Greenest City Scholars Program

VF&RS Energy Usage Audit and Recommendations

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07/31/2015

Introduction

This report was written as part of the Greenest City Scholar Program established through a partnership between the City of Vancouver and the University of British Columbia. Each GC Scholar project is designed to help Vancouver reach its goal of being the Greenest City by 2020. This project falls under the Greenest City 2020 Goal of "Green Buildings" and is intended to help the Vancouver Fire and Rescue Service (VFRS) towards meeting the City's target for 2020.

The decision to focus on the VFRS buildings, specifically Firehalls and the Chess St. training centre, was due to analysing the VFRS performance in the Green Buildings area over the last 8 years. Unfortunately, this highlighted a significant need to reduce greenhouse gas (GHG) emissions from the VFRS buildings over the next 5 years in order to meet the set targets by 2020. Total energy usage within the Firehalls has fallen from 20,270 eGJ/year (equivalent GJ per year) in 2007 to 19,729 eGJ/year in 2014, a reduction of 3%. However, Figure 1 shows the trend from 2013 to 2014 actually increasing in both energy usage and GHG emissions by 2%.

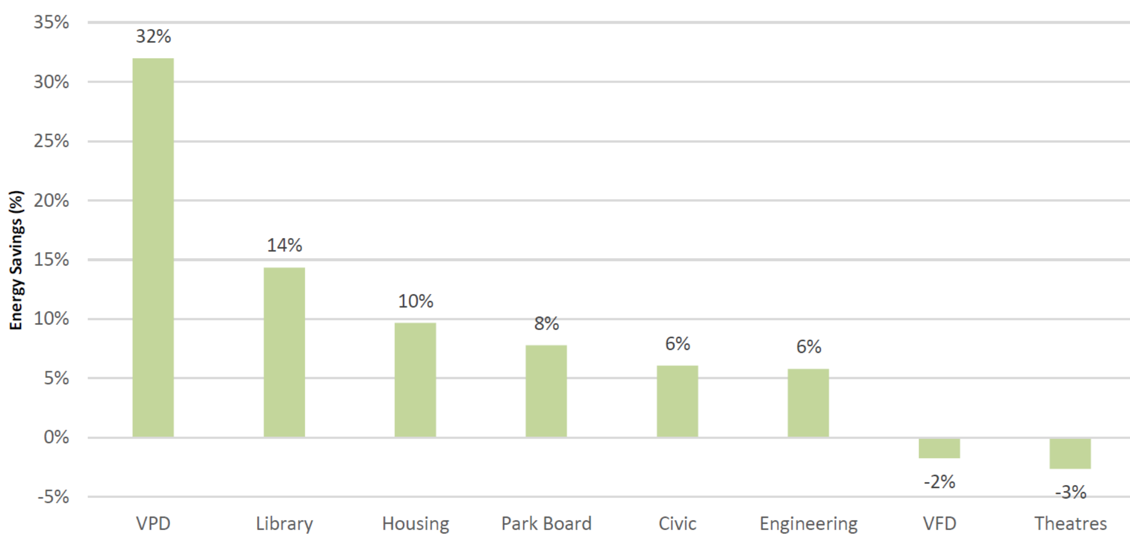

Figure 1 - Chart to Show the Change in GHG Emissions, 2013 vs. 2014

From this data, it was concluded that the focus of the Greenest City Scholars project within the VFRS should be on the reduction of GHG emissions from the VFRS buildings.

There are two main parts to this project:

1. Audit and assessment of current energy usage and practices within the firehalls
2. Technical analysis on recommendations for reducing GHG emissions

Each part is integral to the success of implementing new systems, technologies, and best practices in order to reduce energy usage within the VFRS. The combination of these two elements of the project provide both the background and justification for the recommendations put forth as a result of the investigation. It also provides quantitative data on the projected effect and success of each recommendation along with notes of recommended precaution in some cases.

