it does not look like much was installed. Either the bell tower needs to be brought into the interior envelope by insulating its exterior walls and ceiling or the floor and interior walls of the tower need to be insulated with dense-packed cellulose.

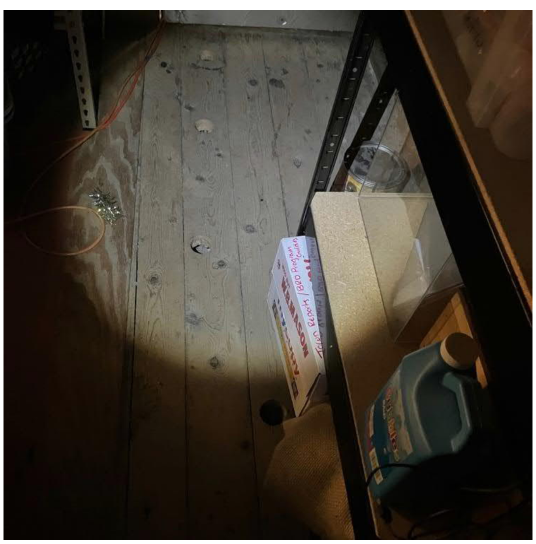


Figure 23 – Holes were drilled for insulation…

Figure 24 – But up close not much insulation is in the floor

| Addition Exterior Walls - Existing | |
|---|---|
| Primary Finish | Brick |
| Wall Framing Type | Wood framed |
| Wall Thickness | Total wall thickness is 10.5” |
| Wall Insulation Type | Dense pack cellulose |
| Wall Insulation R-value | R-19 |

The walls are in good condition but performing below a code compliant (R-19+R-8ci 2x6) wood framed wall. These walls were constructed in 2010. Adding insulation would not be cost effective because it would require an extensive renovation and is not recommended.

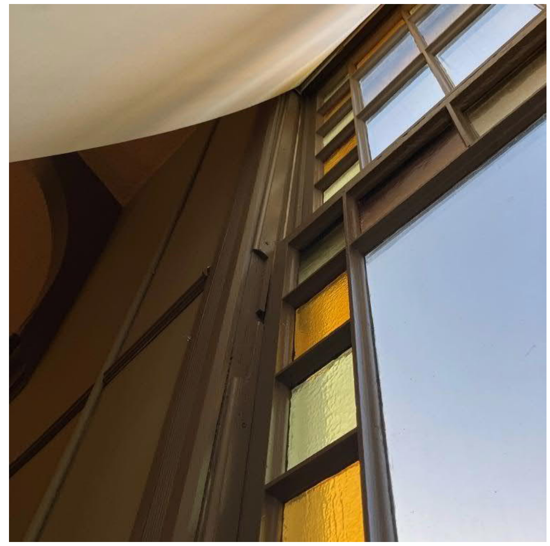
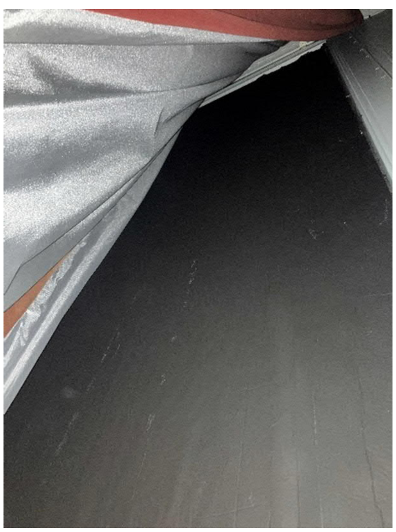
## 4.4. Windows

| Exterior Windows - Existing | | | | | |
|---|---|---|---|---|---|
| Location | Window Framing | Glazing | Storm Windows | Air tightness | R-Value |
| Offices | Wood-framed, operable | Single glaze | Exterior | Poor | R-1.5 |
| Main Hall | Wood-framed, operable | Single glaze | Exterior | Poor | R-1.5 |
| 2010 Additions | Wood-framed, operable | Double glaze | None | Tight | R-3.0 |

***Assessment/Recommendations:***

The old windows are in fair to poor condition and performing below a code compliant (R-2.7) operable window. Improving the windows is recommended.

For the tall windows in the main hall space, consider using insulated blank out panels since they are covered most of the time by shades. Temporary insulated window plugs could be employed similar to the ones shown below. These are 2” rigid foil-faced foam boards with compressed backer rod at the perimeter. The compressed backer rod is important because it reduces the amount of warm air that gets to the window which keeps condensation down. The foil-faced insulation can be painted black for a better exterior appearance. Effectively, the windows will act like “walls”. Before installing rigid insulation plugs, place a desiccant strip at the base of each window sash to absorb moisture from the air.

| | |
|---|---|
|  Figure 25 – Tall windows with shades drawn |  Figure 26 – Typical tall window |
|  Figure 27 – Example insulated window plug |  Figure 28 – from outside the black plug is indistinguishable |

The double hung windows with window weight pockets have air leaks at the head, sill, and at the meeting rails. In some cases, the sashes do not close completely so the air leakage at the head and the meeting rail is even more substantial. Make the upper sash a fixed pane by screwing it shut and caulking it in place. Then, add compression-fit interior storm windows. In rooms with many and/or large windows they do triple duty to reduce energy costs. 1 - In many cases they double the R-value of the window, 2 - they reduce air leakage around the window sashes, and 3 - they decrease radiant losses from the human body to the windows. People feel warmer when in the room so they leave the thermostat at a lower setting.

Figure 29 - Air leakage where the top sash does not close fully.

Figure 30 - Air leakage at the meeting rail.

