THE IMPACT OF WINDOW-TO-WALL RATIO ON ENERGY INTENSITY OF EXISTING OFFICE BUILDINGS IN ONTARIO AND QUEBEC

by

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the impact of window-to-wall ratio on energy intensity of existing office buildings in ontario and quebec

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Abstract

Energy codes, such as SB-10, provide significant impact on the thermal performance of the building envelope. For design of new buildings, a window-to-wall ratio (WWR) of 40% is considered as a threshold in Ontario for using prescriptive solutions for thermal resistance of the enclosure. This study will demonstrate the relationship of the energy intensity of the existing office building to the WWR, through analysis of 15 office buildings located in Ontario and Quebec. Recent studies indicate that building geometry can influence the energy efficiency of the building; nevertheless, factors that impact energy intensity of existing buildings are not researched in full, and this study's aim is to minimize the knowledge gap in this field of literature. The outcome of this research shows that WWR directly influences energy intensity of the building. Energy balance calculations and energy loads distribution showed that WWR impacts on average 15% of overall energy consumption.

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Introduction

The inspiration for this study came due to of the importance of window-to-wall ratio (WWR) that is being given during the design of new buildings. Several studies have been done for various types of buildings with a view, to quantify the impact of WWR and envelope characteristics on the total energy consumption of the building. These studies have shown that there is a significant impact on the total energy consumption because of the WWR. For instance, Dogrusoy & Tureyen (2007) and Ross (2009) in their studies showed that WWR, has slightly overpowering results on energy use in commercial buildings than other building geometry parameters. In addition, Ferdous (2012) research outlines that WWR influences the energy intensity of existing office buildings. The current OBC requirements put a threshold of WWR of 40% up to which the thermal characteristics of the building envelope may be chosen based on prescriptive requirements. The manner in which this 40% is established is not very well understood.

All the studies that have been examined were carried out on buildings using energy modeling and typical shapes. There is hardly any information on the energy consumption in existing buildings and its relationship to the WWR. Furthermore the shapes assumed in many of these studies are much different from the architectural form that some of the existing buildings take. This study explores the possibility of using actual energy consumption data along with actual architectural forms and building envelope characteristics to examine the type of relationship that exists between the WWR and the energy consumption. This study also explores the potential for changes in envelope characteristics to contribute to reduction in energy consumption of the existing buildings. Additionally, the findings of this study that are reported here, will discuss the weight of potential benefits of WWR calculations when assessing energy consumption, by evaluating guidelines of Level 1 energy audits.

Chapter 1

Literature review

Energy conservation and sustainability are subjects of great interest in today's society; this applies especially to the commercial and institutional sector due to very high and growing demand for energy. According to National Resources Canada (2008), commercial and institutional (C&I) establishments accounts for two third of the housing sector. Survey specifies that 36% of commercial and institutional establishments are located in Ontario, 22% in Quebec, 18% in the Prairies, 16% in BC and 8% in Atlantic Canada. In addition, Ontario accounts for the highest amount energy consumption, approximately 30% each; Quebec stands third with 23% of overall energy consumption. Therefore C&I sector in Ontario and Quebec requires close attention in terms of energy efficiency. Typically, efforts to reduce energy consumption in the C&I sector are put towards research and development of energy efficient building technologies such as equipment, heating and air conditioning (HVAC), lighting and ventilation systems. It is not very common to proceed with passive technologies such as WWR ratio to achieve energy efficiency in the existing building. Despite common strategies, WWR solution has been promoted on a large scale through different mechanisms, including building codes and incentives. Supplementary standards SB-10 to the Building Code address WWR specifications and compliances to how it should be implemented. For design of new buildings a WWR of 40% is considered as a threshold in Ontario allowing for the use of prescriptive solutions for thermal resistance of the enclosure.

Following literature review was completed to identify factors that relate to the WWR and its impact on energy use/energy loads. Also to review how or whether WWR gets taken into account in energy audits of existing buildings. And to set a benchmark values for energy intensity, literature review was summarized to get an idea about the energy performance of existing buildings.

1.1 Building Energy Intensity

Canada's commercial and institutional establishments, cold climate and vast geography all contribute to it being a highly energy-intensive country (The Conference Board of Canada, 2013). Energy intensity is a total primary energy supply per unit of gross domestic product (GDP) (The Conference Board of

Canada, 2013). Currently Canada ranks last for energy intensity in comparison to 17 peer countries (some of the countries are Ireland, Switzerland, Italy, U.K. and others). In 2009, Canadian primary energy supply was 0.25 tonnes of oil equivalent (toe) per US$1,000 GDP, in comparison to the peer country average of 0.15 (toe). The positive aspect of this is that Canada has reduced its energy intensity by 39% since 1971 (The Conference Board of Canada, 2013), and slowly reducing even more; therefore, increased awareness of energy conservation and sustainability are beneficial on the large scale.

The Conference Board of Canada (2013) defines energy intensity in GDP, but in this report, calculations of energy consumption will be expressed in gigajoules [GJ], floor area will be expressed in square meters [m^2], and energy intensity will be expressed in gigajoules per square meter [GJ/m^2], as per Natural Resources Canada's Office of Energy Efficiency (OEE). In addition energy intensity can be adjusted for the energy consumed in producing electricity (for fuel choices such as natural gas, oil, coal, biomass or fuel wood); energy intensity is defined as total energy consumed, divided by total floor area, for the reference year (National Resources Canada, 2008).

Every year, Natural Resources Canada's Office of Energy Efficiency (OEE) estimates Canada's energy consumption by economic sector; these studies collected energy data, and estimated energy consumption in the C&I sector. Commercial and Institutional Building Energy Use Survey (CIBEUS) is a detailed study that was conducted on behalf of the Office of Energy Efficiency of Natural Resources Canada (NRCan). This is the first survey of its kind conducted to provide detailed information on the commercial sector. This survey gathered data on energy consumption, energy intensity and the physical and energy efficient characteristics of commercial and institutional buildings located in Canada. Survey was completed in 2000, and all the data was analyzed, summarized and published in 2002. Report (OEE, 2002) was based on data in major Canadian cities, and concluded that in year 2000, the overall energy intensity was 1.59 GJ/m^2. In 2003 the first Consumption of Energy Survey (CES) was completed. This report focused exclusively on Canada's universities, colleges and hospitals. This survey covered all ten provinces, and showed results as energy intensity for universities to be 2.04 GJ/m^2, for colleges to be 1.48 GJ/m^2 and for hospitals to be 2.65 GJ/m^2 (OEE, 2003). A year later in 2004 another survey was performed to cover much broader C&I sector, and energy intensity results in this survey were estimated as 1.6 GJ/m^2 (OEE, 2004). Later in 2006 Statistics Canada conducted Commercial and Institutional Consumption of Energy Survey (CICES) for Natural Resources Canada, collecting 2005 data. For business and institutions, energy intensity was estimated as 1.54 GJ/m^2 (OEE, 2005). This report gathered data on the age of establishment, also on energy sources used for space heating, space cooling and water heating. (OEE, 2005) report contains in-depth analysis of each of these variables. In 2011 similar survey estimated that in 2008 Canadian C&I sector comprised of almost 470,000 establishments occupying 705 million square meters of floor area. (OEE, 2011) also estimated energy intensity for Canadian C&I sector as 1.23 GJ/m^2, in addition, the report provides values for Ontario only as 1.02 GJ/m^2 in comparison to higher values in Quebec and Prairie. The most recent survey report that is available to the public was published in 2013 based on survey data in 2009. Report claims that in 2009 there were 482,000 C&I buildings; it is 12,000 more than just a year ago, and these establishments are occupying about 766 million m^2 of floor space (OEE, 2013). Report estimates that in 2009 the overall energy intensity of C&I buildings in Canada was 1.10 GJ/m^2, this value is lower than in previous study, and considerably lower than in all previous surveys. 27% of all C&I buildings in Canada were at least 50 years old, but buildings built in the 1970s had the highest proportions of both floor space and energy use. Report claims that Survey of Commercial and Institutional Energy Use (SCIEU) 2009 estimated that 46% of the C&I buildings were renovated between 2005 and 2009. The most common type of building renovations was lighting, and it's around 26%. Only 4.6% of C&I buildings underwent additions or reductions, and 23% underwent windows and insulation refurbishment (OEE, 2013).

To review the fluctuating energy intensity value, an evaluation of all survey results prepared by OEE and Natural Resources Canada was done. The summary of data from reports was compiled in Figure 1.1 to determine if the fluctuations in energy intensity value over the years were decreasing or increasing. Specifically, the last survey performed in 2009 reports claims a considerable decrease in energy intensity value in C&I Canadian sector. In addition, every year, the Office of Energy Efficiency publishes the Energy Use Data Handbook that provides a statistical overview of Canada's sectorial energy use as well as GHG emissions. This handbook (Natural Resources Canada Handbook, 2014) summarizes and compares energy intensity data estimated in every survey. Among the other sectors, this handbook provides data on energy consumption of C&I sector per year starting from 1990 (Fig. 1.1). Energy intensity in 1990 was estimated as 1.68 GJ/m^2, and the most recent value of energy intensity is provided for 2012 equals to 1.43 GJ/m^2. Handbook tables demonstrate 14.9% decrease in energy consumption from 1990, and almost 19% decrease from 2000, 2002 and 2003.

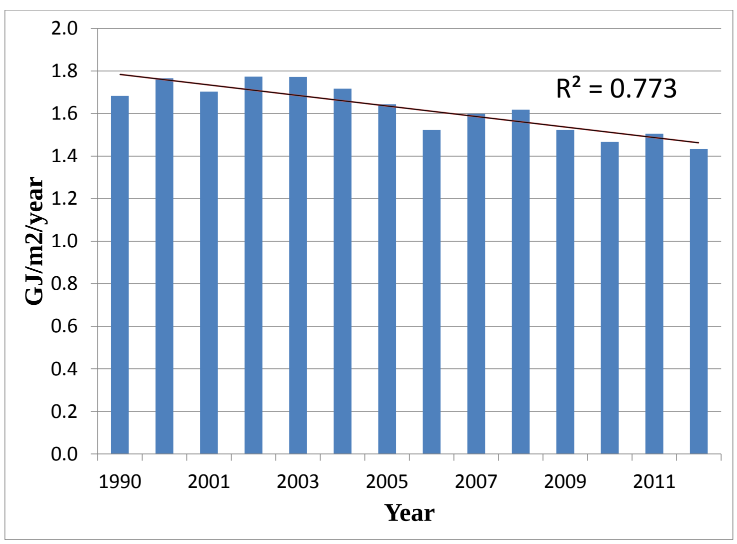


Figure 1.1: Energy Intensity in GJ/m^2 for Commercial/Institutional Sector (Natural Resources Canada Handbook, 2014)

To establish benchmark value for energy intensity of commercial and institutional buildings, in ad-

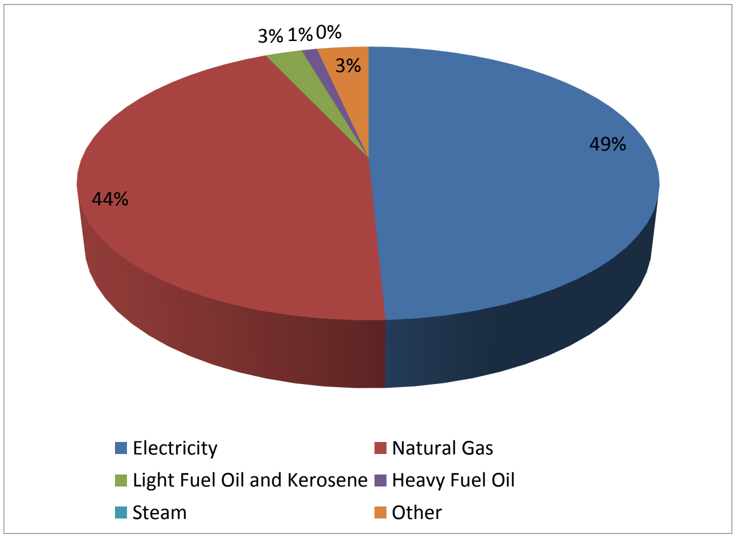


Figure 1.2: C&I Energy Use by Energy Source

dition to previous literature, BOMA BEST Energy and Environment Report (BBEER) were reviewed. BBEER is Canada's leading assessment and certification program that provides benchmark data and performance success case studies. 3,562 buildings have achieved BOMA BESt certification and/or re-certification across Canada since 2005 (BOMA, 2014). Report shows that average energy use intensity for certified Office Buildings is 27.1 ekWh/ft^2/yr (or 1.05GJ/m^2/year).

Based on percentages of energy consumption by Ontario and Quebec, as well as percentages of institutional and commercial buildings located in these two provinces, this information was combined with Natural Resources of Canada Handbook data for 2012; the following can be summarized. In Canada, total C&I energy use for 2012 was equal to 1069.2 (PJ) with the following breakdown for energy use by energy source (Figure 1.2), energy use by end-use (Figure 1.3) and energy use by activity type (Figure 1.4), with total energy intensity of 1.43 (GJ/m^2/year) based on total floor space 741 (million m^2).

Summary: from the above data, it can be concluded that Canadian offices account for 34.9% of overall energy consumption, with total floor area of 305.15 (million m^2), and energy intensity of 1.22 (GJ/m^2/year). Approximately 22% of these offices are located in Ontario and 18% in Quebec. It was noticed that Quebec accounts for 23% of total energy consumption, and Ontario, not too much higher, is accounted for 30%. Based on total C&I energy of 1,069.2 (PJ) Quebec infrastructure and commercial sector consumes significantly less energy of 44.26 (PJ) than Ontario 70.56 (PJ). Energy intensity is directly dependent on the total floor area of the building, and building envelope characteristics do not influence these calculations. Buildings total energy consumption indicators, based on building orientation, size and facade components, can provide a breakdown on how does actual energy data relates

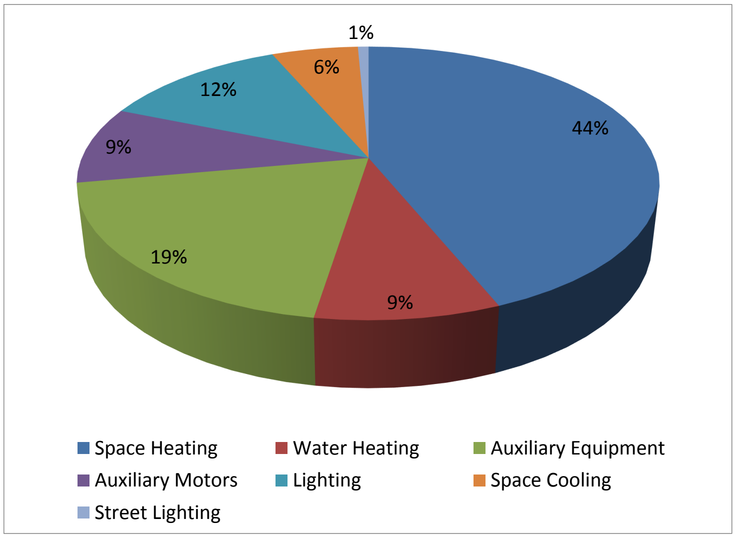


Figure 1.3: C&I Energy Use by End-Use

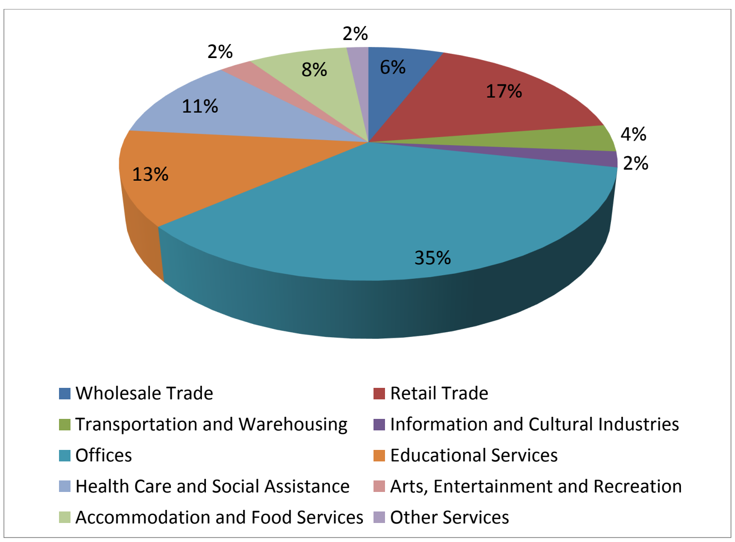


Figure 1.4: C&I Energy Use by Activity Type (PJ) in Canada

to building envelope characteristics.