It should be noted that each recommendation was, at least in part, put forward or endorsed by members of the Firefighters Union as well as being endorsed by members of Senior Management.

Methodology

In order to get a complete overview and understanding of elements related to energy usage and GHG emission in the Firehalls, it was decided that the project should contain 4 key elements, listed below:

1. Visit all 20 Firehalls
2. Have discussions with, and procure relevant documentation from, equipment and apparatus manufacturers
3. Arrange meetings with members of the senior management of the VFRS and senior City of Vancouver (CoV) staff
4. Conduct cost-benefit analyses on potential recommendations

Visit all 20 Firehalls

The reason behind visiting all 20 Firehalls was to gain an understanding of the inner workings of each particular hall as well as to get information from the teams who work specifically in each hall to find out their views on energy usage and management within the halls. As the current Firehalls range from 3 to 60 years old and from small halls with 1 piece of apparatus to large halls with multiple pieces of apparatus, coupled with offices for management and maintenance teams; there is a large variation in the types of energy usage in each hall as well as many design idiosyncrasies from one hall to the next.

This understanding was gained by conducting an approximately 15 minute walk-through and visual assessment or each hall individually. During this walk-through, various pieces of information were gained such as identifying obvious areas of energy loss; layout of the hall for identifying optimal heating zoning; equipment in use; dimensions of the bays; lighting setup; HVAC design, etc.

The second and probably most important part of the visits to the halls was to have a 30-45 minute discussion with the crew working in that hall. This was so beneficial to the project because the way a Firehall operates is very different to a regular workspace, such as an office building, in that the halls are manned 24/7 and fulfil a number of needs not usually synonymous with the workplace. These include, areas to shower and decontaminate after being in an active fire; rest and relaxation spaces to recuperate the body between physically demanding callouts; cooking and eating facilities for multiple members; and specifically required areas for training drills and large, heavy equipment.

The value in discussing with the crews in each hall was that they are very familiar with the specific workings of each hall and already know many of the deficiencies and ways that energy is currently being lost and wasted. In addition to this, the majority of firefighters come from a trade's background including electricians, plumbers, carpenters, etc. and by nature are generally termed as "problem-solvers". This, along with their outgoing nature, meant that the crews within each Firehall provided a lot of suggestions for how to improve the usage of energy within the hall as well as the technical details for how to implement such solutions.

Discussions with Manufacturers

As an extension of ideas for energy-saving measures within the halls, it was advantageous to contact the manufacturers of specific pieces of equipment to get their input as to recommended designs and operating limits that their equipment is designed to operate within. Two major manufacturers were the focal point of conversations:

1. Spartan / Smeal: Manufacture Truck Chassis' / Aerial Equipment
2. All-American: Manufacture all new hose for use within the VFRS

The discussions with Spartan & Smeal were to determine the operating temperature parameters of the equipment in order to conclude how warm the equipment needed to be stored at when not in use. Though they are motorized equipment and the bays are essentially like a home garage in that respect, the equipment is very expensive and specifically designed to optimally fight fires. For this reason, there are a number of things to consider when looking for a minimum operating temperature that may have been required to be warmer than a typical personal vehicle.

The separate discussions with All-American were to determine similar parameters for the usage, storage, and maintenance of fire hose. 19 of the existing Firehalls have towers whose main usage is to hang and dry the hose to make it easier to handle, prevent excessive damage, and to prevent the build-up of mould and mildew on the hose jackets.

Meetings with Senior Management of VFRS & Senior CoV Staff

This part of the approach was to impart knowledge from experts within various fields that relate to the project. From the VFRS side, discussions with Assistant Chiefs and Deputy Chiefs were conducted to get a better understanding of the management of facilities within the VFRS. It also enabled the utilization of their vast experience within the service alongside their specific technical strengths to endorse or refine ideas that had been identified as possible solutions. There is also the added benefit that people at this level of the VFRS organization have a better insight into the future plans for the service and how this may impact or aid certain approaches and halls.

