THE ECONOMICAL BENEFITS OF CONDUCTING AN ASHRAE LEVEL II ENERGY AUDIT

by

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ABSTRACT

Conducting an ASHRAE Level II Energy and Water audit provides building owners opportunities to save energy and water in their buildings. The ASHRAE Level II Energy Audit will fulfill the requirements for BOMA BESt Energy Assessment and IESO's saveONenergy Electricity Survey and Analysis. The IESO saveONenergy allows building owners to receive monetary incentives to improve their energy efficiency.

Energy audits are an effective method to increase energy efficiency for commercial buildings. However, there are multiple levels of energy audits set by ASHRAE (Level I, II, and III) which varies the level of detail and economic benefit.

The role of this research is to explore the benefits of a Level II energy audit and the economic benefit of a office tower located in Toronto. This building had an ASHRAE Level I audit two years ago and a case study will be performed to evaluate the level of detail and economic benefit of a Level II Energy and Water audit.

The tower was evaluated according to ASHRAE Level II guidelines and the results obtained were an Energy Star score for the building, benchmarking against BOMA BESt buildings, energy conservation measures (ECMs), financial savings, payback periods and CO_2 savings. They were separated into low/no cost measures, capital measure, other measures and impractical measures. If the building managers were to target all of the recommended ECMs, a total of $300,000 in utility costs per year would be saved. This is equivalent to 1,700,000 ekWh saved per year and a 6% reduction of their current energy use. Further more, the total energy use intensity (EUI) would improve from 26.2 ekWh/ft^2 to 24.7 ekWh/ft^2.

This case study has allowed a comparison for the two different types of energy audit. Compared to a Level I energy audit, there is a lot more detail which can provide a better potential savings as there are more engineering calculations involved for mechanical equipment, reviewing of drawings, observation of mechanical equipment, and interviews with the building operators

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1.0 INTRODUCTION

Each building has its own unique complex system. Building energy management systems (BEMS) provides data, such as the building's energy use. Gathering information about the building's energy use is essential to evaluating areas where the building is no longer performing as intended.

As buildings age, their energy performance decreases. And with the changing climate and growing population, more resources will be required to meet these requirements. Based on research by Isaac and vanVuuren (2009) for commercial buildings on a global scale, climate change results in a decrease of heating by 30 percent, however increases the cooling demand by 70 percent.

Buildings have been considered as a large energy consumer. About two thirds of this energy is used for heating, cooling, and ventilation (Omer, 2008).

It is important to observe the consumption behaviour of buildings to identify specific energy saving measures. This can be done through performed energy audits. An energy audit is considered the first step for retrofitting. An energy audit for a building consists of an understanding of the energy consumption profile through collection of historical energy consumption of the building, and to find energy saving opportunities through a cost-benefit analysis.

1.1 ASHRAE LEVEL 1, 2, 3 ENERGY AND WATER AUDITS

A method of reducing energy consumption and greenhouse gas emissions is to conduct an energy audit and to resolve the problems identified through the audit. There are no standard definitions of energy audits. Energy audits can be distinguished through different levels of effort. The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) provides a guideline for commercial building audits in *Procedures for Commercial Building Energy Audits (2011)"*.

The ASHRAE Energy Audit divides the energy audit into three different levels:

- Preliminary energy use analysis: The building is evaluated using its Energy Use Intensity (EUI) which uses existing utility data (annual).
- Level I: A walkthrough of the building's systems (mechanical and electrical) and conducting interviews with the building operators. A more high level approach.
- Level II: A more thorough walkthrough where details are required using actual measurements. An energy saving measure and cost analysis are considered.
- Level III: A more in-depth analysis of capital intensive investments/modifications. This requires use of software to understand return of investment on each investment/modification.

All of these processes are aimed to reduce the energy use and greenhouse gas emissions of buildings. The energy audit process will eventually lead to recommissioning work of the building if there are issues with the mechanical systems in the building.

1.2 CURRENT ENERGY AUDITS FOR BUILDINGS

Canada's commercial building sector uses significant amount of energy and produces a large amount of carbon emissions. Overall, it uses 14% of the end-use energy consumption and contributes to 13% of Canada's carbon emissions. Technologies which could make this sector more energy efficient while reducing environmental impact are not being pursued. Therefore the number of carbon emission and energy consumption continue to grow. (Government of Canada, 2009)

For small to medium sized enterprises, the same issue comes up again: lack of information regarding energy consumption trends lead to lack of incentive to conduct an energy audit (Schleich et al., 2008).

An issue to some building owners is the upfront costs to conduct an energy audit. An ASHRAE Level II audit for a 100,000 square foot building can cost between $6,000 to $25,000. For some building owners, it is preferable to hire a low-bid auditor to complete the work. At times, hiring a cheaper auditor is not as worthwhile considering that the quality of the work will not be high: where a clear description of what work needs to be done and highlight energy conservation measures. This would affect the overall building, causing the energy saving measures to be missed (Avina, 2013).

2.0 LITERATURE REVIEW

2.1 ISSUES WITH ENERGY LEVEL I BASED AUDITS

The United Technologies Research Center (UTRC) is led by a team of scientists and engineers where new techniques and tools are used while streamlining data gathering methods. This is to reduce the amount of work required for a preliminary building assessment to determine the eligibility for a retrofit. Currently, it is known as ASHRAE Level I and II audits, this is a screening tool for any upgrades needed for a retrofit.

For this case study, there were three independent energy auditors who evaluated Building 101 located at the Philadelphia Navy Yard in Philadelphia. It was built in 1911 and renovated in 1999 as an office building.

The UTRC reviewed the three different energy auditor reports for Building 101 prior to their own audit. Company A performed a Level II audit and company B and C used the data from a Level I audit.

It was found that the data used for the auditing process varied amongst the three companies. For example, Company A listed the building area to be 61,700 ft^2 (5,732 m^2) which includes the basement. Company C listed the area is 83,059 ft^2 (7,716 m^2). Dasgupta et al. (2012) mentioned the building floor area (gross) to be 75,156 ft^2 (6,982 m^2). The issue is that they do not know how the information was determined.

There were differences amongst the reports from all of the companies. Company A and C estimated R values to be 3.2 and 5.3 $m^{2o}C/W$ for the roof. There were also discrepancies between the window descriptions such as good windows vs leaky windows. The same goes for the HVAC system where data was contradicting and listing equipment which does not exist. There were other issues where the energy end use breakdown would vary widely and very little evidence of how numbers were derived.

Information used from the utility bill was also reflected differently as one company averaged values over a year while the other used values from the last bill received.

The analysis shows different results for the three audits. There were Energy Conservation Measures (ECMs) which were fairly consistent in all three audits; however, most of them were not documented in either one or two energy audits. The costs, energy savings, and cost savings varied from each audit.

Through the analysis of Building 101, the UTRC team concluded that the auditing and analysis process needs to be standardized. This involves data to be collected and measured consistently. It could also involve using a simulation tool and analyzing building data for consistency.

If building data is unavailable, data from similar buildings should be used based on type, location and usage for benchmarking purposes. The DOE Commercial Buildings Energy Consumption Survey

Database (CBESCS, 2013) or Survey of Commercial and Institutional Energy Use – Buildings--2009 by (Natural Resources Canada, 2012) are useful statistical reports which could be used.

Using the nameplates of HVAC systems is not 100% accurate due to the degrading age of the equipment. Aligning the equipment use with the bills would provide a more accurate depiction of the energy consumption.

Building parameters need to be adjusted based on actual energy data. Default values can originally be assumed, however adjustable parameters will need to be used to match the calculated data with the actual utility bills.

More accurate calculations are required for the initial cost of retrofit options. Some retrofit options require detailed information that is sometimes not included in the scope of an energy audit. The economic analysis could be highly skewed.

The URTC proposes a newer methodology for the missing information in building audits and the retrofit process. They suggested that for Level I audits to include elements of a Level II audit. They have proposed five stages:

1. Data gathering needs to complete input information such as building location and general characteristics, schedules and HVAC type. Unknown data will used data from existing buildings of similar type.
2. A tool needs to estimate the performance of the building. A baseline is needed of the building by energy and equipment type. This will provide information on the equipment alone and how it interacts with the building envelope.
3. The method of unknown and uncertain parameters being calibrated and baseline energy consumption has been determined; this allows the auditor to provide ECMs such as savings and payback periods.
4. As some ECMs are related, they can be grouped together. Energy savings of a single ECM or a group of ECMs can be used.
5. For uncertain areas, the auditor can quantify the energy savings by using a sensitivity analysis. This includes weather and schedules. This provides the auditor with information of which parameters have a large impact on energy use.

Overall, more analysis is required to deliver Level I Energy Audits as what has been shown can be of large variability in data inputs and outputs. There was also little consideration of how specific ECM recommendations interact with other ECMs.

2.2 AVOIDING ENERGY AUDIT PROBLEMS: PICKING QUALITY ENERGY AUDITORS

One of the main issues outlined by Avina (2013) is that there is a lack of standardization for energy audits. There is a wide fluctuation about how a proper energy audit should be performed where hours can range from 5 to 80 hours. These different hours of work indicate that there is a lot of differences between what work needs to be done.

ASHRAE defines Level I, II and III requirements. However, not all energy auditors will deliver the same results or even quality. Avina (2013) placed a bit for $4,500 for a Level I audit. He lost to his competitor who offered a Level I audit for $823. Unfortunately the quality of the work delivered was sub par and it was not done properly. The unfortunate part was that the clients are not aware of what consists of an energy audit.

There are a large number of companies which will perform energy audits for free. Those companies generally want to sell their product. Their intent is to not provide a proper ASHRAE Level energy audit; rather it focuses only on their product. There are also energy audits which are not performed by proper energy auditors. Utility companies are also offering free energy audits, but again, it is not experienced energy auditors, rather staff that perform them.

Energy auditing requires a thorough understanding of the mechanical equipment: chillers, air handlers, boilers, control system, domestic hot water, etc. It takes many years to achieve this.

Selecting an experience energy auditor is very important. Avina (2013) suggests someone of 10 years. Usually ask for a CV and references. An energy auditor should be a P.Eng. or a Certified Energy Manager (CEM). A sample audit might also be required.

Avina (2013) also suggests speaking to different companies and placing all categories in a matrix to score the potential energy auditors. This will help make a thorough decision and best for your building.

2.3 IMPACT AFTER THREE YEARS OF THE SWEDISH ENERGY AUDIT PROGRAM

Currently the saveONenergy has incentives to save energy in Ontario. One of which is an Audit Funding program to allow building owners to conduct energy audits where the incentive can cover up to 50% of the cost (IESO, 2017). The money could be used for equipment replacement, changes in operation and other areas where building energy consumption can be improved. At the current moment, the information regarding the impacts of this program is limited.

The European Commission (EC) launched the Energy Service Directive (ESD) in 2006 as well as an energy savings target of 9% (European Commission, 2006). The area studied was small and medium sized enterprises (SMEs) in the European Union. SMEs collectively in Europe are known to use large amounts of energy, but the not individual firms themselves.

The Swedish energy audit program subsidizes an energy audits for eligible buildings are those that use more than 500 MWh/year or farms with over 100 livestock. Backlund and Thollander (2014) examine the reported energy audit data and review the potential energy efficiency improvements and cost efficiencies in this program. Schleich et al. (2008) observed areas which were limited in the commerce and commercial sector and discovered that there was a lack of information between the user and energy consumption patterns of buildings. Energy audit programs help the user to overcome the lack of information to energy efficiency and increase the use of technologies which were energy efficient.

Backlund and Thollander (2014) draw information from other energy audit studies from other parts of the world such as Australia, US and Germany. In Australia and Germany, to implement energy efficient measures were approximately successful at a rate of 77-80% (Anderson and Newell, 2004). In the US and Sweden, the number of energy efficient measures is not quite as high, only at a rate of 40-53% (Tonn and Martin, 2000). In Germany, there was more support for these processes which allows for higher implementation rate (Fleiter et. al., 2012). Unfortunately Fleiter (2012), it was also known that the higher the capital or investment cost, the more unlikely that the measures will be used and considered a barrier to energy efficiency.

Backlund and Thollander (2014) discuss the measures in more detail. The 241 firms in total have suggested 2,043 energy efficiency measure improvements that has total potential savings of 25,500 MWh/year. The firms ended up or will end up implementing about 48% of the suggested measures, which totals to 91,700 MWh/year. The largest potential savings was with ventilation, space heating and lighting at about 56%, 47%, and 53% respectively.

It was estimated that to implement those 1848 measures which were reported to have investment costs, it would cost approximately €20,300,000. This cost does not include energy audits, capital costs, or any other hidden or transaction cost. All of these firms have confirmed to invest in 45% of the cost. The largest area of focus for all firms was in space heating and ventilation.

The lowest energy efficiency measure investment cost would be 0. This is due to measure not requiring any upgrade or technologies. This would include adjusting technologies or changing behaviours of the building users. This would account for 9% of energy improvements.

The average annual energy efficiency improvement from the program could be between 860 and 1,270 MWh/year which totals to 6,980 and 11,130 MWh/firm potential energy efficiency improvement. The average implemented energy efficiency improvement per firm was 460 to 660 MWh/year. It was concluded however that access to funds to implement these energy efficiency measures would definitely be a barrier to implement due to lack of capital funding and lack of investment of energy efficient technologies.

2.6 POST ENERGY AUDIT: HVAC COMMISSIONING FOR EXISTING BUILDINGS

Issues related to energy related problems are usually reported in building commissioning and energy audits (Wang et al, 2013). Most of the issues found in existing building are related to the air handling units, heating water plants, and chilled water plants (Portland Energy Conservation Inc, 2009). Most of the issues involved the operation and maintenance controls of the mechanical systems which are also outlined in Energy Level II audits (Mills, 2009). After the reviewing the findings of a Level II energy audit which involves the mechanical system and system inefficiencies, a commissioning job can be performed to improve the energy efficiency of the mechanical system without replacing equipment.

