ENERGY AUDIT: FIRE STATION 231

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1.0 Executive Summary

1.1 Background of Project

A walkthrough energy audit was performed by Humber College Students at Fire Station 231, located at 740 Markham Road in Toronto, Ontario. The facility is a three story (plus basement) 13,225 ft^2 building constructed in 1960. The building consists of bedrooms, offices, locker rooms, washrooms and a living room, a kitchen, and a workout facility.

Primarily, the central boiler plant located in the basement mechanical room provides heat for the entire building via electric baseboards. Some supplemental heat is supplied by two packaged rooftop units, one located on the roof and one located above the dispatch office. These units are only required when the boiler system is not meeting the demands of the occupants as they are manually controlled.

Cooling is provided to all three floors (not including the basement) via the chiller located on the ground level. If the chiller is not meeting the demands of the occupants on the third floor the main rooftop unit is used to make-up for its shortcomings.

Lighting fixtures were retrofitted in 2011 with T8 fluorescent lamps, while exit signs remained incandescent.

Energy consumption, utility data and building equipment have been analyzed and based on the findings from this analysis this report will recommend opportunities for energy consumption and cost savings.

1.2 Energy Efficiency Measures Overview

Various energy and cost saving measures have been investigated and recommended to reduce the energy demand of the building. Both low hanging and higher cost recommendations have been made and justified using various financial analyses.

The low hanging fruit are low cost, high return investments that yield notable savings. Replacing weather stripping along windows is one of these opportunities. As well, lighting equipment retrofits can result in energy savings over time. The retrofit of all exit signs from incandescent lamps to zero-watt photoluminescent signs will contribute to electricity savings. As well, installing occupancy sensors in the majority of rooms will yield sizeable electricity savings. The most significant low cost opportunity is the injection of a high-efficiency heat transfer fluid, which will improve the overall efficiency of the buildings boilers thus reducing energy consumption.

Other savings opportunities recommended include insulated window shades, boiler replacements with several options and heat recovery units.

1.2.1 Feasibility Analysis

The feasibility of each energy conservation measure has been detailed below. Please refer to the energy conservation measure section for financial analyses and corresponding recommendations.

2.0 Building Description

2.1 Site Overview

Fire Station 231 is located within the City of Toronto East Command Division at 740 Markham Road. Built in 1960, the original function of the building was a central calling station for the East Command. The station has since undergone several upgrades over the last 15 years, and has been re-commissioned as a fully functional fire hall. The building operates on a 24-hour schedule with up to 25 occupants on average. The main floor consists of offices, a training room, one bedroom and a corridor. The second floor is mainly comprised of offices and bedrooms. The third floor is largest area with the highest occupant use, consisting of a kitchen, living room, exercise room, locker-room, shower room, as well as offices and bedrooms. The basement contains the mechanical/electrical rooms and equipment storage.

2.3 Systems

2.3.1 Building Envelope

Building renovations occurred in 1995 and 2011 to update the facility and resulted in the replacement of portions of the roof, exterior walls and the addition of a stairwell. The following are the original and corresponding upgraded envelope components:

Roof

The main roof has not been replaced to date. The roof is in good condition; however, it should be noted that significant ponding may cause long term negative effects. The below chart lists the roof components and the corresponding R-value for each material:

Existing Roof	R-value
1.5" Steel Deck	0
3" insulation (EPS)	16.8
1/2 " Fiberboard	1.32
Torch Down Bitumen Membrane	2
Cap Sheet	1.5
Total R-Value	21.62

The R-values of the roof components was determined using the archtoolbox resource, which provides technical references for building envelope materials.

Exterior Walls

All exterior walls were upgraded in 1995 when the building was initially renovated to include an exterior stucco finish. The walls are in good condition with no visible cracks or gaps. The following is a breakdown of the exterior wall components:

Above Grade Exterior Walls	R-value
4" Metal Studs w/ R-12 Batt	5.5
6 Mil Poly Vapour Barrier	0
1/2" Sheathing	1.32
Typex 5/8"	0.2
2" Rigid Insulation (EPS)	10
Stucco Finish	0.2
Total R-value	17.22

The resource used to determine wall component R-values was Archtoolbox, which is used by architects as a technical reference.[1]

Windows

All windows in the facility were originally single pane, double sash windows with ¼" air fill and aluminum frame. An image of the original windows can be referenced in Photo 1 in Appendix 11.6. When renovations occurred in 1995, the windows in the living room and kitchen were replaced with double pane 516 Isoport thermally broken insulated windows, of which half are operable. The windows are in fair condition, with many window seals requiring replacement. One window, located in the dispatch office, is cracked.

Doors

There are seven overhead doors that service the apparatus bay. These steel frame doors, which are illustrated in Photo 2 in Appendix 11.6, consist of insulated steel. The main entrances to the building and apparatus bay are glass single pane doors. There are three other doors, which are primarily used as emergency exits and consist of insulated steel with a steel frame construction. All doors are in very good condition with no visible repairs required.

[1] http://archtoolbox.com/materials-systems/thermal-moisture-protection/24-rvalues.html

2.3.2 Mechanical Systems

Heating and Cooling

Primarily the central boiler plant located in the basement mechanical room provides heat for the building. This plant consists of two 512 kBtu atmospheric boilers rated at 82% efficiency; the boilers were installed approximately 10 years ago. Boiler specifications are referenced in *Appendix 11.2*.

The boilers are piped as an injection loop in a primary/secondary loop configuration. Supply water temperatures and boiler staging are controlled by a digital controller, with supply water temperatures being re-set based on outdoor air temperatures. Each room, excluding washrooms and the main floor dispatch office, is equipped with baseboard radiators for heating. Baseboards are supplied with hot water through the building's primary loop and are controlled with wall-mounted dials that open or constrict the hot water valve. While these boilers are in good operating condition, they are older and running at a lower efficiency than current market alternatives.

In addition to this, there are three separate packaged rooftop units, two for heating and cooling and one solely for cooling. The rooftop unit located above the dispatch office is intended to serve only that space. The first floor plan, found in *Appendix 11.1*, shows the location of this room. A thermostat located in the dispatch office controls heating and cooling into the space.

This is similar to the packaged rooftop unit that serves the third floor living room; however, the baseboard radiators also serve this space when heating is required. When the radiators are not meeting the heating demands of this high occupancy space, the occupants can manually activate the rooftop unit via a thermostat. The specific location of the living room can be found on the third floor plan in *Appendix 11.1*.

The central cooling system, a Trane TCH075 cooling-only horizontal unit located outside on the ground floor, adjacent to the training room, serves all three floors of the building. The thermostat that controls the incoming air temperature is located in the Captain's office on the first floor; one thermostat controls the temperature of all spaces on all floors. Alternatively, if the chiller is not meeting the demands of the occupants on the third floor the main rooftop unit is used to make-up for the shortcomings of the central cooling system. The packaged unit is in fair operating condition, however operates at lower efficiency due to deteriorated insulation on supply duct entering the building. The specifications for all packaged units can be referenced in *Appendix 11.2 – Existing Building Systems Cut Sheets*.

2.3.3 Electrical Systems

Lighting throughout the entire building consists of 32-Watt T8 lamps with magnetic ballasts. The janitor's closet contains one incandescent lamp. Exit signs are original incandescent lamps. Approximately 15% of the lamps were in need of replacement during the site visit.

The majority of task lighting for the offices and bedrooms is equipped with a 40W halogen desk lamp. On average approximately 35% of the installed task lighting was in use during the four walk-throughs completed.

2.3.4 Water Systems

Water systems in the building consist primarily of standard flush toilets, washroom and kitchen sinks with aerators and standard flow showerheads. No running or leaking fixtures were observed. All of the fixtures are original installations; some bathroom sinks are missing aerators.

2.3.5 Renewable Energy Systems

The solar DHW system described above is the only renewable energy system on site; it was installed in 2010 and is in good working condition. System components are referenced in photos *3* & *4* in *Appendix 11.6*.

2.4 Drawings

Building drawings were created using Autodesk Revit 2013. Four floor plans that detail the room dimensions and activity use can be found in *Appendix 11.1*.

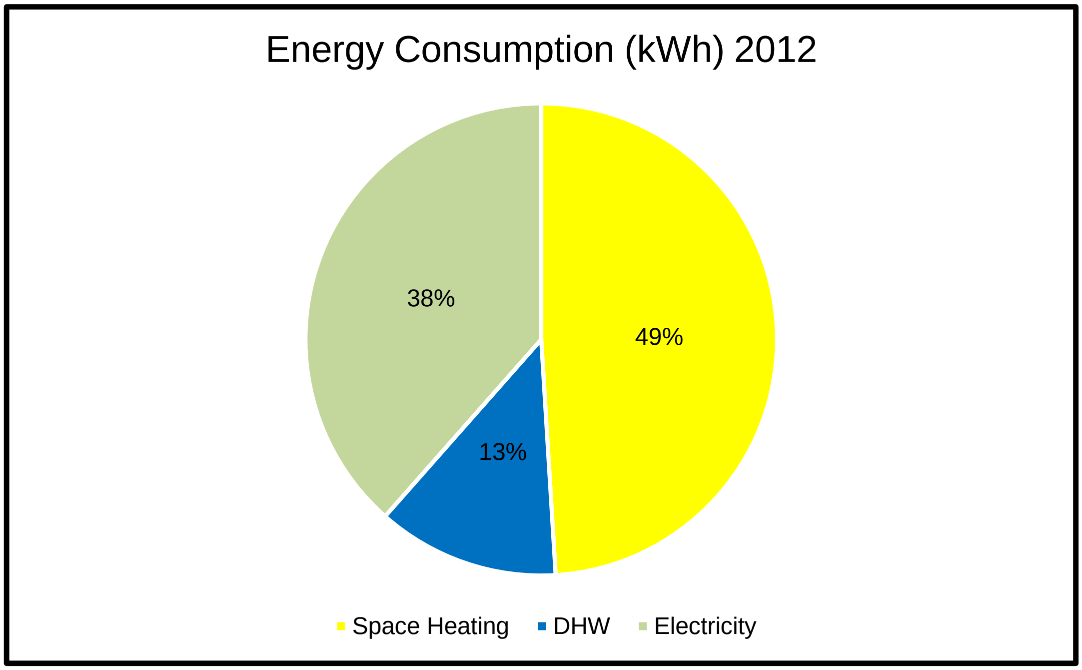
3.0 Utility Analysis

3.1 Overview

This section presents the results of historical analysis of electricity, natural gas and water consumption data over a two-year period from 2010 to 2012. All consumption data was provided from utility invoices and analyzed for a two-year period. All graphs and corresponding data found in this section were extrapolated from utility analysis performed in the energy analysis software *RetScreen Plus*, of which the results can be referenced in *Appendix 11.3.2*. By analyzing the utility bills of this building, changes in consumption over time can be determined and potential savings can be recommended.

After completing the energy analysis from the provided utility billing data and recorded inventory from the walk-through audit, the following end-use allocation for energy consumption was derived (graph below). The percentages of each allocated end uses show the significance of each system within the building.

As can be seen below, electricity is the main energy consumption in the building, followed by space heating and then DHW.



Energy Consumption (kWh) 2012	
Space Heating	178,055
DHW	45,390
Electricity	139,742

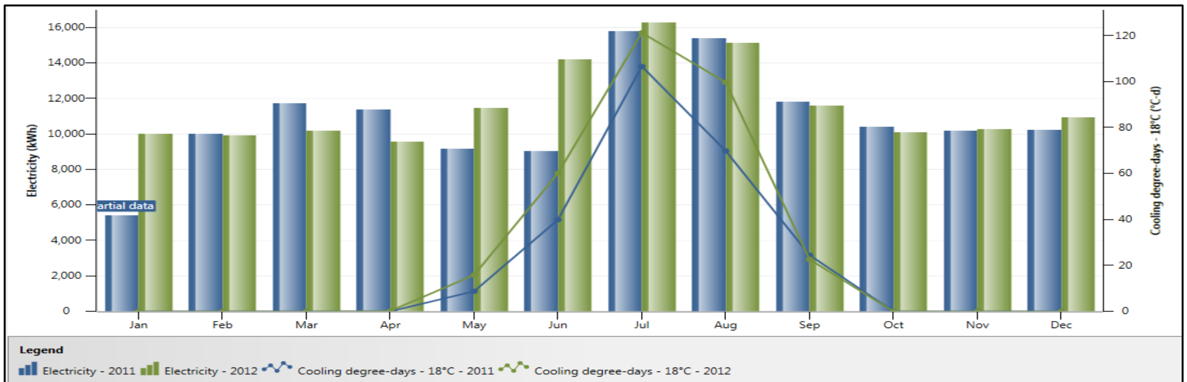
3.2 Energy Use Profile

3.2.1 Electricity

Electricity consumption for FS231 followed a seasonal variation, with higher consumption periods occurring in the summer cooling period. Increased summer consumption is due to electric cooling provided by three packaged rooftop units. Loads that consume electricity outside of the cooling period are designated as base-load. These loads occur irrespective of seasonal heating and cooling needs. Examples of these loads are lights, appliances and plug loads. *Graph A,* found in *Appendix 11.3.1* shows April as the lowest consumption month at 9,555 kWh. July is the month with the highest electricity consumption, which coincides with summer cooling needs.