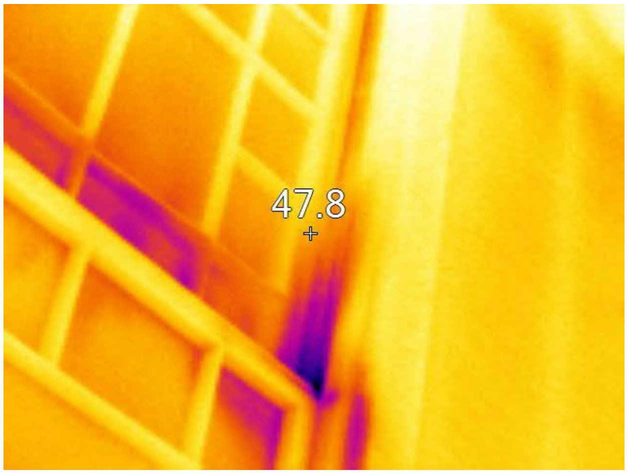



Figure 31 - Air leakage at the meeting rail

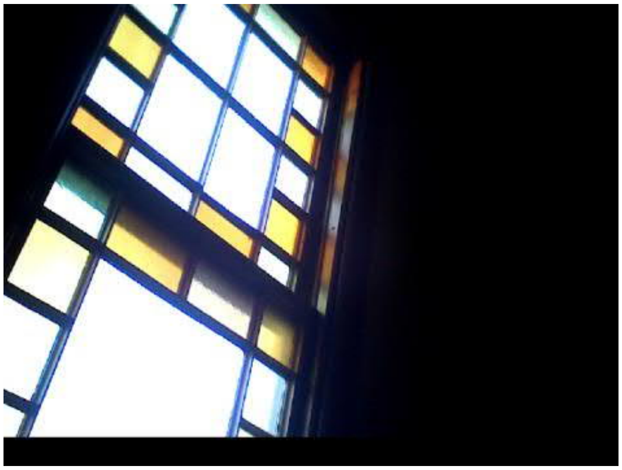


Figure 32 - Visible Light Image

## 4.5. Doors

| Exterior Doors - Existing | | | |
|---|---|---|---|
| Building Doors | | R-Value | Weather-stripping |
| Main Entrance Doors | Solid core wood | R-1 | Needs repair |
| Secondary Entrance Doors | Solid core wood | R-1 | Needs repair |
| Addition Doors | Wood | R-5 | Effective |

***Assessment/Recommendations:***

The original doors are in fair condition but performing below a code compliant (R-4.75) insulated door. Improving the doors is recommended.

The door to the bell tower (currently unconditioned space) is insulated weather-stripped but does not close tight to the weather-stripping. It needs a latch that pulls it tight to the weatherstripping and we recommend more than 1 inch of rigid insulation on the door.

Figure 33 – the door does not close tight to the weather-stripping

Figure 34 – We recommend a second layer of rigid insulation on the door

The center weather-stripping on the main hall entrance was done relatively recently, but it is starting to pull off and will need to be reinstalled.

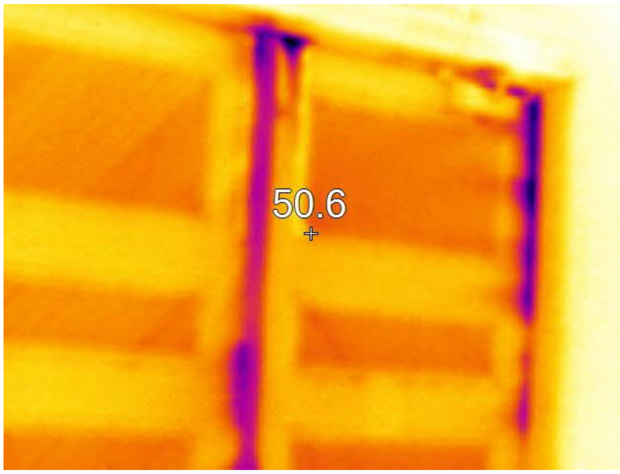



Figure 35 - Air leaks at failed weather-stripping

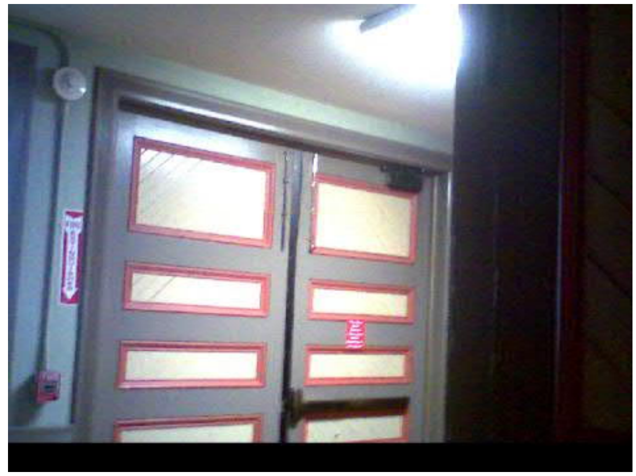


Figure 36 - Visible Light Image

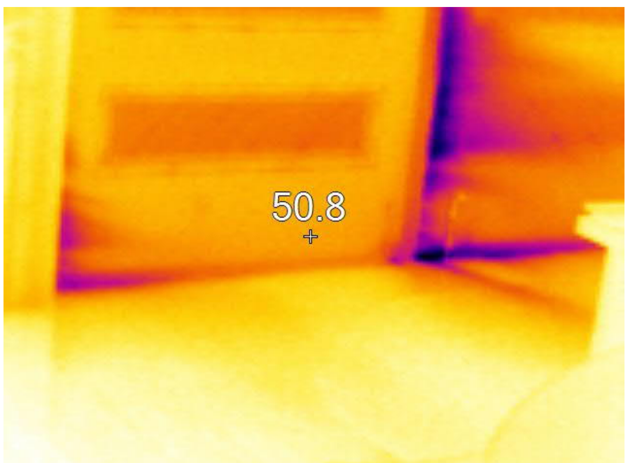



Figure 37 - Air leaks at failed weather-stripping

Figure 38 - Visible Light Image

## 4.6. Air Tightness

| Blower Door Test Results | | | |
|---|---|---|---|
| Indoor Temperature (ºF) | 60 | CFM/sf at 75 Pa. | 1.00 |
| Outside Temperature (ºF) | 33 | Test Notes | Calm winds. |
| Total Surface Area (s.f.)* | 16,090 | | |
| CFM at 75 Pa. | 16,155 | | |