Functional and passive testing are techniques used for all commissioning projects. A continual process for a monitoring-based commissioning requires information such as mechanical drawings, architectural drawings, and equipment specifications. Figure 1 demonstrates a cyclical process developed to determine the functionality of the building and to make sure that it is working properly.

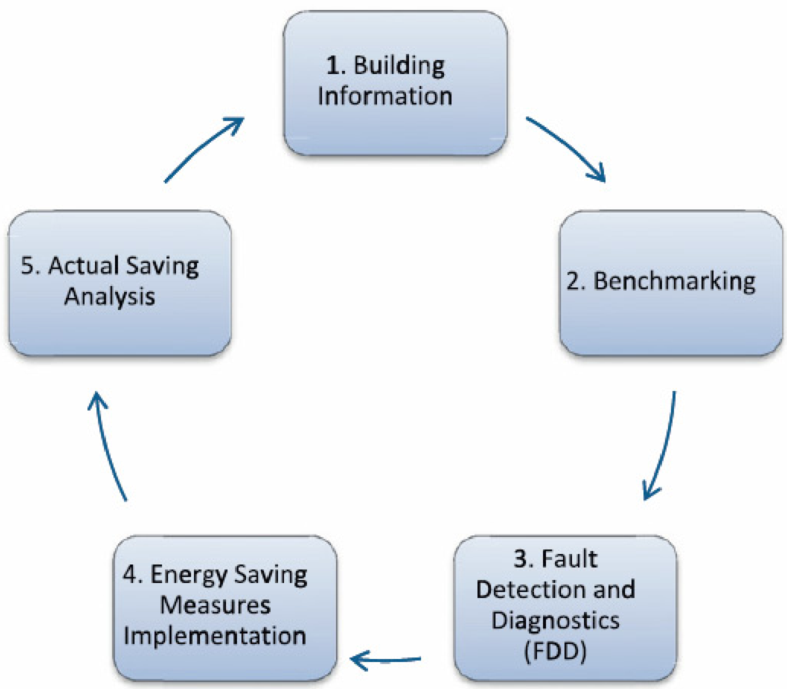

Figure 1: Flow chart for Monitoring-based Commissioning (Wang et al., 2012)

Wang et al. (2012) conducted a commissioning of an existing building for their HVAC systems. This involved functional testing, whereby it was a bottom up approach: to test out and confirm the performance of the components, subsystems and systems over a range of operating points and to determine the cause of any faults. A list of energy conservation measures (ECMs) are prioritized and implemented for the HVAC systems.

This paper conducts a review of a four-storey building called Building 90 at the Lawrence Berkeley National Laboratory. This building was constructed in 1959. The team reviewed architectural drawings and mechanical systems based on the documentation available.

The main characteristics of the building are as follows:

- One occupied basement floor
- External walls and floor do not have adequate insulation
- Single pane windows
- Average occupancy is 350 people
- Building operation: Monday to Friday 7:00 am to 6:00 pm
- Lighting 4 foot T8 lamps with electronic ballasts.
- Lighting controls: infrared and ultrasonic motion sensors

The air handling units were originally constant volume providing heating and ventilation with 100% outdoor air. It was retrofitted and a return air duct was installed and variable frequency drives (VFDs) were installed on the supply and return fans. Direct expansion (DX) coils were also installed which are connected to the condensing stage of the unit using the evaporative condenser.

Portfolio Manager was developed by the U.S. Environmental Protection Agency's (USEPA) Energy Star. The tool measures the buildings performance and compares it to similar buildings with similar climate, and characteristics. The score is rated on a scale of 1-100. The Portfolio Manager uses 12-month utility data. For this particular building, the energy use intensity (EUI) is 268 kWh/m^2/year; which is 70% lower compared to similar commercial buildings nationwide. The electricity use is 57% higher and the gas usage is 79% higher than similar commercial buildings nationwide. Based on this information, it is determined that the natural gas usage in heating conditions is inefficient.

Following the performance of the commissioning process, the following ECMs were suggested and summarized.

1. ECM #1: Reduce room temperature setpoints: Natural gas consumption for space heating can be greatly reduced without affecting the thermal comfort of the building. The rooms can be decreased by 0.5-2.8^{o}C. The model was able to predict savings with this approach.
2. ECM #2: Adjust the setpoints for the DX cooling stages (four): Adjusting the cooling setpoints for DX cooling can optimize its use and reduce the cooling energy required. The model was able to predict energy savings.
3. ECM #3: Pre-cooling the building thermal mass: This is referred to as night purge where the building's thermal mass is cooled by the cooler outdoor air the night before. Ventilation fans bring in cooler air at night.

4. ECM #4: Correcting the damper position for the economizer as it was 100% during heating mode, wasting energy.
5. ECM #5: Damper was leaking 19% and was discovered through functional testing
6. ECM #6: Delay start up of the HVAC system to reduce energy waste. This will not affect thermal comfort.
7. ECM #7: Reset temperatures during hot days where warm up energy use is minimized as previously cooling energy is used later in the afternoon.

Simulations were run and the existing building data was the baseline model. It was estimated that each measure can save up to 0.7% to 6.9% annually of source energy. The ECMs which were most beneficial were correcting the air damper and optimizing the start. During unoccupied hours, the building was able to use 51% less natural gas with the implementation of a better morning warm up process.

2.7 SUMMARY

Based on the literature review, there are major benefits to performing an ASHRAE Level II Energy Audit over a Level I audit. Since Level I audits are a high level approach, there are many issues regarding oversight and inconsistency with the data collection process. With a Level II energy audit, opportunities such as commissioning can be performed. Since measurements are taken during a Level II audit, energy deficiencies will be present. With a Level II audit, the objective is to present findings and recommendations which are more useful at an economic level; building owners can make better informed decisions based on the findings.

3.0 OBJECTIVE OF CASE STUDY

This study is aimed to examine how Energy Level II can help identify the potential for saving energy and reducing carbon emission in buildings. This is to be achieved through a case study in a commercial building located in Toronto.

For this specific case study A Level I energy audit could cost from $8,000 to $12,000 while the Level II Energy Audit costs $14,000 (IESO, 2017). The saveONenergy program does not cover a Level I Energy Audit.

The building has already gone through a recommissioning performed in 2012 and Energy Audit Level I performed in 2012 by two separate companies. At this time, the building management wanted an ASHRAE Level II Energy and Water Audit to evaluate how the building is performing and to determine if upgrades to the building are needed. Conducting a Level II energy audit satisfies the requirement to maintain the building's BOMA BESt certification.

As part of this case study, the objective is to evaluate the cumulative sum of savings after performing an Energy Level I audit and recommissioning over a span of five years and the expected energy savings after performing the Energy Level II audit.

Analyzing the energy use of the building over time will be valuable for building owners to determine what type information they should be expecting and how well each type of audit or commissioning analysis can benefit the building.

4.0 DESCRIPTION OF BUILDING FOR CASE STUDY

The case study involves a 600,000 ft^2 (55,700 m^2) commercial office complex that consists of a modern office tower and a 100,000 ft^2 (9,300m^2) historical building located in Toronto. The tower was constructed in the 1990s and the historical portion was constructed in the 1890s. The building has twenty-eight storeys above grade, and two levels of below grade parking. For the purpose of this case study the complex is referred to as QOE.

The building envelope consists of a steel stud frame with a curtain wall system with approximately 60% window to wall ratio. The historical building envelope is a masonry wall with updated double glazed windows and a window to wall ratio of approximately 35%. Complex cooling is provided by a chillers located in the QOE penthouse and chilled water is distributed via compartment units in QOE, and fan coil units in the historical portion. The chilled water system rejects heat to two cooling towers. The complex also has two cooling towers solely for the owners' servers, these are located on the rooftop of the historical building. Building heating is provided by five boilers, unit heaters, heat exchangers reheat coils. Domestic hot water is provided by a separate natural gas boiler. The historical building is heated using district steam heating and an electric domestic hot water boiler in the summer. Domestic hot water is heated by steam in the winter.

The building has a general schedule of 6:00 am to 7:00 pm Monday to Friday. There is a small number of staff present between 9:00 pm to midnight Monday to Friday and present on weekends.

5.0 METHODOLOGY

The ASHRAE Energy Level II audit will be using the 2004 reference of "Procedures for Commercial Building Energy Audits". In the guide, it provides best practices to perform energy data gathering and analysis. LEED EB:O&M also references this guide.

Figure 2: ASHRAE Level I/II Energy Audit Flow Process

As seen in Figure 2, ASHRAE Level I and II follow the same flow process; however the approach to the energy audit is different between the two.

Before the site visit, the first step involves gathering historical data of the building. This involves mechanical and electrical base building drawings. This information can be used to gain an understanding of the building and its functionality before the site visit. Utility data is often presented at this stage as well to benchmark how the building is performing through tools such as Energy Star and BOMA BESt performance reports. Energy Star is voluntary program set up by the Environmental Protection Agency (EPA) for building owners to input their building data for energy efficiency. This is achieved through an Energy Star score from 1-100, where 100 is very efficient building (Environmental Protection Agency, 2016). A score of 75 or higher means that the building is a high performing building and is eligible for an an Energy Star Certification. BOMA BESt releases a report every year providing EUIs for all different commercial buildings in the private and public sector for each province or territory (BOMA Canada, 2016). Using Energy Star and BOMA BESt provides an insight to how the building is function before the site visit to help the energy auditor to target potential problematic areas. Stacking plans are often provided to determine the occupancy levels of the building in the last several years to the present. This can change the energy and water consumption throughout the building.

During the site visit, interviews are conducted with building management to determine what recent changes or retrofits have been made, typical occupancy levels, building operating hours, typical lighting hours, and HVAC operation hours. A tour around the facility is often performed to review mechanical equipment as well as observe a typical floor layout, counting light fixtures, washroom fixtures and areas where retrofits have been done. Seals around exterior doors are often made to see the level of energy loss through infiltration. At this time interviews with the building operators are also performed to help with the understanding of the mechanical systems and issues that they often encounter. Conducting interviews with the staff provides an insight of problematic areas which could be factors to equipment inefficiencies.

After the site visit, a report is generated based on the interviews and observations made during the site visit. The issues which could be tackled easily and involve very small capital are often targeted first because they are easy areas to fix. Items such as adjusting lighting and HVAC controls to meet the occupancy of the building are often the first suggestion as it involves a simple adjustment on the BAS system. Engineering calculations are performed to determine energy savings as well as reduction in GHG emissions, cost to implement and payback period. ECMs are suggested in a sequential manner and very important to not treat each ECM separately as ECMs tend to interact with another one. This needs to be taken into account when proposing ECMs. The ECMs listed tend to follow in a sequential manner by the building management and must be written accordingly.

Analysis of the data is also performed to determine where the end use energy breakdown occurs. This provides an idea of where energy is allocated. A typical energy end use profile set by NRCan in Figure 3.

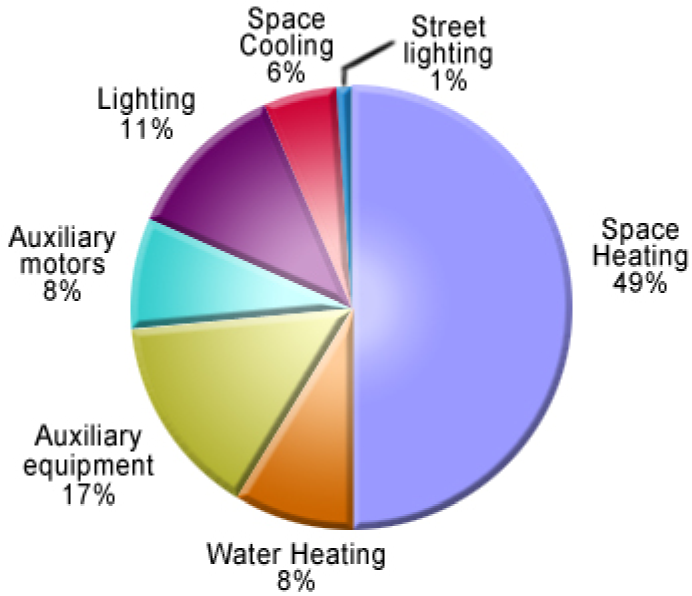

Figure 3: Commercial Sector Energy Use (NRCan, 2015)

5.1 DATA ANALYSIS AND DISCUSSION

Monthly utility data was provided by building management as both tabular data and copies of monthly utility bills. For benchmarking purposes the Utility bills from the May 2015 to April 2016 were used. Table 1 summarizes the utility costs and consumption for the property. Square footage for benchmarking includes twenty-seven above ground floors, one below grade floor, and three levels of underground parking as this is all conditioned space.

Table 1: Utility Data for QOE (May 2015 – April 2016)

Utility	Annual Consumption	Consumption Intensity	Annual Cost	Cost Index
Electricity Consumption	12,000,000 ekWh	18.1 ekWh/ft² (195 ekWh/m²)	$ 1,600,000	2.35 $/ft² (25 $/m²)
Electricity Demand	2,300 kW	3.4 W/ft² (37 ekWh/m²)	$ 240,000	0.37 $/ft² (4 $/m²)
Natural Gas	440,000 m³	6.9 ekWh/ft² (74 ekWh/m²)	$ 110,000	0.17 $/ft² (1.8 $/m²)
Steam	1,700,000 lbs (770,000 kg)	1.2 ekWh/ft² (13 ekWh/m²)	$ 66,000	0.10 $/ft² (1.1 $/m²)
Water	37,000 m³	0.610 m³/m²	$ 120,000	0.19 $/ft² (2 $/m²)

Based on the information outlined in Table 1, it doesn't provide a proper representation of the energy consumption of the building. Section 6.1 outlines the End Use breakdown by utility.

5.2 BENCHMARKING QOE WITH BOMA BEST AND ENERGY STAR PORTFOLIO

The Building Owners and Managers Association (BOMA) Canada represents the Canadian commercial building industry. BOMA Building Environmental Standards (BESt) is a national green building certification program for existing buildings. BOMA BESt evaluates buildings and measures them against the following criteria: energy, water, air, comfort, health and wellness, custodial, purchasing, waste, site, and stakeholder engagement.