2011-2012 Electricity Consumption – Cooling Degree Days (CDD)

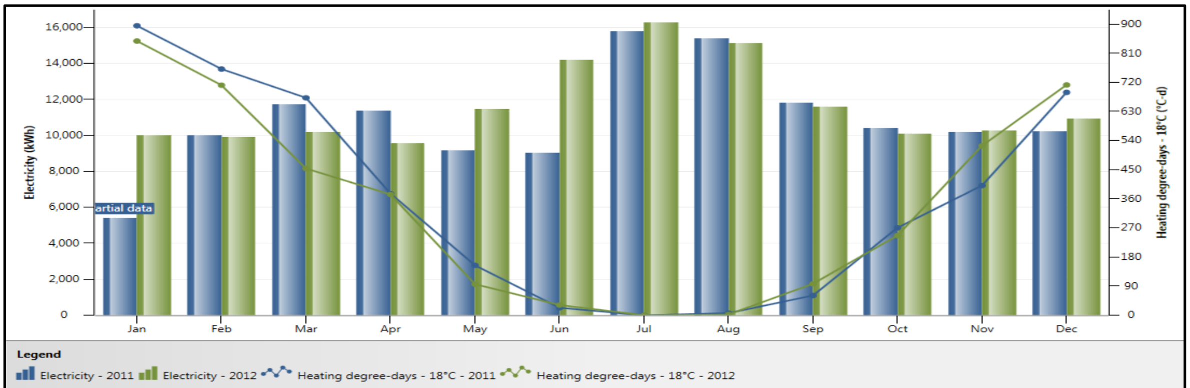
There is a strong correlation between cooling-degree days (CDD) and electricity usage. Cooling-degree days are a means of tracking the amount of time each month that the outside temperature is above the reference cooling set point of 18 C. The amount of time above the cooling set-point will determine the amount of cooling needed, thus the number of cooling-degree days for a given month will correspond to increased electricity usage for cooling—the graph below shows this correlation. The curve of the CDD graph moves up in the cooling season (April-Oct), which is followed closely by a rise in electricity use for those periods. This represents the electricity consumption for HVAC systems associated with cooling.



Months	Electricity kWh 2011	Electricity kWh 2012	Cooling degree-days - 18°C °C-d 2011	Cooling degree-days - 18°C °C-d 2012
Jan	5,401	10,012	0	0
Feb	10,012	9,922	0	0
Mar	11,731	10,175	0	0
Apr	11,406	9,555	0	0
May	9,194	11,488	9	16
Jun	9,031	14,236	40	60
Jul	15,787	16,286	107	121
Aug	15,402	15,131	70	100
Sep	11,820	11,612	24	23
Oct	10,415	10,101	0	0
Nov	10,185	10,282	0	0
Dec	10,253	10,942	0	0

2011-2012 Electricity Consumption – Heating Degree Days (HDD)

Comparing electricity loads to HDD electricity consumption provides incite into the water-pumping loads required for heating. In this case, we see that electricity consumption does not fluctuate greatly with HDD in the heating season. From this we understand that pumping loads for the building are not a significant energy draw.



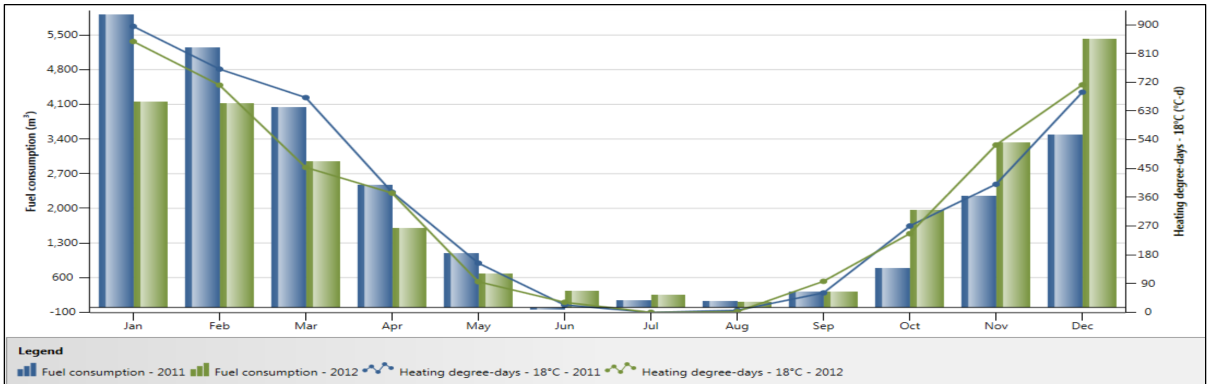
Months	Electricity kWh 2011	Electricity kWh 2012	Heating degree-days - 18°C °C-d 2011	Heating degree-days - 18°C °C-d 2012
Jan	5,401	10,012	895	848
Feb	10,012	9,922	762	712
Mar	11,731	10,175	672	454
Apr	11,406	9,555	376	374
May	9,194	11,488	154	96
Jun	9,031	14,236	23	32
Jul	15,787	16,286	0	0
Aug	15,402	15,131	7	2
Sep	11,820	11,612	61	97
Oct	10,415	10,101	271	247
Nov	10,185	10,282	401	524
Dec	10,253	10,942	689	712

3.2.2 Natural Gas

Natural Gas consumption for Fire Station 231 followed a definite seasonal pattern. Consumption was very low in the summer cooling season, and high in the winter heating season. Thus, baseload consumption for natural gas, or consumption that is not dependent on seasonal variation, can be determined from a reference summer month and multiplied by 12, to get an annual base-load. For Fire Station 231, gas usage during the summer months is attributed solely to domestic hot water. Baseload gas consumption is shown in Graph B found in Appendix 11.3.1.

2011-2012 Gas Consumption – Heating Degree Days (HDD)

There is a strong weather correlation between heating degree-days and natural gas consumption. During the winter months when a significant amount of heat is required, the number of heating-degree days correspondingly increase. Heating-degree days represent the number of days the outdoor temperature is under the reference point, which is generally set at 18 C. Therefore, the number of heating-degree days calculated for each month represents the amount of heating needed for each month.



Months	Fuel consumption m³ 2011	Fuel consumption m³ 2012	Heating degree-days - 18°C °C-d 2011	Heating degree-days - 18°C °C-d 2012
Jan	5,923	4,161	895	848
Feb	5,262	4,135	762	712
Mar	4,056	2,959	672	454
Apr	2,483	1,613	376	374
May	1,093	684	154	96
Jun	-47	332	23	32
Jul	153	259	0	0
Aug	130	121	7	2
Sep	324	314	61	97
Oct	798	1,965	271	247
Nov	2,258	3,328	401	524
Dec	3,499	5,421	689	712

In the graph above, January has 848 heating-degree days, meaning the need for heating will be more significant than in August, with only 2. The purpose of this graph is to demonstrate that the fire stations' gas consumption is correlated to the weather data, which is expressed by the number of heating-degree days. In other words, the curve of the heating-degree line matches the extents of the monthly consumption (represented by each bar), indicating that the building heating and domestic hot water system is working as expected. The 2012 Total Natural Gas Use was extrapolated to determine consumption patterns; the majority of gas consumption for the station is for space heating with the remainder used for domestic hot water (DHW). The end-use allocation chart further supports the heating with the remainder used for DHW. The chart found in the End Use Allocation section below further supports the findings from above. Based on this preliminary analysis, the savings for space heating would be more beneficial than for DHW.

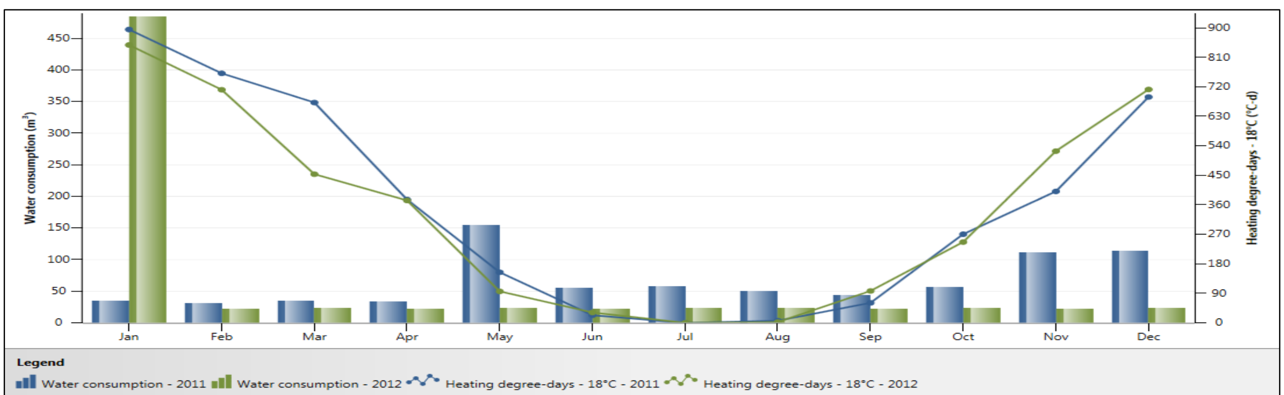
3.2.3 Water

Water consumption for FS231 did not follow any seasonal patterns for the 2012 year. Base-load consumption was 25 m^3 per month, which was constant for the entire year of 2012. The absence of seasonal variation means that water usage for the station is largely internal, with negligible amounts needed for irrigation in the summer.

The 2011-year saw more variation in water usage. Spikes for water occurred in May and November through January, which can be noted in Graph C found in Appendix 11.3.1. These extra loads could be attributed to resupply of fire-trucks or uncommon maintenance on the station that requires extra water. Savings for water will be sought out in baseload systems – low-flow fixtures, waterless urinals, aerators for faucets, etc.

Water Consumption – Heating Degree-Days (HDD)

Water consumption for FS231 did not correlate to heating-degree days. As can be seen in the graph below, a rise or fall in HDD did not cause a corresponding increase or decrease in water consumption. This means that water loads are dependent on factors outside of seasonal variation, such as facility operations and occupant needs.

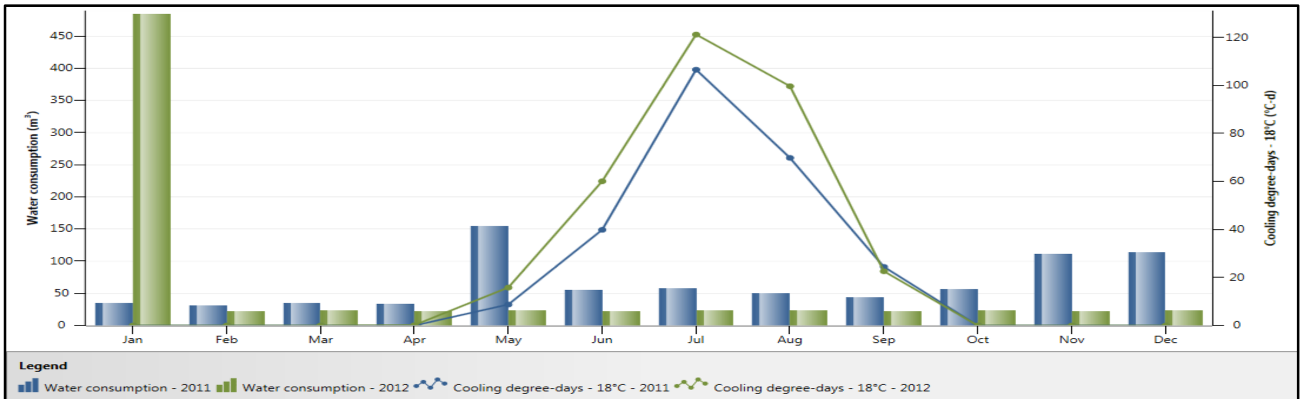


Months	Water consumption m³ 2011	Water consumption m³ 2012	Heating degree-days - 18°C °C-d 2011	Heating degree-days - 18°C °C-d 2012
Jan	35	485	895	848
Feb	32	22	762	712
Mar	35	24	672	454
Apr	34	23	376	374
May	155	24	154	96
Jun	56	23	23	32
Jul	58	24	0	0
Aug	50	24	7	2
Sep	44	23	61	97
Oct	57	24	271	247
Nov	111	23	401	524
Dec	115	24	689	712

Water Consumption – Cooling Degree-Days (CDD)

Water consumption for FS231 did not correlate to cooling-degree days in 2012 (green bars). As can be seen in the adjacent graph, a rise or fall in CDD did not cause a corresponding increase or decrease in water consumption during the 2012 year.

There does appear to be a slight increase in water usage during the summer months of 2011 (blue bars). It is not possible to tell if this is due to irrigation needs, however, because loads also increased during this year for periods outside of the defined cooling period, as shown by the CDD curve on the graph. Consumption for FS231 is thus related to factors outside of weather, such as occupancy, events,



Months	Water consumption m³ 2011	Water consumption m³ 2012	Cooling degree-days - 18°C °C-d 2011	Cooling degree-days - 18°C °C-d 2012
Jan	35	485	0	0
Feb	32	22	0	0
Mar	35	24	0	0
Apr	34	23	0	0
May	155	24	9	16
Jun	56	23	40	60
Jul	58	24	107	121
Aug	50	24	70	100
Sep	44	23	24	23
Oct	57	24	0	0
Nov	111	23	0	0
Dec	115	24	0	0

3.2.4 Renewable Energy

In 2010, FS231 was retrofitted with a 6-panel solar thermal DHW system, which *Photo 5* in *Appendix 11.6* illustrates. According to the gas consumption end use graph, an average of 4,104 m^3 of natural gas is required for domestic hot water annually. This translates to approximately 46,375 kWh of energy required to heat the water. In 2011, the solar water heater produced 3,648 kWh of energy that was used to heat the water from the city supply. It produced significantly less energy the following year at 1,258 kWh, which may have been due to external factors such as poor sun exposure or lag in maintenance. While it currently produces marginal amounts of energy for heating the water, if in the future the price of natural gas rises, expanding the solar system can recognize potential savings.

3.3 Rates

The following energy rates were determined based on class consensus. The students of Humber College's Sustainable Energy and Building Technology program agreed upon a set of rates for electricity, natural gas and water. The agreed upon rates can be seen below:

Electricity	\$0.088786/kWh
Natural Gas	\$0.22801/m^3
Water	\$2.71371/m^3

The natural gas rate was averaged based on the tiered pricing system of Enbridge Gas. The tiered charges for natural gas use were combined and averaged resulting in a rate of \$0.064811/m^3. A \$0.06651/m^3 cost adjustment credit for past overcharging was also factored into the rate. All additional monthly charges, including the supply, transportation and delivery charges were averaged resulting in a rate of \$0.16985 m^3 and applied to the averaged pricing and credit rates. The final rate as seen above is a result of combining all of these charges.