1.2 Role of WWR in Building Energy Consumption

In order to analyze the relationship between WWR and the energy intensity of the building, a number of papers were reviewed with regards to factors influencing the building's energy intensity. (Harvey, 2013) in his research identifies essential principles of low-energy design, and lists important steps in the design of low-energy buildings, these are: building orientation (this includes also surface area-to-volume ratio and thermal mass), high performance building envelope, passive systems (heating, cooling, ventilation and daylighting), individual energy devises (to ensure that energy devises can be controlled individually based on necessity of users), and proper commissioning of the building. Also (Harvey, 2013) distinguishes between energy loads and energy use. The term load refers to the amount of heat that has to be added or removed from the building to maintain the desired indoor temperature. Energy loads directly depend on the following factors: climate, the form and orientation of the building, external shading, characteristics of the building envelope (including insulation, fenestration properties, WWR and air tightness) and desired indoor comfort (temperatures during the heating and cooling seasons). Additional factors are also internal heat from equipment, lighting and human occupancy. (Harvey, 2013) explains that energy uses are given by the heating and cooling load divided by the efficiency of the building's systems and equipment. Therefore the main difference between energy loads and energy use is that energy loads are established at the design stage and can be predicted by simulation and estimations, but energy uses are variable unit and directly depends on current efficiency of the building, which can only be determined by analyzing energy bills. To summarize: modifying the building's design or influencing energy uses (stirring them towards energy efficiency) is the only way to minimize energy loads.

Summary: upon review of the (Harvey, 2013) research, it can be concluded that WWR is inversely directed to low-energy building designs, as well as energy consumption of these buildings. WWR has an important role to play in reducing energy intensity of the commercial building sector, and help to maximize the return on investment in energy-efficient technologies. Building energy intensity can be minimized by bringing into focus, the percentages of efficient building envelope window to wall; thus generating savings that could partly balance additional costs for pricey high-efficiency equipment and high-performance envelope. Harvey (2013) in his report provides that the average total energy use in commercial buildings in the United States and Canada is 266 kWh/m^2/year (or 0.97 GJ/m^2/yeah), whereas the average energy use of the same if complying with the ASHRAE 90.1-2004 standard would be 157 kWh/m^2/year (or 0.57 GJ/m^2/year), this could provide savings of 41%.

1.3 WWR Role in Typical Energy Audits

Mainly energy audits are conducted to analyze the energy consumption of the building and to make a preliminary list of energy efficiency measures. Typically, the report produces following actions: reduce wastage at the source, use of high-efficiency products, optimize use of facilities to ensure best possible comfort for occupants and of course minimize energy consumption. Energy audits very rarely include any discussion on building envelope assemblies; they don't analyze current thermal resistance of building envelope and only propose immediate actions to building envelope if significant damage is evident.

Energy auditing of a building can range from a short walk-through of the facility to a detailed analysis with computer simulations. (Krarti, 2010) in his book presents simplified analysis methods to evaluate energy conservation opportunities in commercial buildings, and these methods are based on well-established engineering methods. Book is also used as reference for practitioners as well as textbook for students. Generally, four types of energy audits can be distinguished: walk-through audit (during which immediate and inexpensive actions can be concluded), utility cost analysis (detailed analysis of energy bills are performed to identify the patterns of energy use, peak demand, weather effects and potential energy savings; this audit should be performed in combination with walk-through audit), standard energy audit (during which comprehensive energy analysis of the energy systems are conducted; in addition to walk-through audit and utility cost analysis, the standard energy audit includes the development of a baseline for the building's energy use, energy savings and cost-effective measures), and detailed energy audit (subsequently, during this audit, instruments are used to measure energy; to evaluate possible energy retrofits for the building, computer simulations are used). Energy modeling is performed during the standard energy audit; these include: baseline energy modeling, degree-day methods and linear regression models, as well as payback analysis.

To evaluate if building envelope characteristics are analyzed during energy audit and to what extent building envelope retrofits are considered, general procedure of detailed energy audit was reviewed in more details. Building envelope is considered as one of energy conservation measures (ECMs), and is recommended to be evaluated during walk-through survey, wherein the auditor should determine the actual characteristics of the building envelope, and all necessary repairs. (Krarti, 2010) specifies that energy audit of the envelope is especially important for residential buildings, and it's believed that for commercial and institutional buildings improvements to the building envelope are often not cost-effective due to the fact that modifications to the building envelope are often too expensive. Nevertheless, it is highly recommended to perform audit for envelope components systematically not only to determine the potential for energy savings but also to ensure the integrity of its overall condition. Main concerns are always thermal bridging and moisture condensation, and no concerns in regards to WWR are mentioned during energy conservation measures (ECMs).

Summary: it can be concluded that although building envelope is an important item during energy audit, it is very rarely considered during an actual audit of the existing building. Because WWR is typically part of building envelope evaluation, therefore WWR is not considered during energy audit either.

1.4 Establishing Effective WWR Based on Energy Efficiency

1.4.1 Fenestration Systems and Daylighting

In the building concept, fenestration systems are typically the main source of sunlight, therefore directly related to daylighting potentials of the building. ASHRAE defines fenestration systems as assemblies and components of windows and openings located on building envelope (ASHRAE Handbook Fundamentals, 2005). While fenestration can be extremely beneficial by providing daylight access, natural ventilation and visual communication between the interior and exterior, if glazed areas are not properly designed it can negatively impact energy consumption of the building. The following three papers were reviewed to outline significance of fenestration systems and its impact on building's energy efficiency.

First literature (ASHRAE Handbook Fundamentals, 2012) is a manual that provides current engineering procedures and practices, and it was reviewed to summarize key points of daylighting. (Ko, 2009) is a dissertation paper that provides research on fenestration and daylighting, and summarizes this information into guidelines; this paper was reviewed to conclude if energy conservation through daylight can overpower energy loss due to lowering thermal resistance of the building envelope. (Public Works and Government Services Canada, 2002)'s report is a daylighting guide for Canadian commercial buildings and it provides a 10-step guide for daylighting design process; this guideline was reviewed for fenestration design concept and WWR calculations.

Fenestration system in the building is typically a component with the lower thermal resistance, therefore fenestration properties such as configuration of fenestration openings, window area, U-factor solar heat gain coefficient (SHGC) and visible transmittance (VT) have to be considered to achieve energy efficient buildings. According to Ko (2009), the size of the fenestration plays an important role in saving energy.

ASHRAE Handbook explains key points of daylighting, these points are: daylighting is the illumination of a building's interiors by sunlight; daylight affects visual performance, lighting capacity, health, human performance and energy efficiency; daylight can provide significant energy conservation of the building and reduce electric lighting if utilized properly (ASHRAE Handbook Fundamentals, 2005). Though daylight provides above-mentioned benefits, on the other hand, it could create an issue in the energy efficient design parameters related to energy conservation due to lowering thermal performance of the building envelope. If fenestration area is oversized, this can directly contribute to increasing the building's energy consumption. Therefore proper fenestration design should be integrated with other building parameters to achieve energy efficient building.

In the report prepared by Public works and Government Services Canada (2002) the same conclusion is made that daylight can adversely impact thermal resistance of the building due to bigger window sizes, resulting in higher energy consumption. The report provides a 10-step daylighting design process; selecting optimal window placement, room size, window area and space configuration can provide adequate and uniform daylight for rooms around the building perimeter. The report also provides an equation for WWR calculations, where the net glazing area (windows area minus mullions and framing) is divided by gross exterior wall area (width of the bay by floor-to-floor height). In addition, the report provides alternative procedures on how required WWR can be calculated for a standard room with specific properties. Calculations provide typical WWR value as 0.3 (fraction), from where required net glazing area can be calculated by multiplying the WWR by the wall area.

Summary: daylight can significantly reduce energy consumption utilized for artificial indoor lighting; based on a number of researches, energy savings of 15% to 45% can be achieved by a daylighting scheme, depending on shape and climate zone of the building (Ko, 2009). Although daylighting benefits can be significant, oversizing fenestration area can negatively impact thermal resistance of the building envelope as well as contribute to overheating and glare. Therefore two main components: fenestration design and WWR will be reviewed further.

1.4.2 Fenestration Thermal Efficiency

One can easily assume that the disadvantage of beneficial daylighting is a lower thermal resistance of a building, solution being to increase thermal resistance of the fenestration part of the building envelope. Consequently, a fenestration part of building envelope can be over-insulated to accommodate lost thermal efficiency; the high costs of these, however, may result in them not being very feasible. To examine the relationship between windows and building energy consumption, and explore existing opportunities for improving energy use in existing buildings, additional literature was reviewed.

In Tzempelikos (2005) report, benefits of advanced glazing products are discussed. Recently these products have replaced traditional double-glazed windows and have low-emissivity glazing (low-e) that includes a special coating on one of the surfaces, this coating dramatically reduces the longwave radiation and minimizes heat losses (Tzempelikos, 2005). The report explains how various types of advanced glazing allow the dynamic use of building envelope, and how they help to maintain interior thermal needs, and at the same time respond to outdoor climate. In addition, author sufficiently reviews different types of advanced glazing such as electrochromic, thermochromic, translucent, photochromic and gasochromic glazing. Through analysis of different research literature, the Tzempelikos claims that by selecting proper fenestration, annual energy consumption can be reduced drastically (from 11% to 18%) in comparison to conventional double-glazed windows. The report provides detailed guidelines for selecting WWR, as well as recommendations for choosing shading device properties and control in conjunction with electric lighting operation. Guidelines include option from selecting WWR from theoretical graph, or by calculations through formulas. With supporting calculations, the author demonstrates that daylight availability ratio and thermal loads always increase as WWR increases for all orientations. WWR is directly influencing energy demand of the building; nevertheless energy demand for both heating and cooling can be considerably reduced if windows would have higher thermal resistance (Tzempelikos, 2005).

Summary: by improving building envelope characteristic, energy use of existing building can be also improved, therefore WWR is a very important factor that impacts energy use compared to other components of building envelope, due to its very low thermal resistance.

1.4.3 Window-to-Wall Ratio (WWR)

Further literature was reviewed to investigate to what extent WWR impacts energy consumption compared to other parameters such as building orientation and shading; and what is preferred occupants' optimal size of the windows. In (Dogrusoy & Tureyen, 2007) field study, occupants' visual satisfaction was achieved when window area occupies 44 - 100% of the wall area. Occupants in the (Ludlow, 1976) study preferred the window area of 50-80% for visual satisfaction, which was significantly lower than that of the (Dogrusoy & Tureyen, 2007). This percentage is higher, and could be due to study being completed much earlier than Dogrusoy & Tureyen field study. Occupants are more aware the importance of thermal efficiency. Another study which took place in Canadian office concluded by (Boubekri, Hull, & Boyer, 1991) found that the optimal size of the window was between 15% and 25% of the total wall area, and 40% was found to be a maximum acceptable limit. This study was based on relaxation study, and study suggests that sunlight penetration can promote relaxed feelings and overall satisfaction.

Thesis research completed by (Ross, 2009) demonstrates the impact of architects on environmental loads imposed by building through building form, orientation and enclosure design, including WWR design. The report summarises best practice design approaches, and highlights that facade design strategy with WWR between 20% and 40% are most functional. Through simulations and calculations, research also suggests list of operations that lead to lower energy intensity of the building; research emphasizes that by modifying WWR within the previously mentioned percentage range, would lead to more energy efficiency. WWR has stronger impact on the energy intensity than building form, orientation, window orientation and shading (Ross, 2009). In addition, the more WWR was reduced, the bigger affect it had on energy intensity of the building, and therefore energy intensity was lowered. The report identifies that 5% reduction in energy-use-intensity occurred with each 20% decrease in the WWR.

(Ferdous, 2012) in her report investigated the potential of building geometry to minimize energy consumption in office buildings. Five different geometries were modeled as commercial occupancies in the context of Toronto, Ontario, and examined with various design parameters: WWR and external static shading devices. The modeling was performed with WWR of 30%, 50%, 70% and 80% for all five building geometries; total height, floor to ceiling height for each floor and gross floor area were kept the same of all buildings. To investigate driving force affecting the thermal conditions of a building climate analysis were performed, as well as space heating, cooling and interior lighting energy loads. Results showed that the consumption for space heating almost doubled for each plan type (with inclusion of the shading devices) when WWR was increased from 30% to 80%. The consumption for space cooling energy had also gradually increased when WWR increases (with no shading), but only varied a little when the shading was in place. Lighting energy was significantly impacted by WWR, as the WWR increased the energy demand for lighting reduced. To summarize the research, author claims that as WWR increased gradually from 30% to 80%, the total annual energy consumption for every modeled archetype also increased, and effect was more significant than the building shape (Ferdous, 2012). Below are results summary charts to represent the impact of WWR on energy intensity from Ferdous' report. The increase in total energy use ranged from 10.9% to 16.3% as WWR increased.

When WWR increased from 30% to 80%, results for individual energy factors in Ferdous' report are following (for Square shape building, no shading): heating energy increased by 45.9% (from 222 MWh to 410 MWh); cooling energy increased by 18.14% (from 76.62 MWh to 93.6 MWh), however cooling energy was found to be dependent on interior lighting energy. From above WWR has significant impact on occupants' visual and mood satisfaction, but even more significant, it had an effect on total energy demand of the building.

However papers above conducted on site or simulation studies to calculate required WWR; there are already established standards that provide acceptable WWR percentage. In Europe, energy performance standards for buildings are guided by the European Commission's Energy Performance in Buildings Directive. In US, each state develops their individual building codes, and many directives vary by state. As an example, in California, the California Energy Commission (which sets building standards) and the California Public Utility Commission (which regulates utilities) are both pursuing decrease of energy intensity. However, each state has different standards; there are two bodies providing a baseline for building energy codes, these are: International Energy Conservation Code (IECC) and the American Society of Heating, Refrigeration and Air conditioning Engineers, (ASHRAE) Standard 90.1 Energy Standard for Buildings except Low Rise Buildings (Ryan, 2012). In Canada, codes and standards for energy efficiency and window-to-wall specifications are Supplementary Standard SB-10 to the Building Code (energy efficiency for housing). In addition ASHRAE standards also act as a baseline for energy efficiency in Canada.

Specific standards recommendations concerning the fenestration of the facade also differ from country to country (Motuziene & Juodis, 2010). For instance, ASHRAE (2004) recommends WWR to be from 20% to 40%; some of the European countries such as Norwegian standards for building energy performance NS 3031:2007 recommends that the glazing area must not exceed 20% of the heated wall area; however in Canada the recommended fenestration area is calculated due to the dimensions of the room, and the calculations usually give WWR a value close to 30% (PWC, 2002).

SB-10 under its prescriptive requirements, states for minimum performance requirements in the code, specifies that for non-residential occupancy buildings, the gross area of fenestration to the gross area of peripheral wall measured from grade to the top of the most upper ceiling shall be less than 40%. If the glazed area exceeds prescriptive requirements, this area shall comply with additional (higher R-value) prescriptive approach. As it has been discussed previously in this report in fenestration systems and daylighting section, a glazed area is directly related to both heating and cooling loads in the buildings. Thermal performance of glazing units significantly contribute to heat loss through the building envelope, therefore impact heating loads and overall energy demand of the building. In addition, a glazed area can cause unwanted heat gains that contribute to increased cooling loads. SB-10 also specifies maximum solar heat gain coefficient (SHGC), to oversee unmanaged heat gains. The main objectives for introducing limit percentage for W in SB-10 prescriptive requirements are to minimize heat loss in winter and heat gain in summer.

Summary: based on literature review above, WWR plays an important role for occupant's satisfaction and energy efficiency of the building. WWR is summarized in the Table 1.1 below.