Meetings with the CoV staff were critical to understanding how the City prioritizes and performs both capital and maintenance work as well as for learning the processes and finding the right contacts for the implementation of energy saving and management tools or solutions. Multiple Project Managers on various projects for the VFRS and the Manager of Energy & Utilities were consulted over the course of the project and provided a valuable set of expertise in forming a final set of recommendations to the department.

Cost-Benefit Analysis of Potential Recommendations

The final part of the method used for evaluating and providing recommendations for reducing energy usage and GHG emissions was to conduct a cost-benefit analysis on each of the suggested options. This is a crucial step in the process as the VFRS has a limited budget and so to provide recommendations that could be quickly implemented would require either a very low capital, or maintenance, cost or, at the very least, a definitive and robust benefit to the service within a decisive timeframe.

The cost-benefit analyses also provided the justification for prioritizing different solutions and gave a solid backing to endorse the implementation of these solutions. The relative impact of each option is given by the benefit that it will provide on both an economic scale and on an environmental scale in the reduction of GHG emissions whilst saving the VFRS money.

Major Findings

From the investigation, two major areas were highlighted where significant improvements could be made to the efficiency and usage of energy within the VF&RS:

1. Hose Towers
2. Apparatus Bays

When considering major uses of energy, and consequently the most likely areas for big improvements, lighting and electricity usage in general are often the first to be considered, as these are obvious, visual uses of energy. However, it is usually heating, ventilation and air-conditioning (HVAC) systems that are the least efficient and provide the biggest losses within buildings, especially older buildings like many of the City's Firehalls.

In addition to this, the majority of the Firehalls have HVAC systems that are powered by natural gas rather than electricity. Given that, in the province of British Columbia, most of the electricity is provided by hydroelectric generation, the GHG emissions resulting from HVAC systems using natural gas are significantly higher than the equivalent energy usage from electric powered systems, such as lighting and common appliances.

- 1ekWh (equivalent kilowatt-hour) of Natural Gas = 443g CO_2 emissions
- 1ekWh of electricity produced by hydropower = 10g CO_2 emissions

With this in mind, it became apparent very quickly that the hose towers and apparatus bays within almost every Firehall stood out as being inefficient for heating and heat losses.

Hose Towers

The hose towers are currently used primarily for drying hose after they have been cleaned, following a fire. Each tower has at least one heater used to warm the tower for the purpose of drying the hose. This practice is commonplace as the old hose that used to be used within the VF&RS was cotton-jacketed and consequently was susceptible to mould, mildew and deterioration when wet. However, the newer composition of hose in service is designed to be fully resistant to mould and deterioration when wet as it is rubber lined on the inside and manufactured from a composite, treated fabric material called Duracote™ on the outside. A company called All-American, or one of their subsidiaries, manufactures all of the hose currently in use in the VF&RS and uses the above composition.

Through conversation with Russ Miller, Product Manager at All-American, it was confirmed that the hose now being used by the VF&RS does not need to be dried to provide reliable, functional attack hose for fighting fires.

This statement is supported by Training Officer, Eric Froese, who added that the hose does not need to be dried with added heat but as the hose still needs to be cleaned after usage in a fire, it would be beneficial to drip-dry the hose in the existing towers to reduce the excess weight. This is not essential as the excess weight from residual water is in the order of a few pounds and would not impair the firefighters from using the hose effectively but would be worth keeping as a standard practice in halls that have existing towers.