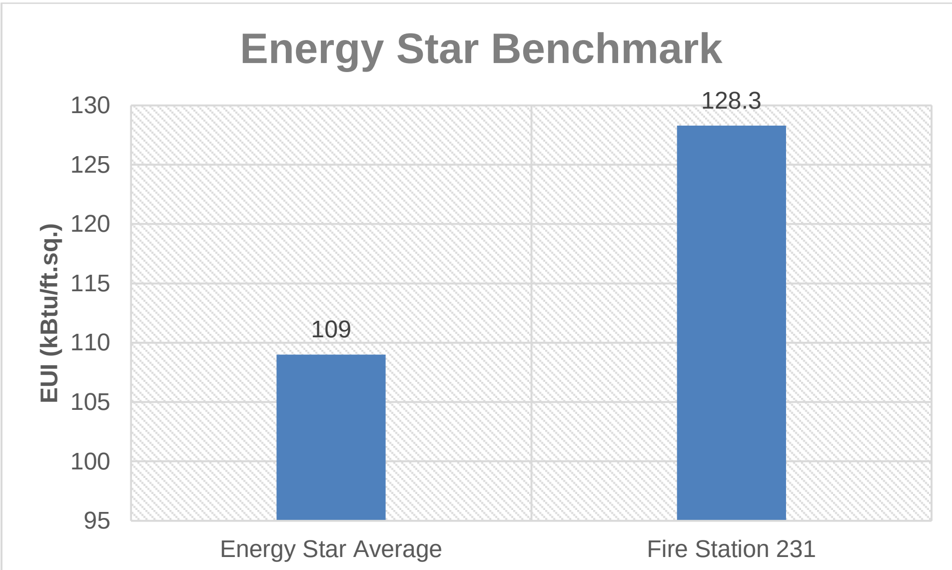
The electricity rate was based on time-of-use rates from Toronto Hydro and determined as a weighted average based on the number of hours per week that fall under each interval. This resulted in the average rate found above.

Water rates were based on the block rate set by the City of Toronto for all consumers, including industrial consumption of first 6,000 m^3.

It should be noted that there will be a slight discrepancy in the electricity and natural gas rates referenced in this report and actual rates due to averaging.

3.4 Benchmarking

Benchmarking provides building owner/operators with a standardized way to compare their own performance with other buildings of similar size. The intent is to test the efficacy of current energy savings initiatives while also providing motivation and targets for future energy management decisions.



Energy Star Benchmark Comparison

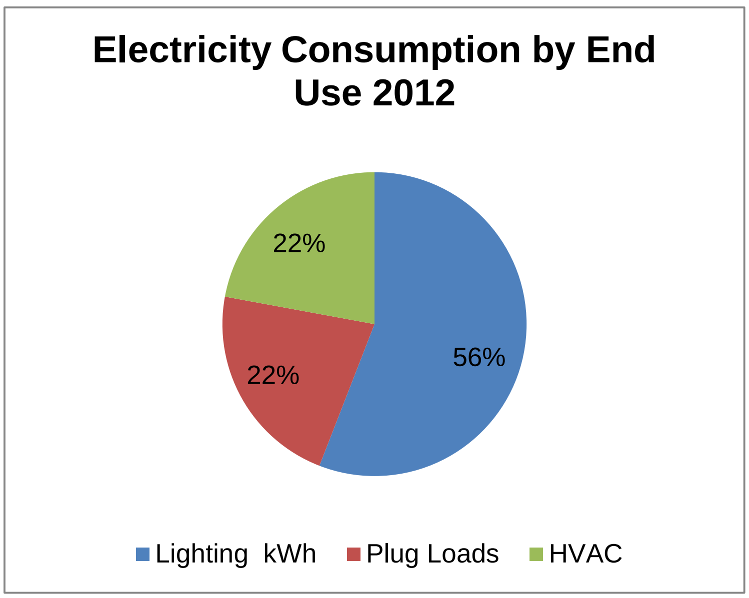
Benchmark values were determined using the Energy Star Portfolio Manager available from Energy Star's online resources. Utility and building data was entered into Portfolio Manager, which enabled an Energy Use Intensity (EUI) output comparison, as seen in the graph above.

The results of this comparison show that FS231 uses around 15% more energy per square foot than the average building in the benchmark. This is a sign that there will be some energy savings initiatives that can be implemented to help lower the Energy Use Index (EUI) and overall utility costs for the building.

3.5 End Use Allocation

3.5.1 Electricity

The chart below represents estimated electricity consumption by end use. By determining the power consumption and occupancy schedule of the station's plug loads and lighting we were able to determine the annual consumption of the building loads. Based on this chart, the most significant savings will be accomplished by retrofitting HVAC systems or components that directly impact HVAC performance. While HVAC yields the greatest opportunity for savings, measures for lighting and plug load efficiency will be recommended.



Total Electricity (kWh) 2012	
Lighting	78116
Plug Loads	30735
HVAC	30892
Total	139742

3.5.1.1 HVAC

The building's mechanical systems consume a significant amount of electricity in comparison to the other end uses; approximately 22% of the annual electricity consumption is from the HVAC systems. The building has a complex network of mechanical systems, with two boilers heating most areas of the first, second and third floors via electric radiators and two packaged rooftop units that are used to compensate for the shortcomings of the radiators. Further to this, a third packaged heating/cooling unit is used to cool all floors of the building, with the other two units used as backup. As a result of the addition of these three rooftop units, the HVAC system in this building is oversized. As well, the radiators, which were installed in 1960, are dated and inefficient. These factors indicate that there is the potential for significant HVAC energy savings. These calculations were derived using the equation below; tables can be found in *Appendices 11.3.3 End Use Allocation.*

*Consumption Equation (kWh) = Nameplate Power Input * Hours Used/Week * 8760 Hours/Year*

3.5.1.2 Plug Loads

The plug loads represent 22% of the electricity consumption of the building. The plug loads of this building are rather high because of the nature of the space. On average there are about 25 people occupying the building at any given time, which means that the appliances, office and multimedia equipment must suit the needs of such a group. Savings from plug load end use can be obtained simply by occupant awareness. During the walk-through a significant amount of unoccupied spaces had plug loads in use, task lamps, computers and televisions were on in many rooms. These calculations were derived using the equation below; tables can be found in *Appendices 11.3.3 End Use Allocation.*

*Consumption Equation (kWh) = Power Input * Hours Used/Week * 8760 Hours/Year*

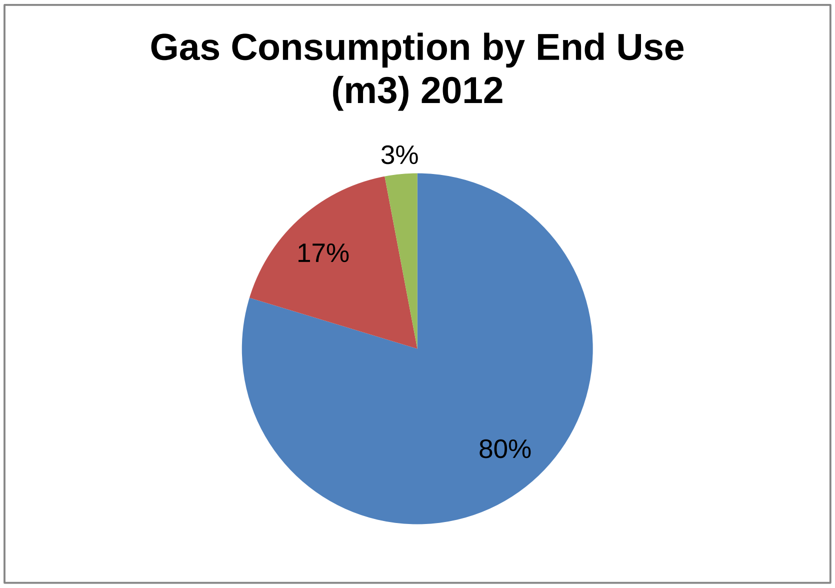
3.5.1.3 Lighting

The building's lighting systems consume the most significant amount of electricity in comparison to the other end uses; approximately 56% of the annual electricity consumptions is for lighting. All rooms are serviced by GE Ecologic 32W - T8 lamps and on/off light switches. There is the potential for lighting energy savings if all of the lamps were retrofitted to T5 fluorescent lamps with occupancy sensors. It was noted during the walk-through that most unoccupied rooms had the lights on. The feasibility of a lighting retrofit will be detailed in the energy conservation measure section. These calculations were derived using the equation below; tables can be found in *Appendices 11.3.3 End Use Allocation*

*Consumption Equation (kWh) = Lamp Wattage * Hours Used/Week * 8760 Hours/Year*

3.5.2 Natural Gas

The chart below represents estimated gas consumption by end use. The annual consumption of the space heating, domestic ho water and cooking loads was determined by examining the power consumption of all systems, as well as the occupancy schedule of the station. The chart below indicates that the most significant savings will be accomplished by retrofitting the space heating systems.



Gas Consumption (m3) 2012	
Space Heating	18,879
DHW	4,104
Cooking	14
Total	20,203

3.5.2.1 Heating

Space heating represents approximately 76% of the building's gas consumption. There are two boilers that provide heat to the space via electric radiators. These boilers are about 10 years old and are resultantly not working at optimal efficiency. By upgrading the existing space heating systems there is the potential for substantial energy savings.

Consumption Equation (m^3) = Total Gas Consumption – (DHW Consumption + Cooking Consumption)

3.5.2.2 Domestic Hot Water

Solar water heating and gas-fired domestic hot water (DHW) heating systems are used in conjunction for this building. A portion of the hot water for the building is heated via a closed-loop solar-thermal DHW system. The solar energy collected from the rooftop solar collectors is transferred to a glycol loop which runs into the mechanical room heat exchanger. Heat is transferred into DHW which is stored in storage tanks. If water temperatures are high enough, no additional heating from the gas-fired system is needed and water is fed into the building DHW loop. If DHW does not meet setpoint temperatures as it passes through the DHW heater, then additional heating will be provided using natural gas.

Domestic hot water is responsible for approximately 20% of the annual gas consumption at FS231. Energy savings are possible if the building relies more heavily on the SHW to meet demand. These calculations were derived using the equation below; tables can be found in *Appendices 11.3.3 End Use Allocation*

*Consumption Equation (m^3) = (Summer Baseline – Cooking Consumption) * 12 Months*

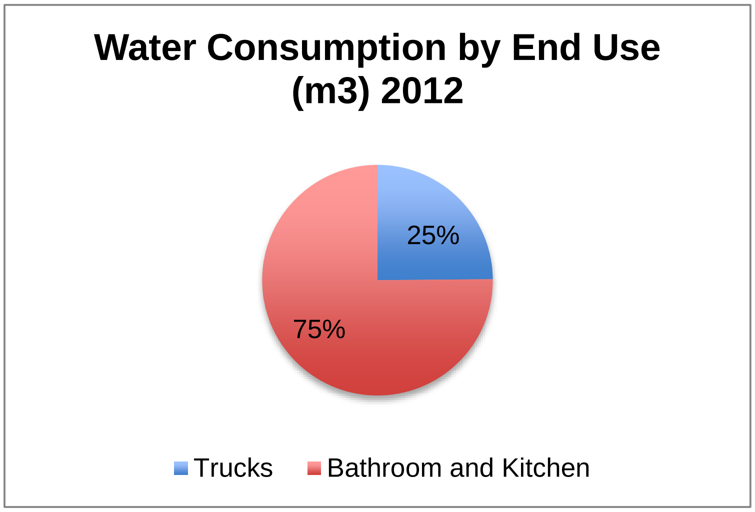
3.5.2.1 Cooking

Cooking represents a marginal percentage of gas consumption in the building. Cooking simply consists of the two gas stoves that service the main kitchen. By determining the power output of these appliances along with the occupancy schedule, it was determined that cooking accounts for approximately 4% of the total annual gas consumption.

*Consumption Equation (m^3) = Power Input * Hours Used/Day * 744 Hours/Month*

3.5.3 Water

The chart below is a representation of the estimated water consumption by end use for the building. The end use consumption was determined by estimating the power consumption of both loads, as well as occupancy use. It is evident that the greatest water savings can be accomplished by retrofitting the bathroom and kitchen water consuming appliances/devices.



Water Consumption (m3) 2012	
Trucks	240
Bathroom & Kitchen	725.3
Total	985.3

3.5.3.1 Trucks

The truck water storage tank stores up to 5000 litres. An occupant interview revealed that the storage tank was filled on-site an average of once per month, as local fire hydrants are used more frequently. Thus the maximum tank size was used to determine the annual on-site water consumption of four trucks. This yielded an annual water consumption of 240 m^3.

Consumption Equation (m^3) *= Tank Storage Size * Litres/Month * Number of Trucks*

3.5.3.2 Bathroom and Kitchen

By extrapolating the water consumption of the trucks from the water bills, it was assumed that the remainder would be allocated to the bathroom and kitchen. Thus, this end use is assumed to consume approximately 75% of the on-site water.

Consumption Equation (m^3) *= Total Water Consumption – Truck Consumption*

All end-use allocation calculations can be referenced in *Appendix 11.3.3 – End Use Allocation.*

4.0 Energy Model

The building energy model was completed using eQuest energy simulation software. The following sections are a summary of the modeling process and results.