*Six-sided surface area of the envelope bounding conditioned space, includes above and below grade surfaces.

| Building Air Tightness Comparison | |
|---|---|
| Type | CFM/sf at 75 Pa. |
| This Building | 1.00 |
| Leaky Construction | > 0.50 |
| Average Construction | 0.21 to 0.50 |
| High Performance Construction | < 0.20 |
| Ultra Tight Construction | < 0.08 |
| Overall Assessment | The building is extremely leaky |

***Assessment/Recommendations:***

The building air tightness is performing significantly worse than a code compliant (0.30 CFM/sf at 75 Pascals) building. Improving the air tightness is recommended.

In addition to the other air sealing measures described above, air seal the joint where the addition walls meet the existing brick. This can be done with clear caulk applied at the joint and tooled into mortar joints.

Please note: We recommend dedicated combustion air systems for fuel-fired appliances; an HVAC engineer should be consulted to review the mechanical ventilation when planning improvements that will improve the air tightness of the building.

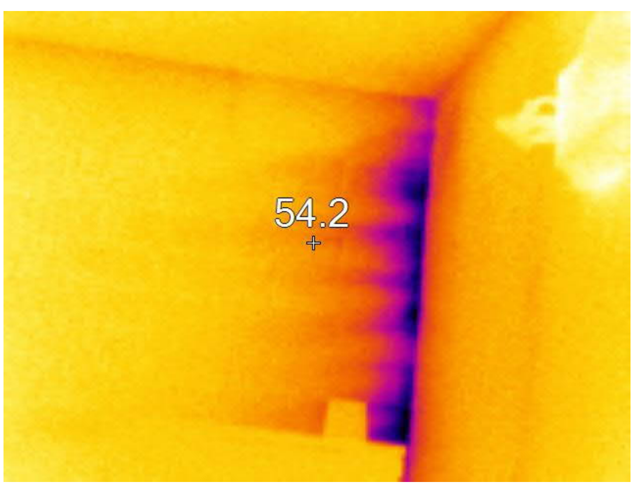



Figure 39 – Air leak where addition wall meets existing brick

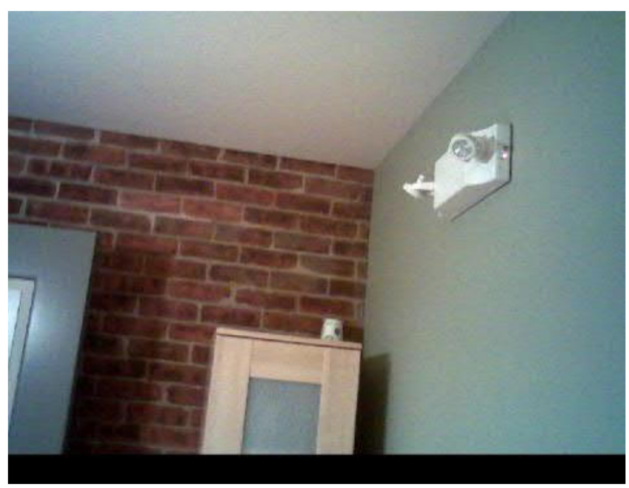


Figure 40 - Visible Light Image

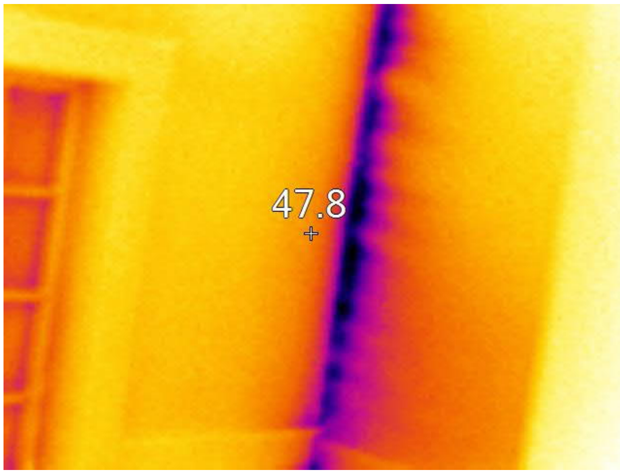



Figure 41 - Air leak where addition wall meets existing brick

Figure 42 - Visible Light Image

| Building Envelope – Recommended ECMs | | | | |
|---|---|---|---|---|
| Type | Walls | Windows | Doors | Air Sealing |
| Fuel Savings (Gal Fuel Oil) | 700 | 150 | 20 | 10 |
| Investment Cost | $55,100 | $8,200 | $300 | $50 |
| Annual Energy Cost Savings | $2,100 | $425 | $60 | $35 |
| Payback (Years) | 26.3 | 18.7 | 4.8 | 1.4 |

# 5. Building Heating, Ventilating, and Air-Conditioning (HVAC)

The entire building is heated with a hot water system consisting of a single oil-fired boiler, radiant floor, numerous fin tube radiators, and associated piping. Multiple multi-zone ductless heat pump systems provide heating and cooling to the lower level of the building. A single heat recovery ventilator and associated ductwork provides ventilation to the lower level of the building. There is no mechanical ventilation on the upper level besides the manually controlled bathroom exhaust fans.