Table 1.1: Literature Review Findings Summary

Literature Review	WWR%	Impact
Dogrusoy & Tureyen, 2007	44% - 100%	Occupants visuals (based on field study)
Ludlow, 1976	50% - 80%	Occupants Satisfaction (based on design tools used by author)
Boubekri, Hull, & Boyer, 1991	15% - 25%	Occupants Satisfaction (based on study in the office room of a typical size and how it influenced workers' mood)
Ross, 2009	20% - 40%	5% reduction in energy-use-intensity occurred with each 20% WWR (based on designed series of prototypes of office building)
Ferdous, 2012	30% - 40%	45.9% increase in heating energy consumption from 30% to 80% (based on modelling of five building shapes)
Ferdous, 2012	30% - 40%	18.14% increase in cooling energy consumption from 30% to 80% (based on modelling of five building shapes)
PWC, 2002	30%	Based on energy efficiency calculations
ASHRAE, 2004	20% - 40%	Based on energy efficiency analysis
SB-10	below 40%	Based on energy efficiency analysis

1.5 Literature Review Summary

From the above reviewed information it can be concluded that for most part WWR is not taken into account in audits of existing buildings perhaps because this has not been addressed previously. But, by looking at the collected information, it is evident that WWR has impact on energy use and energy load of the building. Therefore, by introducing parameters of WWR analysis into energy audits could at least alert owners about the possibilities of envelope improvements. BOMA average energy value of 1.05GJ/m^2/year will be used as benchmark guide value in case-study building analysis. As well as, WWR of 40% will be used as maximum value of existing buildings analysis, as per Ontario prescriptive solutions for thermal resistance of the enclosure.

Chapter 2

Scope and Approach

The approach of this study is to determine and quantify to what extent WWR influences energy usage of office buildings selected for this research. This will be achieved by reviewing and evaluating utility bills and calculations of energy consumption of each building; data was provided by SNC Lavalin, Operational and Maintenance department. For this study to be successful it was required to draw upon the energy consumption data for existing buildings. Pursuing the inspiration of this idea through the workplace it was determined that energy data of existing commercial buildings could be obtained. Initial exploration of this data determined that it was complete in terms of energy usage by fuel type and month for several years of occupancy. The availability of this data encouraged further pursuit of this topic.

Research will analyze actual energy data of existing buildings, and conclusions will be made on how this data relates to a building envelope characteristics. Thorough calculations and analysis research will evaluate the significance of WWR in comparison to other energy consumption indicators such as number of stories, building orientation and window and opaque thermal performance based on heating and cooling loads.

2.1 Research Questions

Research Questions:

- How does energy intensity of existing case-study office buildings compare with averages for similar buildings and those that would be resulting from application of current standards?

- In determining potential for energy savings in existing case-study buildings what is the impact of envelope upgrades on energy consumption?

- How does the energy intensity of existing case-study buildings using square meter of gross area measure vary with the WWR of that building?

- Should analysis of WWR be introduced into energy audit (Level One) report?

Chapter 3

Methodology

To carry out the research, 15 case-study buildings were reviewed and analyzed with respect to the research questions. Microsoft Excel was used for most of the calculations, and served the best for the intended purpose of this research. Assumptions were made and adjusted based on common practices. Analysis and comparisons are based on the calculation results.

Methodology section is separated into three main subsections: description of buildings, calculations and analysis. This section briefly outlines the methodology adopted in current research, however more detailed explanation of methodology process is shown in the Figure 3.1 below.

In addition, detailed calculations and explanations on some of the topics are included in appendices at the end of the paper.

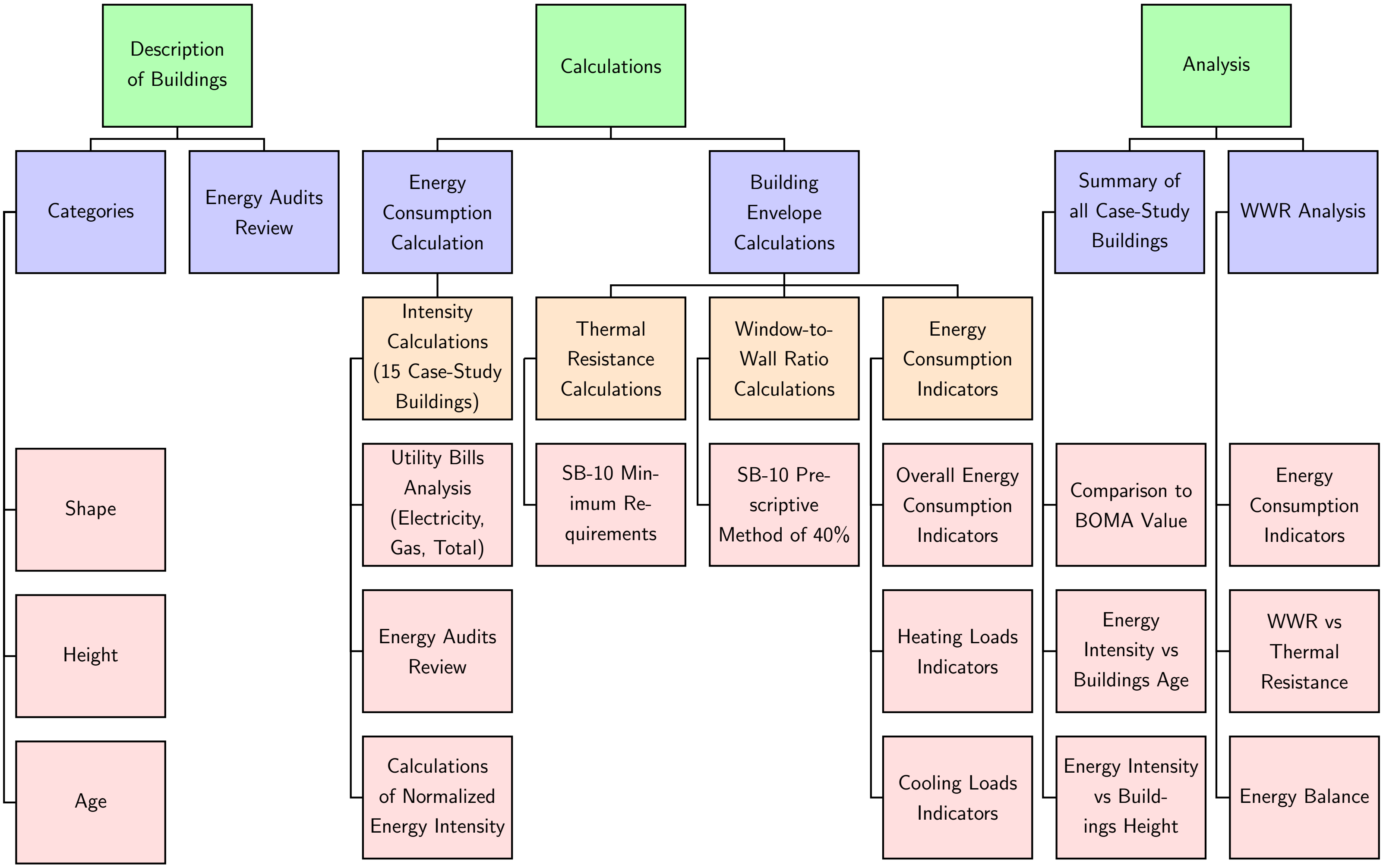


Figure 3.1: Methodology Framework

3.1 Description of Buildings

3.1.1 Categories

Fifteen office buildings were selected for this study, eleven of case-study buildings are located in Ontario and four located in Quebec province of Canada. These fifteen buildings were selected because they represent typical buildings within a portfolio of office buildings managed by SNC Lavalin. All case-study buildings are different in shape, height and age. Buildings were categorized in the following manner:

Category 1 Shape:

Case-study buildings were divided into four different categories shown in the Figure 3.2.

Photo of each building's shape was taken from Google Earth web source. As shown above most of the buildings have a complex irregular shape, however when buildings were selected they represented typical office buildings in Ontario/Quebec provinces. Table 3.1 summarizes repetition of each shape category. Shape names were chosen in the following manner: if building footprint has very distinctive square or rectangular shape they would be called accordingly; but if building footprint has more than four distinguishable corners they would fall under complex category; however to make it simpler, they still would be related to the square or rectangular shape.

Table 3.1: Buildings' Shape Summary

Shape	Quantity
Square	3
Rectangular	4
Complex - Square	2
Complex - Rectangular	6

Three of the square buildings that are located in Ottawa have very similar shape and are located at the same office site, but the height of each building varies. Four rectangular buildings also vary in height, two of them are 2 floors only, one is 4 floors in height and fourth building is a high rise. Most of the complex shape buildings also have complex flooring height, meaning they have an irregular number of floors in different parts of the building. It was noted that although case-study building were chosen for being typical office structures, but more than half of them have a complex and a non-standard shape of the footprint. Only 3 buildings have a square shape, and 4 rectangular; the rest have non-typical complex shapes. In (Ferdous, 2012), the report author analyzes five distinguishing types of building shapes: square, rectangular horizontal, rectangular vertical, cross and h-type. Based on case-study buildings selected for this study, only seven building can fall under these categories of geometric descriptions, and the rest would require more complex simulations.

Category 2 Height:

Fifteen case-study buildings were divided into three categories based on their height, the Figure 3.3 shows all buildings and the above number represents how many floors each building has.

Buildings were grouped into three categories with regards to height: low-rise buildings from 1 to 3 floors, mid-rise from 4 to 5 floors, and high-rise from 6 and up. 15 buildings spread out; five evenly in each category.

Category 3 Age:

Most of the buildings were constructed between 1975 and 1990; only one building was constructed in 1873 and one was constructed after 1990, in 1993. None of the buildings is under Ontario or Quebec Heritage Properties act. Figure 3.4 shows all 15 building based on the year of construction.

1 Building A - Toronto, Ontario		6 Building F - Scarborough, Ontario		11 Building K - Ottawa, Ontario, Tower A	
	Complex - Square		Rectangular		Square
2 Building B - Mississauga, Ontario		7 Building G - Ottawa, Ontario		12 Building L - Montreal, Quebec	
	Complex - Rectangular		Rectangular		Complex - Rectangular
3 Building C - Toronto, Ontario		8 Building H - Ottawa, Ontario		13 Building M - Vaudreuil-Dorion, Quebec	
	Rectangular		Complex - Rectangular		Rectangular
4 Building D - Mississauga, Ontario		9 Building I - Ottawa, Ontario, Tower C		14 Building N - Côte-St-Luc, Quebec	
	Complex - Square		Square		Complex - Rectangular
5 Building E - Mississauga, Ontario		10 Building J - Ottawa, Ontario, Tower B		15 Building O - Gatineau, Quebec	
	Complex - Rectangular		Square		Complex - Rectangular

Figure 3.2: Category 1 Various Shapes of Case-Study Buildings (Retrieved from Google Earth)

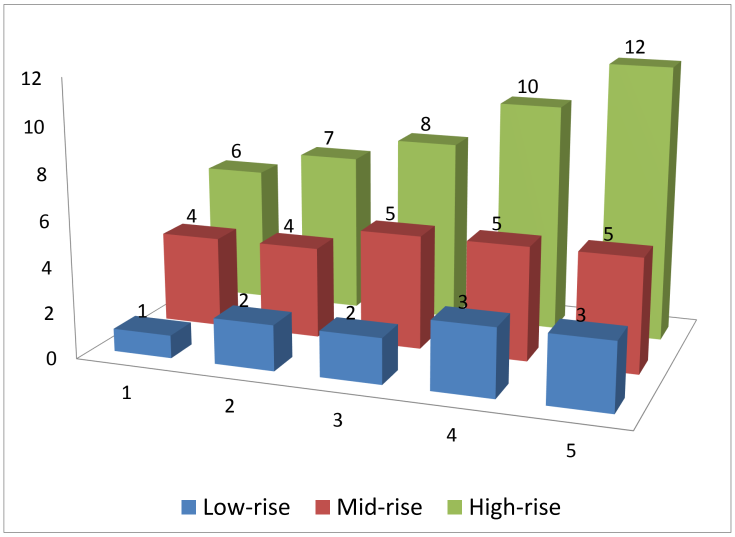


Figure 3.3: Category 2 Height of the Case-Study Buildings

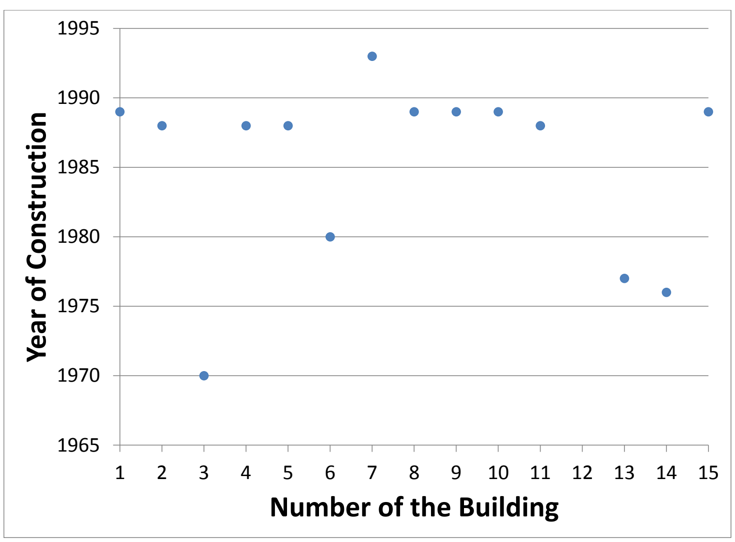


Figure 3.4: Category 3 Year of Construction of Case-Study Buildings

3.1.2 Energy Audits Overview

Table 3 summarized information for all fifteen buildings: building shape, height and year of construction; in addition, the gross floor area for each building is included as well as the buildings locations.

Table 3.2: Buildings Description Summary

# Location	Building Shape	Building Height	Building Construction Year	Gross floor area m^2
1 Building - Toronto, Ontario	Square	12	1989	25,424
2 Building - Mississauga, Ontario	Complex Shape	6	1988	8,225
3 Building - Toronto, Ontario	Rectangular	8	1970	9,240
4 Building - Mississauga, Ontario	Complex Shape	10	1988	15,712
5 Building - Mississauga, Ontario	Complex Shape	1	1988	6,332
6 Building - Scarborough, Ontario	Rectangular	2	1980	2,130
7 Building - Ottawa, Ontario	Rectangular	4	1993	8,180
8 Building - Ottawa, Ontario	Complex Shape	5	1989	5,020
9 Building - Ottawa, Ontario, Tower C	Square	3	1989	4,854
10 Building - Ottawa, Ontario, Tower B	Square	5	1989	8,270
11 Building - Ottawa, Ontario, Tower A	Square	4	1988	6,162
12 Building - Montreal, Quebec	Complex Shape	7	1873	3,518
13 Building - Vaudreuil-Dorion, Quebec	Rectangular	2	1977	8,022
14 Building - Cote-St-Luc, Quebec	Rectangular	5	1976	7,943
15 Building - Bellehumeur, Gatineau, Quebec	Complex Shape	3	1989	5,518

Building #1 is located at Toronto, Ontario.

Overview: the 12-story building is mainly office space with underground parking (three levels with 304 parking stalls); a penthouse is on the mechanical level, and the main level includes a few stores and a cafe. Total gross area is 25,424 m^2. Building was constructed in 1989. Typical office hours are Monday to Friday from 7am to 6pm, and Saturdays from 9am to 6pm. The building is typically closed down on Sundays.

Energy audit 1 was completed in June, 2013 by SNC Lavalin O&M department. During this audit, assessment of the energy savings potential for the facility was completed, and a site walk-through was conducted that included interviews with site personnel. The following information was summarized based on the building audit. Energy consumption of the building is moderately high in comparison to similar office buildings in same region. The primary HVAC system of the building consists of gas fired boilers, serving the perimeter radiation units for building heating, and the MUA (make-up air) unit for heating the ventilation air. AHU (air-handling unit) is located on each floor for air distribution. Cooling of the building is provided by cooling towers, and they are designed in a way to be shut off during the winter months when cooling is not required. Lighting in the building has been upgraded in cafe service area and office areas to lower voltage. Cafe area lighting was proposed to be upgraded from 20 MR16-30 walls each pot-lights, to LED MR17-7 wall each, however these changes were not implemented yet. Office area lighting is primary 32 watt T8 2 lamp fixtures. There is no humidifier equipment in the building.

Building #2 is located at Mississauga, Ontario.

Overview: A 6 story building that is mainly office space with underground parking as well as a penthouse mechanical level. The building's first floor includes various retail stores. Total gross area of the building is 8,225 m^2, and it was constructed in 1988. Typical office hours are Monday to Friday from 7am to 7pm. The building is typically closed down on Saturdays and Sundays.

Energy audit 1 was conducted on May, 2013 by SNC Lavalin O&M department. During energy audit an assessment of energy savings of facility was completed. In addition, a site walk-through was performed as well as interviews with site personnel. From the energy audit, the following information was summarized. Energy consumption of the building is moderately high in comparison to similar office buildings in the same region. The primary HVAC system is provided by water cooled heat-pumps. Two packaged rooftops units serve the common areas of the building and the main level. However tenants of the retail area receive their own electric bills, these were included in calculations to represent overall usage. The gas fired MUA (make-up air) unit provides ventilation air to the building. Domestic hot water is provided by a gas-fired atmospheric heater with re-circulation pumps. There is no humidifier equipment in the building.