Every year BOMA Canada releases the BOMA BESt National Green Building Report which details 562 buildings (in 2015) that achieved BOMA BESt Certification between in 2014. The report provides trends and performance results across all different types of buildings.

QOE's EUI will be benchmarked against BOMA BESt 2015 (Figure 4). QOE's EUI of 25 ekWh/ft² (270 ekWh/m²) is close to the BOMA 2015 Average EUI of 28.6 ekWh/ft² (310 ekWh/m²). When compared to the Energy Star Portfolio Manager database, the energy performance of this property is within the top 26% of Canadian office buildings.

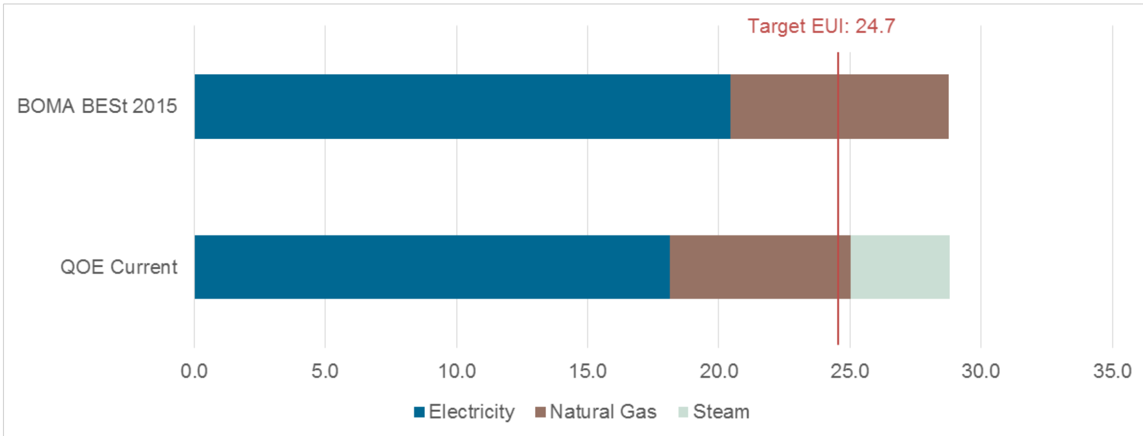

Figure 4: BOMA BBEER Average Electricity and Natural Gas Use in Ontario Compared to QOE

For Energy Star, QOE scored 73. Compared to other buildings of the same size and occupancy, the building is performing very well.

5.3 END USE BREAKDOWN

Figure 5, Figure 6, and Figure 7 present energy consumption and cost by end use. Since energy end-uses are not sub-metered at this property the breakdowns are based on an analysis of utility bills, as well as the equipment power consumption and expected runtime based on the hours of operation or if the equipment is likely to be used. For example, emergency related equipment is not part of the daily processes of a building and therefore their base load has been manually reduced by best estimates.

Heating end use includes space heating for all areas and domestic hot water heating. Energy for heating and cooling of ventilation air is identified as Ventilation (heating) and Ventilation (cooling) respectively.

Based on Figure 5, the largest energy consumers of the building are plug loads and lighting. Plug loads refer to computers and personal devices plugged in. The lighting refers to the all of the many older light fixtures that are still using the old fluorescent T8 lamps—which consume a lot of energy. A possible ECM based on Figure 5 is reducing the number of fixtures and switch over to LED lamps. With cooling, the pumps that were attached to variable frequency drives (VFDs) were found to be operating at 100% rather than a portion of the load. Recalibrating the VFD would fix this problem and reduce energy consumption. Domestic hot water heated by electricity is only used in the summer, which explains the extremely small percentage, almost making it negligible.

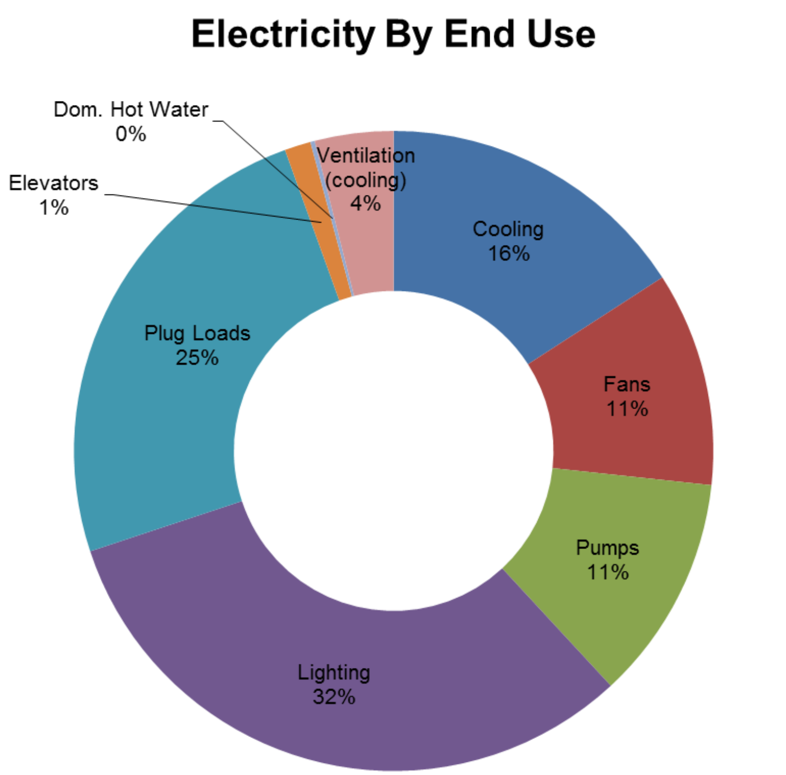

Figure 5: Electricity by End Use

In terms of overall energy, space heating is a significantly large portion of the total energy consumption at QOE's main tower as seen in Figure 6. Considering the historical portion of the building, steam is used for space heating accounts for only 3% of the total energy use. However, the argument is that the historical part of the building is smaller than the tower and would require less heating than tower. Lighting continues to be considered a large energy consumer which enforces the ECM for the lighting fixtures to be reduced and retrofit to LED fixtures. Plug loads is not a controllable factor other than educating the tenants and developing program to conserve energy throughout the work day. In comparison to the rest of the energy consumed, domestic hot water is very small in comparison, almost negligible.

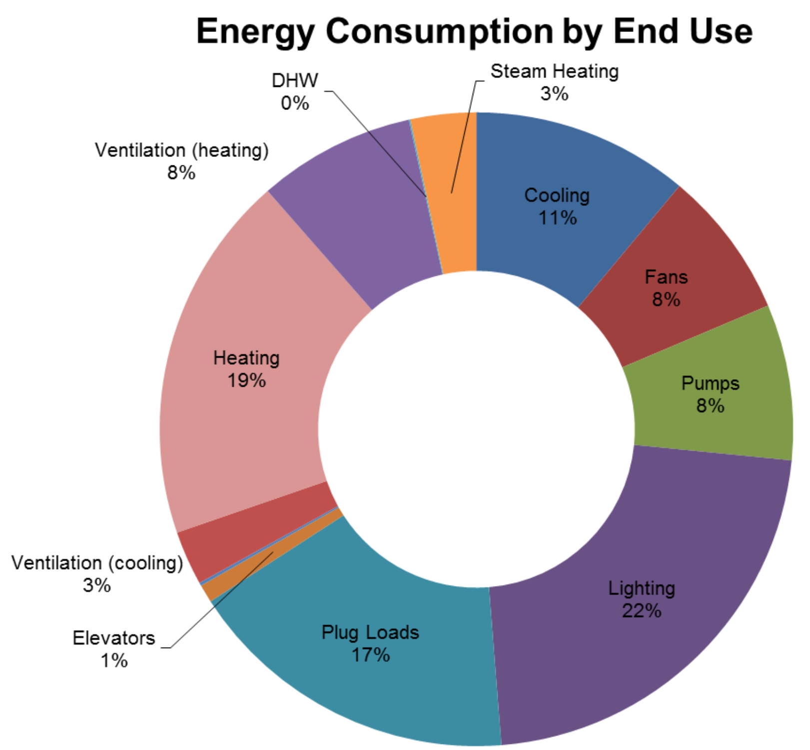

Figure 6: Energy Consumption by End Use

Based on the energy cost, electricity loads such as lighting and plug loads take is large portion of the cost due to the higher cost of electricity is high as seen in Figure **7**. Heating is fairly low at 4% and this is due to the cheap price of natural gas. In comparison to steam which is at 4%, the cost of steam is higher than for natural gas. A possible ECM would be to convert the heating of the historical building to natural gas to reduce the cost. However, the issue would be the increase in carbon emissions. Detailed analyses were done in Appendix B.

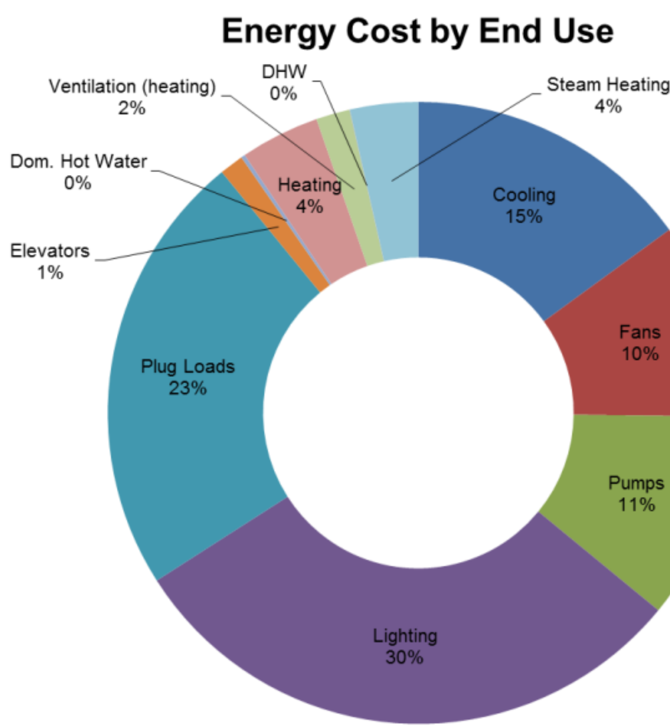

Figure 7: Energy Cost by End Use

5.4 ELECTRICITY

The plotted monthly electricity consumption in Figure 8 shows a relatively flat distribution throughout 2013-2016. It is noticed that the electricity consumption in 2016 is higher compared to previous years (2014-2015); prior to that time, retrofits have been made to the building after a level I audit and recommissioning to improve electricity efficiency such as installing T8 LED tubes for a number of floors, VFDs on heating, chilled water, and DCW booster pumps. The electricity consumption is expected to be lower than it is currently. This is an indicator that there are potentially issues with the mechanical systems.

The summer peak consumption is relatively constant between 2013, 2015, and 2016 (2014 is likely lower due to a relatively cool summers) and winter peaks are generally consistent. It may be that some VFDs are not operating as expected and therefore not providing savings where they should.

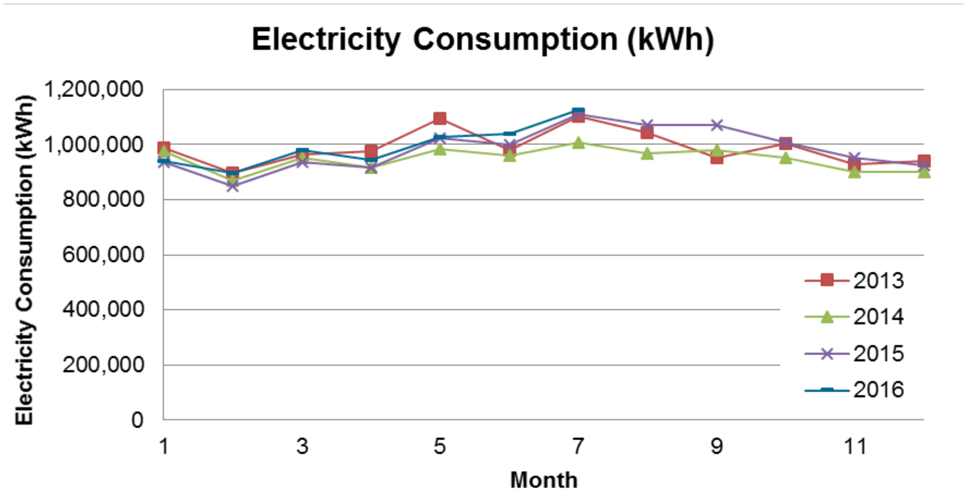

Figure 8: Electricity Consumption by Month

Based on Figure 9, there is some reduction in electricity demand for 2015 and 2016 as compared to 2013 data. Unfortunately there wasn't information for 2014. The summer peak is consistent with the operation of one of the two chillers at QOE. However for heating demand in 2015 and 2016 shows no increase in January/February; which would be indicative of electrical heating.

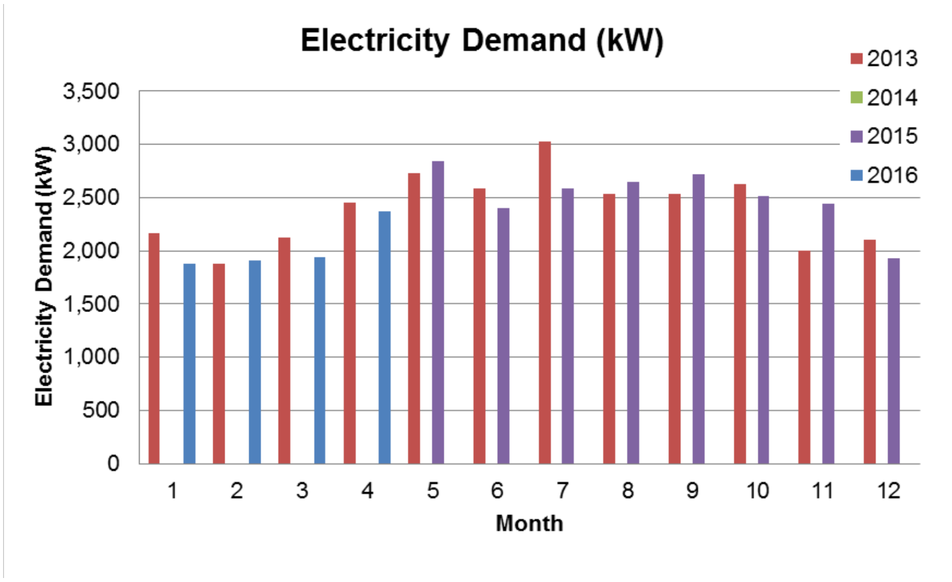

Figure 9: Electricity Demand by Month

Based on the information provided, it appears as though the cost of electricity is significantly higher in 2016 compared to previous years of 2013 to 2015 as shown in in Figure 10. This correlates with the electricity increase Figure 8**Error! Reference source not found.**. It is expected that the electricity cost will increase due to the increasing price per kWh.