| HVAC Central Equipment - Existing | |
|---|---|
| Type | Oil-Fired Hot Water Boiler, Non-Condensing, Single Stage Burner |
| Venting | Vented Through Chimney, Dedicated Combustion Air Supply Fan |
| Quantity | 1 |
| Make / Model | Buderus / G215-6 |
| Capacity | Heating – 256 MBh |
| Rated Efficiency | Heating – 86% AFUE |
| Electrical Power | 120V, 60Hz, 1Ø |
| Year Installed / Age | 2010 / 14 Years |
| Location / Spaces Served | Boiler Room / Entire Building |
| Control | Hot Water Supply Temperature Setpoint, Maximum: 248°F<br>Hot Water Supply Temperature Setpoint: Electronic Controller |


Figure 44 – Existing Oil-Fired Boiler


Figure 43 – Existing Boiler Controller

| HVAC Central Equipment - Existing | | |
|---|---|---|
| Type | Hot Water Circulation Pump, PSC-Type Motor, Single Speed | Hot Water Circulation Pump, PSC-Type Motor, Single Speed |
| Quantity | 5 | 1 |
| Make / Model | Taco / 007 | Taco / 010 |
| Capacity | 10 gpm, 7.5 ft. head | 14 gpm, 8 ft. head |
| Rated Efficiency | 50% motor eff. (est.) | 50% motor eff. (est.) |
| Electrical Power | 120V, 1Ø, 60Hz, 0.75A, 1/25hp | 120V, 1Ø, 60Hz, 1.1A, 1/8hp |
| Year Installed / Age | 2010 / 14 Years | 2010 / 14 Years |
| Location / Spaces Served | Boiler Room / Individual Zones | Boiler Room / Individual Zones |


Figure 45 – Existing Hot Water Circulation Pumps

| HVAC Terminal Equipment - Existing | |
|---|---|
| Type | Heat Recovery Ventilator |
| Quantity | 1 |
| Make / Model | Lifebreath / 300DCS |
| Capacity | Max Net Air Flow @ 0.4 in. w.g. – 235 cfm |
| Rated Efficiency | 75% SRE |
| Electrical Power | 120V, 1Ø, 60Hz, 2.9A |
| Year Installed / Age | 2010 / 14 Years |
| Location / Space Served | Boiler Room / Lower Level Only |
| Control | Timer |


Figure 46 – Existing Heat Recovery Ventilator


Figure 47 – Existing Ventilation Fan Controller

| HVAC Terminal Equipment - Existing | |
|---|---|
| Type | Ductless Heat Pump |
| Make / Model Indoor Units | (5) Mitsubishi / PKFY – P08NBMU-E, (1) Mitsubishi / PKFY – P12NHMU-E |
| Make / Model Outdoor Units | (2) Mitsubishi / PUMY – P48NHMU |
| Capacity, Each Outdoor Unit | Cooling – 48 MBh, Heating – 54 MBh (nominal) |
| Rated Efficiency | Cooling – 15.5 SEER, Heating – 3.14 COP |
| Electrical Power, Each Outdoor Unit | 208/230V, 1Ø, 60Hz, 26A |
| Year Installed / Age | 2010 / 14 Years |
| Location / Space Served | Lower Level Offices |
| Control | Programmable Thermostats, Set to 68°F - 70°F (varies) |

Figure 48 – Existing Interior Heat Pump Ductless Units


Figure 50 – Existing Programmable Thermostats

Figure 49 – Existing Exterior Heat Pump Units

| HVAC Terminal Equipment - Existing | |
|---|---|
| Type | Hot Water Fin-Tube Radiator |
| Year Installed / Age | Lower Level - 2010 / 14 Years, Upper Level – Unable to Verify |
| Location / Space Served | Throughout Building |
| Control | Non Programmable Thermostats<br>Setpoints: Occupied 68°F – 70°F, Unoccupied 65°F |

Figure 51 – Existing Fin-Tube Radiator

| HVAC Insulation - Existing | |
|---|---|
| Pipe Insulation | Hot water piping has fiberglass insulation which appears to be in good condition. |
| Duct Insulation | HRV system ductwork has foil-faced fiberglass insulation which appears to be in good condition. |

***Assessment:***

1. **Ventilation** – The existing mechanical ventilation system appears to provide appropriate airflow to the lower level during periods of occupancy. Based on the current building occupancy of the upper level (minimal), the benefit of adding a ventilation system would be minimal.
2. **Thermostats -** When the entire building or individual spaces within the building are unoccupied, thermostat temperature setpoints should be reset, and set to the same temperatures to minimize energy use. Replacing the existing thermostats with new, programmable ones would both reduce energy use, and could improve occupant comfort by automatically having the building at its occupied temperature setpoint at the start of the occupied time. Additionally, the control of the heat pumps should be integrated with the backup hot water radiators on the lower level so that the radiators only operate when needed (rarely).
3. **Motor Efficiency** - The PSC-type hot water pump motors are relatively inefficient versus modern EC-type motors.
4. **Heating Capacity vs. Demand** – The heating capacity of the existing boiler appears to be approximately as much as required for the maximum building heating demand based on its size and construction. The heating capacity of the existing heat pump system appears to be enough to heat the spaces it serves for the majority of the heating season. If recommended building envelope insulation and air sealing ECMs were implemented, the boiler capacity would be greater than the maximum building heating demand, and the heat pump would be able to meet the heating demands of

the spaces it serves for a longer portion of the heating season. If the equipment were overside, more frequent on/off cycling leading to reduced operational efficiency and equipment life would result.

5. **Heating System** - The existing mid-efficiency boiler appears to be in good condition, and has approximately nine years of RUL. The existing heat pump systems appear to be in fair condition and are nearing the end of their RUL. Replacing the existing oil-fired boiler with a new high efficiency gas-fired model, or adding an electric heat pump system to operate in conjunction with the existing boiler are possible options. A wood pellet-fired boiler does not appear to be a feasable option due to it's larger physical size and the limited amount of equipment manufacturers and capacities available.