4.1 Zoning

Zoning specifications were made according to the three rules of zoning:

- Zones served by same HVAC system
- Zones with a similar function
- Zones with similar loads

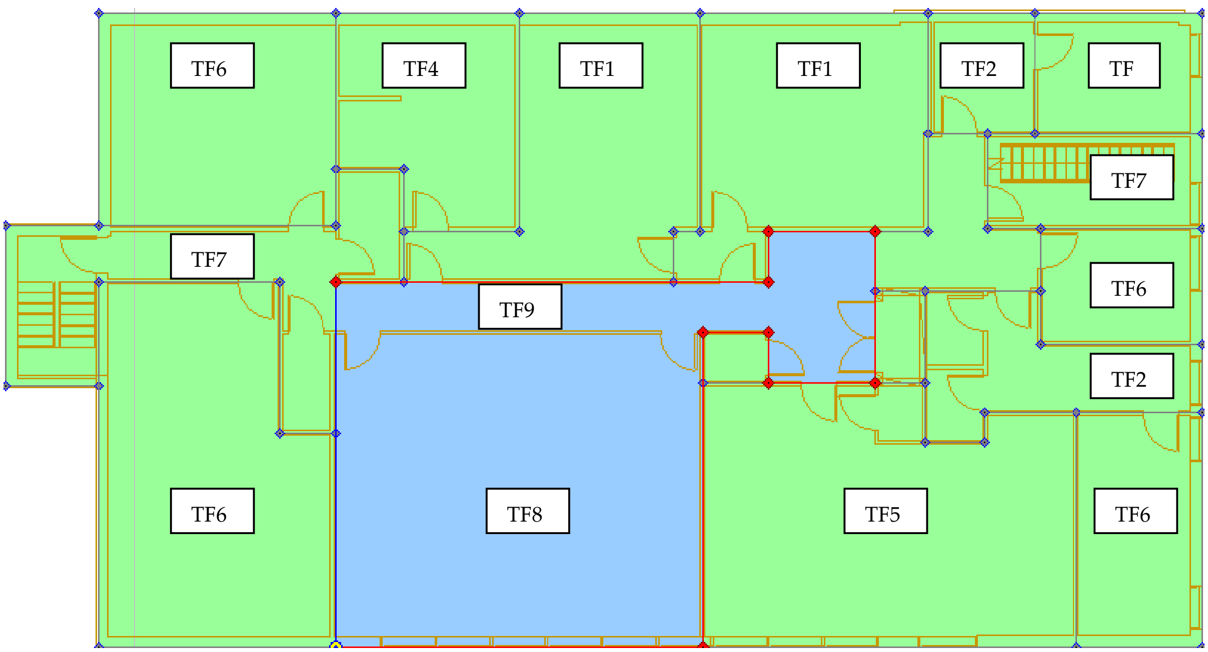
Below is the zoning selection for the third floor. This zone is shown to show the separation of HVAC systems that serve this floor. The green zones are all grouped together because they are served by the same packaged DX cooling/Hot Water Coil heating system. The blue zones are served separately by the Lennox 12.5 ton packaged rooftop unit.

Each floor has been zoned with respect to the HVAC systems serving each floor. Initially only two zones were to be used for the third floor, however each room contains an individual thermostat that controls the temperature in each zone by means of radiator valve which controls the flow of water through the coils in each zone.

Zoning diagrams can be found for the basement, first, and second floors within the appendices. Please see *Appendix 11.4.1* for other floor zoning diagrams.

3rd Floor Zoning

		Zoning Rules			
Zone #	Third Floor Zones	Same HVAC	Same Function	Same Loads	Selection Basis
TF1	Gym	Yes	No	No	HVAC
TF2	Office	Yes	No	No	HVAC
TF3	Restrooms	Yes	Yes	Yes	HVAC
TF4	Changeroom/Lockers	Yes	Yes	Yes	HVAC
TF5	Kitchen	Yes	No	No	HVAC
TF6	Bedrooms	Yes	No	No	HVAC
TF7	Corridor	Yes	No	No	HVAC
TF8	Living Space	Yes	No	No	HVAC
TF9	Corridor	Yes	No	No	HVAC



4.2 Input Data

Profile

Building Type: Custom or Mixed Use
Region: Ontario Region A
City: Toronto

Season Definitions

Two seasons were defined in the eQuest energy model.

- Summer – Cooling: April 10 – October 10
- Winter – Heating: October 11 – April 9

The changeover dates were selected by analyzing consumption data taken from the utility bills. These dates were selected as consumption for natural gas decreased markedly in the month of April and did not increase much past the assumed consumption level for domestic hot water until sometime in October.

Major Envelope Inputs

All envelope specs were obtained either from the provided architectural drawings or from discussions with City of Toronto – Facilities and Maintenance staff members. Every effort was made to model equivalent R-values for wall and roof assemblies, while equivalent construction materials were selected for slab-on-grade floors, windows, and doors. The following tables illustrate this data.

Actual Building Specs	
Above grade walls	**R-value**
4" Metal Studs w/ R-12 Batt	5.5
6 Mil Poly Vapour Barrier	0
1/2" Sheathing	1.32
Typex 5/8"	0.2
2" Rigid Insulation (EPS)	10
Stucco Finish	0.2
Total R-value	17.22
Below grade walls	**R-value**
6" Concrete	1
Roof	**R-value**
1.5" Steel Deck	0
3" insulation (EPS)	16.8
1/2 " Fiberboard	1.32
Torch Down Bitumen Membrane	2
Cap Sheet	1.5
Total R-Value	21.62
Slab on Grade	**R-value**
4" Concrete	0.8

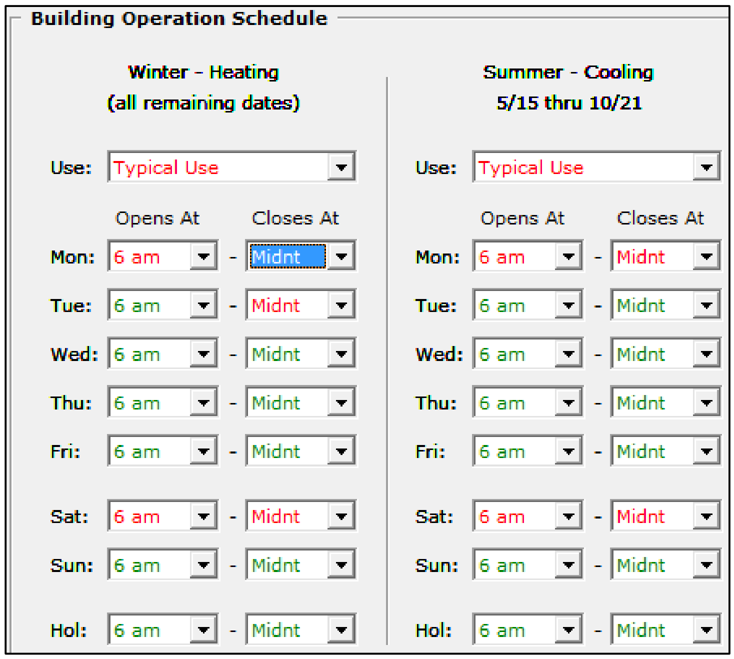
eQuest Input	
Above grade walls	
Construction	Metal frame, 2x4, 16 in. o.c.
Ext. Finish/Color	Stucco/Gunite, Gray, light oil
Exterior Insulation	1/2 in. fiber bd sheathing (R 1.3)
Add'l Insulation	R-11 Batt
Interior Insulation	1 in. polystyrene (R-4)
Total R-value	16.3
Below grade walls	
6" Concrete	
Roof	
Construction	Metal frame > 24 o.c.
Ext. Finish/Color	Asphalt pavement, weathered
Exterior Insulation	3 in polyisocyanurate (R-21)
Add'l Insulation	None
Interior Insulation	N/A
Total R-value	21
Slab on Grade	
Exposure	Earth Contact
Construction	4 in. Concrete
Ext/Cav Insul	No perimeter insul.

Actual Windows	
Category	*Type*
Existing Window Stock	Single pane, double sash
Retrofitted Windows	Double pane 5/16" Isoport
Actual Doors	
Category	*Type*
Apparatus Bay doors	Steel, insulated
Entrance doors	Glass, single pane
Emergency exit doors	Steel, insulated

eQuest Modeled Windows			
Glass Category	*Glass Type*	*Frame Type*	*Frame Wd (in)*
Single Clr/Tint	Single Clear 1/4 in. (1001)	Alum w/o brk, operable	2
Double Clr/Ting	Double Clear, 1/4 in, 1/4 Air (2003)	Alum w/o brk, operable	2
eQuest Modeled Doors			
Glass Category	*Glass Type*	*Frame Type*	*Frame Wd (in)*
Insulated steel			
Single Clr/Tint	Single Clear 1/4 in. (1001)	Alum w/o brk	2
Steel Hollow core w/o brk			

Building Operation Schedule

This building is officially a 24-hour operations facility. Firefighting staff are always present in the building, however an assumption was made that the building was not at full operational capacity for the full 24 hours. The building operation schedule was selected as occupied between 6 am – Midnight, as shown in the input screenshot below.



In order to avoid the building being under heated during the unoccupied hours, the heating and cooling temperature setpoints were set to be equal for both occupied and unoccupied hours. In this way, the only impact of the operation schedule would be on the electrical systems – lighting and miscellaneous loads. It was assumed that these loads would be largely shut off in the late hours of the night.

Interior Lighting, Miscellaneous, Cooking Loads

Total number of lighting fixtures and corresponding wattages were used to calculate lighting densities for each space. Similar calculations were done for plug and cooking loads. These calculations and corresponding loads can be found in the *Appendices 11.3.3: End Use Allocation*. Lighting demand was reduced by multiplying the total demand by the diversity factor. The assumption is that lights will only be operational for 50% of the time during occupied hours. The same process was followed for each floor and corresponding tables can be found in *Appendix 11.4.1 - eQuest Inputs* under *Lighting, Miscellaneous, and Cooking Loads*. The chart below shows the eQuest inputs for lighting, miscellaneous, and cooking loads for the 3rd floor.

3rd Floor		
Lighting		Diversity Factor = 0.5
Area Type	**Lighting (W/sq.ft)**	**Diversified Lighting (W/sq.ft)**
Office (General)	1.4	0.7
Locker and Dressing Room	2.6	1.3
Kitchen and Food Prep.	1.8	0.9
Residential (Bedroom)	1.4	0.7
Exercise and Gym	1.4	0.7
Residential (General Living)	2.4	1.2
Restrooms	1.6	0.8
Corridor	1.6	0.8
Misc. Loads		
Area Type	**Load (W/sq.ft)**	**Diversified Load (W/sq.ft)**
Office (General)	3.4	1.7
Locker and Dressing Room	0	0
Kitchen and Food Prep.	17.8	8.9
Residential (Bedroom)	3	1.5
Exercise and Gym	9.2	4.6
Residential (General Living)	1.4	0.7
Restrooms	0.2	0.1
Corridor	1.6	0.8
Cooking Loads		
Area Type	**Load (m^3/sq.ft)**	**Diversified Load (m3/sq.ft)**
Office (General)	0.6	0.3

HVAC

Heating and cooling inputs were entered into eQuest via specifications gathered from individual system cut sheets. Equipment documentation can be found in the *Appendix 11.2 – Building Systems Inventory*.

Zone heating and cooling in eQuest stipulates that only 1 system is able to serve 1 zone. It is not possible to assign 2 hvac systems for 1 zone, as was the case at Fire Hall 231. The actual operations of FH 231 saw the hydronic boilers serving the heating loads during the winter season, and the Trane packaged AC unit meeting cooling loads during the summer season. In order to model the two systems it was necessary to create one packaged cooling and heating system with specifications similar to the two individual systems. A summary of these inputs is found below.

Main Heating & Cooling System

System Type Name	Packaged DX cool / Hydronic Heat				
Cooling Source	DX Coils				
Heating Source	Hot Water Coils				
System Type	Packaged VAV with HW Reheat				
Seasonal Thermostat Setpoints		Occupied		Unoccupied	
	Winter - Heating	76	77	82	77
	Summer - Cooling	76	0	82	0

Summer heating setpoints were set to 0 in order to eliminate summer heating loads, as setting the heating boilers to 'Off' during this season was overridden by the setpoints, creating zone heating when there were no loads. Winter heating setpoints were set to a higher value than was given at the boiler control. This was in an effort to simulate actual consumption loads found during the winter months. The assumption was founded on the heating systems having to work harder because windows were often left open in the building, even when outdoor temperature would have caused an increased heating load.
All HVAC system specifications can be found in Appendix 11.4.1 eQuest Inputs under HVAC Equipment Specifications.

HW Plant Equipment

Hot water plant equipment includes the 2 hydronic boilers, circulation pumps and zone radiators. All hot water plant equipment inputs were obtained from specification sheets for all equipment found on site. A summary of this data along with eQuest inputs can be found in Appendix 11.4.1 eQuest Inputs under HVAC Equipment Specifications.

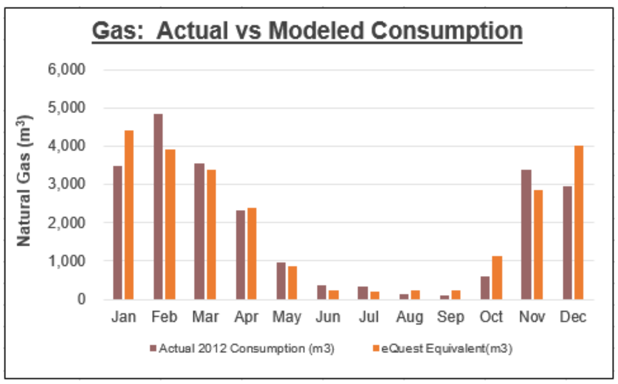
Domestic Hot Water Inputs

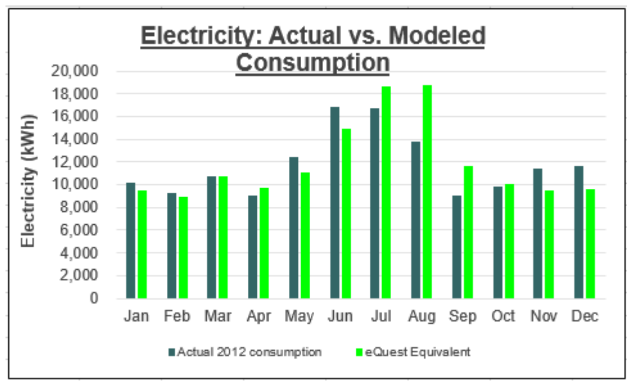
Equipment for DHW included a solar thermal preheat, high efficiency water heater and two storage tanks. All DHW inputs were obtained from specification sheets for all equipment found on site. A summary of this data along with eQuest inputs can be found in Appendix 11.2 – Building Systems Inventory.