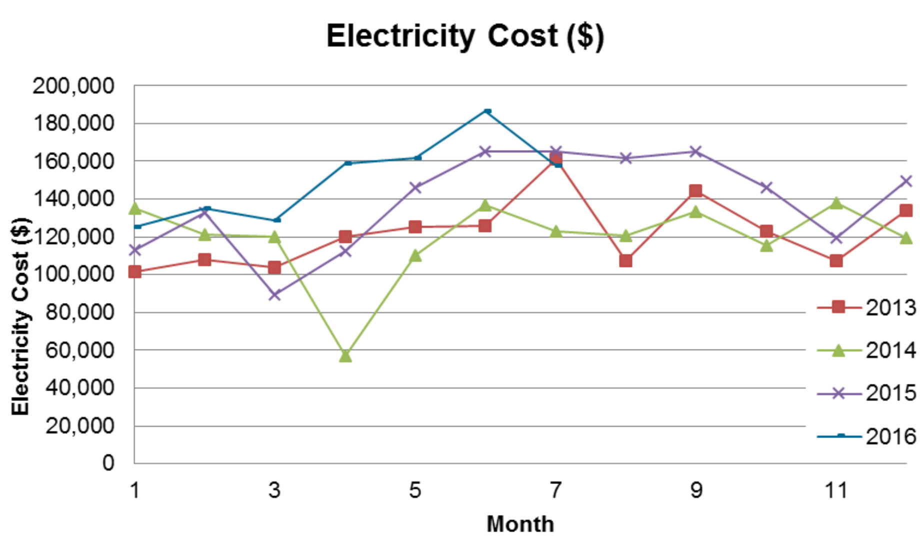

Figure 10: Electricity Cost by Month

5.5 NATURAL GAS CONSUMPTION

Figure 11 shows a profile of natural gas consumption between 2013 and 2016. Figure 12 shows the cost profile for natural gas between 2013 and 2016. The consumption and cost profile for natural gas shows a decrease in gas consumption in 2016. This is consistent with a reduction in heating degree days seen between 2015 and 2016 (Climate Canada, 2016). This profile is consistent for a commercial office building and shows little abnormalities for the last two years with exception of high heating use in September 2015.

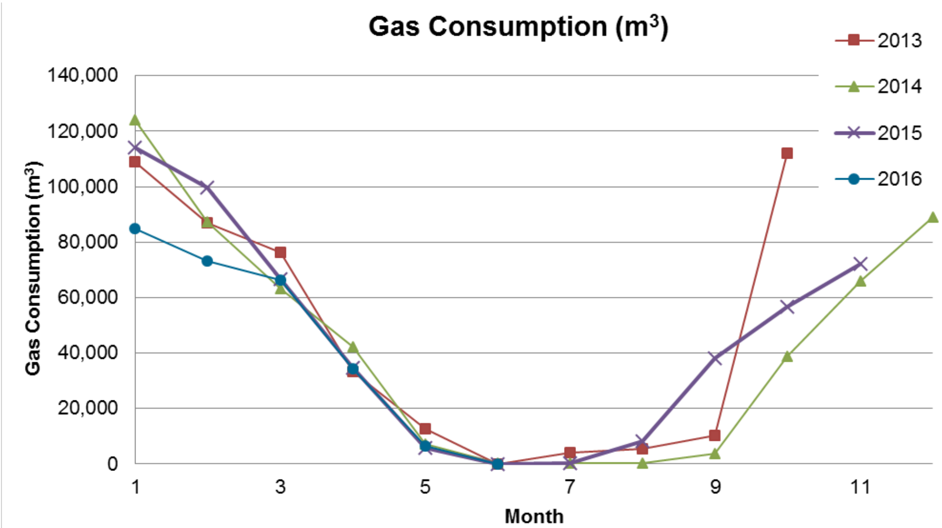

Figure 11: Natural Gas Consumption by Month

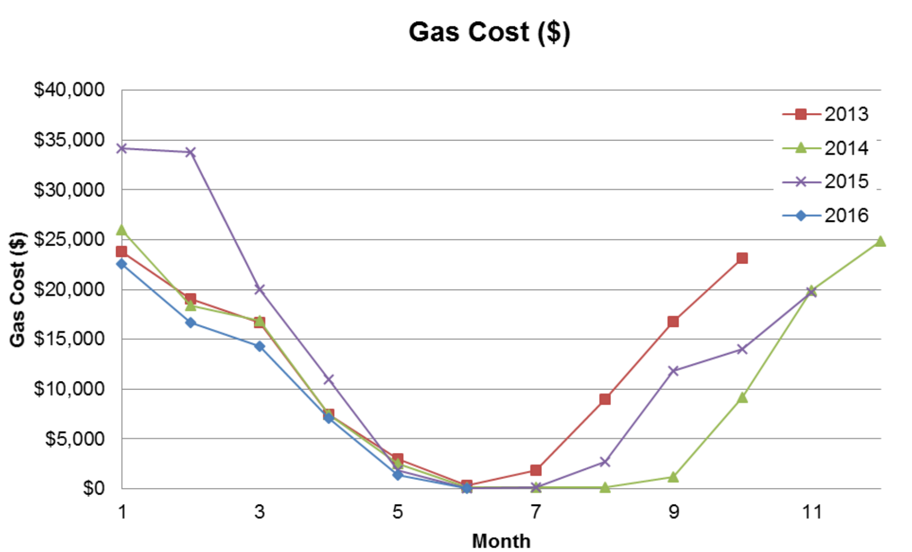

Figure 12: Natural Gas Cost by Month

5.6 STEAM

The consumption and cost profile for steam as seen in Figure 13 and Figure 14 appears normal for this building. Steam usage is generally zero from June to September as the domestic hot water is heated with an electric what heater during this time.

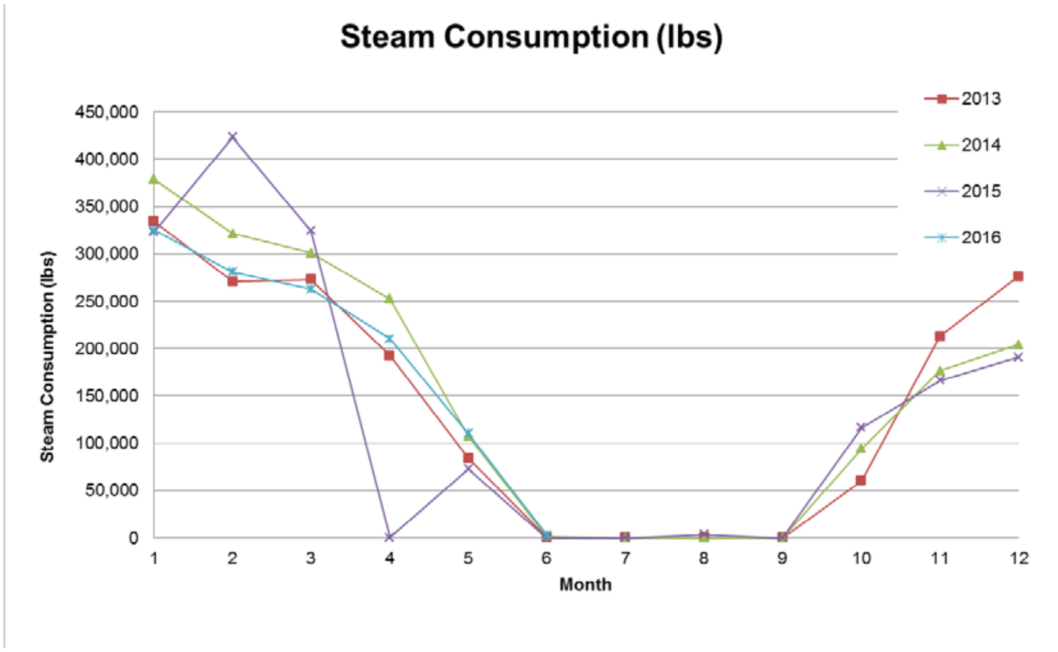

Figure 13: Steam Consumption by Month

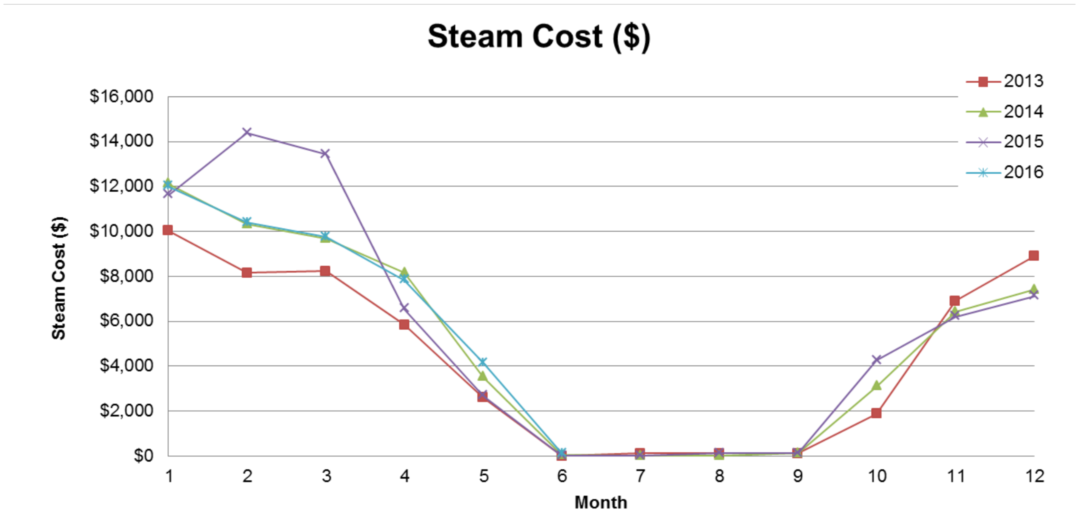

Figure 14: Steam Cost by Month

5.7 HEATING DEGREE DAY ANALYSIS

Figure 15 presents heating degree day (HDD) regression analysis. To obtain the heating degree day, a location was selected to collect weather data. In this case, Toronto was the point of reference. A base temperature must be selected to obtain the heating and cooling degree days. In this case it was 52°F (15°C) and 75°F (24°C) for heating and cooling, respectively. These values were chosen based on the highest R^2 value (based on the line of best fit) that could be obtained. The reason this was done to accurately represent the building balance point whereby at a specific temperature the heat gain is equal to the heat loss with the similar concept as cooling.

There are twelve points per year as each point represents a month. These values were normalized by dividing the HDD of a specific month by the number of days of the corresponding month. The y-axis represents the amount of natural gas used per HDD/day increase.

A review of the heating degree days and natural gas consumption indicates that the 2015 natural gas consumption per degree day has decreased compared to 2014. This is identified by the decrease with the slope of the line showing that for a given outdoor air temperature less heating energy was required. Gas use of 2015 and 2014 are fairly consistent when normalized for heating degree day.

The y intercept has almost doubled over two years; this indicates that the non-weather related loads (kitchen and domestic hot water) may have changed slightly.

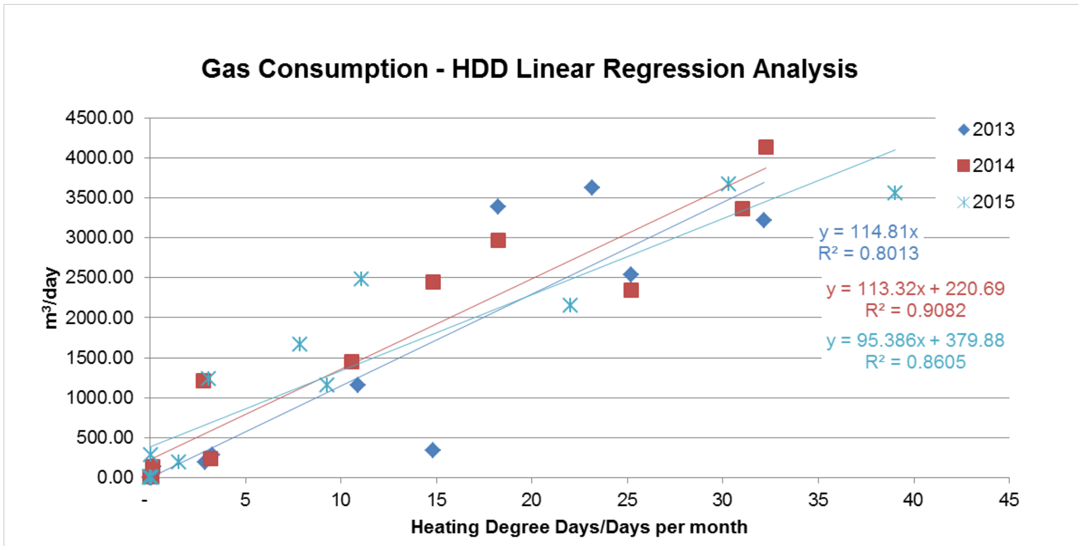

Figure 15: HDD Linear Regression Analysis for Gas Consumption

A review of the heating degree days and steam consumption indicates very little change from 2013 to 2015. Steam use of 2015 and 2014 are fairly consistent when normalized for heating degree day.