Building #3 is located at Toronto, Ontario.

Overview: 8-story building with two levels of underground parking and a penthouse mechanical room. The building was built in 1970 and serves mainly as an office facility. Typical office hours are Monday to Friday from 7am to 7pm, and Saturdays from 9am to 6pm. The building is usually closed on Sundays. The total gross area of the building is 9,240 m^2.

Energy audit 1 was completed in September, 2013 by SNC Lavalin O&M department. Audit was conducted to achieve measures to reduce energy consumption. During this audit assessment of the energy savings potential of the facility was completed, and a site walk-through was conducted that included interviews with site personnel. From energy audit following information for Building #3 was summarized. Energy consumption of the building is moderately high in comparison to similar office buildings in same region. The HVAC is provided by high-pressure air handler serving the perimeter induction units. Heating and cooling for the air handlers and perimeter induction units are provided by gas fired atmospheric hot water boilers and centrifugal chiller. A single return fan is controlled by the ambient static pressure return air. There is no humidifier equipment in the building.

Building #4 is located at Mississauga, Ontario.

Overview: a 10-story building is mainly an office building with an approximate number of 500 occupants. The building was constructed in 1988 and has a total gross area of 15,712 m^2. Building has an indoor parking lot and mechanical penthouse. Typical working hours are from Monday to Friday from 6am to 7pm, and Saturday from 6am to 7pm, on Sundays, the building is closed.

Energy audit 1 was completed in June, 2013 by SNC Lavalin O&M department. During this audit, an assessment of the energy savings potential of the facility was completed, and a site walk-through was conducted that included interviews with site personnel. This site audit allowed for the initial selection of energy conservation measures. From energy audit following information was summarized. Energy consumption of the building is average in comparison to similar office buildings in same region. Water source heat-pumps provide HVAC for the building with gas fired boilers and a cooling tower. A gas fired MUA (make-up air) unit brings outside air and deliver ventilated air back. There is a humidifier in the building. Building also has Building Automation System to control heat pumps and other major equipment.

Building #5 is located at Mississauga, Ontario.

Overview: single story strip building containing 18 retail and office tenants. Building has floor gross area of 6,332 m^2, and has outdoor parking lot around the exterior and at the back of the building. Building was constructed in 1988. Typical building operating hours are from Monday to Friday from 6am to 11:30pm, on Saturdays from 7am to 6pm, and on Sundays the building is closed.

Energy audit 1 was completed in July, 2013 by SNC Lavalin O&M department. During this audit assessment of the energy savings potential of the facility was completed, and a site walk-through was conducted that included interviews with site personnel. From energy audit following information was summarized. Energy consumption of the building is very low in comparison to similar building in this region. This could be attributed to the fact that some of the tenants pay for electricity independently, which is not captured by energy bills. Therefore 25% will be added to energy index value to approximate missing data. The HVAC is provided by 40 roof top units. The RTUs are electric cooling and natural gas heating and many are still original equipment since 1988. Building also has Building Automation System (BAS) and controls scheduling of equipment. Energy audit for this building suggests completing refurbishment for a roof as signs of deterioration are showing; however this was not done yet.

Building #6 is located at Scarborough, Ontario.

Overview: the building is a combination of office space and retail space, with 2,130 m^2 of gross floor area. The building was constructed in 1980. Already two first level energy audits were performed for this building, but no upgrades were completed yet. Typical building operating hours are from Monday to Friday from 6am to 7pm, on Saturdays from 7am to 6pm, and on Sundays the building is closed. However each office operates on a different schedule and as result has different hours of work.

Energy audit 1 was completed in March, 2014 by SNC Lavalin O&M department; a previous energy audit was conducted in April 2011 however no upgrades were implemented to the building. During March 2014, audit assessment of the energy savings potential of the facility was completed, and a site walk-through was conducted that included interviews with site personnel. From energy audit, the following information was summarized. Energy consumption of the building is relatively low in comparison to similar building in this region. But this is could be due to the fact that some tenants receive individual bills and although it was a priority to track all bills for this building, but some bills could be paid separately. Therefore for further calculations and comparison energy index will be increased by

10% to approximate missing information. By applying this assumption this would bring the overall level of energy consumption to more realistic value. Heating and cooling for second floor of the building is provided by packaged rooftop units (electric cooling and gas heating) with VAV system. Building also uses electric fan-coil heaters (this used at the entrance), and individual split A/C systems with electric heaters in the air-handling unit. The fresh air to the building is provided by louvers. All tenants are individually metered for energy consumption, therefore pay for it separately.

Building #7 is located at Ottawa, Ontario.

Overview: 4 story building is mostly an office building with typical building operating hours from Monday to Friday from 8am to 5pm, on Saturdays and Sundays, the building is closed (except rooftop units). Building was constructed in 1993, with total floor area of 8,180 m^2.

Energy audit 1 was completed in December, 2008 by SNC Lavalin O&M department. During this audit information was collected on site and preliminary calculations included description for each measure of energy savings. From energy audit, the following information was summarized. Energy consumption of the building is slightly higher in comparison to similar building in this region. Increased energy consumption is due to the rooftop units operating 24/7, but because the building has a big atrium energy, consumption balances due to the wasted floor space. Domestic hot water is heated by electric water heaters located through the building. Building does not have Building Automation System; all controls on HVAC equipment are mechanical or pneumatic. Building has variable air volume (VAV) rooftop units that provide conditioned ventilation air to the 3rd and 4th floors of the building, similar smaller units provide conditioned air to the atrium. Air-handling units (AHU) provide air to the suites on the rest of the floors. Atrium is heated by three gas-fired rooftop units.

Building #8 is located at Ottawa, Ontario.

Overview: A 5-story building, mostly an office building with total floor area of 5,020 m^2, and heated underground garage. Building was constructed in 1989. Typical building operating hours are from Monday to Friday from 7am to 7pm, on Saturdays from 7am to 5pm, and on Sundays, the building is closed. Garage operates 24/7.

Energy audit 1 was completed in November, 2008 by SNC Lavalin O&M department. During this audit discussions with client for background information was completed, in addition site visit and discussions with building operators was conducted, all this information was analyzed with backup of utility bills and analysis of potential retrofit measures were prepared. From energy audit, the following information was summarized. Energy consumption of the building is very high in comparison to similar building in this region. Building has high energy consumption due to following factors: first is the rooftop equipment that operated 24/7, also heated underground parking (maintained to 15C during winter), and in addition make-up air (MUA) units appears to be oversized. Domestic hot water for the building is provided by electric water heater in the basement electrical room. Building does not have Building Automation System, and all controls on HVAC equipment are mechanical or pneumatic. Climatemaster rooftop units provide conditioned ventilation air to the building, and it operates 24/7. Building also has electric humidifier, but it is not operating. Rooftop also holds packaged heat/cool unit, and various split A/C condensing units.

Building #9 is located at Ottawa, Ontario, Tower C.

Overview: A 3-story building is an office building contracted in 1989, with total floor area of 4,854 m^2. Building has exterior parking for 165 spaces, there is no interior parking. Typical building operating hours are from Monday to Friday from 7am to 7pm, and its typically closed on Saturdays and Sundays.

Energy audit 1 was completed in June, 2010 by SNC Lavalin O&M department. During this audit assessment of the energy savings potential of the facility was completed, and a site walk-through was conducted that included interviews with site personnel. From energy audit, the following information was summarized. Energy consumption of the building is average in comparison to similar building in this region. Heating in the building is provided by electricity. Domestic hot water also is provided by electricity and is sourced by water tanks. Energy audit that was performed for this building suggests upgrading windows glazing, given the age of the building the glazing is not up to current efficiency level, and heat penetration through building envelope into the building is higher.

Building #10 is located at Ottawa, Ontario, Tower B.

Overview: a 5-story building is an office building constructed in 1989 with total floor area of 8,270 m^2. Total building occupancy is 732 with current occupancy of approximate 600 people. Typical building operating hours are from Monday to Friday from 6am to 6pm; however some tenants remain in the building until 8pm.

Energy audit 1 was completed in December, 2010 by SNC Lavalin O&M department. During this audit assessment of the energy savings potential of the facility was completed, and a site walk-through was conducted that included interviews with site personnel. During site visit some of the areas were not accessible due to security concerns, but nevertheless site audit allowed for the initial selection of energy conservation measures. From energy audit following information was summarized. Energy consumption of the building is very high in comparison to similar building in this region, and in comparison to BOMA energy efficient building value of 1.05 GJ/m^2/year however it is much lower than average National Resources Canada value of 1.43GJ/m^2/year. High energy consumption is due to the data center which is located in the basement and ground floor of the building. Generally data center requires higher amount of equipment and consumed more energy. Therefore to provide more accurate assumptions, data center is factored out of analysis as 25% of the buildings overall energy usage (based on the area of data center). The electricity used by the tenants of data center is related to cooling equipment. The facility is equipped with an electrical meter by the utility to maintain night and holiday schedules. In addition, the building has Building Automation System (BAS) to monitor and control key systems of the building. Building heating is served by electricity, and there is no natural gas in the building. The main entrance vestibule of the building is heated by an electric forced fan heater. The building air side system consists of two air handlers, and building cooling is supplied by roof-mounted air cooled chiller.

Building #11 is located at Ottawa, Ontario, Tower A.

Overview: A 4-story building was built in 1988 with total floor area of 6,162 m^2. Typical building operating hours are from Monday to Friday from 6am to 6pm; however, some tenants remain in the building until 8pm. The building is closed on Saturdays and Sundays.

Energy audit 1 was completed in July, 2011 by SNC Lavalin O&M department. During this audit assessment of the energy savings potential of the facility was completed, and a site walk-through was conducted that included interviews with site personnel. From energy audit, the following information was summarized. Energy consumption of the building is average in comparison to similar building in this region. Similarly as Building B, Building A heating is served by electricity, and there is no natural gas in the building. Energy audits completed for B and A Buildings recommend switching to natural gas, as natural gas is available on site (servicing Building C) and can be utilized for other two buildings. HVAC system in the building is air cooler chiller and circulating pump. Energy audit also suggests upgrading window glazing, due to the similar reasons as in Building C.

Building #12 is located at Montreal, Quebec.

Overview: A 7-floor office building was constructed in 1873 and has undergone a few upgrades in 1987 and 1988. Occupancy of the building is around 150 people, and typical building operating hours are from Monday to Friday from 7am to 6pm, closed on Saturdays and Sundays.

Energy audit 1 was completed in March, 2015 by SNC Lavalin O&M department. During this audit assessment of the energy savings potential of the facility was completed, and a site walk-through was conducted that included interviews with site personnel. From energy audit, the following information was summarized. Energy consumption of the building is relatively low in comparison to similar building in this region. Building does not have Building Automation System (BAS) however there is a remote monitoring. In 2011 new make-up air unit was installed on the roof to supply fresh air. A variable speed-cooling tower operates year-round and serves the heat pump units on each floor. The cooling tower operates with pan heater to deal with cooling loads that occur in the winter months. Constant speed pumps in the penthouse level serve condenser water from the cooling tower to a heat exchanger. Domestic hot water is supplied with electric hot water tanks. Each floor has heat pump air handlers. Building has no insulation and constructed on multiple courses of stone and brick. Windows are double glazed, but are in fair to poor condition.

Building #13 is located at Vaudreuil-Dorion, Quebec.

Overview: A one story building with partial second floor at the main entrance. Building was constructed in 1977 with total floor area of 8,022 m^2. At the beginning, the building was intended to be a shopping center, however currently, the ground floor is occupied by offices and a billiard hall/restaurant partially, and the second floor is occupied by offices. Typical building operating hours are from Monday to Friday from 7am to 5pm, with the billiard hall and restaurant, having late hours past midnight. Billiard hall and restaurant is also open on Saturdays and Sundays. Approximate occupancy is 120 people.

Energy audit 1 was completed in March, 2015 by SNC Lavalin O&M department. During this audit assessment of the energy savings potential of the facility was completed, and a site walk-through was conducted that included interviews with operations personnel. From energy audit, the following information was summarized. Energy consumption of the building is average in comparison to similar building in this region. The building is not equipped with a building automation system, many systems run continuously as there is no means of scheduling. The heating and cooling system is composed of packaged rooftop units installed on the rooftop of the building. Supplementary heating in the form of several electric baseboard heaters is also used. Domestic hot water is supplied to the building by multiple electric boilers.

Building #14 is located at Cte-St-Luc, Quebec.

Overview: A 5 floor office building was constructed in 1976 with a total floor area of 7,943 m^2. Building consists primary of offices with typical building operating hours are from Monday to Friday from 7am to 8pm. But the building also has Montreal Police space on the ground floor, which operates 24 hours a day. The approximate occupancy of the building is 300 people. Building has heated underground parking lot.

Energy audit 1 was completed in March, 2015 by SNC Lavalin O&M department. During this audit assessment of the energy savings potential of the facility was completed, and a site walk-through was conducted that included interviews with site personnel. From energy audit, the following information was summarized. Energy consumption of the building is relatively high in comparison to similar building in this region, and in comparison to BOMA energy efficient building value of 1.05 $GJ/m^2/yr$ however it is lower than average National Resources Canada value of 1.43$GJ/m^2/year$. Energy audit completed for this building specifies that building is not energy efficient. The building is not equipped with a building automation system; all controls are manual and standalone, therefore scheduling is not controlled. The heating and cooling system is composed of through-the-wall heat pumps installed on the building facades. All units are controlled locally on the unit. In addition there are three heat pumps on the roof. The cooling system is equipped with an indoor cooling tower. Also, there are unit heaters throughout the building, particularly in the underground parking lot. These heaters operate continuously in the winter period. Fresh air in the building is supplied from the penthouse, and this equipment also operates continuously. The buildings domestic hot water is supplied through electric water heaters.

Building #15 is located at Gatineau, Quebec.

Overview: A 3-floor building was constructed in 1989 with total floor area of 5,518 m^2. Building is a typical office with approximate occupancy of 200 people. Typical building operating hours are from Monday to Friday from 7am to 6pm, and closed on Saturdays and Sundays.

Energy audit 1 was completed in October, 2014 by SNC Lavalin O&M department. During this audit assessment of the energy savings potential of the facility was completed, and a site walk-through was conducted that included interviews with site personnel. From energy audit, the following information was summarized. Energy consumption of the building is high in comparison to similar building in this region. HVAC requirements are met by rooftop units, with electric baseboard heaters installed around the perimeter of the floors to compensate for any heat loss. Central chiller supplies air conditioning, but it only serves ground and top two floors. The rest of the building is equipped with air handling units. Electric water heater provides domestic hot water. Building has an electrical humidifier.

3.2 Calculations

3.2.1 Energy Intensity Calculations

To determine energy intensity of each case-study building, meta-analysis data set will combine energy-use data from utility bills and audits Level 1 measures, from two sources namely: EnergyCAP and CAMS (SNC Lavalin O&M databases).

Utility bills information (electricity and natural gas consumption) for the range of years was obtained through energy tracking service, which monitors billing data using the EnergyCAP software application. This data was considered in the analysis to obtain an overall picture of the buildings monthly and annual energy consumption. EnergyCAP software provides the following information: actual data (summary, commodity of electric, natural gas, and water; monthly consumption, greenhouse gas emissions. For each category, data is split up into: total cost, energy cost percentage, daily average cost. Savings: summary, commodity, monthly (water, natural gas). For each commodity: monthly energy bills and demand.

For each case-study building utility invoices were analyzed, following procedure was utilized and all results and summary can be found in Appendix A. Utility bill analysis (general overview of the buildings various energy consumption levels), utility analysis summary (general overview of various consumption data for the particular facility), trending report for high energy consumption year and low energy consumption year (this is an equivalent kWh per square meter graph of the various types of energy used in the facility normalized by number of days in the month. Equation per month is as follows: kWh per month/building area m2/#days per month. By dividing the GJ/m2 values by the number of days in a given month, energy consumption is normalized). Comparison of energy intensity for high energy consumption year and low energy consumption year, average energy intensity is plotted to be compared to the BOMA benchmark value. Linear Regression for total energy consumption per degree days (here mathematical equation that defines the linear line is given on the graph itself. The relationship between energy consumed and weather (degree days) was plotted. The higher the degree days, the higher the energy consumption should be. The dots on the graph represent actual energy (electricity and natural gas) consumption. This is measured by the value R2 and the closer R2 is to 1.0 the better the trending. For buildings with negative trending, there may be an opportunity for improvements, if the dot is above the line; this indicates an occasion where high consumption may not have been warranted. During utility bills evaluations, attention was paid to understanding utility rate structure that applies to the facility, also to notice any additional utility monthly charges and disregard any inconsistent data.