4.3 Results

Parameters selected in eQuest were based as closely as possible on the systems found within Fire Hall 231. Results of the model have shown consumption values to be within acceptable limits of energy modeling guidelines that aim for 5-10% difference. The values generated for Natural Gas showed a 4% difference from the actual on an annual basis, while electricity consumption was very close at 1% annually.

While these values are very close to actual annual consumption values, it does not mean that the model was able to mimic exactly the operations of the building month by month. As shown in the graphs representing actual vs. modeled consumption below, there were months when actual consumption did not resemble modeled at all.





Differences in consumption from actual to modeled occur for a number of factors. In this case the major differences are coming at the height of the heating and cooling seasons, for gas and electricity respectively. The likely explanation for this is occupant operations.

Upon inspection of the building it was found that windows were often left open in many rooms on multiple floors. The reason for this was that there is no mechanical ventilation of many of the rooms, making the need for outdoor air met only by opening windows. This type of ventilation strategy would have the largest impact during the peak heating and cooling seasons, causing spikes in gas consumption in the winter and electricity in the summer, as the systems work harder to try and maintain setpoints.

During the shoulder months when the difference between outdoor and indoor air temperatures is usually much less, actual consumption vs. modeled closely resemble each other, as the impacts of opening windows for ventilation are not as high for the heating and cooling systems.

Further details on the energy model can be found in *Appendix 11.4.1.*

4.3.1 Calibration

HVAC

- Main heating and cooling systems packaged as a single system in eQuest because heating and cooling inputs cannot be from separate systems.
- Heating setpoint set higher than what would be expected to take into account high infiltration rates from open windows
- Chiller efficiency set lower because of damaged duct insulation at supply fan.

Scheduling

Schedules set to 18 hours per day. Technically the building is occupied and manned 24 hours, however the assumption is that during the evening and early morning the building is operating at a minimum. In order to maintain heating setpoints during this time, the occupied and unoccupied values were set at the same value.

Lighting

Lighting demand subjected to diversity factor of 50% which reduces overall loads by half during occupied hours. This assumes that not every light will be on for the duration of the occupied hours.

DHW

Inlet temperature for DHW heater set at 75 F to simulate solar thermal inputs. Natural gas use for DHW in summer months was much lower than expected. Therefore it was assumed that occupant hot water use per day was much lower than ASHRAE standards. Using DHW equipment specifications, natural gas use evened out at 7.5 gal/person/day.

4.3.2 eQuest Limitations

Packaged HVAC
Basement zoning - Conditioned spaces for heating but the packaged will also condition for cooling, even though the chiller does not serve the basement.

Air Leakage
Quantification of air leakage due to open windows was difficult. Matching consumption values for peak heating/cooling seasons was largely impossible due to leakage rates depending on individual occupant comfort levels.

5.0 Energy Conservation Measures

5.1 Building Envelope Measures

5.1.1 Windows

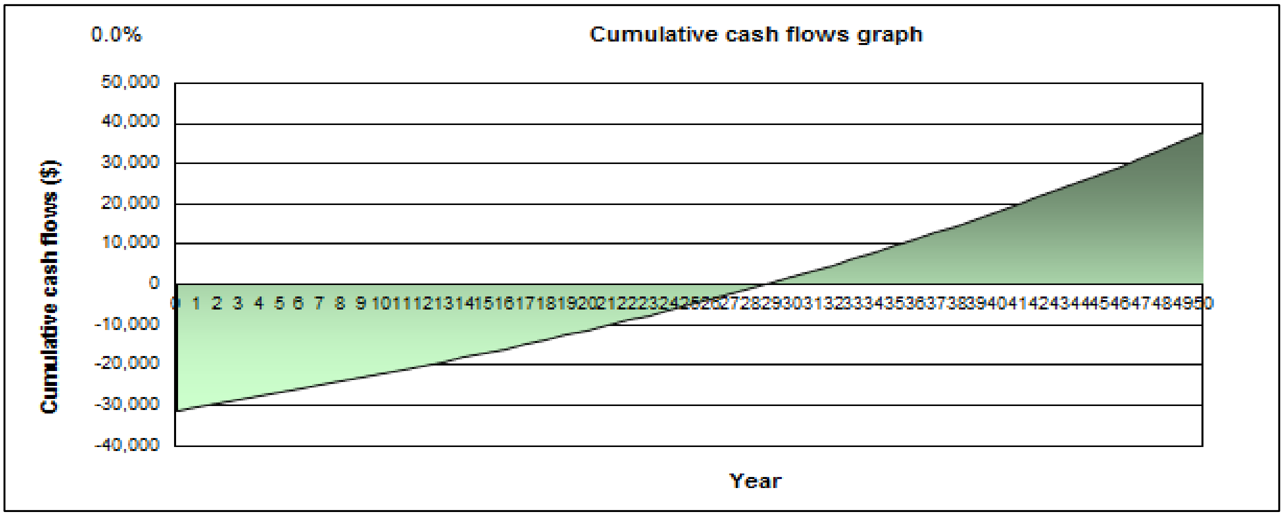
5.1.1.1 Existing Conditions

All windows in the facility were originally single pane, double sash windows with ¼" air fill and aluminum frame. When renovations occurred in 1995, the windows in the living room and kitchen were replaced with double pane 516 Isoport thermally broken insulated windows, of which half are operable. The windows are in fair condition, with many window seals requiring replacement. One window, located in the dispatch office, is cracked.

5.1.1.2 Retrofit Conditions

Option 1: **Fiberglass Double Pain Replacement**

Measure	Estimated Project Cost	Estimated Govt. Rebate / Incentive	Estimated Annual Electrical Savings	Simple Payback (Years)
Fiberglass Double Pain	$31,148.36	$N/A	$797	39.1



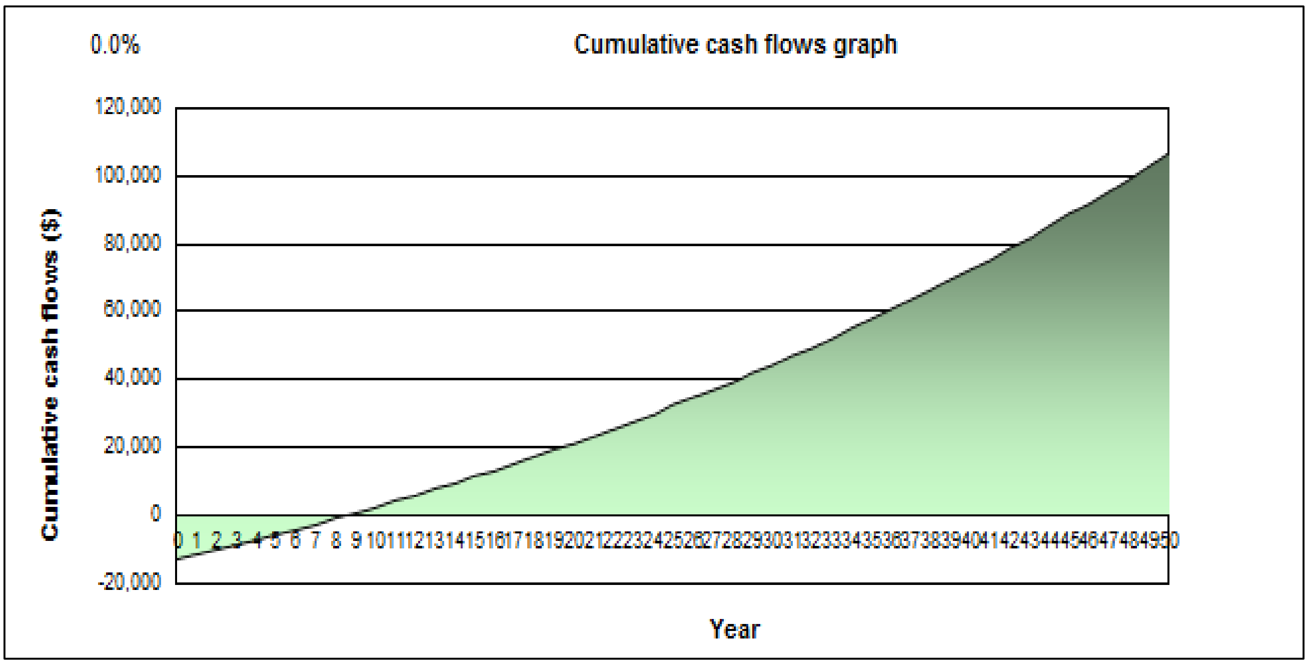
Financial viability		
Pre-tax IRR - assets	%	3.0%
Simple payback	yr	39.1
Equity payback	yr	28.7

Please refer to *Appendix 11.7* – Energy Conservation Measure Calculations for RETScreen4 energy simulation data and calculations.

Even though replacing inefficient windows with high efficiency fiberglass double pain windows has the potential to save a significant amount of energy and garner annual savings of $796, this option is not economically feasible due to a long payback period (39 years). Please refer to *Appendix 11.7 – Energy Conservation Measure Calculations* for the product information.

Option 2: Insulated Shades (Window Quilt[2]) Installation

Measure	Estimated Project Cost	Estimated Govt. Rebate / Incentive	Estimated Annual Electrical Savings	Simple Payback (Years)
Insulated Shades for Windows (Window Quilt)	$12,840.88	N/A	$1,379	9.31



Financial viability		
Pre-tax IRR - assets	%	12.9%
Simple payback	yr	9.3
Equity payback	yr	8.5

Please refer to *Appendix 11.7* – Energy Conservation Measures Calculations for RETScreen4 energy simulation data and calculations.

Installation of insulated (R-5) shades for windows are a cost effective alternative to the costly window replacement as the simple payback for this option is approximately nine years with annual savings of $1378. Insulated shades not

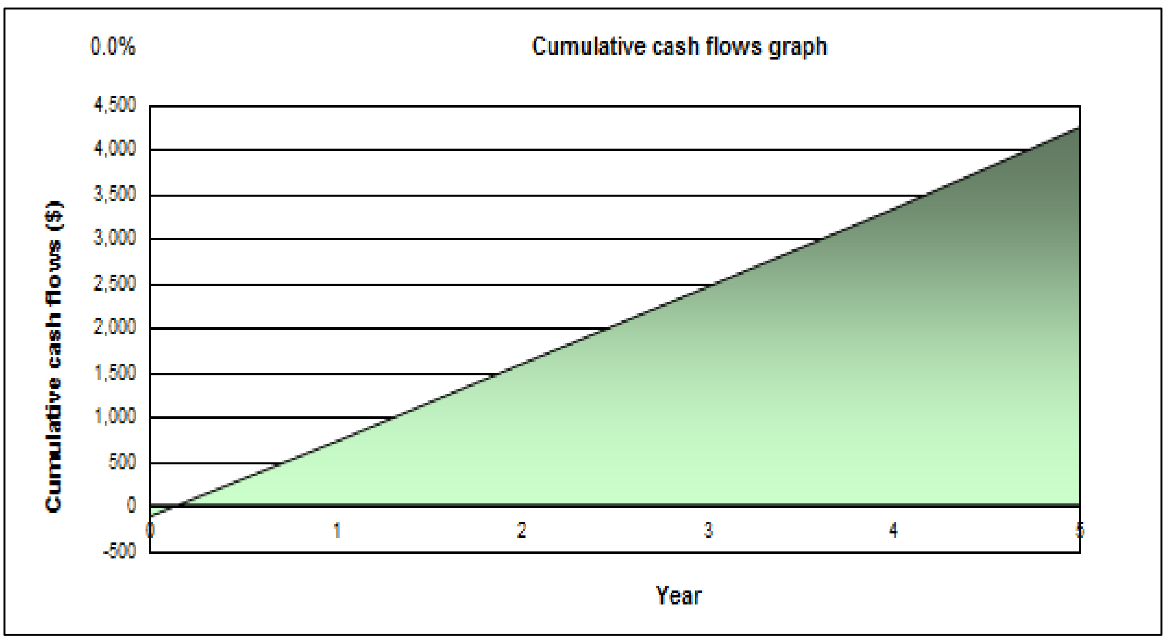
[2] http://www.windowquilt.com/products/full_broch.htm

only reduce energy consumption, they also increase occupant comfort. Please refer to *Appendix 11.5.2* for the product data sheets.

During the site visit it was noted that some of the windows were covered with garbage bags as a means for eliminating daylight. The inconsistent patterns of fire fighters often result in irregular sleeping patterns, which is why constant darkness in some spaces was desired. The insulated shades recommended have 99.5% light blockage properties, creating suitable resting conditions for occupants.

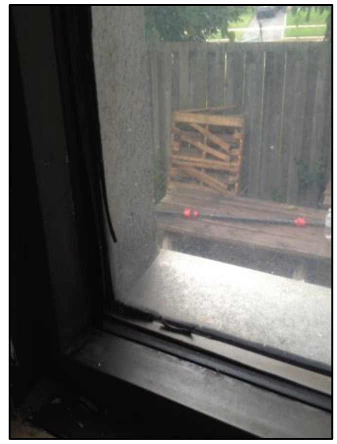
Option 3: Air Sealing / Weather stripping

Measure	Estimated Project Cost	Estimated Govt. Rebate / Incentive	Estimated Annual Electrical Savings	Simple Payback (Years)
Weather Stripping	$100.00	N/A	$820	0.12



Financial viability		
Pre-tax IRR - assets	%	838.1%
Simple payback	yr	0.1
Equity payback	yr	0.1

Please refer to *Appendix 11.7 – Energy Conservation Measures Calculations* for RETScreen4 energy simulation data and calculations.