The y intercept is very similar from 2013 to 2015. This indicates that the non-weather related loads (kitchen and domestic hot water) have not made an impact in steam usage.

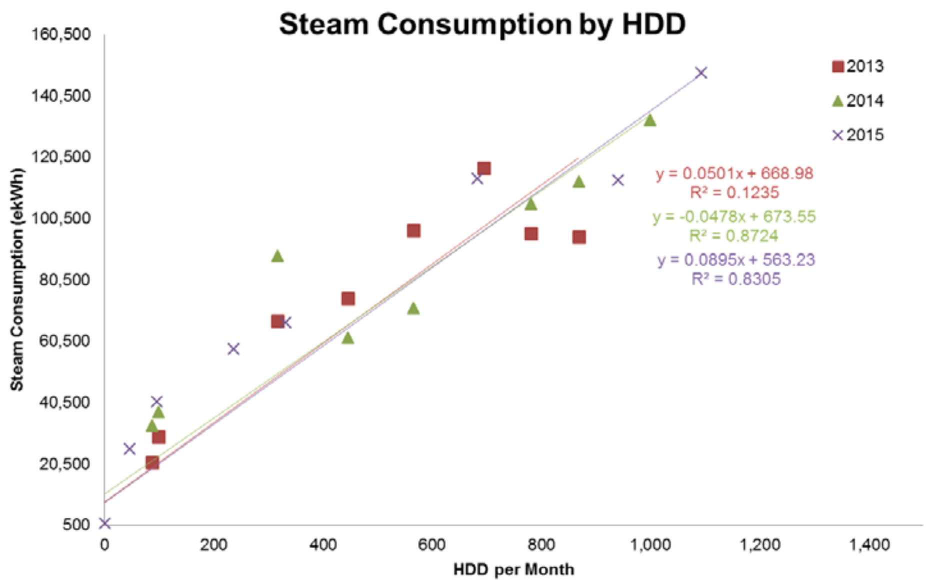

Figure 16: HDD Linear Regression Analysis for Steam Consumption

6.0 ENERGY CONSERVATION MEASURES

A summary of the no/low cost capital measures and capital measures are summarized below in Table 2. The calculations performed to obtain the potential utility savings; cost to implement and simple payback are located in Appendix D.

Table 2: ECM Summary Table for QOE

ECM	Potential Energy Conservation Measures	Utility Savings ($/yr)	Preliminary Opinion of Cost	Simple Payback (yrs)
No/Low Cost Measures				
1.1	Reduce Lighting Schedule (QOE)	$ 18,000	-	Immediate
1.2	Reduce Lighting Schedule (Historical)	$ 2,200	-	Immediate
1.3	MUA Static Pressure Setpoint	$ 3,000	$ 11,000	3.3
1.4	VFD P1/P2	$ 12,000	$ 32,000	1.1
1.5	VFD P3/P4	$ 11,000	$ 40,000	1.2
1.6	Compartment Units Operating Outside of Schedule	$ 3,400	-	Immediate
Capital Measures				
2.1a/b	Office LED and Reduction	$ 222,000	$ 1,200,000	5.4
2.2	Installing Occupancy Sensors	$ 45,000	$ 310,000	6.4
2.3	Office LED (Historical)	$ 6,000	$ 28,000	4.3
2.4	Replace Historical Steam Plant with Boilers	$ 47,000	$ 300,000	6.2

Calculations are described in Appendix D. In summary, if building management decides to implement the ECMs outlined in Table 2 and in Appendix B, the building would be:

- Saving $300,000 in utility costs annually
- Reducing total energy consumption by 1,700,000 ekWh or by 6%
- The facility's EUI would improve from 26.2 ekWh/ft^2 (282 ekWh/m^2) to 24.7 ekWh/ft^2 (266 ekWh/m^2).
- Energy Star Score would increase from 73 to 79, this would mean an increase from 2 to 8 LEED EAc1 points.
- The facility's greenhouse gas (GHG) emissions would reduce by 22 TCO_{2e}/ft^2 (237 ekWh/m^2).
- The estimated cost of upgrades would be about $ 2,100,000 with a 7 year payback.

7.0 WATER AUDIT

The purpose of the water audit is to meet the requirements of BOMA BESt Water Assessment and obtain a LEED Water Efficiency prerequisite credit (WEp1).

Both buildings have individual water meters and their own set of boosters pumps, but all information will be displayed as a single entity. During the time of the site visit, the washrooms were undergoing renovations. Only half of the floors were renovated and the rest is expected to be completed within the next year. This aligns with the 2016 water utility as the water consumption has significantly decreased in 2016 compared to previous years.

7.1 UTILITY ANALYSIS

Figure 17 and Figure 18 show water consumption and cost each month over three years. Water consumption for the year 2016 has a significant decrease to the previous years. The consumption from Jan-July 2016 has decreased by 75% over the same period of the previous year. This represents a cost decrease of almost $6000 or 36% over that same period from 2015. This additional water consumption appears to be consistent with the water consumption pattern from 2015 and does not appear to be weather related.

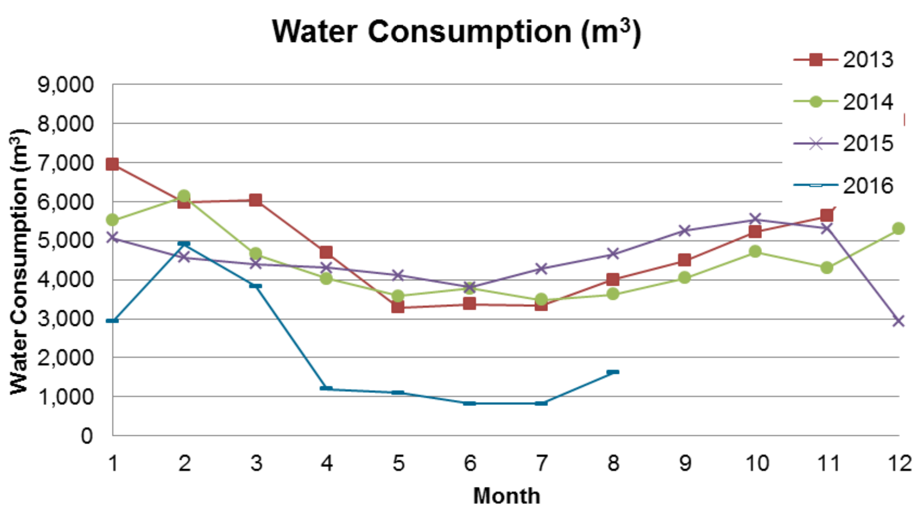

Figure 17: Water Consumption for QOE and Historical

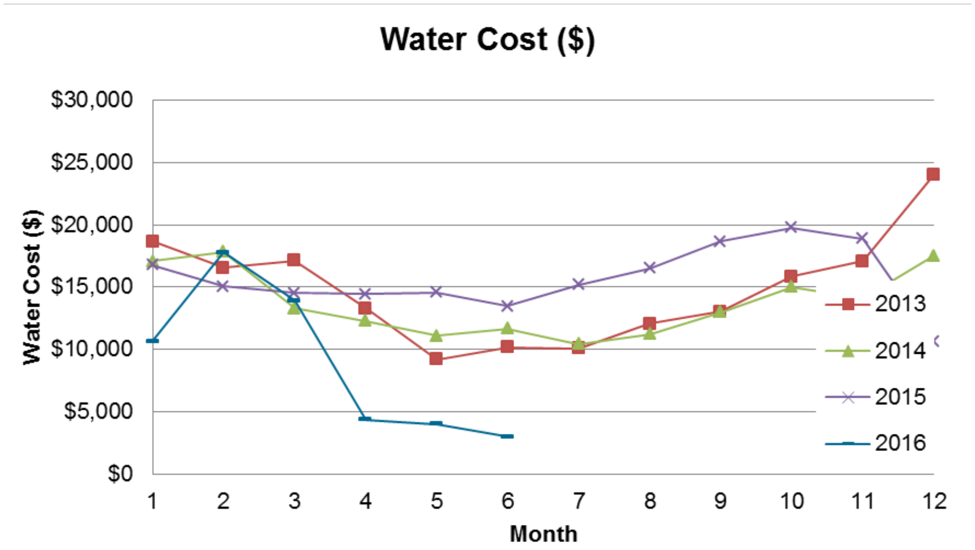

Figure 18: Water Cost for QOE and the historical building

7.2 WATER USE BREAKDOWN

The following chart shows water consumption by end use using Water Efficiency pre-requisite 1 found in the LEED Reference Guide. They include indoor plumbing fixtures and fittings, cooling towers, steam humidification, and restaurants.

All of the water related equipment was identified and inspected. Information related to quantities of equipment, water use ratings, occupancy levels, operations, and facility schedule patterns were provided by the building operator. The calculation methodology for frequency use data for plumbing fixtures were from the LEED EB:O&M.

The water use breakdown is based on available sub metering data and some were calculated based on engineering estimates. During the time of visit, not all urinals or water closets were retrofitted. It is expected that within the next year all of the washrooms would have been renovated.

To calculate the use of water from the cooling towers (evaporation and blowdown), it uses the cooling load. BOMA BESt has a method to calculate this where the cooling tower tonnage is multiplied by a factor of 1.8 gallons per hour (6.8 L/hr) (BOMA BESt Application Guide V2, 2016). Loads for the cooling towers are estimated where a certain percentage of time would be allocated. For blowdown, it is estimated that one third of the water would be used to make up blow down sessions.

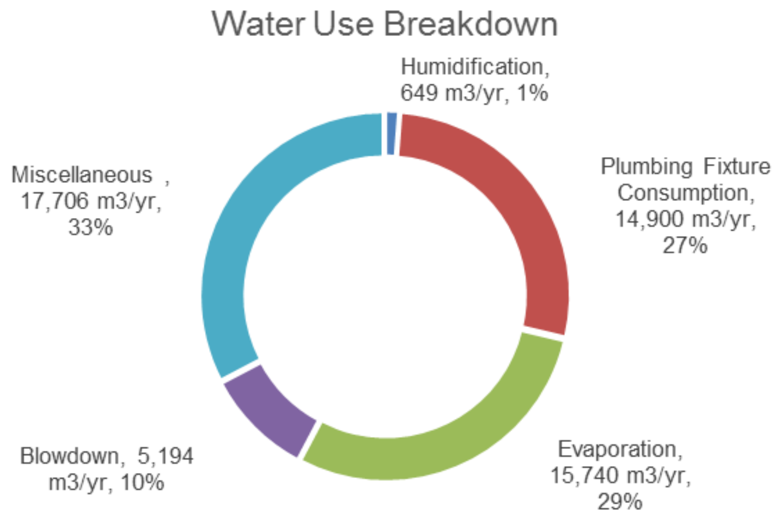

Figure 19: Water Use Breakdown

7.3 WATER CONSERVATION MEASURE (WCM)

As an opportunity, the number of lavatory fixtures have recently been replaced with low flow fixtures, however there is the possibility for future reducing water consumption at the urinals, water closets, and kitchen faucets.

All of the water fixtures will be updated to lower flow fixtures in the near future. A lot of the washrooms will be renovated with the new fixtures in the near future. The following tables show the savings for water closers and kitchen faucets.

Water Closets

Savings:		Costs:	
Utility Cost Savings:	$ 20,469	Total:	$ 139,500
Water Use (m^3)	1,256 m^3/year	Simple Payback (yrs):	6.8

Kitchen Faucets

Savings:		Costs:	
Utility Cost Savings:	$ 862	Total:	$ 3,600
Water Use (m^3)	248 m^3/year	Simple Payback (yrs):	4.2

To makes these changes are well worth the investment to reduce water usage for the building.

7.4 BENCHMARKING

The building was benchmarked against BOMA BESt average Water Use Intensity. Based on Figure 20 below, the water use intensity was calculated to be 0.88 m^3/m^2/year (BOMA Canada, 2016). There are still improvements to be made to improve the water efficiency at this property.

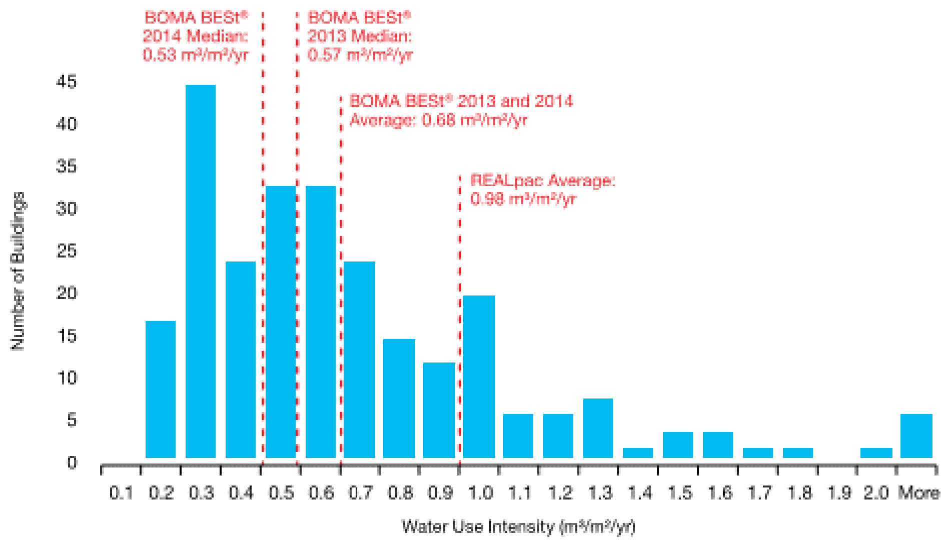

Figure 20: BOMA BESt Average Water Use Intensity (BOMA Canada, 2015)

8.0 CUMULATIVE SUMMARY (CUSUM)

The CUSUM method is used for this case to determine the energy use of QOE and the historical building leading back to the first commissioning report back in 2012. The regression data was used to generate predicted consumption values (baseline). The CUSUM is the sequential analysis technique of partial sums. A regression equation based on the data over the selected time period is used. This is seen as a baseline predicted. The predicted values are measured against the actual values. If the actual value is higher than the predicted value, it is seen to be using more energy than predicted and vice versa if the actual value is less than the predicted value. The difference between the predicted and actual values per month is partial sums and they are sequentially added. This is used to monitor building performance over a time sequence.