Calculations of energy index for Building #1 are shown below as an example; calculations for the rest of the case-study buildings can be found in Appendix A.

Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity and gas. For Building #1 utility bills were provided from December 2006 to March 2015. To complete most accurate analysis, utility bills for 2007 to 2014 were only analyzed because 2006 and 2015 has incomplete data. Following calculations were done based on utility bills: sum of electrical total cost per year, sum of gas total cost per year, sum of electrical consumption per year and sum of gas consumption per year. By having total floor area for the entire building of 25,424 m^2, energy index in GJ/m^2/year was calculated. From calculations it was noticed that 2008 provides inconsistent values in comparison with the rest of years, therefore for calculations of average yearly energy index 2008 year was excluded.

By summarizing utility bills data following calculations were made:

Table 3.3: Building #1 Utility Bills Calculations

Building A - Toronto, Ontario						
Units		kWh		m^3	Total GJ/year	25,424.00
Row Labels	Sum of Electricity Total Cost / Year	Sum of Electricity Consumption / Year	Sum of Gas Total Cost / Year	Sum of Gas Consumption / Year	Total (Electricity + Gas)	GJ/m^2/yr
Year 2006	$41,516.27	421,367.05				
Year 2007	$570,890.60	5,091,354.15	$131,724.54	268,388.00	28,312.91	1.11
Year 2008	$569,094.68	4,972,063.86	$107,359.18	174,537.00	24,392.21	0.96
Year 2009	$579,662.09	5,244,523.90	$119,726.55	248,527.00	28,125.49	1.11
Year 2010	$604,472.94	5,301,976.03	$127,649.39	257,151.00	28,653.13	1.13
Year 2011	$652,951.71	5,468,612.54	$95,527.36	209,070.00	27,464.41	1.08
Year 2012	$702,682.00	5,475,785.13	$54,017.26	225,168.00	28,089.08	1.10
Year 2013	$769,177.23	5,426,172.96	$69,769.34	294,926.00	30,505.47	1.20
Year 2014	$795,137.19	5,486,980.86	$80,626.79	292,762.00	30,643.88	1.21
Year 2015	$189,033.38	1,326,773.63	$79,274.42	229,157.00		
Average	$667,853.39	5,356,486.51	$97,005.89	256,570.29		1.13

As it was specified in energy audit, energy consumption of the Building #1 is moderately high in comparison to similar office buildings in same region; and therefore average energy index which equals to 1.13 GJ/m^2/yr is also high in comparison to benchmark values of BOMA energy efficient building value of 1.05 GJ/m^2/yr or National Resources Canada value of 1.43 GJ/m^2/yr.

Two charts below (Figure 3.5 and 3.6) show electricity and gas consumption per year. Electricity consumption chart demonstrates prominent increase in energy usage, 2012 and 2014 shows the highest values. However gas consumption chart does not increase in such an obvious pattern, but the highest gas consumption values are also in more recent years 2013 and 2014.

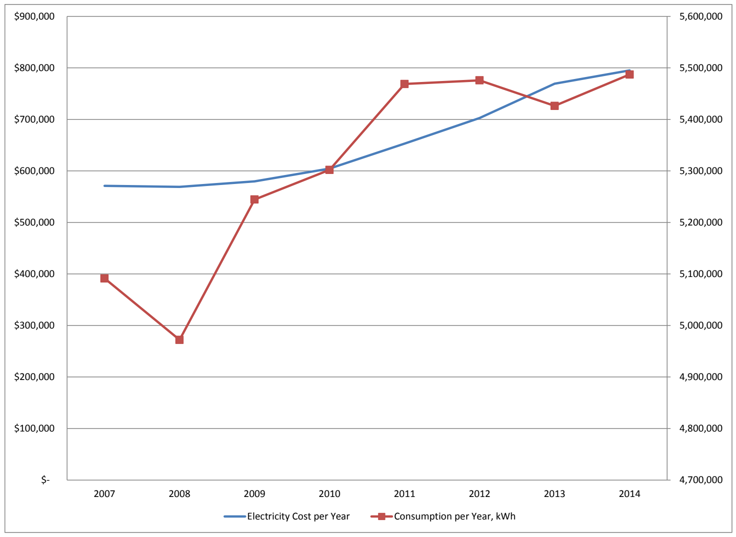


Figure 3.5: Example Building #1 - Yearly Electricity Consumption

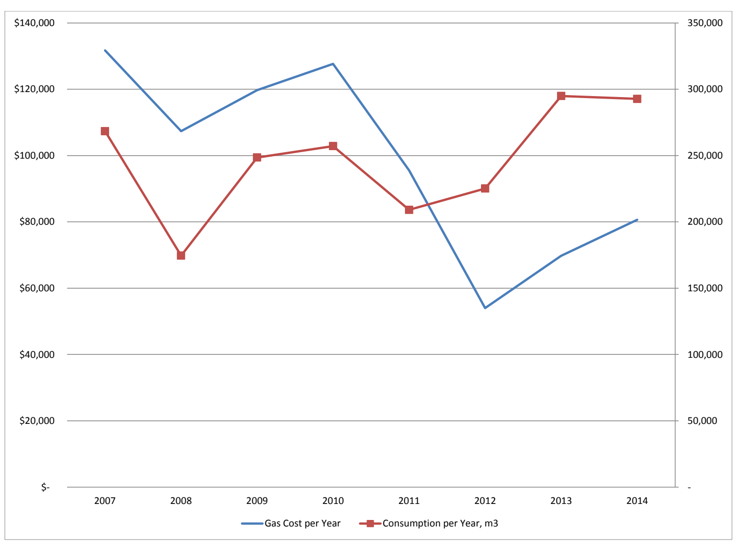


Figure 3.6: Example Building #1 - Yearly Gas Consumption

Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. The chart below (Figure 3.7) shows that energy index value is gradually increasing and currently around 1.21 GJ/m^2/yr. The lowest energy index was in 2011 and highest in 2013. These two years data will be used for further calculations and comparisons.

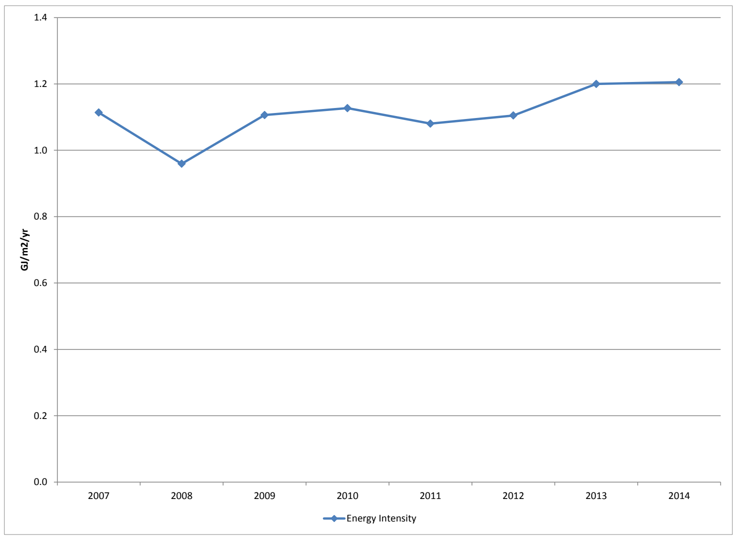


Figure 3.7: Example Building #1 Yearly Energy Intensity Comparison

Because weather varies from day to day and year to year, normalization measures provide the best solution to represent how weather impacts energy consumption of the building. Energy used for heating and cooling is directly dependant on how cold or hot it was during a specific year or season. Weather normalization was applied on year with the lowest energy usage, so it could be compared to the year with highest energy usage. Comparing normalized data showed actual energy consumption not dependant on weather during such periods. Data for heating and cooling degree days was taken from weatherstats.ca webpage. By using total degree days (HDD plus CDD) normalized total energy consumption was calculated for Building #1. Based on plotted results, shown below in the chart (Figure 3.8), it can be concluded that energy consumption for 2013 is higher than for 2011. This proves that regardless of weather conditions, 2013 has higher energy consumptions than in 2011. Implementing trend-line equations, the average equation was calculated:

$$\gamma = 3.1724x + 1340.45$$

From the above equation, normalized average energy index was calculated as 1.14 GJ/m^2/yr; this value is slightly higher than average for 2007 to 2014 years range. Calculated value will be used for further case-study buildings comparison. Figure 3.8 shows linear progression for normalized data with equations.

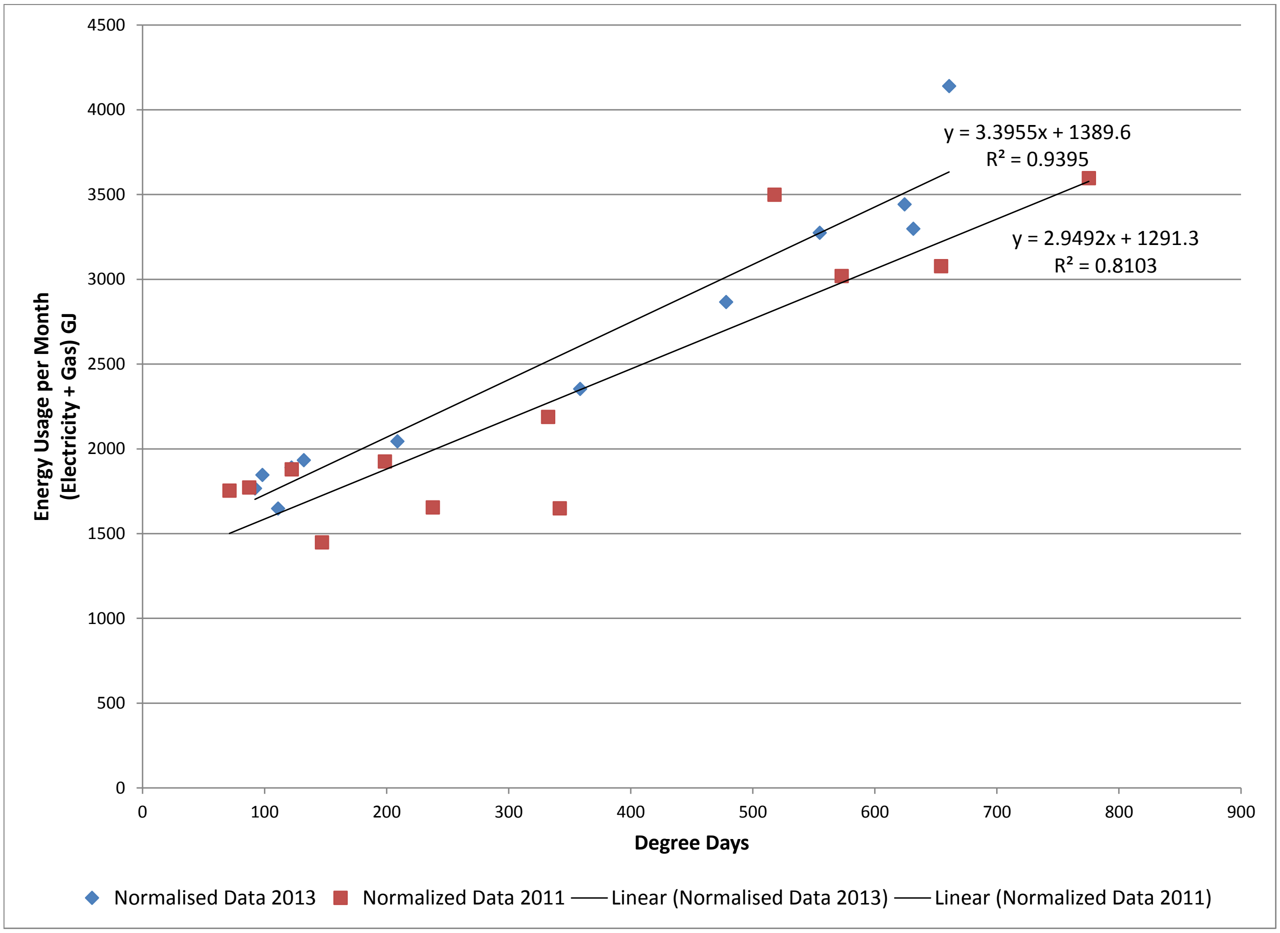


Figure 3.8: Example Building #1 - Normalized Energy Intensity Calculations (year of the highest energy consumption vs. year with lowest consumption)

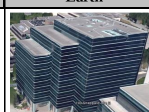
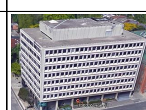
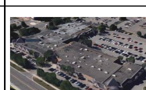
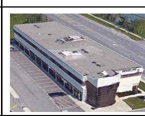
Additional analysis of energy bills for Building #1 can be found in Appendix A. Tables and charts include summarized utility bills actual data used for calculations for 2013 and 2011 years, and calculations of energy index. Also two charts showing how electricity and gas consumption corresponds to heating and cooling periods (for highest and lowest energy consumption years), as well as additional an chart that shows monthly energy intensity for plotted comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity.

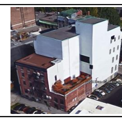
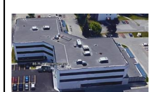
As previously mentioned, a similar procedure was applied to calculate energy intensity for the rest of 14 case-study buildings, and details of calculation can be found in Appendix A.

3.2.2 WWR Calculations

To calculate WWR for each case-study building, architectural drawings were utilized; architectural drawings were available only for four case-study buildings: #1, #2, #3 and #4. From elevations as well as cross-sections details drawings WWR was calculated for each building. For the rest of the building, where architectural drawings were not available, either a site visit was conducted or assumptions were made from photographs and Google Earth 3D images. WWR was calculated based on the equation provided in (Public works and Government Services Canada, 2002) guide. Complete calculations for each building can be found in Appendix B.

Table 3.4: WWR Summary of Case-Study Buildings

	Address	Images from Google Earth	Shape	WWR	Notes:
1	Toronto, Ontario		Complex Shape	44%	Drawings Provided
2	Mississauga, Ontario		Complex Shape	27%	Drawings Provided
3	Toronto, Ontario		Rectangular	39%	Drawings Provided
4	Mississauga, Ontario		Complex Shape	42%	Drawings Provided
5	Mississauga, Ontario		Complex Shape	40%	Site Visit has been Completed
6	Toronto, Ontario		Rectangular	40%	Site Visit has been Completed
7	Ottawa, Ontario		Rectangular	32%	Based on Google Images
8	Ottawa, Ontario		Complex Shape	43%	Based on Google Images

9	Ottawa, Ontario, Tower C		Square	42%	Based on Google Images
10	Ottawa, Ontario, Tower B		Square	42%	Based on Google Images
11	Ottawa, Ontario, Tower A		Square	42%	Based on Google Images
12	Sacrement, Montreal, Quebec		Complex Shape	19%	Based on Google Images
13	Vaudreuil-Dorion, Quebec		Rectangular	25%	Based on Google Images
14	St-Luc, Quebec		Complex Shape	23%	Based on Google Images
15	Gatineau, Quebec		Complex Shape	38%	Based on Google Images

For visualizing purposes images from Google Earth were retrieved and shown in the window-to-wall summary table above (Table 3.4). Summary table contains the following information: building number, building location/name and WWR for each case study building. All images show South orientation of each case-study building.

3.2.3 Building Envelope Thermal Resistance Calculations

Architectural drawings as well as information provided in energy audits reports were used to analyze building envelopes of case-study buildings:

- Building Envelope for Building #1 consists of typical cavity wall with architectural concrete block, concrete block on the inside and insulation in between. Windows are mostly double glazed curtain wall assemblies. Built-up roof with precast concrete pavers, insulation, roofing membrane and structural slab sloped to drain.

- Building Envelope for Building #2 consists of a typical cavity wall with brick from the outside, concrete block and stud framing with R-8 batt insulation. Double glazed windows have thermally broken aluminum window frames. Built-up roof consists of stone ballast on fabrene sheet, rigid insulation, single ply membrane and sloped concrete.

– Building Envelope for Building #3 consists of typical wall system such as tinted gray glazing in precast concrete panels. At the first level, windows are clear glass in aluminum frames. Typical roof system is built-up roofing with rigid insulation, vapor barrier and concrete slab.

– Building Envelope for Building #4 consists of double cable type clear anodized aluminum frame set into curtain wall framing, also insulated prefinished metal siding with frameless butt glazing. Typical roof consists of precast concrete pavers on precast waterproofing membrane and sloped concrete.