   - **Option 1 - High Efficiency Gas-Fired Boiler:** A new high efficiency, condensing, direct-vent, gas-fired boiler with a modulating output burner, stainless steel heat exchanger, and an efficiency rating of 95%+ AFUE could be installed to completely replace the existing oil-fired one. The boiler would operate most efficiently with low-temperature water (130°F), however the baseboard radiators currently operate at medium temperature water (180°F) and would likely have to be replaced with larger ones to provide the necessary heat output.

   - **Option 2 – Electric Heat Pump:** A new heat pump system could be installed and utilized in conjunction with the existing oil-fired boiler, similar to the existing heat pump system which serves the lower level. The heat pump could heat the building for the majority of the year while the oil-fired boiler would operate only on the coldest days.

     - **Option 2A: Air-to-Air, Ductless or Ducted:** The heat pump system would consist of an exterior unit and multiple wall, floor, or ceiling-mounted ductless or ducted interior units located on the upper level with refrigerant piping in between. Heat pump controls would require some work to be integrated with the existing hot water heating system. The indoor units would require condensate drain piping to allow for cooling/dehumidification in addition to heating.

     - **Option 2B: Air-to-Water:** The heat pump system would consist of an exterior unit and an interior unit located in the existing boiler room with refrigerant piping in between. Heat pump hot water piping and controls would be integrated with the existing boiler. The heat pump system could theoretically provide cooling in addition to heating, but doing so would require extensive modifications, replacing all existing fin tube radiators with fan-powered models and condensate drains. The heat pump is only capable of producing low temperature hot water, which the existing system does not currently operate at (as described previously), and modifcations to existing fin tube radiators would likely be required.

The following should be considered when evaluating new systems:

- **Building Envelope Improvements** – This analysis assumes that building envelope ECMs recommended in this assessment report are pursued and the maximum building heating demand is reduced due to their impact. If these ECMs were not pursued, the heating system costs and energy savings would be greater.

- **Replacement Cost** – The existing boiler has many years of RUL and will not require an investment in a replacement unit in the near future. The cost <u>difference</u> between a similar new boiler and a new high efficiency / renewable energy system may be less than the <u>full</u> cost depending on the type of system.

- **Energy Cost Volatility** – Fossil fuel prices typically vary over time by +/- 50%, depending on a variety of factors. Wood and electricity costs are relatively stable over time.

- **Energy Source –** Fossil fuels originate from outside the local geographical region whereas electricity is sourced locally and regionally. Purchasing electricity somewhat contributes to the local economy whereas purchasing fossil fuels has relatively low benefit to the local economy. Propane is widely available through bulk delivery from many local distributors and is already used on site. Electric power already exists and is used at the building. It appears the existing electrical service does have the capacity to support a new heat pump system with few modifications, but an electrical engineer should be consulted to confirm.

- **Environmental Impact** – The oil use of the existing boiler represents the majority of the building's environmental impact (vs. electricity use). Annual $CO_2$e emissions after recommended building enclosure ECMs have been implemented can be reduced further by different amounts depending on the option, from 45% up to 65%.

- **Equipment Life -** For the primary heating equipment, high efficiency gas-fired boilers are expected to have 20 year useful services lives, 25 years for standard efficiency gas-boilers, 15 years for heat pumps.

***Recommendations:***

1. **Thermostats** – The existing thermostats should be replaced with new, programmable ones, that can control both the heat pump and the hot water radiators, and should be set for the building occupied periods.
2. **Motor Efficiency** – When a new, replacement boiler is purchased/installed, the existing pumps should also be replaced with new EC motor pumps.
3. **Heating Capacity vs. Demand** - New heating equipment should be selected with a capacity to match the actual maximum building heating demand, or only a portion of it for hybrid systems. A licensed mechanical engineer should be consulted to determine this.
4. **Heating System** – The air-to-air heat pump / oil hybrid option is not cost-effective from a financial payback alone, however the additional benefits of reduced energy cost volatility, positive local impact, and reduced environmental impact make this a worthwhile investment. The high efficiency gas-fired boiler and air-to-water heat pump options require too large of an investment to justify their benefits, primarily due to the existing fin tube radiators having to be replaced to allow for operation with low temperature hot water.

| Heating System ECMs and RREMs | | | | |
|---|---|---|---|---|
| Type | Mid Eff. Oil-Fired Boiler (Ref. Only) | High Eff. Gas-Fired Boiler | Heat Pump, Air-to-Air / Oil Hybrid | Heat Pump, Air-to-Water / Oil Hybrid |
| Estimated Heating Capacity (MBh) | 235 | 235 | Heat Pump: 65<br>Boiler: 256 | Heat Pump: 65<br>Boiler: 256 |
| Annual Building Fossil Fuel Consumption Offset (%) | 0% | 45% | 65% | 65% |
| Investment Cost | $11,700 | $37,500 | $20,000 | $55,000 |
| Potential Incentives | $0 | $0 | $450 | $10,000 |
| Annual Energy Cost Savings | $0 | $450 | $825 | $725 |
| Payback Including Incentives* | - | 83 Years | 23.7 Years | 62 Years |

**At present time (may be different at time existing equipment reaches the end of its RUL)*

| HVAC – Recommended ECMs | | |
|---|---|---|
| Type | Programmable Thermostats | Integrated Heat Pump / Radiator Control |
| Energy Savings (gal oil) | 100 | 300 |
| Investment Cost | $1,800 | $1,200 |
| Potential Incentives | $600 | $0 |
| Annual Energy Cost Savings | $300 | $300 |
| Payback Including Incentives | 4.0 Years | 4.0 Years |

Figure 52 – Example Lochinvar Brand
High Efficiency Gas-Fired Boiler

Figure 53 – Example Mitsubishi Brand
Air-to-Air Heat Pump with Ductless
Indoor Unit