8.1 ELECTRICITY

The CUSUM graph can be seen below in Figure 21. The first month refers to January 2012 and continues until October 2016. Previous measures can be seen in Appendix B.

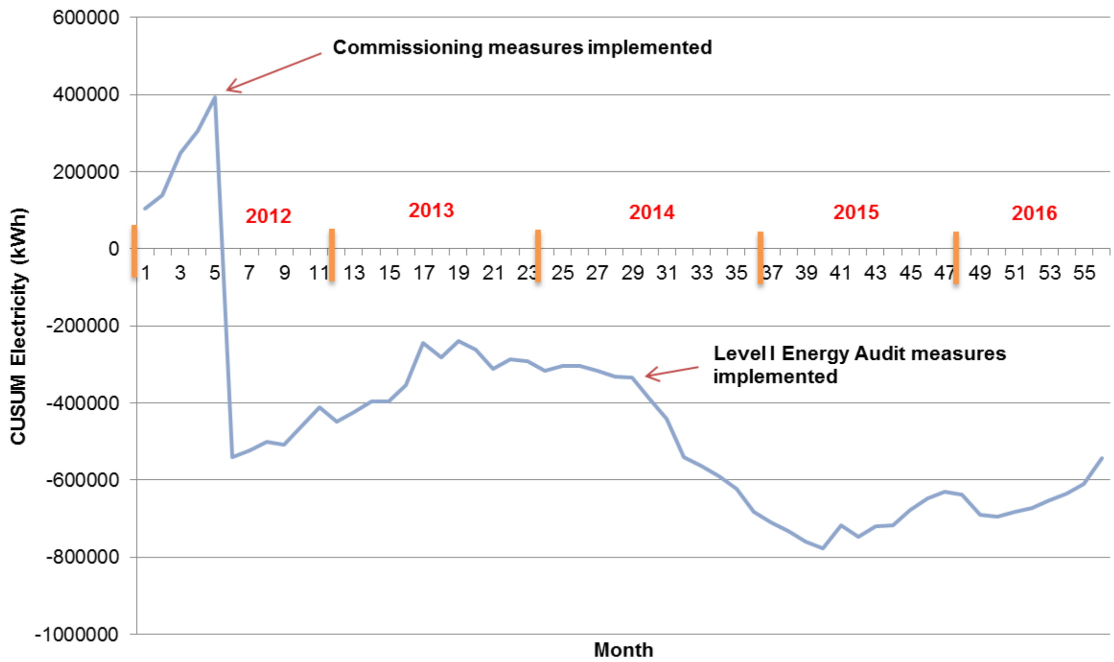

Figure 21: CUSUM for Electricity

For the CUSUM graph, any positive values represent that for that month, the energy consumption is much higher than the baseline predicted value. As months continue, it is seen that there is a shift; this represents the energy consumption to be much less than what was predicted. The negative values show that the energy consumption continues to be below the predicted values.

Considering that the first commissioning report was at the beginning of January 2012, there was a significant change in June of that year which indicates that adjustments were made to the cooling system around that time to reduce the amount of electricity being used in the system. Items which could possibly be mentioned were: raise water temperature setpoint to be higher for the condenser valve as the cooling tower was cooling the condenser water more than necessary, adjust the sequence of operations to not run the pumps during free cooling mode, reducing outdoor air flow as the make up air unit is providing excess air into the building, and reducing tenant override time and only scheduling for certain floors where tenants expect to be occupied past normal building hours. These are some of the examples of where extra electricity is being consumed.

It can be seen that from months July 2012 to May 2014 (months 7 to 29), the electricity consumption was steadily increasing again. The first energy audit (Level 1) was provided to building management in June

2014 (month 30). The main suggestion for that energy audit was to reduce the load of the pumps by installing VFDs. This would decrease the load from 100% to around 75% (based on the BAS when the site visit was performed). As shown in the trend, there was a drop in electricity use until April 2015 (month 40) when electricity consumption began to increase again. This can be caused by changing setpoints due to uncomfortable tenants and forgetting to change it, causing system inefficiencies.

Based on the ECMs provided based on the Level II audit, it is expected that the CUSUM trend will decrease again but at a better rate than when ECMs for the Level I audit was performed. This was based on the more investigation of the inefficiencies of the equipment. This needs to be monitored to determine that amount of electricity which will be used after changes are implemented.

8.2 HEATING (NATURAL GAS AND STEAM)

For the purposes of this analysis, steam was converted into m^3 equivalent to include the Historical Building. The CUSUM for this graph can be seen in Figure 22.

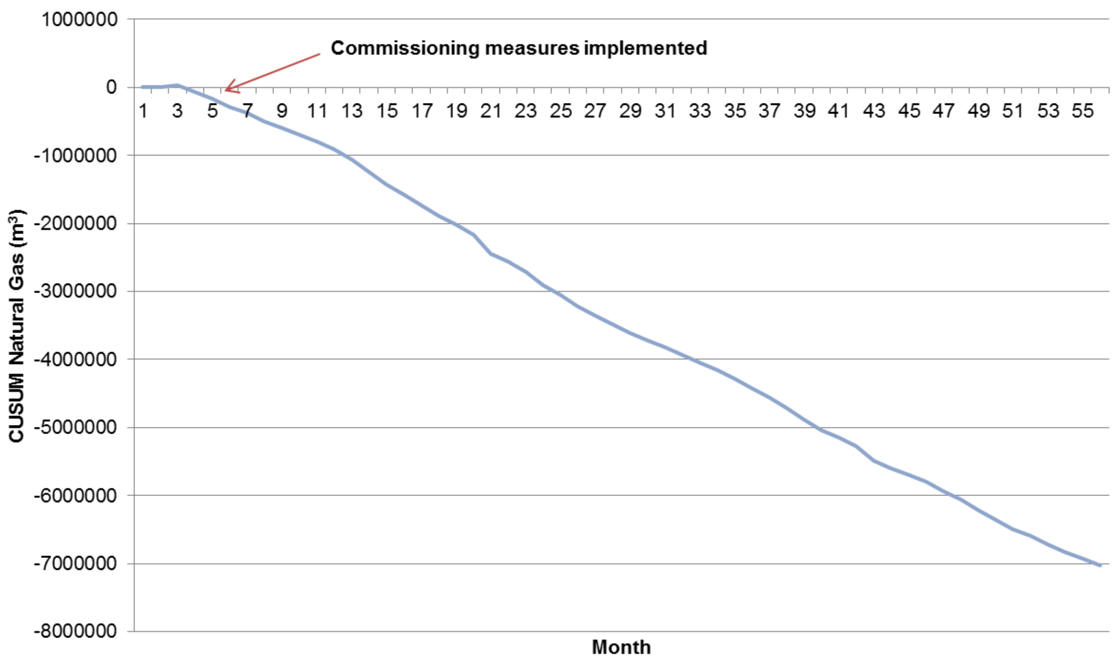

Figure 22: CUSUM for Natural Gas

The first re-commissioning report was released on the first month of that year. Since then, the amount of heat used for each month has been decreasing at a steady pace. This indicates that very little has changed since the first re-commissioning visit. Very little suggestions were made. There is also a change in HVAC schedule to turn off on floors that are not occupied. These change in strategies benefit the building.

Based on the ECMs provided above, it is expected that the natural gas usage will continue to decrease as the building owner is thinking to replace their current boilers with newer higher efficiency boilers. The trend would expect to be steeper.

9.0 CONCLUSIONS

Based on the utility analysis and ECMs suggested, a Level II Energy Audit is much more valuable to a building manager compared to a Level I Energy Audit. While Level I Energy Audits are more high level, it misses evaluating the economic savings. A Level I audit consists of only reviewing major problem areas. In this case study, the only suggested ECMs was to install VFDs for all pumps and LED light fixtures. This helped the energy consumption significantly; however they were easy suggestions without the cost implication.

This is essential for the building owner or management for decision making. More in-depth engineering calculations are involved to portray more accurate financial analysis. The building management is presented with energy savings, costs to implement ECMs and expected payback period. This level of detail provides the building management with a comprehensive level of the financial benefits to implement the suggested ECMs. The financial analysis also justifies specific energy saving projects.

APPENDIX A – SUMMARY ENERGY CONSERVATION TABLE

APPENDIX B – ANALYSIS OF ENERGY CONSERVATION MEASURES

The following presents the analysis of all measures reviewed. This analysis is broken into four sections: no/low cost measures, capital measures, other measures, and impractical measures. Please refer to Appendix A for the ECM summary table that details, energy savings, cost savings, measure costs, and payback.

B.1 NO/LOW COST MEASURES

ECM 1.1 REDUCE LIGHTING SCHEDULE (QOE)

Opportunity: The current base building lighting schedule differs for each floor, but averages 6:30am to 10:30pm. Occupants have the ability call in afterhours lighting with off sweeps on a one hour schedule. Based on a review of compartment unit schedules to lighting schedules there are a number of floors with lighting schedules that exceed compartment unit schedules by 2 to 6 hours (including floors: 8, 9, 11, 12, 15, 16, 18, 19, 20, 25, 26). Reducing the base building lighting schedule to match HVAC schedule if acceptable to tenants would provide significant savings.

Scope: Engage tenants to understand their actual occupancy schedule. Work with individual tenants to set up a schedule that works for their occupants on a regular basis and make sure that all tenants know how to turn on lighting outside of scheduled times. Savings below assume an average 1 hour reduction per day.

Economic Analysis:

Savings:			Costs:		
Utility Cost Savings:	$	18,000	Materials & Labour:	$	-
Electricity Demand:		0 kW	Engineering:	$	-
Electricity Use:		140,000 kWh	Possible Incentive:	$	-
Natural Gas Use:		0 m³	Total:	$	-
GHG Reduction:		15 TCO_{2e}	Simple Payback (yrs):	Immediate	

ECM 1.2 REDUCE LIGHTING SCHEDULE (HISTORICAL)

Opportunity: The current base building lighting schedule differs for each floor, but averages 7:30am to 10:00pm. Occupants have the ability call in afterhours lighting with off sweeps on a one hour schedule. Similar to QOE, the lighting appears to be scheduled in excess of 2 hours beyond HVAC hours reducing the base building lighting schedule to match HVAC schedule if acceptable to tenants would provide significant savings.

Scope: Engage tenants to understand their actual occupancy schedule. Work with individual tenants to set up a schedule that works for their occupants on a regular basis and make sure that all tenants know how to turn on lighting outside of scheduled times. Savings below assume an average 1 hour reduction per day.

Economic Analysis:

Savings:			Costs:		
Utility Cost Savings:	$	2,200	Materials & Labour:	$	-
Electricity Demand:		0 kW	Engineering:	$	-
Electricity Use:		17,000 kWh	Possible Incentive:	$	-
Natural Gas Use:		0 m³	Total:	$	-
GHG Reduction:		2 TCO_{2e}	Simple Payback (yrs):	Immediate	

ECM 1.3 MAKEUP AIR UNIT STATIC PRESSURE SENSORS AND CONTROL

Opportunity: Office ventilation unit has a static pressure setpoint of 1.00 in.wc however the static pressure sensor was showing readings of 0.03 in.wc to 0.05 in.wc. There is likely a malfunction with the sensors, correcting this will allow the fan to modulate to maintain the correct static pressure setpoint.

Scope: Check operation of the static pressure sensors for the office ventilation unit. Repair or replace as necessary. For the purpose of the savings presented below it has been assumed that a 10% reduction in fan speed and airflow can be achieved while maintaining adequate ventilation air.

As part of the LEED recertification process, outdoor air calculations and airflow testing will be required for each compartment unit to demonstrate sufficient outdoor air is being provided. During this process it may worthwhile to test flow at a lower static pressure setpoint to provide further fan power savings.

Economic Analysis:

Savings:			Costs:		
Utility Cost Savings:	$	18,000	Materials & Labour:	$	-
Electricity Demand:		0 kW	Engineering:	$	-
Electricity Use:		92,000 kWh	Possible Incentive:	$	-
Natural Gas Use:		25,000 m³	Total:	$	-
GHG Reduction:		57 TCO_{2e}	Simple Payback (yrs):	Immediate	

ECM 1.4 PRIMARY CHILLED WATER PUMP (P1/P2) VFD CONTROL

Opportunity: Chilled water pumps have been upgraded with VFDs. These pumps were operating on automatic with P1 at 100% and P2 at 0%. It appears that the energy savings associated with VFD follow control is not being attained.

Scope: System flow balancing and setpoints should be reviewed. Based on prior energy audit a flow reduction of 30% was recommended. The savings presented below assume that the 30% reduction is achievable.

Economic Analysis:

Savings:			Costs:		
Utility Cost Savings:	$	15,000	Materials & Labour:	$	-
Electricity Demand:		21 kW	Engineering:	$	-
Electricity Use:		97,000 kWh	Possible Incentive:	$	-
Natural Gas Use:		0 m³	Total:	$	-
GHG Reduction:		11 TCO_{2e}	Simple Payback (yrs):	Immediate	

ECM 1.5 CONDENSER WATER PUMP (P3/P4) VFD CONTROL

Opportunity: Condenser water pumps have been upgraded with VFDs. These pumps were operating on automatic with P3 at 100% and P4 at 0%. It appears that the energy savings associated with VFD follow control is not being attained.

Scope: System flow balancing and setpoints should be reviewed. Based on prior energy audit a flow reduction of 20% was recommended. The savings presented below assume that the 20% reduction is achievable.