A consideration for the removal of heat sources from the towers was how they would be affected in cold conditions without heating as the towers are typically poorly insulated. This concern is dispelled by the NFPA requirements of hose capabilities, as shown from a summary of the NFPA 1961, below:

> **6.10 Cold Bending Test.**
>
> **6.10.1** A 3ft (0.9m) sample of hose shall be provided with test fittings and immersed in a water bath at room temperature for 24 hours.
>
> **6.10.2** The hose shall be removed form the water bath and exposed to room atmosphere for 15 minutes.
>
> **6.10.3** The hose shall be placed in a cold box for 24 hours with the temperature maintained at -20C.
>
> **6.10.4** After 24 hours in the cold box, the hose shall be removed form the box and immediately bent double on itself, 180 degrees, first one way and then the other.
>
> **6.10.5** The hose shall then be allowed to thaw at room temperature for 24 hours and then be subjected to the proof test, as specified in Section 6.2.
>
> - (Hold pressure, etc.)

Apparatus Bays

The apparatus bays are the largest, single area in every Firehall and are used primarily to house the VF&RS emergency vehicles, including the Engines, Ladders, Quints and Medics. On average, the bays occupy almost 50% of the ground level of the Firehall. Due to their size, it is clear that intelligent and efficient heating of these areas can have a significant impact on the equivalent GHG emissions of the Firehalls.

Given the current heating configuration with the Firehalls, the bays are typically kept, or tried to be kept at, the same temperature as the other main living areas – between 20C and 22C. Initially, this seems substantially too high for what is essentially an area used for equipment storage. However, conversations with the crews made it clear that these areas were also used for some physical work and maintenance on the vehicles. In addition, it was highlighted that equipment housed in these areas is very specialized, expensive and may require specific conditions for optimal performance.

To get a clearer understanding of the operational requirements and recommended conditions for optimal performance, contact was made with the manufacturer of the aerial equipment, Smeal; the manufacturer of the vehicles chassis, Spartan; as well as the engines manufacturer, Cummins.

From discussion with Tom Smeal, Product Manager at Smeal, he stated that the bays don’t need to be heated at all in order to keep the aerial equipment well functioning. However, they are based in Nebraska where it gets significantly colder than in Vancouver and they keep their bays at 50F (~10C) in order to make it comfortable for the mechanics to work on the equipment. He pointed to the water tanks and storage within the vehicles as being the only real area of concern as if these freeze then it can cause significant damage. As a result, his recommendation is to keep the bays at minimum above freezing level and suggested 10C as being ideal.

Discussions with both Don Armstrong, Pacific Regional Manager at Spartan, and the team at Cummins provided direction to keep the emergency vehicles with the manufacturer’s recommended temperature range of -10F to 120F (-20C to 45C) and stated that the VF&RS has the same equipment as services in Saskatchewan where they regularly have extreme cold temperatures.

In addition to the temperature levels required for the apparatus bays, there needs to be major consideration to the level of heat insulation, especially from the bay doors and between the other living quarters in order to successfully implement a change in the energy usage and to enable variable temperature levels throughout the hall.

Recommendations

From the investigation into the energy usage of the VF&RS buildings over the last 3 months, a number of recommendations have been suggested, considered and evaluated. The main focus of the recommendations is on the retrofit of existing firehalls, with most of these also being applicable for new halls built in the future but also with a couple of recommendations specific to new halls.

It is expected that each recommendation be considered only as a recommendation, with some data, calculations and information to support each one. From the presentation of findings to the Senior Management team on Wednesday, July 29th, each of the following recommendations had at least partial, initial approval and those that had no approval have been omitted from this report. However, final implementation of these recommendations is to be authorized and confirmed through the expected chain of command, likely initialized by Assistant Chief Tyler Moore and culminating with Fire Chief John McKearney.

Each of the following pages explains a separate recommendation. It should be noted that some of these will impact other recommendations and consideration be given to the interaction between different approaches.

Take Heaters Out Of Hose Towers:

Discussions with All-American (hose manufacturer) & Eric Froese (TO – Emergency Vehicle Operations & Hose)

- Dura-cote™ outside and rubber inside, doesn't need to be dried and won't mould
- Only slightly heavier when wet and will not have a significant effect on usage/manoeuverability
- Given the Vancouver climate and that the towers are attached to a heated building, the hose tower will likely never drop below 0°C.
- In the event that it does drop below 0°C, the water will have almost all drained and any freeze will not prohibit the rolling and usage of the hose
- NFPA 1961 – 6.10: Cold Bending Test
    - 24hrs at -20°C, then bent double, then proof test (hold pressure, etc.)