Figure 54 – Example SpacePak Brand
Air-To-Water Heat Pump

# 6. Building Lighting

| Lighting - Existing | | |
|---|---|---|
| Interior Illumination | Room | Measurement (foot-candles) |
| | Offices<br>Stairs<br>Corridors<br>Bathrooms | 15 – 40<br>6 – 10<br>3 – 34<br>4 – 21 |
| Interior Light Fixtures | Room | Fixture/Technology |
| | Offices, bathrooms, and meeting space<br>Lobby and corridor<br><br>Lobby and corridor<br>Lobby and stairs | Ceiling mounted square, T8 fluorescents<br>Ceiling mounted track lights, a mix of LED and CFL<br>Recessed can lights, CFL<br>Ceiling mounted round, LED |
| Interior Lighting Controls | Manual wall mounted switches and automatic-occupancy wall mounted. | |
| Interior Exit Light Fixtures | LED-type | |
| Exterior Light Fixtures | Area | Fixture/Technology |
| | Porch Overhangs | Recessed downlight, CFL's |
| Exterior Lighting Controls | Manual wall mounted switches. | |

Figure 56 – Existing LED Panel Fixture

Figure 55 – Existing Wall Mounted Light Switches

Figure 57 – Existing Ceiling Mounted LED's

***Assessment/Recommendations:***

1. Interior light fixtures appear to provide illuminance at levels which are higher than what is recommended for the activities which take place in each space; reducing lamp quantity, fixture quantity, or adding dimming controls is recommended.
2. The existing fluorescent bulbs are relatively inefficient and should be replaced with high efficient LEDs.
3. While many interior and exterior lighting controls are manual rather than automatic, building occupants appear to use lights only when needed; the use of automated controls is possible but would result in minimal energy savings and not be cost effective.

| Lighting – Recommended ECMs | |
|---|---|
| Type | Replace fluorescents with LEDs |
| Energy Savings | 3,100 kWh |
| Investment Cost | $2,800 |
| Potential Incentives | $0 |
| Annual Energy Cost Savings | $600 |
| Payback Including Incentives | 4.7 Years |

# 7. Building Domestic Hot Water

| Plumbing Fixtures - Existing | | | | |
|---|---|---|---|---|
| Type | Quantity | Location | Flow Rate | Age |
| Lavatory Faucet | 1 | Bathroom | 2.2 GPM | +/-15 Years |
| Kitchen Faucet | 1 | Break room | 2.2 GPM | +/- 15 Years |

Figure 58 – Existing Lavatory Faucet

***Assessment/Recommendations:***

The existing fixtures appear to be in moderately good condition. They are relatively efficient, but could be replaced with more efficient models. However due to their low usage, the resulting energy savings would be insignificant, and this is not recommended.

| Water Heating Equipment - Existing | |
|---|---|
| Type | Indirect Storage |
| Quantity | 1 |
| Make / Model | Buderus / DIN - 4753 |
| Capacity | Volume – 42 gal |
| Year Installed / Age | 2010 / 14 Years |
| Location | Boiler Room |
| Control | Setpoint: 130°F |

***Assessment/Recommendations:***

The existing water heater appears to be in moderately good condition. It is relatively efficient, but could be replaced with a more efficient electric heat pump model. However due to its low usage, the resulting energy savings would be insignificant, and this is not recommended.

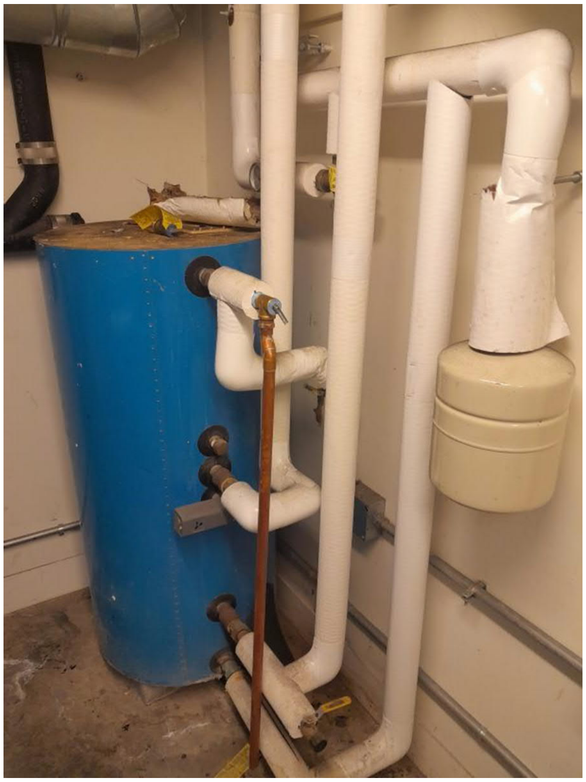


Figure 59 – Existing Indirect Water Heater

# 8. Building Equipment

| Office Equipment - Existing | |
|---|---|
| Type | Desktop Computers, Printers, and Shredders |
| Location | Throughout Building |

Figure 60 – Existing Printer

| Kitchen Equipment - Existing | |
|---|---|
| Type | Mini-Fridge, Microwave, and Coffee maker |
| Location | Break Room Space |

***Assessment/Recommendations:***

The associated energy use of this equipment is relatively minor and/or there doesn't appear to be any equipment replacement or control opportunities to reduce energy use.