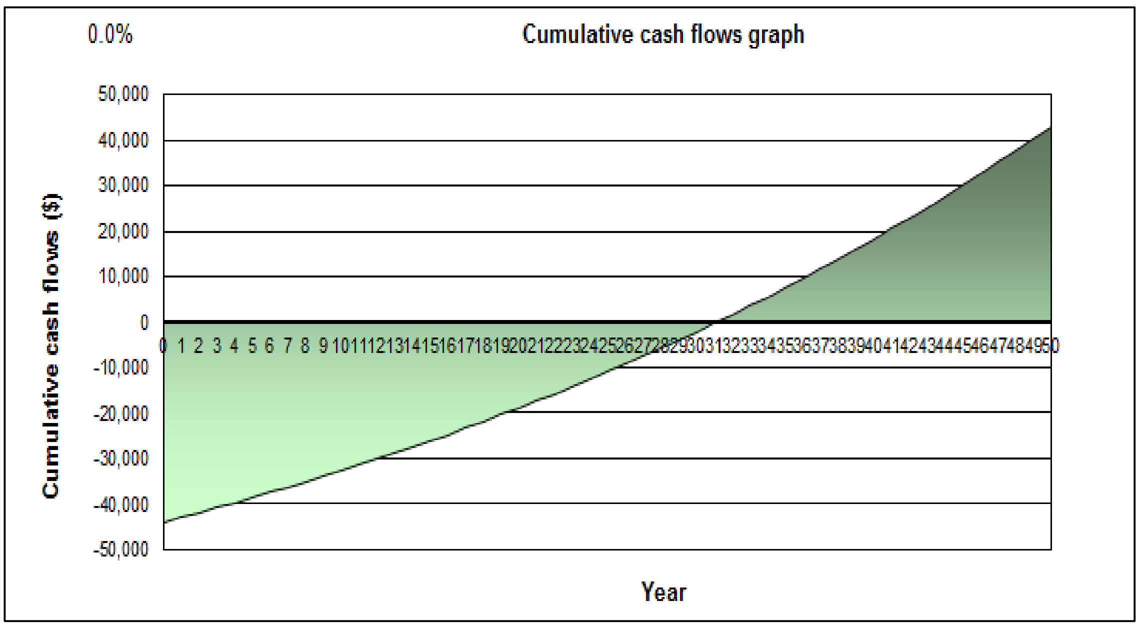
During the site visit it was noted that the seal on a number of windows were in poor condition requiring new weather stripping. Weather stripping is one of the most cost effective retrofit options available in terms of window renewal. Simple payback for weather stripping is less than 2 months with annual savings of $820.

Weather stripping can be applied by the city's internal maintenance work force, FRED, and should be reapplied every 5 years. Annual weather stripping inspections are recommended to maintain optimal conditions of all windows and doors.

Option 4: Combined Envelope Measures Option

This option combines the previous 3 measures outlined above – window retrofit, insulated shades, and weather stripping. This option is recommended for future upgrading, when the windows have reached the end of functional life. Reason being is that there is potential for significant savings, however the payback period is too long to replace existing equipment now.

Measure	Estimated Project Cost	Estimated Govt. Rebate / Incentive	Estimated Annual Electrical Savings	Simple Payback (Years)
Fiberglass Double Pane	$31,148.36	N/A	$1,008	43.8
Insulated Shades for Windows (Window Quilt)	$12,840.88	N/A		
Weather Stripping	$100.00	N/A		



Financial viability		
Pre-tax IRR - assets	%	2.5%
Simple payback	yr	43.8
Equity payback	yr	31.3

Please refer to Appendix 11.7 – Energy Conservation Measures Calculations for RETScreen4 energy simulation data and calculations.

5.1.1.5 Recommendation

It is recommended that the insulated window shades and weather stripping be implemented to maximize energy savings for the building. The insulated window shades prevent the daylight from penetrating the indoor spaces, reducing the solar gain from the summer sun and creating an environment that is more comfortable for occupants. Further to this, window shades provide a quick solution for occupants seeking rooms suitable for sleeping. Weather stripping is a simple, cost effective solution for preventing heat loss in a building. Windows provide the greatest opportunity for heat loss in terms of building envelope and sealing them can help prevent this. With a simple payback of approximately 1.5 months it is evident that this is the most viable option.

5.2 Mechanical System Measures

5.2.1 Heating System

5.1.2.1 Existing Conditions

The Central boiler plant consists of two 512 kBtu atmospheric boilers rated at 82% efficiency that were installed approximately 10 years ago. The boilers are piped as an injection loop in a primary/secondary loop configuration. Supply water temperatures and boiler staging are controlled by a digital controller, with supply water temperatures being re-set based on outdoor air temperatures. Each room, excluding washrooms and the main floor dispatch office, is equipped with a baseboard for heating. These radiators are supplied with hot water through the building's primary loop and are controlled with wall-mounted dials that open or constrict the hot water valve. While these boilers are in good operating condition, they are older and running at a lower efficiency than current market alternatives.

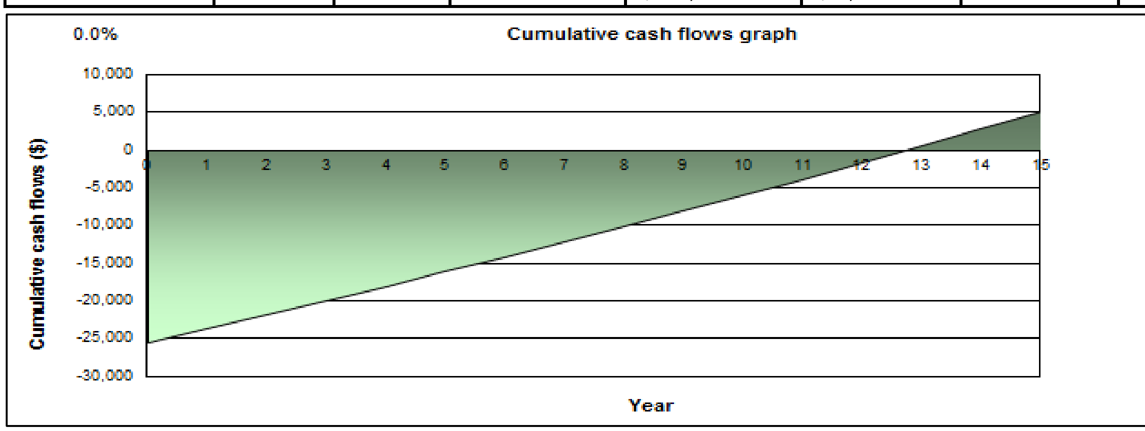
In addition to this, there are two separate packaged rooftop units for heating and cooling. The rooftop unit located above the dispatch office is intended to serve only that space. A thermostat located in the dispatch room controls the rooftop unit, which provides heating and cooling to the space when needed. This is similar to the packaged rooftop unit that serves the third floor living room; however, the baseboard radiators also serve this space when heating is required. When the radiators are not meeting the heating demands of this high occupancy space, the occupants can manually activate the rooftop unit via a thermostat.

5.1.2.2 Retrofit Conditions

There are two possible packaged combinations for retrofitting existing heating systems in order to save energy and money by increasing the efficiency. All options can be applied separately.

Option A: Combined Heating Configuration

Measure	Project Life Span	# of Cycles	Cost for 1 Cycle	Cost for Total Cycles	Annual Savings	Estimated Govt. Rebate/ Incentive	Simple Payback (years)
Boiler Replacement (Condensing Boilers) 2 Units	15	1	$18,550.00	$18,550.00	$1,729.19	$800.00	12.98
High Efficient Heat Transfer Fluid Installation	8	2	$2,351.25	$4,702.50			
VFD Installation, 3 Units				$2,120.00	$42.46		
			Total	$25,372.50	$1,771.65		



Financial viability		
Pre-tax IRR - assets	%	2.3%
Simple payback	yr	14.7
Equity payback	yr	12.8

Please refer to *Appendix 11.7 – Energy Conservation Measures Calculations* for RETScreen4 energy simulation data and calculations.

The first option offers an integrated retrofit system to demonstrate that all measures can work together to create an optimal system. The simple payback period for this option is about 15 years with annual savings of $1771. Replacing mid efficiency (60% seasonal efficiency with a 5% decrease due to the age of the boilers) atmospheric boilers with the high efficiency (85% seasonal efficiency) condensing boilers would increase the boiler efficiency by 15%[3]. Please refer to *Appendix 11.5.3* for the product information.

Heating System Type	Typical Annual Heating System seasonal efficiency (%)
Standard boilers/furnaces (with pilot light)	55 to 65
Mid-efficiency boilers/furnaces (spark ignition)	65 to 75
High-efficiency or condensing boilers/furnaces	75 to 85
Electric resistance	100
Air-source heat pump	130 to 200
Ground-source heat pump	250 to 350

Typical Heating Systems Seasonal Efficiencies

High efficiency condensing boilers require lower flow rates in order to operate as expected[4]. Installation of Variable Frequency Drives (VFDs) satisfies this lower flow rate requirement. Although the simple payback period for the VFD installation is very high at about 50 years and not economically feasible due to pump size, VFD installation is necessary with condensing boilers. Please refer to *Appendix 11.5.3* for product information.

3 Seasonal Efficiency, RETScreen® Software Online User Manual, P.15
http://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&ved=0CCYQFjAA&url=http%3A%2F%2Fwww.retscreen.net%2Fdownload.php%2Fang%2F303%2F0%2FSAH3.pdf&ei=6IWbUt2qDYPvoATd_YLoCw&usg=AFQjCNFlzf0kUmtxdubGPsCg7t5LfB0kbw&sig2=2NRH8o8iEu9roUV4HOo5WA&bvm=bv.57155469,d.cGU

4 NRCan Fact Sheet Condensing boilers.
https://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&ved=0CDIQFjAB&url=http%3A%2F%2Fwww.retscreen.net%2Ffichier.php%2F1301%2FHigh-Efficiency%2520Boilers.pdf&ei=n1qVUqLrI8HY2wWA9ID4DQ&usg=AFQjCNH1IymUTRm_fiLa11buraD8XI4XjQ&sig2=RONFWj2XYOVWXtuXuYQj0g&bvm=bv.57155469,d.b2I

Replacing circulated water with the high efficiency heat transfer fluid (HEHTF) product, Hydromx Nano Thermo™ Technology[5], will maximize and guarantee the boiler efficiency. In addition, the convective nano-technologic mechanism of this fluid product will enable the system to run at even lower flow rates, which will result in additional savings through VFDs.[6] This fluid yields an additional seasonal efficiency of 15% which will bring total seasonal efficiency of Option A to approximately 99%.

This high efficiency heat transfer product also provides microbiological, corrosion & calcification protection, which will enhance the life of the new boilers, as well as the whole system resulting in an increased system lifespan.[7] Please refer to *Appendix 11.5.3* for product information.

Even though condensing boilers and the high efficiency heat transfer fluid increase total seasonal efficiency and save energy, this retrofit option is not economically feasible due to the short lifespan of the condensing boilers (simple payback and lifespan are nearly same).

Considerations:

National Resources Canada's condensing boiler recommendations are listed below.[8] It is highly recommended that the design engineers follow these recommendations on boiler selection to achieve desired efficiencies.

1. Condensing boilers require a low return water temperature to operate at their highest efficiency.

2. Systems should be designed with lower flow rates. This means that piping, pumps and valves should be smaller than those used in mid-efficiency boilers. (VFDs and High efficient heat transfer will enable lower flow rates)

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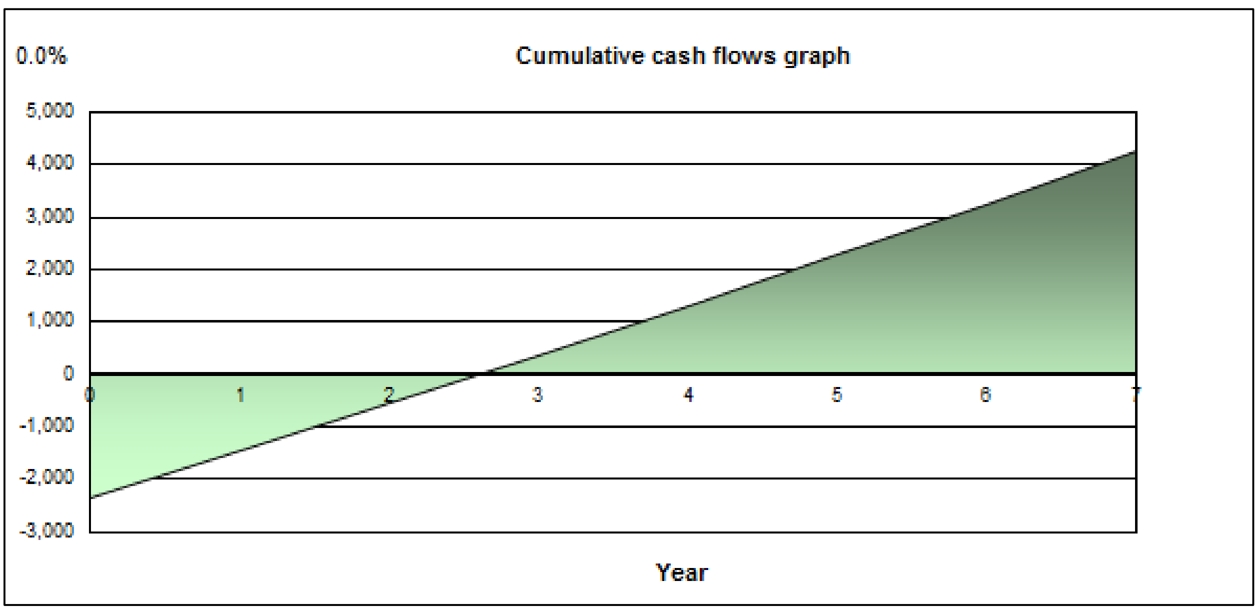
[5] http://greenwaysolutionsco.com/what-is-hydromx/
[6] Please refer to the Appendix: Hydromx Properties Investigation Report
[7] http://www.pbaenergysolutions.co.uk/Portals/0/PBA%20Docs/Hydromx%20PBA%20Product%20Brochure%20v5.pdf
[8] NRCan Fact Sheet Condensing boilers. https://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&ved=0CDIQFjAB&url=http%3A%2F%2Fwww.retscreen.net%2Ffichier.php%2F1301%2FHigh-Efficiency%2520Boilers.pdf&ei=n1qVUqLrI8HY2wWA9ID4DQ&usg=AFQjCNH1IymUTRm_fiLa11buraD8XI4XjQ&sig2=RONFWj2XYOVWXtuXuYQj0g&bvm=bv.57155469,d.b2I