Economic Analysis:

Savings:			Costs:		
Utility Cost Savings:	$	11,000	Materials & Labour:	$	-
Electricity Demand:		34 kW	Engineering:	$	-
Electricity Use:		53,000 kWh	Possible Incentive:	$	-
Natural Gas Use:		0 m³	Total:	$	-
GHG Reduction:		6 TCO_{2e}	Simple Payback (yrs):	Immediate	

ECM 1.6 COMPARTMENT UNITS OPERATING OUTSIDE OF SCHEDULE

Opportunity: Trends show compartment units on floors 8, 11, 16, 19, 24, and 26 and being used over the weekend when there are no scheduled operating time for those units according to the standing HVAC hours. They will need to be readjusted to be turned off when the floors are empty over the weekend.

Scope: Review standing HVAC hours against compartment unit schedule and VFD power trends. Adjust schedule of compartment units to match HVAC standing hours.

Economic Analysis:

Savings:			Costs:		
Utility Cost Savings:	$	3,400	Materials & Labour:	$	-
Electricity Demand:		0 kW	Engineering:	$	-
Electricity Use:		26,000 kWh	Possible Incentive:	$	-
Natural Gas Use:		0 m³	Total:	$	-
GHG Reduction:		3 TCO_{2e}	Simple Payback (yrs):	Immediate	

B2. CAPITAL MEASURES

ECM 2.1(A) OFFICE LED LAMP REPLACEMENT

Opportunity: There is an opportunity to reduce electricity consumption for lighting by replacing the existing fluorescent lamps with LED replacement tubes. Based on past reports we understand that the fixtures have been re-lamped previously with 28 W energy saving fluorescent lamps however we did note that 32W lamps are still present in the lighting storage room. For the purpose of calculating savings we have assumed replacing a 28W fluorescent lamp with a 17 W LED lamp.

Scope: Replace existing fluorescent lamps with 17 W LED replacement lamps. These lamps should be tested in a small area to confirm that light levels and colour is correct prior to completing a full re-lamp.

Economic Analysis:

Savings:			Costs:		
Utility Cost Savings:	$	40,000	Materials & Labour:	$	180,000
Electricity Demand:		69 kW	Engineering:	$	-
Electricity Use:		250,000 kWh	Possible Incentive:	$	13,000
Natural Gas Use:		0 m³	Total:	$	170,000
GHG Reduction:		28 TCO_{2e}	Simple Payback (yrs):		4.3

ECM 2.1(B) FULL LIGHTING SYSTEM RETROFIT

Opportunity: As an alternative option to ECM 2.1 (a) Office LED Lamp Replacement, the entire lighting system can be retrofitted and modernized. This will allow for a higher control of occupant lighting and better lighting quality. This was reviewed by Smith + Andersen in August. The results have been adjusted to account for consumption and demand costs and now a labour cost allowance.

Scope: Replace lighting control system and remove and replace fixtures on a new grid pattern that allows for more efficient lighting. Refer to S+A report for more detailed information.

Economic Analysis:

Savings:			Costs:		
Utility Cost Savings:	$	140,000	Materials & Labour:	$	1,600,000
Electricity Demand:		140 kW	Engineering:	$	-
Electricity Use:		990,000 kWh	Possible Incentive:	$	56,000
Natural Gas Use:		0 m³	Total:	$	1,500,000
GHG Reduction:		109 TCO_{2e}	Simple Payback (yrs):		10.7

ECM 2.2 OFFICE LED (HISTORICAL)

Opportunity: There is an opportunity to reduce electricity consumption for lighting by replacing the existing fluorescent lamps with LED replacement tubes. Based on past reports we understand that the fixtures have been re-lamped previously with 28 W energy saving fluorescent lamps however we did note that 32W lamps are still present in the lighting storage room. For the purpose of calculating savings we have assumed replacing a 28W fluorescent lamp with a 17 W LED lamp.

Scope: Replace existing fluorescent lamps with 17 W LED replacement lamps. These lamps should be tested in a small area to confirm that light levels and colour is correct prior to completing a full re-lamp.

Economic Analysis:

Savings:			Costs:		
Utility Cost Savings:	$	6,000	Materials & Labour:	$	28,000
Electricity Demand:		10 kW	Engineering:	$	-
Electricity Use:		38,000 kWh	Possible Incentive:	$	1,900
Natural Gas Use:		0 m³	Total:	$	26,000
GHG Reduction:		4 TCO_{2e}	Simple Payback (yrs):		4.3

B3. OTHER MEASURES

ECM 3.1 REVIEW DCW1 SETPOINT FOR OVERNIGHT USE

BAS trends show domestic cold water booster pump's VFD operating at 76% overnight compared to 81% during the daytime hours. Domestic water consumption and pump setpoints should be reviewed to determine cause of high flow afterhours.

ECM 3.2 UPDATE MISSING INFORMATION FROM EQUIPMENT BINDER

We noticed that there were some missing equipment data sheets from the equipment binder this binder should be updated as equipment is modified, updated, and changed.

ECM 3.3 DCW2 NOT CONNECTED TO BAS

Domestic cold water booster pump 2 is currently not connected to the BAS. The operators indicated repairs were required.

ECM 3.4 REDUCE FAN SCHEDULE FOR COOLING TOWER

BAS status trends show Cooling Tower 2 Fan 1 turning on and then immediately off on Saturday and Sunday morning at approximately 8:00am. The sequences should be reviewed to determine the cause of this and corrected.

ECM 3.5 CONDENSER WATER PUMP TREND DATA NOT CORRECT

BAS trend shows Condenser Water Pump as off, but the BAS graphics shows that pump is running.

ECM 3.6 CO MONITORING SENSORS

The parking garage CO Monitoring system and exhaust fans were not communicating with BAS at time of our site visit.

ECM 3.7 RETURN FAN 1 INLET VANES NOT FULLY OPEN

During our site visit it was noted that the inlet vanes on Return Fan 1 are not fully open, this may be causing some loss in energy savings from the VFD.

ECM 3.8 EQUIPMENT SCHEDULES

Equipment schedules noted during the site visit the length of time increased compared to schedules noted during prior energy audit and commissioning reports. The increase is in response to tenants requesting longer HVAC hours and it was noted that other systems have increased somewhat as well. It was recommended that building management reviews the schedules of each of the systems to confirm that schedules are set correctly for each space/system served.

ECM 3.9 NO RETURN AIR TEMPERATURE SENSOR FOR 24TH FLOOR COMPARTMENT UNIT

This compartment unit does not appear to have a return air temperature sensor on the BAS. As a result, there is no return air temperature reset schedule. During the time of the site visit this unit was found to be operating with a Supply Air Temperature of 13.3°C with a relatively high VFD output of 72%. This unit is providing air much cooler than the other units, however without a Return Air Temperature sensor it is unclear if the space is being overcooled.

B4. MEASURES REQUIRING FURTHER ANALYSIS

ECM 4.1 REPLACE BOILER PLANT

Opportunity: There is an opportunity to save approximately $10,000 in natural gas costs by replacing boilers with more efficient units such as forced air draft boilers. The savings assumes a replacement with high efficiency natural gas boilers, but not condensing boilers. Based on the current boiler temperature schedules the high temperature required to provide adequate heating capacity would likely not allow condensing boilers to operate in the condensing range without modifications to the system being made.

Additionally, if the steam heating used in Historical were to be replaced with hot water generated by natural gas boilers an additional $47,000 in utility costs can be saved. The location of the mechanical room in the basement of Historical makes venting of boilers a likely difficult and expensive task. It may be more cost effective to add additional capacity to QOE and tie Historical into the hot water loop.

Additional Information Required: While significant savings are possible, a detailed review is required to determine the feasibility and costs of providing a hot water link between QOE and Historical similar to the chilled water link.

ECM 4.2 REPLACE/UPGRADE CHILLED WATER PLANT

Opportunity: There is in opportunity to replace or upgrade the chillers to be more efficient when operating. Based on detailed reviews of similar sized cooling plants, and based on previous reports annual savings on the order of $100,000 may be possible. The plant replacement or upgrade could include variable speed control of the primary chilled water pumps, condenser water pumps, cooling tower control, and variable speed chiller.

Additional Information Required: In order to determine the performance of the current plant and possible savings (and incentives available) it is recommended that the current plant power consumption and cooling load be monitored during the next cooling season to provide a better determination of what cooling load is required. If chillers are planned to be replaced or upgraded, this metering is required to obtain the maximum amount of incentive payment.

ECM 4.3 REPLACE ELECTRICALLY HEATED ROOF TOP UNITS

Opportunity: There is an opportunity to reduce electricity consumption by replacing the electrically heated rooftop units with hydronic heating. Note that while this will lower utility costs, it will increase the greenhouse gas consumption at the property.

Additional Information Required: Based on conversations with building operations we understand these units are owned by the tenant.

B5. PRIOR MEASURES RECOMMENDED

As part of this process we have reviewed the past energy audit to determine progress of implementing prior Energy Conservation Measures (pECMs).

pECM 1: Review Lighting Schedule for Normal Occupancy. Based on conversations with the building operator, the lighting schedules have been adjusted to turn off lighting as soon as tenant allows.

pECM 2: Review Lighting Schedule for Janitorial Usage. Based on conversations with the building operator, the lighting schedules have been adjusted to turn off lighting as soon as tenant allows.

pECM 3: Occupancy Sensors in Back-of-House Corridors. Back-of-House corridors and emergency stairwells have had lighting upgraded to 2 stage occupancy controlled lighting.

pECM 4: VFD for Chilled Water Pumps (P-1/2). Chilled water pumps have been upgraded with VFDs. These pumps were operating on automatic with P1 at 100% and P2 at 0%. It appears that the benefits of a VFD are not being used.

pECM 5: VFD for Condenser Water Pumps (P-3/4). Condenser water pumps have been upgraded with VFDs. These pumps were operating on automatic with P3 at 100% and P4 at 0%. It appears that the benefits of a VFD are not being used.

pECM 6: VFD for Primary Heating Pumps (P-5/6). Primary heating pumps are not equipped with VFDs. This is not recommended for an older boiler system. When the boiler plant is upgraded VFDs should be revisited.

pECM 7: VFD for Heating Water Pumps (P-7/8). Heating water pumps have been upgraded with VFDs. These pumps were not operating during our site visit because heating was not required.

pECM 8: VFD for Secondary Chilled Water Pumps (P-10/11). Secondary chilled water pumps have been upgraded with VFDs. These pumps were operating on automatic with P10 at 0% and P11 at 65%.

pECM 9: VFD for Spray Coil Pump (P-12). A VFD was not installed on the spray coil pump. This would not normally be recommended as a VFD would lower the pressure available and degrade the quality of the spray.

pECM 10: VFD for Secondary Chilled Water Pump (P-44). Secondary chilled water pump has been upgraded with a VFD. This pump was running in automatic at 74% at time of site visit.

pECM 11: VFD for DCW Booster Pump (P-17/18). DCW booster pumps have been upgraded with VFDs. Pump 17 was not operating due to maintenance problems, Pump 18 was operating at 81%.

pECM 12: Scheduling of Supply Fan. During the site visit this unit appeared to operate on a normal schedule.

pECM 13: Additional Recommissioning Measures. During the site visit is appeared that the office and atrium supply fans could benefit from retro-commissioning, or at minimum a review of sequences and calibration of sensors. During the site visit it was noticed that the atrium supply fans was operating with dampers set for minimum outside air and the chilled water valve open at 37%. Outside air temperature was 4°C cooler than return air temperature; it is likely that the free cooling setpoint can be raised higher to benefit more from outside air free cooling.

Similar behavior was visible in the supply fans in the mechanical rooms, in which there are likely savings available by raising the free cooling setpoint.

pECM 14: Soft Starter for Second Chiller. From our understanding chillers are planned for replacement in the next couple of years, additional capital spent on chillers will not likely payback in the short life remaining.

pECM 15: Dynamic Reset of Cooling Tower Setpoint. It appears that the cooling tower still has a static setpoint, a reset schedule would provide energy savings when the outside air wet bulb temperature is high.

pECM 16: Energy Awareness of Program. We are unaware of any energy awareness programs in place. However operations staff are cognizant of energy consumption of the systems and operate equipment to reduce energy consumption to the best of their ability.

pECM 17: Conversion of Historical Heating from Steam to Natural Gas. This has not been completed. Saving estimated from switching to natural gas is estimated at $41,000. Instead of bringing natural gas into Historical, where venting boilers from the basement mechanical room would be difficult, it may be possible to bring heating water over from QOE, similarly to how chilled water system was shared. We recommend that this be reviewed prior to replacing the boilers at QOE.

pECM 18: Conversion of Historical DHW from Steam / Electric to Natural Gas. This has not been completed. While bringing in building heating water may be available from QOE may be feasible, bringing in domestic hot water is less likely. However, based on the relatively low load of domestic hot water in the building the best option of savings may be local electric domestic hot water heaters.

APPENDIX C - BUILDING INFORMATION

General Details			
Customer Name	Intentionally Removed for Confidentiality		
Location of Facility	Toronto, Ontario		
Contact	Intentionally Removed for Confidentiality		
Contact Title	Intentionally Removed for Confidentiality		
Contact Phone	Intentionally Removed for Confidentiality		
Contact E-mail	Intentionally Removed for Confidentiality		
Primary Activity	Commercial (Office and Retail)		
Typical Occupancy Schedule for Facility	6:00 am to 7:00 pm		
Typical Lighting Schedule	6:00 am to midnight		
Typical HVAC Schedule	6:00 am to midnight		
Facility Occupancy (approximate # people)	2495		
GFA	600,000 ft^2	Storeys:	30
Building Construction:	Steel Framed		
Cladding:	Curtain Wall System with approximate 60% window to wall ratio		
Parking:	3 levels of below grade parking are present on P2-P4. P1 is the concourse level.		
Heating :	Five boilers (5,000 MBH input, 4,000 MBH output) heat the hot water loop for QOE. The heating loop is configured in a primary secondary loop with constant volume primary pumps and variable volume secondary pumps. The secondary loop provides hot water for space heating via perimeter wall fin heating, ventilation air tempering via hot water coils, and ground floor heating via fan coil		

units.