At A Minimum, Set Timers for the Heaters:

Average height of hose tower ~ 20m (65ft)
Average cross section ~ 5m x 5m = 25m^2 (16ft x 16ft = 250ft^2)
Average volume ~ 500m^3 (17,000ft^3)
1kJ/°C/m^3 = 500kJ/°C
ACH ~ 20
(ACH = air changes per hour)
BTU/°C = 20(ACH) x 500kJ = 10,000/°C
(BTU = British Thermal Units)
For a 10°C rise → 10 x 10,000 = 100,000 BTU
Heaters rated at ~ 100,000 BTU/h
Set timers for 1 hour

Don't Construct Hose Towers In Every New Hall:

For the same reasons as the above, hose towers may not be essential and can save a significant amount of money in the design and construction phase if not included in new halls.

Careful consideration must, however, be given for training requirements and drills:

- From Bethany Dobson's report last year, centralized training was recommended:
    - Chess St./#10/#17 currently, may be expanded in future
- Consider training of probationary officers that typically takes place in the towers
- Iconic landmark of a Firehall – is it important to VF&RS or the public?

Reduce Thermostat for the Bays to 15°C, From 22°C:

Re-program DDC for heating zones & controls

This is the hardest area to heat and the biggest area for heat loss.

Given the opening of the large bay doors, energy loss through the doors when closed, and the inefficiency of these doors' weather stripping/sealing, the bay will usually sit at a colder temperature in winter. Trying to heat to 22°C is neither feasible nor necessary.

However, careful consideration needs to be given to the connected areas. Where possible, full separation from the bays to the living quarters must be achieved.

Using www.degreedays.net → Change from 20°C to 15°C = -1141 degree days/year

20°C is 1997 degree days/year in Vancouver City.

1141/1997 = 57% reduction in Heating. Given that the bay accounts for half of the volume of an average firehall (excluding that it is the hardest to heat and loses the most energy), this equates to a 57/2 = 29% decrease in energy used for heating.

Conservatively, assume 80% of Gas usage is for heating
→ 80% x 29% = 23% savings

$124,589 on Gas in the last 12 months → $28,655 Savings
= 68 tonnes per year of GHG emissions reduction
→ Equivalent of a 19.2% decrease
- (Target for 2020 is a 20% decrease)

Reconfigure DDC controls for heating:

- Direct Digital Control (DDC) is the automated control of conditions by a digital device. In this case, the thermostats within the firehalls are used as inputs to a central control system, the DDC, that is operated by real estate and facilities management (REFM)

- Set areas so that the sleeping areas are ~2°C cooler than the other living spaces
    - Typically, humans are more comfortable in a cooler sleeping environment than the daily living temperature
    - Most of the dorms are on the top floor of the firehalls and receive heat from the lower areas throughout the day

- The heating zone for the apparatus bay should be separate from the rest of the hall
    - Bays set to 15°C during the day, maybe 10°C at night

- To optimize further, take temperature readings through the day
    - Also, consider the South/West facing rooms that receive more sun

Trip Switch to Turn Off Heaters in the Bay When the Bay Doors Are Open:

Currently, the heaters used in the bays continue to run whilst the bay doors are open, essentially heating the outside environment for the period the doors are open. The recommendation is to install a simple trip switch that would stop the heaters form running, anytime the bay doors are open.

Each Heater = 100,000 BTU/hr = 100,000J/hr = 0.1GJ/hr
1GJ = $11 → each heater ~$1.10/hr to run
Usually 2 heaters per bay, gives savings of $2.20/hr the door is open

Even if doors are open just 1hr/day → 365 x $2.20 = $803/year

Permanent closure of pole holes not in service:

A number of pole-holes, usually directly into the bay, are no longer used and have been temporarily closed off with fabric “teepee” style wrapping and cardboard covers.