3. Heating coils and radiators should be sized for a higher rate of heat transfer at lower supply water temperatures. (High efficient heat transfer fluid retrofit will eliminate for additional radiator retrofit)

4. Condensing boilers can function with smaller venting pipes, although more expensive stainless steel is required for larger boilers. Smaller systems can use PVC pipe, which can be directly vented to sidewalls[9]*.*

Option B: High Efficiency Heat Transfer Fluid

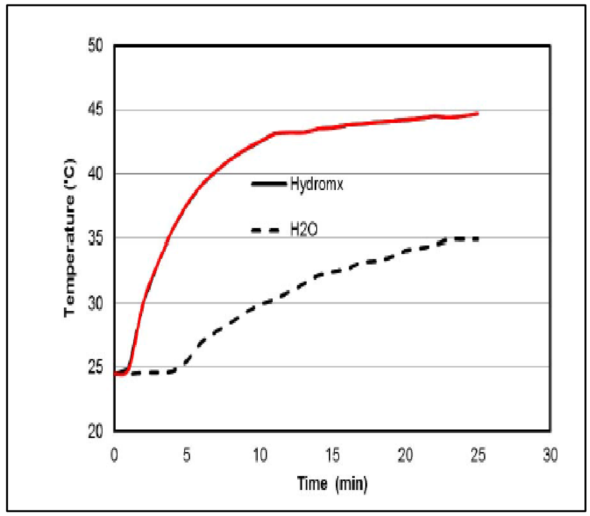
Measure	Project Life Span	# of Cycles	Cost for 1 Cycle	Annual Savings	Estimated Govt. Rebate/Incentive	Simple Payback (years)
High Efficient Heat Transfer Fluid Installation	8	1	$2,351.25	$865.00	N/A	2.72



[9] NRCan Fact Sheet Condensing boilers. https://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&ved=0CDIQFjAB&url=http%3A%2F%2Fwww.retscreen.net%2Ffichier.php%2F1301%2FHigh-Efficiency%2520Boilers.pdf&ei=n1qVUqLrI8HY2wWA9ID4DQ&usg=AFQjCNH1IymUTRm_fiLa11buraD8XI4XjQ&sig2=RONFWj2XYOVWXtuXuYQj0g&bvm=bv.57155469,d.b2I

Please refer to Appendix 11.7 – Energy Conservation Measures Calculations for RETScreen4 energy simulation data and calculations.

The second option offers to keep the existing atmospheric boilers, which are approximately 10 years old. By implementing the high efficiency heat transfer fluid, the system efficiency will increase. The existing seasonal efficiency of the boiler is 60% and will increase significantly (by 15%) with the injection of this fluid. This option is the most feasible option as it has a simple payback period of about 3 years with annual savings of $865.



As mentioned above, the microbiological, corrosion & calcification protection properties of this product may enhance the life of the existing boilers, resulting in a longer system lifespan[10].

This fluid product is 30% more efficient in heat transfer than water and case studies indicate that this product creates energy and cost savings of up to 30%.[11] Using a conservative approach and assumed that this product will cause only 15% seasonal efficiency increase.

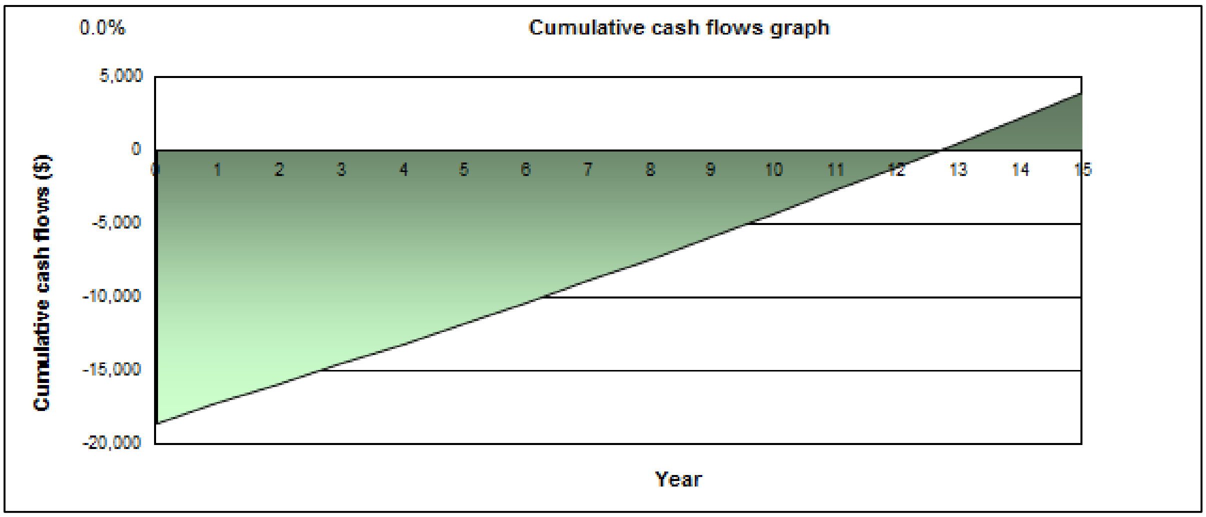
Option C: Condensing Boiler Replacement

Measure	Project Life Span	# of Cycles	Cost for 1 Cycle	Annual Savings	Estimated Govt. Rebate/Incentive	Simple Payback (years)
Boiler Replacement (Condensing Boilers) 2 Units	15	1	$18,550.00	$1,271.47	$800.00	13.9

10 http://www.pbaenergysolutions.co.uk/Portals/0/PBA%20Docs/Hydromx%20PBA%20Product%20Brochure%20v5.pdf
11 http://www.pbaenergysolutions.co.uk/References/CaseStudies.aspx

The simple payback period for this option is about 14 years with annual savings of $1271. While a simple payback of 15 years does not seem unfeasible, the lifespan of a boiler is usually only between 15 and 20 years. Thus, with this in mind this energy savings opportunity may not be reasonable in the context of this building.

Please refer to Appendix 11.7 – Energy Conservation Measures Calculations for RETScreen4 energy simulation data and calculations.



Financial viability		
Pre-tax IRR - assets	%	2.4%
Simple payback	yr	14.6
Equity payback	yr	12.7

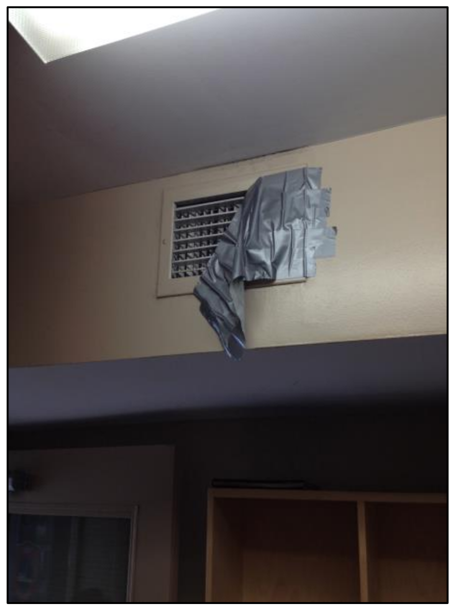
5.1.2.5 Recommendation

It is recommended that Option B: High Efficiency Heat Transfer Fluid, be implemented as an energy conversation measure. This option has the lowest cost for the highest return. It can be easily implemented and will have significant effects on the efficiency of the mechanical systems. A boiler replacement will be required within the next 10 years and at that time it would be recommended that Option A be considered. Replacing the existing systems with high efficiency condensing boilers that include the high efficiency heat transfer fluid and variable frequency drives will yield noteworthy short and long term savings.

5.2.2 Ventilation

Although there are three separate packaged rooftop units available there is an enormous need for fresh air within the building. The rooftop unit located above the dispatch office is intended to serve only that space and does not provide fresh air to rest of the first floor. The main packaged air handling unit is the sole air distribution system for the first and second floors and provides partial air distribution to the third floor; this unit does not provide heating in the winter or shoulder months. During this time there is no fresh air entering the spaces. During the site visits, which fell in the heating season, it was noted that many windows were kept open by occupants to satisfy their comfort requirements.

As well, it was noted that several air grills were covered with paper and duct tape to alleviate discomfort caused by high air-flow.



It is highly recommended that a system that balances air-flow and distributes treated air uniformly be installed. It is also highly recommended that heat recovery ventilators be installed on each floor, regardless of the payback considerations as a means for supplying fresh air during the heating season. Heat recovery ventilators capture some of the energy from the exhaust air and pretreat the fresh make up air increasing indoor air quality, which was evidently a significant issue in the building.

Necessary Ventilation Measure: Air Balancing & HRV Installation

Measure	Cost	Estimated Govt. Rebate/Incentive	Total Cost
Air Balancing	780	N/A	780
HRV Installment (160 CFM x 3)	9000	216	8784

Please refer to *Appendix 11.5.3* for product information.

5.3 Electrical System Measures

5.3.1 Lighting

5.1.3.1 Existing Conditions

Fire station 231 has a total of 631 32-Watt T8 Fluorescent lamps and 9 exit sign fixtures. At this time, LED technology is not efficient enough to justify the replacement of the T8 lamps. However, there are other retrofit measures that can be employed to offset lighting consumption.

5.1.3.2 Retrofit Conditions

Exit Sign Replacement

Measure	Cost	Annual Savings	Simple Payback (years)
Exit Sign Replacement	$1,080.00	$207.81	5.2

Please refer to *Appendix 11.7 – Energy Conservation Measures* Calculations for energy savings calculations.

We recommend the replacement of all existing exit sign fixtures with 0-Watt photo-luminescent exit signs. The simple payback period for this retrofit is 5.2 year with annual savings of $208. Due to the fact that the new photo-luminescent exit signs do not require any maintenance and do not wear out, the annual savings will be fixed throughout the life of the building.

Please refer to *Appendix 11.5.4* for the product information.

Occupancy Sensor Installment

We recommend installing 41 occupancy sensors within the building to minimize wasted caused by occupant habits. Occupancy Sensor installation is one of the most cost effective retrofits with a simple payback of 2.4 years and an annual savings of $1342.

Measure	Cost	Annual Savings	Simple Payback (years)
Occupancy Sensor Installation	$3,280.00	$1,342.01	2.4

Please refer to *Appendix 11.5.5* for the product information.

5.4 Water System Measures

5.4.1 Domestic Hot Water Heater

5.1.4.1 Existing Conditions

Water systems in the building consist primarily of standard flush toilets, washroom and kitchen sinks with aerators and standard flow showerheads. No running or leaking fixtures were observed. All of the fixtures are original installations, with some bathroom sinks missing aerators.

5.1.4.2 Retrofit Conditions

Measure	Cost	Annual Savings	Simple Payback (years)
Installation of low flow fixtures	$ 6,128.95	$51.40	119
			NOT FEASIBLE

Please refer to *Appendix 11.7 – Energy Conservation Measures Calculations* for energy saving calculations.

The installation of low flow bathroom and kitchen fixtures is not economically feasible for this project.

6.0 Operations and Maintenance

A contractor that is sourced through the City of Toronto completes the operations and maintenance performed on-site. Any item that needs to be repaired or replaced, large or small must be reported to the City of Toronto's maintenance contact line, known as FRED. Once notified, a FRED representative will arrive on-site to investigate and implement any requested repair or replacement for equipment. The occupants of the fire hall are expected to leave most operations and maintenance to these representatives. However, occupants are responsible for control indoor zone setpoints via wall thermostats that regulate water flow to the radiator coils.

Based on their personal comfort levels, the occupants can raise or lower the temperature of either system. Allowing occupant control has resulted in unscheduled and unnecessary mechanical system use.

During the walk-through, it was noted that the central boiler system was in use and was evidently overheating the space as the occupants had turned the rooftop air-conditioning unit on to offset the heat. Photo 7 in Appendix 11.6 is an image of the thermostat that controls the rooftop unit that serves the living room. This photo was taken during the month of November, when the radiators were operating as a means to cool the overheated space. Further to this, the windows were open allowing the mixture of heat and cool air to escape from the space.

Occupants are also in control of operating the lighting in the building. An on/off switch services each room, some rooms with multiple switches to control multiple sets of lamps. The walk-through indicated that occupants did not pay significant attention to lighting as most unoccupied spaces had the lights and multimedia equipment on.

It is recommended that a more comprehensive approach to operations and maintenance be established. Training and awareness of building occupants and regular maintenance visits of FRED representatives will allow the building systems and equipment to perform as expected. It was clear that the building occupants have no accountability in terms of repairs, reporting and replacements, which has evidently resulted in a lack of concern for the upkeep of the building.

Damaged equipment, filters and lights requiring replacement were in abundance throughout the space. Further to this, it was apparent that maintenance visits focused solely on the repairs that were reported. General maintenance and upkeep was not evident as it was noted that the insulation on the main packaged unit was in very poor condition. *Photo 6* in *Appendix 11.6* showcases the damage on the HVAC unit. As well, the grill on the outdoor air exhaust for the generator was almost completely covered in debris.

Training and awareness will not only establish accountability, but will also encourage the building occupants to take greater pride in their working environment. It is recommended that FRED contractors make routine visits, at least on a monthly basis, to take note of any repairs that occupants may not be aware of. Many significant repairs may be out of the scope of the building occupants and if regular maintenance is not performed they may go undetected for an extended amount of time. If the building systems are routinely monitored and maintained it is likely that they will perform as expected.