# 9. Appendices

## 9.1. Appendix A - Other Supporting Documents

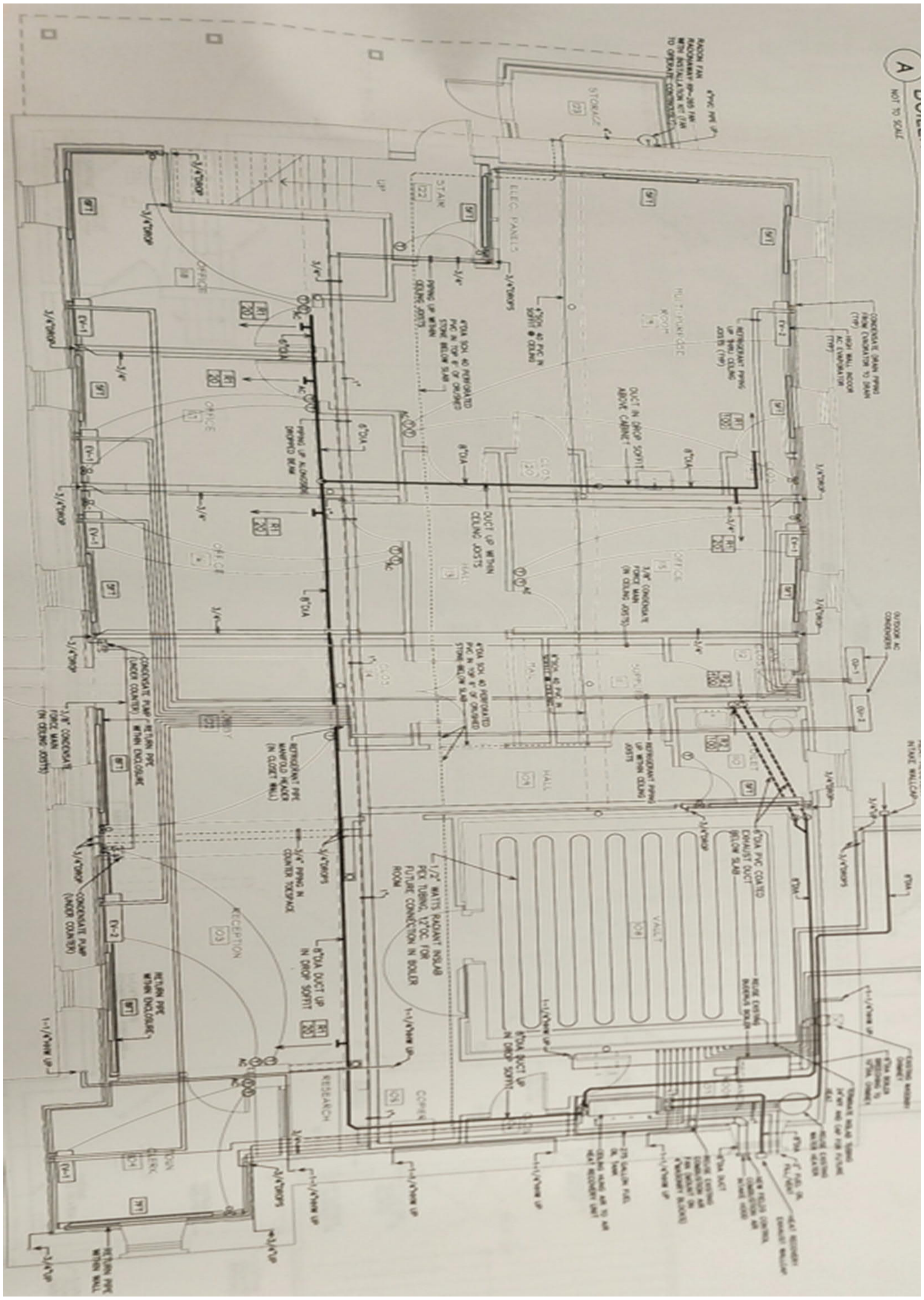


Figure 61 – First Floor (Not To Scale)