– Building Envelope for Building #9, #10 and #11 consists of granite and double glazed curtain wall, and built-up roof. Insulation values could not be ascertained on site without destructive testing; therefore assumptions for thermal resistance will be made. Windows are heavily tinted.

Architectural drawings were only available for four buildings, but one set of drawings (for building #4) was incomplete; therefore, building envelope components were not specified. Also, energy audits only provided brief building envelope description for buildings #9, #10 and #11, and calculations of thermal resistance were not possible. Due to such restrictions, thermal resistance was only calculated for buildings #1, #2 and #3.

For thermal resistance calculations, assumptions for building envelope assembly components were based on ANSI/ASHRAE/IES Standard 90.1-2010 (CHAPTER 26), Table 4 Typical Thermal Properties of Common Building and Insulating Materials. However architectural drawings provided typical walls and roof construction components, but because construction specifications were not available, numerous assumptions had to be made. Assumptions are listed in spreadsheets used for calculations, and can be found in Appendix C.

Existing building RSI-values are compared to "Minimum thermal values requirements of building envelopes as per SB-10", Climate Zone 6, TABLE SB5.5-6, (Supersedes Table 5.5-6 in ANSI/ASHRAE/IESNA Standard 90.1). Based on this, calculation tables (can be found in Appendix C) specify whether higher greater thermal resistance of building component is required or determines if it satisfies the minimum requirements.

Summary table below shows thermal resistance of three main building envelope components: wall, roof and windows. All these components are area dependent, therefore effective thermal resistance for overall building envelope for each building was calculated. Following formula (as per SB-10 guidelines) was utilized to calculate effective thermal resistance:

$$R_o = 3R_iA_i/A_o = (R_1A_1 + R_2A_2 + ... + R_nA_n)/A_o$$

By analyzing this data it can be concluded that buildings with higher WWR have lower effective thermal resistance due to bigger fenestration area in comparison to more thermally resistant opaque area. Table 6 provides summary of calculated thermal resistance.

Table 3.5: Three Case-Study Buildings Summary (Includes Thermal Resistance for Building Envelope Component)

		Thermal Resistance ($K * m^2/W$)			
#	Address	Wall	Roof	Window	Effective
1	Building A - Toronto, Ontario	1.62	0.47	0.15	0.98
2	Building B - Mississauga, Ontario	2.12	0.13	0.15	1.59
3	Building C - Toronto, Ontario	0.34	1.59	0.15	0.27

3.3 Analysis

3.3.1 Analysis of Energy Audits

To complete energy audits, SNC Lavalin follows the standard format of reporting, and after reviewing 15 energy audit reports (Phase One) it was concluded that all reports follow similar outline: overview and general information of the building, general findings that included analysis from the utility bills, energy index calculations and load factor analysis, also the initial selection of Energy Conservation Measures (ECM), and at the end energy conservation measures. The conservation measures section includes existing conditions and proposed solutions for various building systems and equipment, such as lighting fixtures replacement, upgrade of thermostat control, retrofit of heating /cooling equipment and others. Some of the audit reports also proposed to conduct further calculations as a solution; such calculations were: to perform heat loss calculations to estimate correct size of heating/cooling equipment, perform retro-commissioning audit on building automation system to identify energy and efficiency opportunities, conduct HVAC capital study that will include analysis and moving forward plan, upgrade lighting schedule, development of replacement plan by providing analysis and ranking the order of which units will be upgraded, and others. As a result, each report provides executive conservation measure summary where high level cost estimate for all upgrades is listed. Reports also provide the next step section, where anticipated implementations are discussed and high level plan of actions is provided.

After analyzing all 15 energy audit (Phase One) reports, it was observed that building envelope was only briefly discussed in four reports. Building #3 report proposes to replace single pane outdated windows with new, double pane, thermally broken, solar reflective windows. Building #5 report proposes to upgrade the existing roof due to ponding and signs of deterioration. Building #9 and #11 reports propose to upgrade existing windows by adding supplemental window glazing/shading to help reduce the heat penetration during the cooling season. From this, it can be concluded that building envelope upgrade is not typically considered as a part of the potential energy and cost savings measure during phase one energy audits analysis. However most of the reports claim that energy audit is based on an established process to identify measures for reducing energy consumption (perform renovations to eliminate thermal bridges), measures for improving occupant comfort, and measures for reducing greenhouse emissions, but very small percentage of them discussing building envelope concerns. It is explained in one of energy audit reports, that to eliminate thermal bridges in the building would require a full building retrofit; accurately calculating the savings for such a major project is beyond the scope of such report.

3.3.2 Energy Intensity Analysis, Summary of Case-Study Buildings

Below is the summary of all 15 case-study buildings. Table 3.6 provides the year range for which energy bills were available, electricity consumption and cost, gas consumption and cost, and energy intensity result for each building. All case-study buildings are office facilities with typical office hours and in most cases with typical occupancy (except #2 and #6 with retail space, #13 with billiard hall/restaurant space, and #14 with space dedicated for Montreal Police). Based on these and other differences, buildings have inconsistent energy consumption.

Table 3.6: Summary of Case-Study Buildings (Energy Intensity Calculations)

			ELE		GAS		Average Energy Intensity		
	Address	**Utility Bills Year Range**	**Average Total Cost / Year ($)**	**Average Consumption / Year (KWH)**	**Average Total Cost / Year ($)**	**Average Consumption / Year (m3)**	**GJ/m2/yr**	**GJ/m2/yr normalized**	**GJ/m2/yr Final**
1	Building A - Toronto, Ontario	2007-2014	$667,853.39	5,356,486.51	$97,005.89	256,570.29	**1.13**	**1.14**	**1.1**
2	Building B - Mississauga, Ontario	2007-2014	$246,967.41	2,121,842.88	$30,556.21	82,817.17	**1.20**	**1.21**	**1.2**
3	Building C - Toronto, Ontario	2003-2014	$243,666.24	1,912,409.76	$61,633.94	158,362.63	**1.38**	**1.36**	**1.4**
4	Building D - Mississauga, Ontario	2007-2014	$393,477.17	3,421,947.30	$24,532.29	58,556.00	**1.08**	**1.09**	**1.1**
5	Building E - Mississauga, Ontario	2007-2014	$57,028.61	454,068.77	$10,124.45	17,995.13	**0.36**	**0.36**	**0.5**
6	Building F - Scarborough, Ontario	2007-2014	$32,743.33	237,522.04	$12,132.57	26,522.25	**0.86**	**0.93**	**1.0**
7	Building G - Ottawa, Ontario	2007-2014	$282,673.76	2,358,438.23	$13,849.99	31,961.50	**1.18**	**1.21**	**1.2**
8	Building H - Ottawa, Ontario	2007-2014	$208,720.71	1,829,845.48	$35,640.60	81,764.75	**1.92**	**1.93**	**1.9**
9	Building I - Ottawa, Ontario, Tower C	2008-2014	$165,954.52	1,358,046.07	$2,335.47	4,622.00	**1.04**	**1.07**	**1.1**
10	Building J - Ottawa, Ontario, Tower B	2000-2014	$689,483.72	6,121,641.06	n/a	n/a	**2.66**	**2.34**	**1.8**
11	Building K - Ottawa, Ontario, Tower A	2007-2014	$219,269.84	1,827,859.22	n/a	n/a	**1.07**	**1.10**	**1.1**
12	Building L - Montreal, Quebec	1998-2014	$63,716.21	739,530.00	$8,208.07	14,663.06	**0.91**	**0.94**	**0.9**
13	Building M - Vaudreuil-Dorion, Quebec	2007-2014	$149,787.57	1,692,200.50	$5,466.17	8,189.04	**0.91**	**0.92**	**0.9**
14	Building N - Côte-St-Luc, Quebec	2007-2014	$233,884.37	3,060,853.33	n/a	n/a	**1.39**	**1.47**	**1.5**
15	Building O - Gatineau, Quebec	2007-2014	$161,054.78	1,907,417.14	$29,264.89	64,138.80	**1.68**	**1.69**	**1.7**

As it was specified previously, energy intensity benchmark value is used from BOMA report, where average energy use intensity for certified Office Buildings, is 27.1 ekWh/ft^2/yr (or 1.05GJ/m^2/yr). The chart below (Figure 3.9) demonstrates the comparison of energy intensity of each case-study building to BOMAs average value.

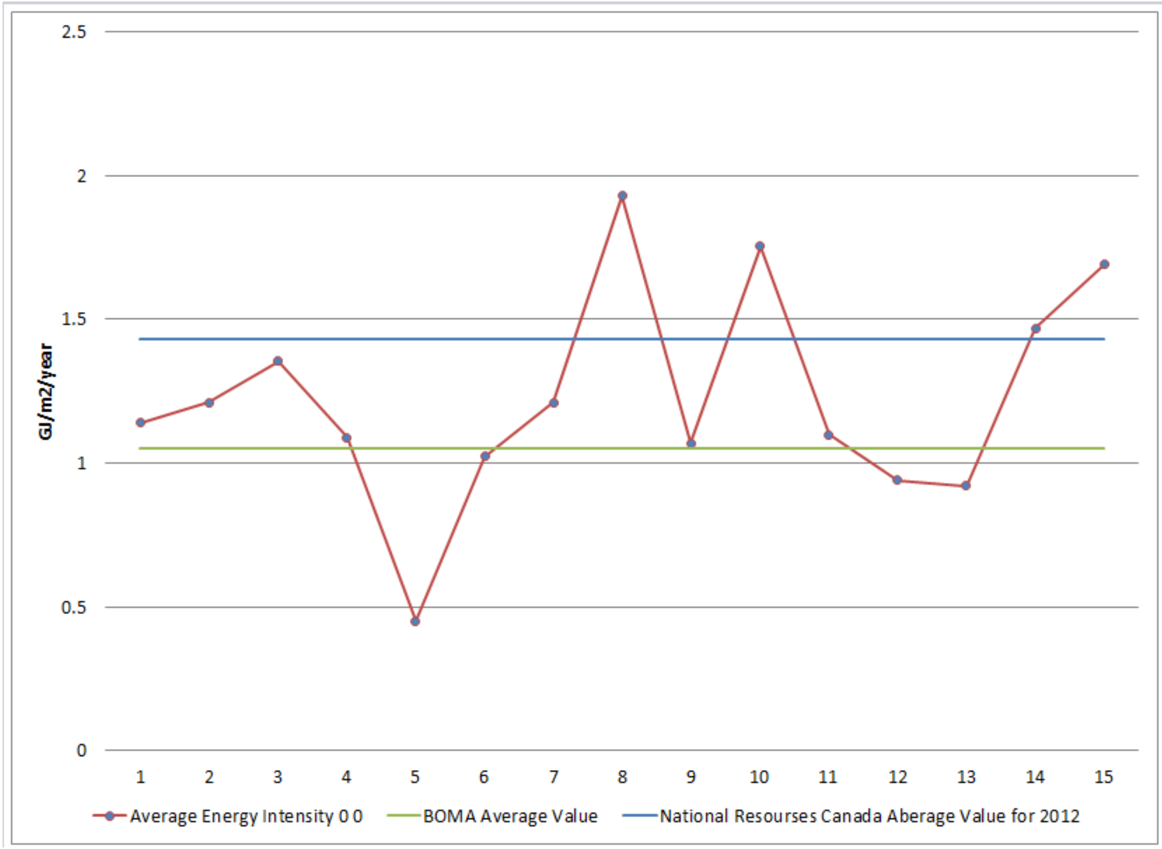


Figure 3.9: Energy Intensity vs. BOMAs Average Value

Two buildings #8 and #10 show significantly higher value from the benchmark value and building #5 shows very low value in comparison to the rest of the buildings. More than half of the case-study buildings have energy index value around benchmark BOMA value; this demonstrates that buildings are performing at levels as per BOMA benchmark.

As it was mentioned before, buildings are divided into four main shape categories, however in charts below (Figure 3.10) combined complex shapes into one category.

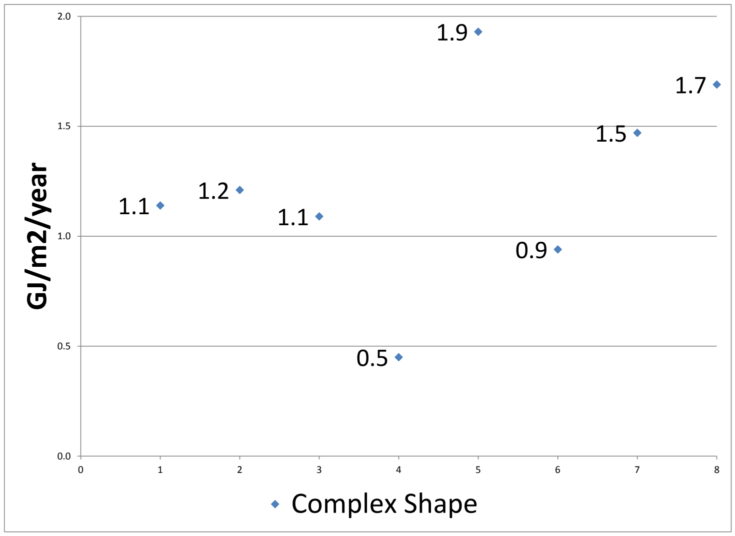


Figure 3.10: Energy Intensity vs. Building Shape Category (Complex Shape)

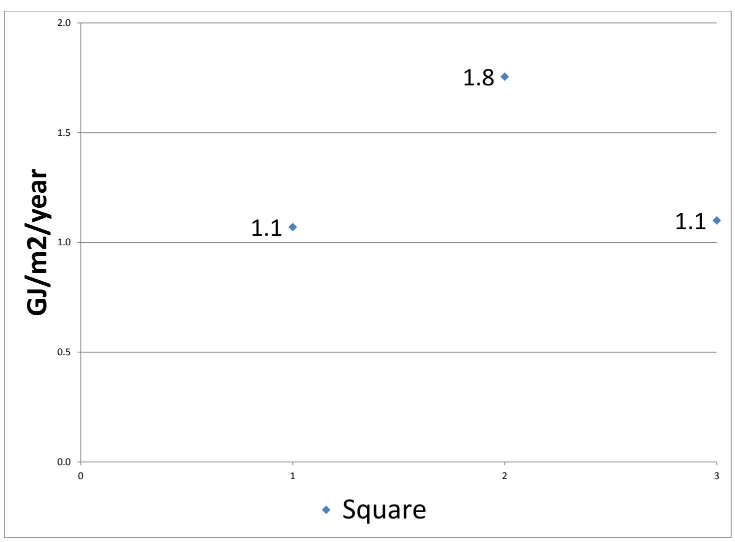


Figure 3.11: Energy Intensity vs. Building Shape Category (Square Shape)

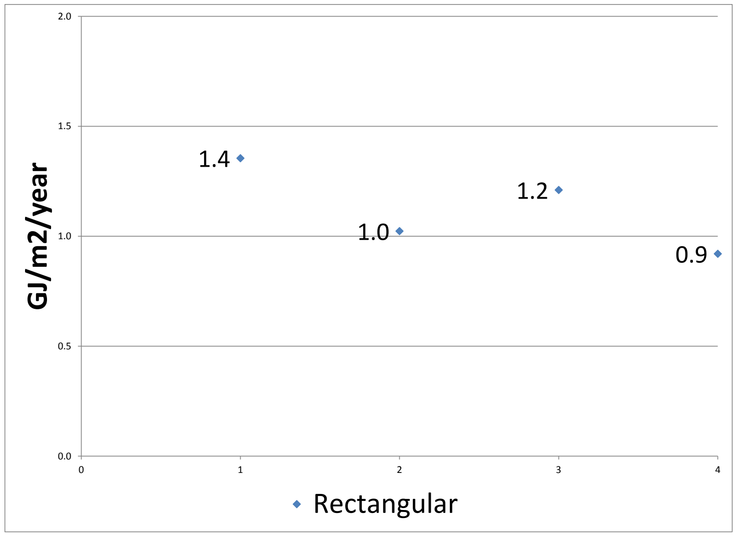


Figure 3.12: Energy Intensity vs. Building Shape Category (Rectangular Shape)

By grouping building based on their building shape, analysis didnt show much of the consistency. Buildings in all categories have energy intensity values higher than BOMA benchmark energy intensity value; however square shape category, which only contains three buildings, has only energy intensity higher than BOMA value and not lower.

Following analysis were conducted to conclude how age of the building influence energy intensity results, and linear progression was plotted (Figure 3.13).