Primary Heat Pumps

ID	Make	Model No.	Motor Size (hp)
P-5	S.A. Armstrong	-	7.5
P-6	S.A. Armstrong	-	7.5

Secondary Heat Pumps

ID	Make	Model No.	Motor Size (hp)
P-7	S.A. Armstrong	-	50
P-8	S.A. Armstrong	-	50

District steam heating provides heat to the fan coil units via shell and tube heat exchangers in Historical.

Cooling:

Cooling for both buildings is provided by a chilled water plant located in the QOE penthouse. The system consists of two Trane Centrifugal Chillers (CHE089) chillers, with an original capacity of 900 tons each. The machines have since had the capacity reduced to 859 tons following the conversion to R123 refrigerant in 2009.

Heat is rejected to two 2-cell cooling towers with variable speed fans. The chilled water loop uses a plate-and-frame heat exchanger. Water-side free cooling can be performed.

The general schedule of the chiller is from 5am to 11pm.

Primary Chilled Water Pumps

ID	Make	Model No.	Flow Setpoint (gpm)	Motor Size (hp)
P-1	S.A. Armstrong	-	600	50
P-2	S.A. Armstrong	-	600	50

Secondary Chilled Water Pumps

ID	Make	Model No.	Flow Setpoint (gpm)	Motor Size (hp)
P-10	Aurora	-	1050	40
P-11	Aurora	-	1050	40

Condenser Water Pumps

ID	Make	Model No.	Motor Size (hp)
P-3	S.A. Armstrong	-	75
P-4	S.A. Armstrong	-	75

Ventilation:

QOE: Each floor has its own Compartment Unit VAV system except for floors 4 and 5 (these share the compartment unit).

Each compartment unit receives ventilation air form SF-26 the makeup air unit.

Additional air handling unis serve the following spaces:

- Atrium
- Restaurant
- Concourse

The parking garage has CO/NOx sensors to control ventilation in the space.

Compartment Units

ID	Make	Model No.	Floors Serviced	Flow Rate (cfm)
SF-7	Trane	-	27th Floor	16500
SF-8	Trane	-	26th Floor	18000
SF-9	Trane	-	25th Floor	16500
SF-10	Trane	-	24th Floor	19500
SF-11	Trane		23rd Floor	19500
SF-12 to SF-25	Trane		8th to 22nd Floor	20000 each
SF-38	Trane	-	4th to 5th Floor	14000
SF-39	Trane	-	3rd Floor	14000

SF-40	Trane		2nd Floor	9000

Supply Air

ID	Make	Model No.	Areas Serviced	Flow Rate (cfm)
SF-26	Chicago Blower	-	Office Make Up Air	55000
SF-27	Chicago Blower	-	Atrium Supply Air Unit	45400

Historical: Outdoor air is provided to floors 1-4 by SF-51 and 5&6 by SF-52 each being VAV systems. The seventh floor is served by electric roof top units.

ID	Make	Model No.	Areas Serviced	Flow Rate (cfm)
SF-51	N/A	N/A	Office Make Up Air	55000
SF-52	N/A	N/A	Office Make Up Air	45400

General Schedule per Floor

ID	Monday to Friday	Saturday	Sunday/Holiday
2	7am to 9:25pm	-	-
3	7:15am to 9:30pm	-	-
4	7:35am to 9:30pm	-	-
5	7:45am to 9:30pm	-	-
8	7am to 6pm	-	-
9	7am to 7pm	-	-
10	6am to 10pm	8am to 4pm	-
11	5am to 8 pm	-	-
12	5am to 8pm	-	-
14	6am to 12am	8am to 11pm	8am to 10pm
15	6am to 1am	8am to 8pm	8am to 10pm
16	5am to 7 pm	-	-

17	24/7	24/7	24/7
18	7am to 9pm	8am to 8pm	8am to 8pm
19	7am to 6pm	-	-
20	7am to 9pm	-	-
24	7am to 9pm	-	-
25	5am to 7:30pm	-	-
26	6am to 9pm	-	-
27	7am to 11pm	-	-

Plumbing:

Domestic hot water is provided via dedicated boiler for QOE. Historical uses district steam in the heating season, during the cooling season and electric boiler is used.

There are two DCW booster pumps.

DCW Booster Pumps

ID	Make	Model No.	Motor Size (hp)
P-17	Darling	-	25
P-18	Darling	-	25

Plumbing Fixtures

ID	Make	Model No.	Flow
Water Closet (new)	American Standard with Sloan Electronic Dual Flush	3351.101 and 8111-1.6/1.1	6 Lpf
Urinal (new)	American Standard with Sloan Flushometers	6590 001 And 8186-0.5	1.9 Lpf
Lavatory (new)	Toto Standard EcoPower Faucet	TEL5GS	0.64L/10 sec cycle

Electrical Systems

Interior Lighting:

Interior lighting in the major space types include:

- Elevator Lobby: Halogen MR-16 lamps, 75W fluorescent
- Atrium: LEDs
- General: T8 fluorescent lighting (4' x 2' 28WT8 lamps)
- Lighting Fixtures

ID	Make	Model No.	Watts	Lumens
T8 Linear Fluorescent (4 foot)	General Electric	T8 Starcoat ECO	32	4100K
Compact Fluorescent Light	Sylvania	DULIX T/E IN	42	3500K
Flood	Sylvania	Capsylite	75	1060K
LED	Liteline	PAR38	19	4000K

General Schedule per Floor

ID	Monday to Friday	Saturday	Sunday/Holiday
2	7am to 9:25pm	-	-
3	7:15am to 9:30pm	-	-
4	7:35am to 9:30pm	-	-
5	7:45am to 9:30pm	-	-
8	7am to 6pm	-	-
9	7am to 7pm	-	-
10	6am to 10pm	8am to 4pm	-
11	5am to 8 pm	-	-
12	5am to 8pm	-	-
14	6am to 12am	8am to 11pm	8am to 10pm
15	6am to 1am	8am to 8pm	8am to 10pm
16	5am to 7 pm		
17	24/7	24/7	24/7
18	7am to 9pm	8am to 8pm	8am to 8pm
19	7am to 6pm	-	-
20	7am to 9pm	-	-
24	7am to 9pm	-	-
25	5am to 7:30pm	-	-
26	6am to 9pm	-	-
27	7am to 11pm	-	-

Exterior Lighting:	N/A
Parking Lighting:	Parking Lighting is controlled by the BAS. Fixtures are 8’ single lamp 25W T8

APPENDIX D - CALCULATION DETAILS

Utility data was gathered for electricity (kWh), natural gas (m^3), steam (lbs) and water (m^3). The utility timeline used was from June 2015 to July 2016. The following conversion factors were used to obtain ekWh (REALpac, 2015):

	Divide the number of:	By:	To Obtain:
Quantity of heat energy	megajoules (MJ)	3.6*	ekWh
	gigajoules (GJ)	0.0036	ekWh
	British thermal units (Btu)	3412*	ekWh
	Therms (thm)	0.03412	ekWh
	Multiply the number of:	**By:**	**To Obtain:**
Quantity of natural gas	Cubic feet (cf)	0.2931*	ekWh
	100 Cubic feet (Ccf)	29.31	ekWh
	Cubic meters (m3)	10.35*	ekWh
Quantity of propane	Litres (L)	7.028*	ekWh
Quantity of fuel oil (#2)	Litres (L)	10.611*	ekWh
Quantity of steam (onsite generation)	kilo-pounds (klbs)	351.41£	ekWh
	Million pounds (Mlbs)	351406.8£	ekWh
Quantity of District Heating (steam)	kilo-pounds (klbs (Dist))	468.54†	ekWh
	Million pounds (Mlbs (Dist))	468542.4†	ekWh
Quantity of District Cooling (chilled water)	ton-hours (ton*h)	0.9¥	ekWh
Quantity of Deep Lake Water Cooling	ton-hours (ton*h)	0.285£	ekWh

*Conversion factors as per NRCan.

†District steam has beenfurther adjusted from onsite generated steam by a factor of 1.333 to account for an average efficiency of 75%. This factor is an average reported efficiency factor of three district energy providers in Toronto.

¥Conversion factor represents an average reported kW/ton value of two district cooling providerd in Toronto.

£Conversion factors as per Enwave.

To calculate the use index, the amount of energy used was divided by the gross floor area. The usage rates were determined from the cost divided by the energy type. The cost index was calculated using the cost divided by the gross floor area.

Utility Type	Consumption			Cost		
	Actual	Equivalent	Use Index	Rate	Total Cost	Cost Index
Electricity Consumption	11,982,550 kWh	11,982,550 ekWh	18.1 ekwh/sq	0.13 $/kWh	1,553,851 $	2.35 $/sq.ft
Average Demand Charges	2,261 kW		3.419 W/sq.ft	107.00 $/kW	241,923 $	0.37 $/sq.ft
Natural Gas	440,421 m³	4,558,352 ekWh	6.89323 ekwh/sq	0.2510512 $/m³	110,568 $	0.17 $/sq.ft
Water	54,189 m³		0.88 m3/m2	3.4784328 $/m³	188492.09 $	0.29 $/sq.ft
Steam	1,668 1000LB	781,371 ekWh	1.18 ekWh/sq	39.867042 $/1000	66,485 $	0.10 $/sq.ft
Chilled Water	0 Ton-hc	0 ekWh	0.00 ekWh/sq	#DIV/0! $/Ton-hour	$	0.00 $/sq.ft
	Total	17,322,272 ekWh		N/A N/A	2,161,319 $	3.27 $/sq.ft
	EUI	26.2 ekWh/sq.ft				

For all ECMs, the savings are calculated based on existing conditions and proposed conditions. The areas which are considered part of the savings calculations are electricity demand, electricity use and natural gas use. Each of these calculated savings use current constant rates such as the electricity consumption rate as noted in the table above.

Simple payback is calculated using the total cost to implement the ECM (materials and labour, engineering services, and possible incentive savings) divided by the utility savings per year.

For greenhouse gas emissions, the emission factors for CO_2 were obtained from the National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada (Part 3). 2014 values were used.

CO_2 per 1000lbs of steam	72.4g/1000lbs
CO_2 per m^3 natural gas	1891 g/m^3
CO_2 per ekWh electricity	110 g/kWh

ECM 1.1 Reducing Lighting Schedule (QOE): Currently, the average lighting schedule for the base building is 6:30 am to 10:30pm. For the proposed lighting schedule, it was estimated that the average number of hours to be reduced would be one hour between all the compartment units as a conservative measure. A lighting list was developed using base building drawings and counting light fixtures of a typical floor. Areas where base lighting fixtures were not available, a sample floor lighting density was calculated and applied to floors with known floor areas.

ECM 1.2 Reducing Lighting Schedule (Historical): Currently, the average lighting schedule for the base building is 7:30 am to 10:00pm. For the proposed lighting schedule, it was estimated that the average number of hours to be reduced would be one hour between all the compartment units as a conservative measure. A lighting list was developed using base building drawings and counting light fixtures of a typical floor. Areas where base lighting fixtures were not available, a sample floor lighting density was calculated and applied to floors with known floor areas.

ECM 1.3 Makeup Air Unit Static Pressure Sensor and Control: The ventilation equipment such as the makeup air unit will provide the outdoor flow of fresh air into the building. It will be conditioned to a certain air temperature for the building to use. Using the psychrometric chart, the supply air enthalpy and humidity grains can be determined.

The typical meteorological year weather data were collected (by the hour) was dry bulb temperature (Celsius and Fahrenheit) and humidity. These were used with the psychrometric chart to determine the humidity ratio per hour.

These values were then separated into temperature bins and the humidity ratio was averaged across the lower and upper bins. A mid point was determined and enthalpy could be obtained using the psychrometric chart. The total number of hours where the temperature stayed within the lower and upper bin was also determined. Knowing the end conditions of the supply air temperature and the different climate conditions possible throughout the year, the latent energy required bringing the outdoor air conditions to the supply air temperature and humidity for different times of year can be calculated. This energy is totaled throughout the year to give the total energy use of the ventilation system.

Within this ventilation system are fans. These fans affect the static pressure in the ventilation system. The current fan has a rated HP and converted to brake horse power and using fan laws can determine the kW demand. To reduce the load of the system, a new fan schedule was suggested where a percentage of the load will be based on the number of hours that the ventilation system will be on.

This method saves energy in electricity and natural gas.

ECM 1.4 Primary Chilled Water Pump (P1/P2) VFD Control: The calculations are very similar to ECM 1.3 where the VFDs control the speed of the pump is controlled by impellors. The speed of the impellor dictates how much electricity is used. The same law can be applied for impellors as it does for fans. At the time of the walk-through, the pumps were operating at 100%

ECM 1.5 Condenser Water Pump (P3/P4) VFD: The calculations are very similar to ECM 1.3 where the VFDs control the speed of the pump is controlled by impellors. The speed of the impellor dictates how much electricity is used. The same law can be applied for impellors as it does for fans. At the time of the walk-through, the pumps were operating at 100%.

ECM 1.6 Compartment Units Operating Outside of Schedule: The average power usage is based on the shop drawings and specs provided by the client. The scheduled times that the compartment units were operating can be found on the BAS system. Using the number of hours operating when no one is scheduled to be in the building and the average power usage calculates the annual energy savings per year.

ECM 2.1 Office LED Lamp Replacement and Full Lighting Retrofit: Based on the interviews with the building operators, the type of lamps used were mostly 4 feet 32W T8 fluorescent bulbs. Base building lighting plans provide the number of light fixtures per floor. Certain floors were renovated with LED lighting. It was assumed that the rest of these were still the old lighting fixtures. A 17W LED bulb was suggested for the base building lighting fixtures. An existing and proposed calculation was performed to determine the electricity savings.

For the full lighting retrofit, there are currently plans with a mechanical engineering firm to redesign the lighting layout for each floor depending if they are leased out to tenants or belong to the building owner.

This includes reducing the number of lighting fixtures and replacing them with LED fixtures. We were given access to this report and made calculations based on the reduced fixtures with LED bulbs.

ECM 2.2 Office LED (Historical): For the Historical building there are still existing fluorescent bulbs being used throughout. The calculations are the same as ECM 2.1.

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