7.0 Training and Awareness

Training and awareness will be crucial to the reduction in energy consumption in the building. As mentioned in the above section, a lack of accountability has resulted in occupant negligence in terms of building operations and maintenance. Opportunities to improve occupant comfort and increase energy conservation can be established by developing a training and awareness program that focuses on the following:

- Comprehensive understanding of the heating/cooling systems and how to appropriately adjust the settings.
- How to optimize room comfort via thermostat control.
- Tools for conserving energy.

The intention of integrating occupants into the overall operation of the building is to develop a sense of ownership and pride amongst the fire fighters, hopefully resulting in a general improvement in energy conservation.

Aside from training, memos and posters placed throughout the building will remind the occupants of energy conservation tips and may be an effective tool in establishing accountability for the occupants.

8.0 Renewable Energy

A pre-existing solar hot water heater is mounted on the roof of the building; no recommendations will be made for the implementation of another renewable energy system at this time. Current priorities for efficient measures involve the improvement of existing HVAC and lighting systems.

9.0 Incentives

Often the economics of energy conservation measures make the implementation of energy efficient measures impractical. With the institution of government incentives and rebates, the immense capital cost of many energy efficient installations has been offset. These incentives further encourage building owners to take the necessary steps for reducing the energy consumption of their building. There are a number of incentives available in Toronto for replacing existing building systems with more efficient alternatives. Ontario Power Authority (OPA) offers a variety of incentives through the saveONenergy program. As well, Enbridge Gas offers incentives for HVAC equipment replacement. The following details the applicable incentive programs for this audit:

Enbridge Gas: Condensing Heating Boiler

A rebate is offered for the installation of a condensing heating boiler. The incentive is a fixed amount for commercial applications and requires the boiler to have an annual fuel utilization efficiency of minimum 90%. The total customer incentive amount is $800 ($400 x 2 boilers).

Enbridge Gas: Heat Recovery Ventilation (Hrv) System

The installation of a heat recovery ventilation (HRV) system is an opportunity to receive a rebate. A customer that installs a system with a minimum heat recovery effectiveness of 61% may be eligible for $0.20/CFM. The HRV selected has a CFM of 360; therefore, the total incentive amount for the three HRV systems is $216.

OPA: saveONenergy - Occupancy Sensors

This program provides an incentive for the implementation of occupancy sensors. This energy conservation measure, which has been recommended for fire station 231 is eligible for both the prescriptive and engineered track. It is recommended that the prescriptive track be selected to maximize incentive potential at $1,600.

10. Recommendations and Conclusions

Fire Station 231 expends a significant amount of energy where it is not required and can therefore benefit from the recommended energy efficiency upgrades. These energy saving upgrades have been identified and analyzed to verify their relevance. Based on analyses performed for this energy audit, several energy conservation measures were determined and previously defined based on feasibility.

The section below presents the feasible measures recommended and the financial factors associated with them.

Air Sealing / Weather stripping

Measure	Estimated Project Cost	Estimated Govt. Rebate / Incentive	Estimated Annual Electrical Savings	Simple Payback (Years)
Weather Stripping	$100.00	N/A	$820	0.12

Insulated Shades (Window Quilt) Installation

Measure	Estimated Project Cost	Estimated Govt. Rebate / Incentive	Estimated Annual Electrical Savings	Simple Payback (Years)
Insulated Shades for Windows (Window Quilt)	$12,840.88	N/A	$1,379	9.31

Exit Sign Replacement

Measure	Cost	Annual Savings	Simple Payback (years)
Exit Sign Replacement	$1,080.00	$207.81	5.2

High Efficiency Heat Transfer Fluid

Measure	Project Life Span	# of Cycles	Cost for 1 Cycle	Annual Savings	Estimated Govt. Rebate/Incentive	Simple Payback (years)
High Efficient Heat Transfer Fluid Installation	8	1	$2,351.25	$865.00	N/A	2.72

Occupancy Sensor Installment

Measure	Cost	Annual Savings	Simple Payback (years)
Occupancy Sensor Installation	$3,280.00	$1,342.01	2.4

Necessary Ventilation Measure: Air Balancing & HRV Installation

Measure	Cost	Estimated Govt. Rebate/Incentive	Total Cost
Air Balancing	780	N/A	780
HRV Installment (160 CFM x 3)	9000	216	8784

The other measure that are not listed here would be better left for capital budgeting and end-of-life replacements. Selections of these measure would provide energy savings for the building when retrofits become necessary. Furthermore, these recommendations may become feasible in terms of CO2 reduction strategies should this become more of a priority in the future.

10.1 Summary Tables

10.1.1 Building Envelope

Window Replacement

	Project Life Span	# of cycles	Cost for 1 cycle	Demand Reduction Electricity kW	Electricity kWh	Natural Gas m³	Annual Total Energy Savings GJ	Annual M.Tonnes CO2 Avoided	Retrofitting Cost	Annual Savings	Simple Payback/ Yrs
Fiberglass Double Pain	N/A	N/A	N/A	N/A	N/A	4419	166	8.2	$31,148.36	$1,008.00	43.8
Insulated Shades for Windows (Window Quilt)	N/A	N/A	N/A						$12,840.88		
Air Sealing/ Weather stripping	N/A	N/A	N/A						$100.00		
									$44,089.23		

	Project Life Span	# of cycles	Cost for 1 cycle	Demand Reduction Electricity kW	Electricity kWh	Natural Gas m³	Annual Total Energy Savings GJ	Annual M.Tonnes CO2 Avoided	Retrofitting Cost	Annual Savings	Simple Payback/ Yrs
Fiberglass Double Pain	N/A	N/A	N/A	N/A	N/A	3493	131	6.5	$31,148.36	$796.61	39.10

	Project Life Span	# of cycles	Cost for 1 cycle	Demand Reduction Electricity kW	Electricity kWh	Natural Gas m³	Annual Total Energy Savings GJ	Annual M.Tonnes CO2 Avoided	Retrofitting Cost	Annual Savings	Simple Payback/ Yrs
Insulated Shades for Windows (Window Quilt)	N/A	N/A	N/A	N/A	N/A	6046	227	11.3	$12,840.88	$1,378.64	9.31

	Project Life Span	# of cycles	Cost for 1 cycle	Demand Reduction Electricity kW	Electricity kWh	Natural Gas m³	Annual Total Energy Savings GJ	Annual M.Tonnes CO2 Avoided	Retrofitting Cost	Annual Savings	Simple Payback/ Yrs
Air Sealing/ Weather stripping	N/A	N/A	N/A	N/A	N/A	3595	135	6.7	$100.00	$820.00	0.12

10.1.2 Mechanical Systems

Ventilation

	Project Life Span	# of cycles	Cost for 1 cycle	Demand Reduction Electricity kW	Electricity kWh	Natural Gas m³	Annual Total Energy Savings GJ	Annual M.Tonnes CO2 Avoided	Retrofitting Cost	Annual Savings	Simple Payback/ Yrs
Air Balancing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$780.00	N/A	Necessity
HRV Instalment 160CFM x 3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$9,000.00	N/A	Necessity

Heating

Heating Option A Configuration	Project Life Span	# of cycles	Cost for 1 cycle	Demand Reduction Electricity kW	Electricity kWh	Natural Gas m³	Annual Total Energy Savings GJ	Annual M.Tonnes CO2 Avoided	Retrofitting Cost	Annual Savings	Simple Payback/ Yrs
Boiler Replacement (Condensing boilers), 2 Units	15	1	$18,550.00	N/A	N/A	7583.00	284.00	14.00	$18,550.00	$1,729.19	14.7
High Efficient Heat Transfer Fluid Installation	8	2	$2,351.25						$4,702.50		
VFD Installation, 3 Units	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$2,120.00	$42.46	
									$25,372.50	$1,771.65	

Heating Option B Configuration	Project Life Span	# of cycles	Cost for 1 cycle	Demand Reduction Electricity kW	Electricity kWh	Natural Gas m³	Annual Total Energy Savings GJ	Annual M.Tonnes CO2 Avoided	Retrofitting Cost	Annual Savings	Simple Payback/ Yrs
High Efficient Heat Transfer Fluid Installation	8	1	$2,351.25	N/A	N/A	3791	142	7	$2,351.25	$865.00	2.72
									$2,351.25		

Heating Option C	Project Life Span	# of cycles	Cost for 1 cycle	Demand Reduction Electricity kW	Electricity kWh	Natural Gas m³	Annual Total Energy Savings GJ	Annual M.Tonnes CO2 Avoided	Retrofitting Cost	Annual Savings	Simple Payback/ Yrs
Boiler Replacement (Condensing boilers), 2 Units	15	1	$18,550.00	N/A	N/A	5576.00	209.00	10.40	$18,550.00	$1,271.47	14.6

	Project Life Span	# of cycles	Cost for 1 cycle	Demand Reduction Electricity kW	Electricity kWh	Natural Gas m³	Annual Total Energy Savings GJ	Annual M.Tonnes CO2 Avoided	Retrofitting Cost	Annual Savings	Simple Payback/ Yrs
VFD Installation, 3 Units	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$2,351.25	$42.46	49.9

10.1.3 Electrical Systems

	Project Life Span	# of cycles	Cost for 1 cycle	Demand Reduction Electricity kW	Electricity kWh	Natural Gas m³	Annual Total Energy Savings kWh	Annual M.Tonnes CO2 Avoided	Retrofitting Cost	Annual Savings	Simple Payback/ Yrs
Exit Sign Replacement	N/A	N/A	N/A	270	2365.20	N/A	2365.20	1.7	$1,080.00	$207.81	5.2

	Project Life Span	# of cycles	Cost for 1 cycle	Demand Reduction Electricity kW	Electricity kWh	Natural Gas m³	Annual Total Energy Savings kWh	Annual M.Tonnes CO2 Avoided	Retrofitting Cost	Annual Savings	Simple Payback/ Yrs
Occupancy Sensor Installation	N/A	N/A	N/A	N/A	15274.4384	N/A	15274.4384	10.8	$3,280.00	$1,342.01	2.4

4' 32W T8 Flourasent Replacement to LED	Project Life Span	# of cycles	Cost for 1 cycle	Demand Reduction Electricity kW	Electricity kWh	Natural Gas m³	Annual Total Energy Savings GJ	Annual M.Tonnes CO2 Avoided	Retrofitting Cost	Annual Savings	Simple Payback/ Yrs
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not feasible

10.1.4 Water Systems & Renewable Energy

Water System Measures

	Project Life Span	# of cycles	Cost for 1 cycle	Demand Reduction Electricity kW	Electricity kWh	Natural Gas m³	Annual Total Water Savings m³	Annual M.Tonnes CO2 Avoided	Retrofitting Cost	Annual Savings	Simple Payback/ Yrs	
High efficiency fixture instalment	N/A	N/A	N/A	N/A	N/A	N/A	18.94	N/A	$6,128.95	$51.40	119.2	Not feasible

Renewable Energy

	Project Life Span	# of cycles	Cost for 1 cycle	Demand Reduction Electricity kW	Electricity kWh	Natural Gas m³	Annual Total Energy Savings kWh	Annual M.Tonnes CO2 Avoided	Retrofitting Cost	Annual Savings	Simple Payback/ Yrs	
Solar H.W. High Efficient Heat Transfer Fluid Installation	N/A	N/A	N/A	N/A	N/A	N/A	1313.7	0.926	$ 519.38	$28.80	18.0	Not feasible

10.2 Priority Lists

While the lowest hanging fruit (least expensive upgrades) would traditionally be recommended as immediate priorities, the lack of outdoor air ventilation in the building must be addressed. Windows were found to be open when the building was being conditioned, which is believed to be a result of having no fresh air intake. The implementation of heat recovery ventilators (HRVs) is vital to the reduction in this wasted energy and is believed to be the highest priority. HRVs will improve occupant comfort, reducing the need to compensate for the lack of fresh air that leads to wasted energy in the building.

The lowest hanging fruit – occupancy sensors, exit sign replacements, weather stripping, and heat transfer fluid - are all affordable retrofits that will yield recognizable savings. As low cost, high return recommendations these measures should be high priority.

Mechanical system upgrades should be a substantial priority given the amount of energy expended on compensating for the primary unit's shortcomings. By upgrading the boiler systems or components, the primary mechanical system should be able to serve the entire building. Ideally, this will result in a reduction in the use of the two rooftop units that essentially serve as back-up systems.

All other measures are higher cost recommendations that would be considered low priority. They are end of life solutions that should be considered when equipment, systems, or building components need to be replaced.

10.3 Conclusions

Fire Station 231 can obtain significant energy and related cost savings by implementing measures that were identified in this energy audit. Opportunities to improve the mechanical systems will result in significant enhancements to occupant comfort. Other, lower cost opportunities will yield reductions in energy consumption for the building. All recommendations will result in overall operating savings.

Alongside these recommendations, training and awareness will also be vital to optimize building efficiency. A lack of accountability on the part of both the occupants and maintenance contractors has resulted in negligence in concern to building system upkeep. By developing a program that allows occupants to better understand the functioning of the building and its systems, a greater sense of responsibility can be established among them.

It is also fundamental to the efficient functioning of the building that a more thorough operations and maintenance program be developed. It is clear that contractors do not perform regular inspections on the building and the result of this is disregarded and damaged equipment. Scheduled building inspections and maintenance will allow for all systems to continually function at optimal efficiency.

The building's energy use is above average according to energy star benchmarks, which indicates that the energy conservation measures suggested present an opportunity to obtain substantial savings.

11. Appendices (Digital Format)

11.1 Floor Plans & Drawings

11.2 Building Systems Inventory

11.3 Utility Analysis Report

11.4 Energy Model Report

11.5 Technical Documents

11.6 Photos

11.7 Energy Conservation Measure Calculations

11.8 Project Schedule