Most of the buildings were constructed between 1970 and 1993; only one building was constructed in 1873. Surprisingly Building #12, which was built in 19th century, has relatively low energy consumption in comparison to the newer buildings. Figure below (Left) includes all buildings, and demonstrates increasing pattern of trendline direction. Additional figure (that excludes Building #12 that was constructed in 1873), shows very steady pattern however there is also an increase into positive direction. Two buildings with the highest energy consumption were both constructed in the same year 1989. This summarizes that selected case-studies do not imply that older building have higher energy consumption in comparison to newer constructed buildings. Most of the buildings selected for this research are midrise buildings, however to divide these building into categories all building were grouped into low-rise (1 to 3 floors), mid-rise (4 to 5 floors), and high-rise (6 to 12). Each category has 5 buildings. Figure 3.14 shows that linear trendline has increasing pattern in regards to energy consumption of these buildings reflected as energy intensity index. Low-rise buildings show the lowest energy consumption, and mid-rise having the highest. Additionally Figure 3.14 shows how energy intensity correlates with height of each building. From chart can be concluded that, based on case-study buildings, mid-rise building with height

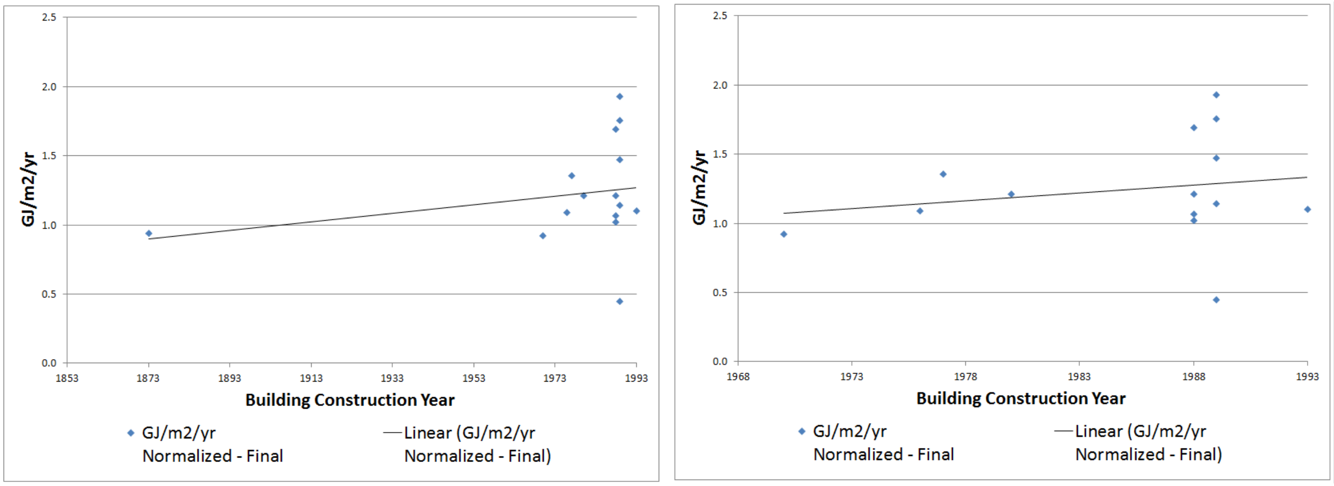


Figure 3.13: Energy Intensity vs. Buildings' Age Category, (Left) all years included, (Right) only more recent years included

4-5 floors have higher energy consumption.

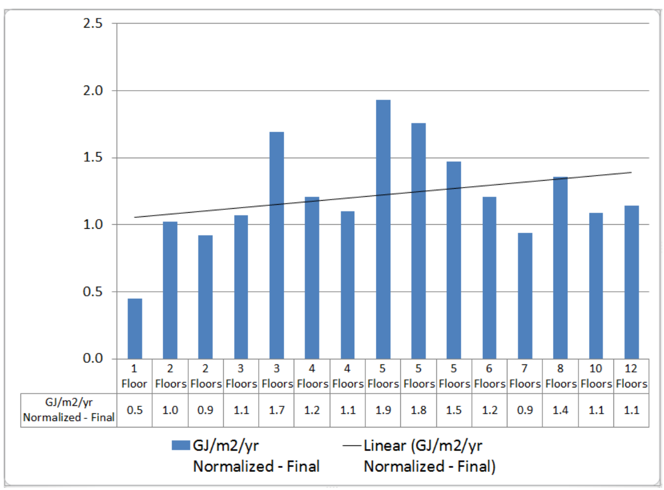


Figure 3.14: Energy Intensity vs. Building Height in Floors

3.4 WWR analysis

Figure 3.15 outlines the relationship between energy intensity and the WWR of 15 case-study buildings. All buildings WWR range between 20% to 45%; only one building has a WWR lower than 20%, as well as none of the building have WWR higher than 45%. Trendline was plotted to identify which direction the chart is approaching: upwards or downwards.

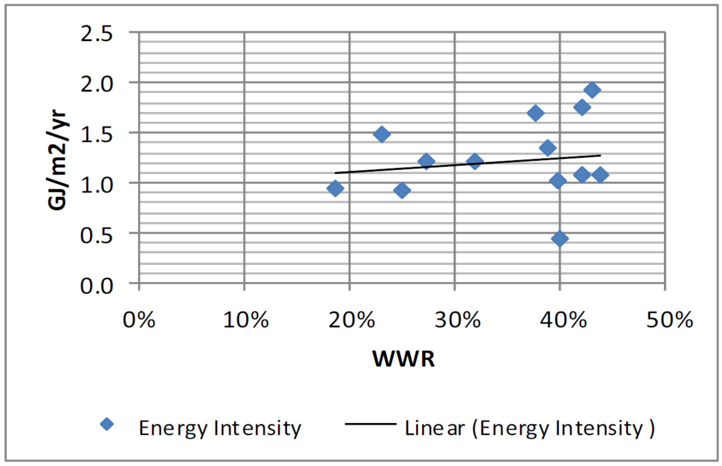


Figure 3.15: Energy Intensity vs. WWR

In addition, WWR was plotted against age of the buildings (Figure 3.16), to see if newer buildings have higher fenestration areas. From the chart below, it is shown that newer building do have higher WWR, and building #12 which was constructed in 1873 has the lowest fenestration area therefore WWR. It has to be noted that energy consumption data for all buildings was analyzed to exclude any inconsistency, as well as normalized to calculate the most accurate average energy index that does not depend on weather conditions for a specific year.

Figure 3.16: Comparison of Case-Study Buildings' Year of Construction vs. WWR

3.5 Thermal Resistance Analysis

Due to limited access to architectural drawings as well as incomplete information, thermal resistance analysis can be only completed for three buildings: #1, #2 and #3. Figure 21 below demonstrates the relationship between effective thermal resistance, WWR and energy intensity.

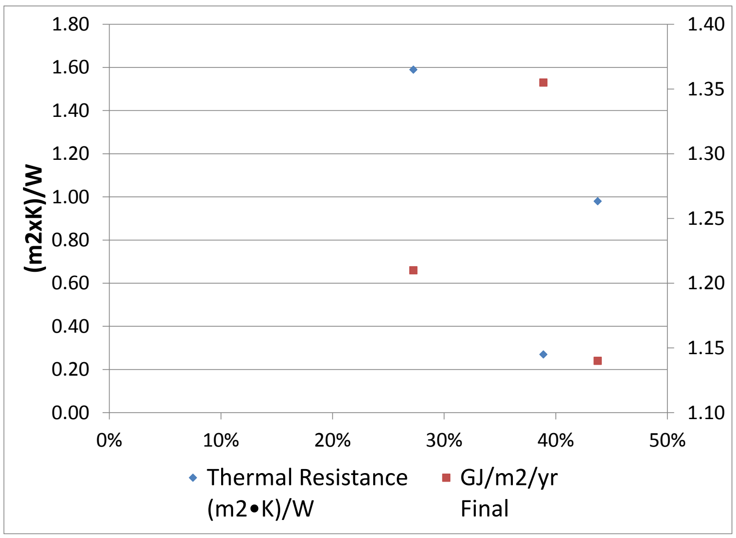


Figure 3.17: Comparison of Case-Study Buildings' Year of Construction vs. WWR

Two buildings, Building #1 and #2 show proportional relationship between thermal resistance and energy intensity; the higher the thermal resistance, the lower energy intensity the building has. Building #3 has very low thermal resistance, and as expected very high energy intensity index and therefore energy consumption. However data was only available for three buildings, but nevertheless results demonstrated an expected outcome. In regards to WWR, results are not very consistent; the building with the highest WWR has 0.98 $(K^*m^2)/W$ effective thermal resistance, which fall at the middle between three buildings. Another two buildings show expected results; the higher the WWR, the lower effective thermal resistance the building has.

3.6 Building Indicators That Impact Energy Consumption

For case-study buildings, major energy consumption breakdown lies between electricity and natural gas consumption. Figure 3.18 show the summary of the percentage breakdown in energy consumption for each facility for the average yearly energy consumption. For comparison purposes, the natural gas and electricity have been converted to common unit of energy (GJ).

	Address	Total Consumption	Electricity Consumption	Gas Consumption	Electricity %	Gas %
1	Building A - Toronto, Ontario	28,827.77	19,283.35	9,544.41	67%	33%
2	Building B - Mississauga, Ontario	10,719.43	7,638.63	3,080.80	71%	29%
3	Building C - Toronto, Ontario	12,775.76	6,884.68	5,891.09	54%	46%
4	Building D - Mississauga, Ontario	14,497.29	12,319.01	2,178.28	85%	15%
5	Building E - Mississauga, Ontario	2,304.07	1,634.65	669.42	71%	29%
6	Building F - Scarborough, Ontario	1,841.71	855.08	986.63	46%	54%
7	Building G - Ottawa, Ontario	9,679.35	8,490.38	1,188.97	88%	12%
8	Building H - Ottawa, Ontario	9,629.09	6,587.44	3,041.65	68%	32%
9	Building I - Ottawa, Ontario, Tower C	5,060.90	4,888.97	171.94	97%	3%
10	Building J - Ottawa, Ontario, Tower B	22,037.91	22,037.91		100%	
11	Building K - Ottawa, Ontario, Tower A	6,580.29	6,580.29		100%	
12	Building L - Montreal, Quebec	3,207.77	2,662.31	545.47	83%	17%
13	Building M - Vaudreuil-Dorion, Quebec	6,396.55	6,091.92	304.63	95%	5%
14	Building N - Côte-St-Luc, Quebec	11,019.07	11,019.07		100%	
15	Building O - Gatineau, Quebec	9,252.67	6,866.70	2,385.96	74%	26%
	Total Average (excluding zero values)				75%	25%

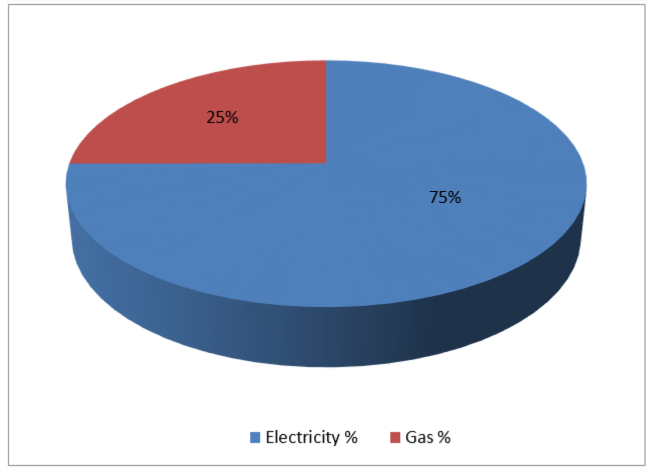


Figure 3.18: (Left) - Case-Study Building Energy Consumption in %, (Right) - Average Percentage

3.7 Energy Balance

In order to identify where energy is used in the buildings, energy balance was completed for the facility. The energy balance identifies the electricity and natural gas consumption by individual systems; it also analyses if that consumption is weather dependant. Energy balance approach demonstrates the overall relative impact of the architectural features on the heating and cooling loads of the building. The larger percentage represents those elements that have a greater impact on heating and cooling loads therefore more attention should be given to these architectural features. Typically energy balance values are estimated based on ammeter readings, equipment schedules and software modelling. Figures 3.19 and 3.20, show energy balance for the typical office building.

Heating Loads	
Number of Stories	25%
Building Orientation	10%
Window to Wall ratio	15%
Window Thermal Performance	15%
Opaque Wall Thermal Performance	30%
Other	5%

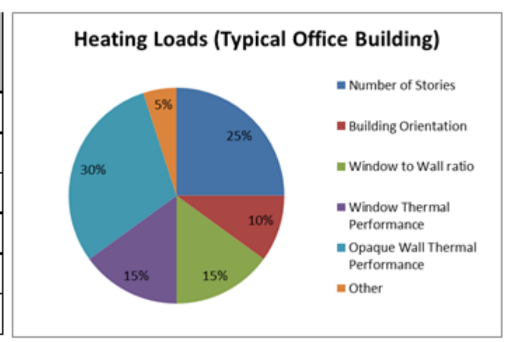


Figure 3.19: (Left) - Heating Loads Percentage Distribution for the Typical Office Building, (Right) - Pie Chart of these Values

Cooling Loads	
Number of Stories	5%
Building Orientation	5%
Window to Wall ratio	35%
Window Thermal Performance	35%
Opaque Wall Thermal Performance	5%
Other	15%

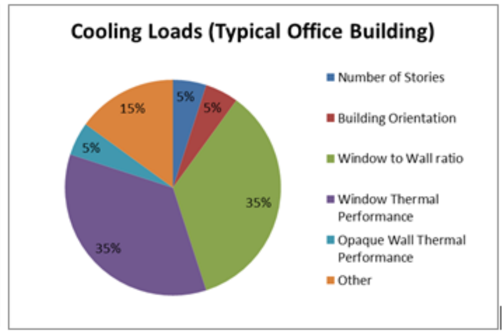


Figure 3.20: (Left) - Cooling Loads Percentage Distribution for Typical Office, (Right) - Pie Chart of these Values

These values were calculated based on case-study energy audits reports as well as Canada Mortgage and Housing Corporation (CMHC), 2014. Research study prepared by Canada Mortgage and Housing Corporation (CMHC), (2014) provides percentages of the overall relative impact of the architectural features on the heating loads and cooling loads for MURBs. Values were slightly adjusted to suit typical office buildings; assumptions were made based on case-study energy audits. The Other category includes all other parameters that might influence a typical office building. Figures 3.19 and 3.20 summarises percentage distribution for heating and cooling. Percentage distribution example can be found in Appendix D.

The pie chart below (Figure 3.21) demonstrates average percentages of energy use by end-use for commercial/institutional buildings as per National Resources Canada (NRC), 2010.

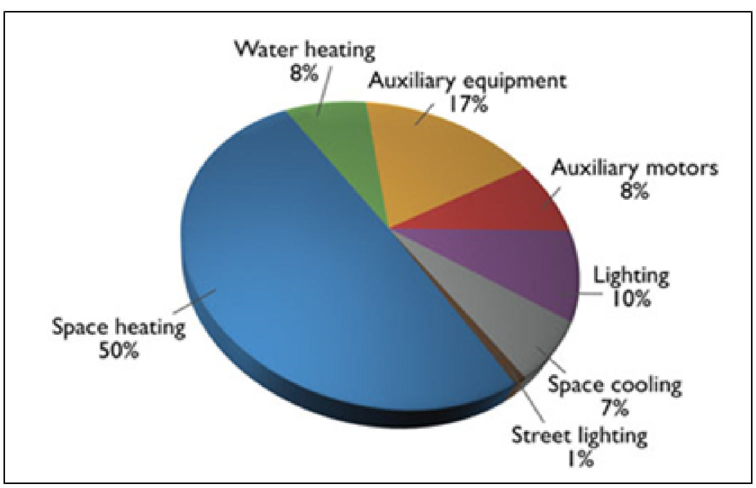


Figure 3.21: Commercial/Institutional Energy Use by End-Use, 2007 (Percent) (NRC, 2010)

Percentage distribution from Figure 3.21 were analysed against energy audit reports for building

#7 (301 Moodie Drive, Ottawa, Ontario), and #8 (303 Moodie Drive, Ottawa, Ontario), and energy balance breakdown was calculated (shown in Figure 3.22).