Replace these with proper, installed closures for de-commission or a trap-door setup for continued usage.

This is more of a safety concern than energy concern, as people can fall through the cardboard, but the heat loss through these DIY installations can still be significant.

Connect the clothes dryer racks to a timer:

As the turn out gear dryers are usually located in locations out of common use, they are often left on continuously, even when gear is already dry. To prevent this, a built in timer switch could be connected to the power supply to minimize the excess use.

Average 1500W = $4.50/day

If left on continuously (quite common), savings could = 50% of 24/7/365 usage

= 50% x $4.50 x 365 = $820/year

Automatic Switch Off of Emergency Lights (2-piece hall):

Richmond Fire Service is working with an Engineering firm on the design of a new hall that includes a programmable lighting system and the controller could be set to allow lights to be shut down after a fixed period of time from the locution trigger.

According to statistics for 2014, 90% of all calls (Emergency & routine) were out of the hall in less than 4 minutes.

3 longest callouts since start of 2014:

- 9:55 on 04/09/15
- 6:48 on 09/26/14
- 5:53 on 05/25/14

It is suggested to set the timer for 5 minutes

- Giving +25% on the 90^{th} percentile.

Or, 10 minutes to incorporate the longest call times through 2014/15.

At night, likely not much change due to Captain manually shutting them off.

During the day, turns on ~40 bulbs = $4.00/day

(Based on $0.10c/day – calculated in the section "Light Sensors")

Automatic Switch Off of (almost) All Lights (1-piece hall):

Still have the timer at 5/10 minutes but turn off all lighting in the hall.

~150 bulbs = $15.00/day

(Based on $0.10c/day – calculated in the section "Light Sensors")

Light Sensors:

The installation of automatic light sensors can provide a simple solution to lights being left on continuously, especially during or after an emergency call when turning out lights is not a consideration.

Before installing these sensors, consider the layout of the room in questions to make sure the sensors are able to detect people in any part of the room to prevent lights turning off while the room is in active use.

Each 32W, T8, 4’ bulb uses 24hrs x 32W/day = .768kWh/day

$0.13/kWh x .768kWh = $0.10/day of usage per bulb

Examples (Given a $16 sensor) –

- Communications office (#1) has 16 bulbs = $1.60/day
  - = 10 days payback

- Battalion Chief’s office (#1) has 12 bulbs = $1.20/day
  - = 15 days payback

- Stores room (#1) has 8 bulbs = $0.80/day
  - = 20 days payback

LED Lighting:

	Existing T8	17W LED	12W LED
Power (W) for 2700 Lm	32	17	12
Purchase Price	$ 2.00	$ 10.00	$ 23.00
Life (hrs.)	30000	36000	50000
Electricity Cost ($/kWh)	0.13		
Total Cost (50,000hrs)	$ 211	$ 124	$ 101
Savings (vs Existing)	-	**$ 87**	**$ 110**
Payback Period (Months)	-	5.7	11.2

*Payback period is calculated based on continuous usage.

Due to the large number of lights in the firehalls and existing inventory of bulbs, the recommendation for LED lighting is to cease the purchase of the existing T8 bulbs but to continue using them and only when one bulb dies, replace it with the replacement LED. This minimizes the upfront capital cost and spreads the investment over a longer period whilst still enabling the VF&RS to reap the energy savings from an early stage.

Kickback to individual firehall's kitty on energy saved:

% Kickback based on the total savings year on year – Aim for 50%

Money reimbursed by REFM to the individual hall's kitty for use at that hall only.

- See Kickback Tool (Excel)

Example:

- Hall #14 total energy bill (Gas & Electricity) for 2014 = $10k
- Hall #14 total energy bill (Gas & Electricity) for 2015 = $8k
- Savings = $2k.
- Kick-back (@ 50%) = $1,000 into Hall #14's kitty fund.
- VF&RS saves $1000 and reduces Energy Consumption
    - By ~20%, hitting City targets.