## 9.2. Appendix A - Other Supporting Documents

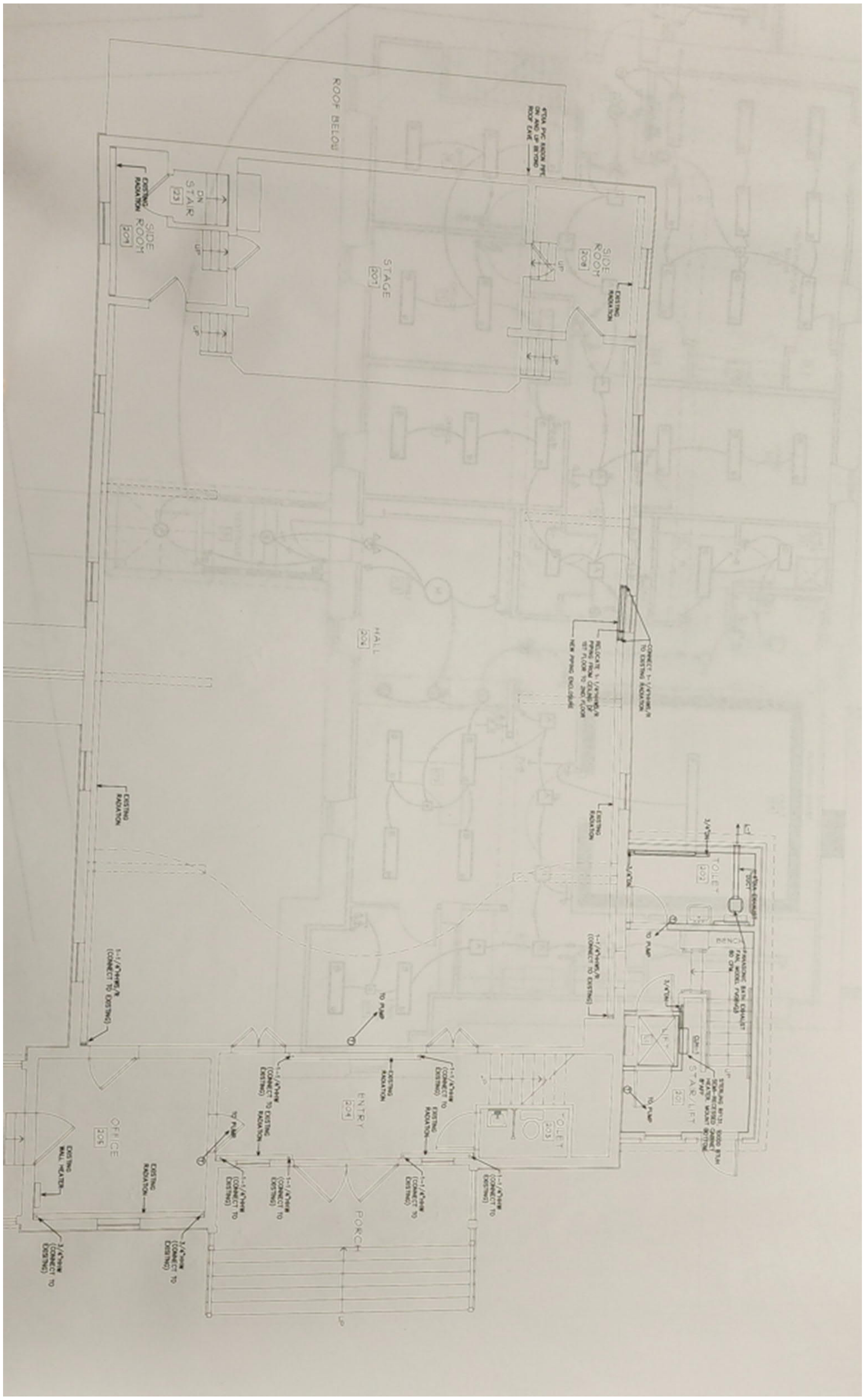


Figure 62 – Second Floor (Not To Scale)

# 10. Glossary of Terms and Acronyms

**AFUE** – Annual Fuel Utilization Efficiency; a measurement of a heating appliance's efficiency, calculated as the ratio of the heat output to the fuel consumed.

**ASHRAE** – American Society of Heating, Refrigerating, and Air-Conditioning Engineers; the governing society responsible for developing building design and efficiency standards and guidelines.

**BTU** – British Thermal Units, a measurement of the heat content of fuels or energy sources. One BTU is the quantity of heat required to raise the temperature of one pound of water by 1°F at the temperature which water has its greatest density – approximately 39°F

**CFM** – Cubic Feet per Minute; a measurement of air movement.

**COP** – Coefficient of Performance; a measurement of efficiency. Calculated as the ratio of useful heating or cooling provided to the work (energy require).

**$CO_2e$** – Carbon Dioxide Equivalent; A measurement of global warming impact for different greenhouse gases using a single unit ($CO_2$).

**DHW** – Domestic Hot Water; typically used in a building for cleaning and bathing.

**DX** – Direct Expansion; a cooling system utilizing refrigerant where the indoor cool is directly in the airstream.

**ECM** – Energy Conservation Measures; changes recommended to reduce energy consumption. These can be No/Low cost items implemented as part of routine maintenance or Capital Cost items to be implemented as a capital improvement project.

**EC** – Electronically Commutated; a type of high efficiency electric motor.

**EER** – Energy Efficiency Ratio; a measurement of equipment efficiency, calculated as the ratio of cooling energy output (measured in BTUs) to electrical energy consumed (measured in watt-hours).

**EUI** – Energy Use Intensity; The sum of the total site energy use per unit of gross building area.

**EUL** – Expected Useful Life; the estimated lifespan of a typical piece of equipment based on industry accepted standards.

**F** – Fahrenheit; the scale of temperature on which water freezes at 32° and boils at 212° under standard conditions.

**HP** – Horsepower; a unit of measurement of power, or the rate at which work is done, usually in reference to the output of motors.

**HSPF** – Heating Seasonal Performance Factor; a measurement of equipment efficiency, calculated as the ratio of heating energy output (measured in BTUs) during the annual heating season to electrical energy consumed (measured in watt-hours) over the same period.

**HVAC** – Heating, Ventilating, and Air-Conditioning

**GHG** - Greenhouse Gases; Gases which trap heat in the atmosphere. Primarily consisting of carbon dioxide ($CO_2$), methane ($CH_4$), Nitrous Oxide ($N_2O$) and fluorinated gases. Carbon dioxide enters the atmosphere through the burning of fossil fuels (oil, natural gas, and coal), solid waste, trees and wood products, and also as a result of other chemical reactions (e.g., manufacture of cement).

**LED** – Light Emitting Diode; a device which emits light when current is applied to it in a relatively energy efficient manner.

**LCC** - Life Cycle Cost; The sum of the present values of (a) **I**nvestment costs, less salvage values at the end of the study period; (b) Non-fuel operation and maintenance costs: (c) Replacement costs less salvage costs of replaced building systems; and (d) Energy and/or water costs.

**PSC –** Permanent Split Capacitor; a type of standard efficiency electric motor.

**PV** – Photovoltaic; a device which converts light into electricity.

**RUL** – Remaining Useful Life; the EUL minus the effective age of the equipment and reflects the estimated number of operating years remaining for the item.

**SEER** – Seasonal Energy Efficiency Ratio; a measurement of equipment efficiency, calculated as the ratio of cooling energy output during the annual cooling season (measured in BTUs) to electrical energy consumed over the same period (measured in watt-hours).

**Simple Payback** – The number of years required for the cumulative value of energy cost savings less future non-fuel costs to equal the investment costs of the building energy system, without consideration of discount rates.

$$Simple\ Payback = \frac{Initial\ Cost}{Annual\ Savings}$$

**SIR** – Savings-to-Investment Ratio; the ratio of the present value savings to the present value costs of an energy conservation measure. The numerator of the ratio is the present value of net savings in energy and non-fuel operation and maintenance costs attributable to the proposed energy conservation measure. The denominator of the ratio is the present value of the net increase in investment and replacement costs less salvage value attributable to the proposed conservation measure. It is recommended that energy-efficiency recommendations be based on a calculated SIR, with larger SIRs receiving a higher priority. A project typically is recommended only if the SIR is greater than or equal to 1.0, unless other factors outweigh the financial benefit.

**W** – Watts; a unit of measurement of power, or the rate at which work is done, usually in reference to the output of motors.

**XPS** – Extruded Polystyrene; a type of foam insulation, typically in board form.