(Note: This a numerical representation rather than a real example)

Due to the effect of many of the previous recommendations, the energy consumption would be expected to reduce significantly without any input from the crews. In light of this, it is suggested that previous recommendations be implemented, hopefully showing and encouraging the Firefighters to be more conscious about energy usage. Then, likely in the following year, introduce the incentive kickback program to help push the program further towards, and hopefully beyond, the final goals of the 2020 CoV target.

Heat-pumps (Air-Source or Ground-Source):

Recommended for new constructions but likely too capital intensive for retrofits. Ground-source heat pumps are now very efficient and can provide significant savings in equivalent energy usage over existing gas furnace systems. In addition, even if the equivalent energy usage was the same, GHG emissions from electrically powered HVAC systems like heat pumps is significantly lower than that of the gas-powered systems due to the way BC produces electricity through mainly hydro powered generation.

Maintenance Repairs (Report to Craig Edwards):

Though there are 20 Firehalls in the VF&RS that combine to be a significant piece of the City of Vancouver's portfolio buildings, each one individually is relatively small-scale. So, when it comes to prioritising maintenance services in the City, larger buildings that belong to the City tend to get more frequent and thorough maintenance schedules and inspections.

To assist the REFM team in highlighting and attending to maintenance issues within the halls, it is recommended that a comprehensive, internal review be conducted to compose a list of existing defects. These lists of defects, one for each hall, should then be shared with Craig Edwards, Manager – Energy & Utilities, of the CoV Engineering department. Craig has requested this approach so that he may direct his team to attend to multiple issues at one time, creating a higher priority for the work and to make it more economical.

There are two clear options to be able to create the deficiency lists and it is suggested that a combination of the two will provide the most consistent and through results that can be used effectively by the REFM team. The first is to have a crew member, or members, from each hall be responsible for conducting a walkthrough of their hall and to produce the list. This method is expected to give a more thorough list as the crew members know their individual halls very well. However, it could also provide inconsistent priority levels, as each crew member is likely to exaggerate the issues with their own hall. The second is to have a member of the light-duty team, possibly from communications as AC Moore has been supervising this project, to travel to each hall and perform the same assessment, providing a more consistent set of lists but maybe lacking in thoroughness. The combination of having a member of the light duty team conduct an assessment alongside a member from each hall should mitigate the issues and provide a comprehensive and consistent set of deficiency lists.

Conclusion:

The Vancouver Fire and Rescue Services are dedicated to helping the City of Vancouver achieve its goal of being the Greenest City in the world by 2020 by reducing the GHG emissions from its buildings. It is expected that this will be achieved primarily by reducing energy consumption within the VF&RS buildings – 20 firehalls and the training centre at Chess St.

From an investigation into energy usage within the City's firehalls, a number of recommendations have been put forward to help reduce the amount of energy used within each hall. The focus was on simple to implement, efficient retrofits to the existing firehalls that provide a cost effective solution to reducing the amount of energy used, and more specifically wasted. This, in turn, will provide the desired reduction in GHG emissions, in order to meet the targets set for 2020.

A summary list of recommendations are listed below:

- Take Heaters Out Of Hose Towers
- Reduce Thermostat for the Bays to 15°C, From 22°C
- Reconfigure DDC controls for heating
- Trip Switch to Turn Off Heaters in the Bay When the Bay Doors Are Open
- Permanent closure of pole holes not in service
- Connect the clothes dryer racks to a timer
- Automatic Switch Off of Emergency Lights (2-piece hall)
- Light Sensors
- LED Lighting
- Kickback to individual firehall's kitty on energy saved
- Heat-pumps (Air-Source or Ground-Source)
- Maintenance Repairs (Report to Craig Edwards)