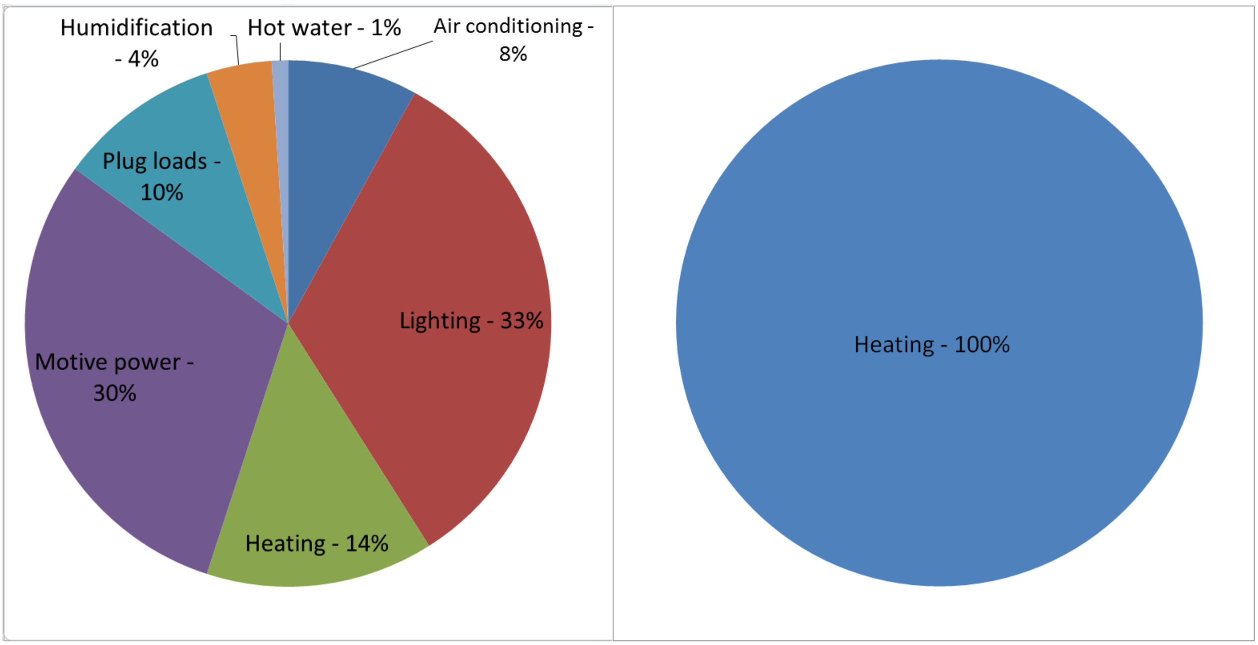


Figure 3.22: Energy Balance of Case-Study Buildings, (Left) Electricity, (Right) - Gas

Buildings total energy consumption indicators include the following: heating (includes the heating load for external areas and the heating load attributed to fresh air), air conditioning (includes cooling and de-humidification of fresh air and the air conditioning load for internal and external areas), lighting (corresponds to the proportion of consumption attributable to light fixtures), motive power (represents consumption associated with pumps, fan motors and elevator motors), plug loads (represents all the loads not included in the other items and electricity consumption of all office equipment including workstations, printers and photocopying machines), humidification (represents consumption associated with the humidification of fresh air), and hot water (corresponds to the heating load required to produce domestic hot water).

Heating, cooling and lighting consume significant percentage of electricity and gas usage of the typical office building. Based on a previously reviewed literature, the exact percentage was not provided on how architectural features of the building impact lighting energy consumption. Therefore, an assumption was made based on calculations provided in Ross (2009) report as WWR accounts for 40% of lighting loads. The following analyses were completed to conclude the total energy consumption impacted by WWR for each case study building. This was achieved by applying energy balance for electricity and gas consumption as well as heating, cooling and lighting loads energy distribution per architectural features, for each case-study building.

Table 3.7: Heating Loads Distribution (Electricity) in GJ Based on Architectural Features Indicators

	Heating Loads Percentage Distribution		25%	10%	15%	15%	30%	5%
			GJ					
	Address	Heating Loads Electricity Balance	Number of Stories	Building Orientation	Window to Wall ratio	Window Thermal Performance	Opaque Wall Thermal Performance	Other
1	Building A - Toronto, Ontario	14%	187,477.0	74,990.8	112,486.2	112,486.2	224,972.4	37,495.4
2	Building B - Mississauga, Ontario	14%	74,264.5	29,705.8	44,558.7	44,558.7	89,117.4	14,852.9
3	Building C - Toronto, Ontario	14%	66,934.3	26,773.7	40,160.6	40,160.6	80,321.2	13,386.9
4	Building D - Mississauga, Ontario	14%	119,768.2	47,907.3	71,860.9	71,860.9	143,721.8	23,953.6
5	Building E - Mississauga, Ontario	14%	15,892.4	6,357.0	9,535.4	9,535.4	19,070.9	3,178.5
6	Building F - Scarborough, Ontario	14%	8,313.3	3,325.3	4,988.0	4,988.0	9,975.9	1,662.7
7	Building G - Ottawa, Ontario	14%	82,545.3	33,018.1	49,527.2	49,527.2	99,054.4	16,509.1
8	Building H - Ottawa, Ontario	14%	64,044.6	25,617.8	38,426.8	38,426.8	76,853.5	12,808.9
9	Building I - Ottawa, Ontario, Tower C	14%	47,531.6	19,012.6	28,519.0	28,519.0	57,037.9	9,506.3
10	Building J - Ottawa, Ontario, Tower B	14%	214,257.4	85,703.0	128,554.5	128,554.5	257,108.9	42,851.5
11	Building K - Ottawa, Ontario, Tower A	14%	63,975.1	25,590.0	38,385.0	38,385.0	76,770.1	12,795.0
12	Building L - Montreal, Quebec	14%	25,883.6	10,353.4	15,530.1	15,530.1	31,060.3	5,176.7
13	Building M - Vaudreuil-Dorion, Quebec	14%	59,227.0	23,690.8	35,536.2	35,536.2	71,072.4	11,845.4
14	Building N - Côte-St-Luc, Quebec	14%	107,129.9	42,851.9	64,277.9	64,277.9	128,555.8	21,426.0
15	Building O - Gatineau, Quebec	14%	66,759.6	26,703.8	40,055.8	40,055.8	80,111.5	13,351.9

Calculations above (Table 3.7) are based on electricity consumption in (GJ). To be able to compare values between all buildings, data was introduced as energy intensity (divided by total floor area of each building); calculated values are shown in the table below. WWR impacts 15% of overall electricity consumption of the heating loads. Table 3.8 contains the same data but is introduced through energy index value (GJ/m^2/year).

Table 3.8: Heating Loads Distribution (Electricity) in GJ/m^2/year Based on Architectural Features Indicators

	Heating Loads Percentage Distribution		25%	10%	15%	15%	30%	5%
			GJ/m2/yeah					
	Address	Heating Loads Electricity Balance	Number of Stories	Building Orientation	Window to Wall ratio	Window Thermal Performance	Opaque Wall Thermal Performance	Other
1	Building A - Toronto, Ontario	14%	0.027	0.011	0.016	0.016	0.032	0.005
2	Building B - Mississauga, Ontario	14%	0.033	0.013	0.020	0.020	0.039	0.007
3	Building C - Toronto, Ontario	14%	0.026	0.010	0.016	0.016	0.031	0.005
4	Building D - Mississauga, Ontario	14%	0.027	0.011	0.016	0.016	0.033	0.005
5	Building E - Mississauga, Ontario	14%	0.009	0.004	0.005	0.005	0.011	0.002
6	Building F - Scarborough, Ontario	14%	0.014	0.006	0.008	0.008	0.017	0.003
7	Building G - Ottawa, Ontario	14%	0.036	0.015	0.022	0.022	0.044	0.007
8	Building H - Ottawa, Ontario	14%	0.046	0.018	0.028	0.028	0.055	0.009
9	Building I - Ottawa, Ontario, Tower C	14%	0.035	0.014	0.021	0.021	0.042	0.007
10	Building J - Ottawa, Ontario, Tower B	14%	0.093	0.037	0.056	0.056	0.112	0.019
11	Building K - Ottawa, Ontario, Tower A	14%	0.037	0.015	0.022	0.022	0.045	0.007
12	Building L - Montreal, Quebec	14%	0.026	0.011	0.016	0.016	0.032	0.005
13	Building M - Vaudreuil-Dorion, Quebec	14%	0.027	0.011	0.016	0.016	0.032	0.005
14	Building N - Côte-St-Luc, Quebec	14%	0.049	0.019	0.029	0.029	0.058	0.010
15	Building O - Gatineau, Quebec	14%	0.044	0.017	0.026	0.026	0.052	0.009

Similar calculations were completed for electricity consumption for cooling loads, gas consumption for heating and electricity consumption for lighting loads based on architectural features indicators for each case-study building. Calculations are summarized into tables and can be found in Appendix D.

3.7.1 Summary for Energy Balance

Table 3.9 and 3.10 summarizes energy consumption impacted by WWR, based on loads percentage, distribution and energy balance in GJ/year and GJ/m^2/year.

Table 3.9: Total Energy Loads Distribution Based on WWR Indicator (GJ) Average per Year

	Loads Percentage Distribution		15%		35%		15%		40%	
			GJ		**GJ**		**GJ**		**GJ**	
	Address	**Heating Loads Electricity Balance**	**Window to Wall ratio**	**Cooling Loads Electricity Balance**	**Window to Wall ratio**	**Heating Loads GAS Balance**	**Window to Wall ratio**	**Lighting Loads Electricity Balance**	**Window to Wall ratio**	**Total WWR Energy Consumption (GJ)**
1	Building A - Toronto, Ontario	14%	112,486.2	8%	262,467.8	100%	38,485.5	33%	707,056.2	1,120,495.8
2	Building B - Mississauga, Ontario	14%	44,558.7	8%	103,970.3	100%	12,422.6	33%	280,083.3	441,034.8
3	Building C - Toronto, Ontario	14%	40,160.6	8%	93,708.1	100%	23,754.4	33%	252,438.1	410,061.2
4	Building D - Mississauga, Ontario	14%	71,860.9	8%	167,675.4	100%	8,783.4	33%	451,697.0	700,016.8
5	Building E - Mississauga, Ontario	14%	9,535.4	8%	22,249.4	100%	2,699.3	33%	59,937.1	94,421.2
6	Building F - Scarborough, Ontario	14%	4,988.0	8%	11,638.6	100%	3,978.3	33%	31,352.9	51,957.8
7	Building G - Ottawa, Ontario	14%	49,527.2	8%	115,563.5	100%	4,794.2	33%	311,313.8	481,198.7
8	Building H - Ottawa, Ontario	14%	38,426.8	8%	89,662.4	100%	12,264.7	33%	241,539.6	381,893.5
9	Building I - Ottawa, Ontario, Tower C	14%	28,519.0	8%	66,544.3	100%	693.3	33%	179,262.1	275,018.6
10	Building J - Ottawa, Ontario, Tower B	14%	128,554.5	8%	299,960.4	100%		33%	808,056.6	1,236,571.5
11	Building K - Ottawa, Ontario, Tower A	14%	38,385.0	8%	89,565.1	100%		33%	241,277.4	369,227.6
12	Building L - Montreal, Quebec	14%	15,530.1	8%	36,237.0	100%	2,199.5	33%	97,618.0	151,584.5
13	Building M - Vaudreuil-Dorion, Quebec	14%	35,536.2	8%	82,917.8	100%	1,228.4	33%	223,370.5	343,052.9
14	Building N - Côte-St-Luc, Quebec	14%	64,277.9	8%	149,981.8	100%		33%	404,032.6	618,292.4
15	Building O - Gatineau, Quebec	14%	40,055.8	8%	93,463.4	100%	9,620.8	33%	251,779.1	394,919.1

Table 3.10: Total Energy Loads Distribution Based on WWR Indicator (GJ/m^2/year)

	Loads Percentage Distribution		15%		35%		15%		40%	
			GJ/m2/year		**GJ/m2/year**		**GJ/m2/year**		**GJ/m2/year**	
	Address	**Heating Loads Electricity Balance**	**Window to Wall ratio**	**Cooling Loads Electricity Balance**	**Window to Wall ratio**	**Heating Loads Gas Balance**	**Window to Wall ratio**	**Lighting Loads Electricity Balance**	**Window to Wall ratio**	**Total WWR Energy Consumption (GJ/m2/year)**
1	Building A - Toronto, Ontario	14%	0.016	8%	0.021	100%	0.011	33%	0.100	0.148
2	Building B - Mississauga, Ontario	14%	0.020	8%	0.026	100%	0.011	33%	0.123	0.179
3	Building C - Toronto, Ontario	14%	0.016	8%	0.021	100%	0.019	33%	0.098	0.153
4	Building D - Mississauga, Ontario	14%	0.016	8%	0.022	100%	0.004	33%	0.103	0.146
5	Building E - Mississauga, Ontario	14%	0.005	8%	0.007	100%	0.003	33%	0.034	0.050
6	Building F - Scarborough, Ontario	14%	0.008	8%	0.011	100%	0.013	33%	0.053	0.086
7	Building G - Ottawa, Ontario	14%	0.022	8%	0.029	100%	0.004	33%	0.137	0.192
8	Building H - Ottawa, Ontario	14%	0.028	8%	0.037	100%	0.018	33%	0.173	0.255
9	Building I - Ottawa, Ontario, Tower C	14%	0.021	8%	0.028	100%	0.001	33%	0.133	0.183
10	Building J - Ottawa, Ontario, Tower B	14%	0.056	8%	0.075	100%		33%	0.352	0.482
11	Building K - Ottawa, Ontario, Tower A	14%	0.022	8%	0.030	100%		33%	0.141	0.193
12	Building L - Montreal, Quebec	14%	0.016	8%	0.021	100%	0.005	33%	0.100	0.141
13	Building M - Vaudreuil-Dorion, Quebec	14%	0.016	8%	0.021	100%	0.001	33%	0.100	0.139
14	Building N - Côte-St-Luc, Quebec	14%	0.029	8%	0.039	100%		33%	0.183	0.251
15	Building O - Gatineau, Quebec	14%	0.026	8%	0.035	100%	0.013	33%	0.164	0.238

Table 3.11: WWR Percentage of Total Energy Consumption

	Address	WWR % of Total Energy Consumption (Normalized)
1	Building A - Toronto, Ontario	13%
2	Building B - Mississauga, Ontario	15%
3	Building C - Toronto, Ontario	11%
4	Building D - Mississauga, Ontario	13%
5	Building E - Mississauga, Ontario	11%
6	Building F - Scarborough, Ontario	8%
7	Building G - Ottawa, Ontario	16%
8	Building H - Ottawa, Ontario	13%
9	Building I - Ottawa, Ontario, Tower C	17%
10	Building J - Ottawa, Ontario, Tower B	27%
11	Building K - Ottawa, Ontario, Tower A	18%
12	Building L - Montreal, Quebec	15%
13	Building M - Vaudreuil-Dorion, Quebec	15%
14	Building N - Côte-St-Luc, Quebec	17%
15	Building O - Gatineau, Quebec	14%

Table 3.11 summarizes the percentage that WWR consumes from overall building energy consumption, based on heating, cooling and lighting energy balance. The same loads percentage distribution was applied for all buildings, but based on normalized energy intensity value, electricity and gas consumption percentages vary; some buildings do not use natural gas for building operations and this also influenced calculations. As per these results, WWR impacts significant percentage of energy consumption for these case-study buildings.

3.8 Analysis Summary

WWR is directly related to energy intensity of existing building, however set of data calculated from fifteen case-study buildings showed very inconsistent analysis. To summarize all data in relationship to energy intensity, box plot analysis were performed. Typically box plot analysis demonstrates statistical analysis of the set of data, but in this case due to sample size bias it act more as the summary and not statistical analysis. This type of analysis was chosen as a very clear approach to demonstrate patterns of response for each category. Here the overall size of the box plot (how much it stretches on the y-axis) shows how spread out the data is. If the box itself is very short, then most of the data is huddled close together. Data in different boxes can be compared by looking at how tall or short the boxes are, and also their position relative to one another. If the boxes are roughly centered, then there is little or no difference in average or median between the data sets. If there is a shift between the boxes, then there likely is a statistically significant difference in average or median for the data sets. From tables below it can be concluded that all of the box plots compared are relatively similar. This implies that there is little significant difference between the data groups.

Figure 3.23 demonstrates frequency of energy intensity value, for here is can be concluded that most of the buildings have energy intensity around 1-1.25 GJ/m^2/year, meaning that they are relatively energy efficient building in relationship to BOMA benchmark.

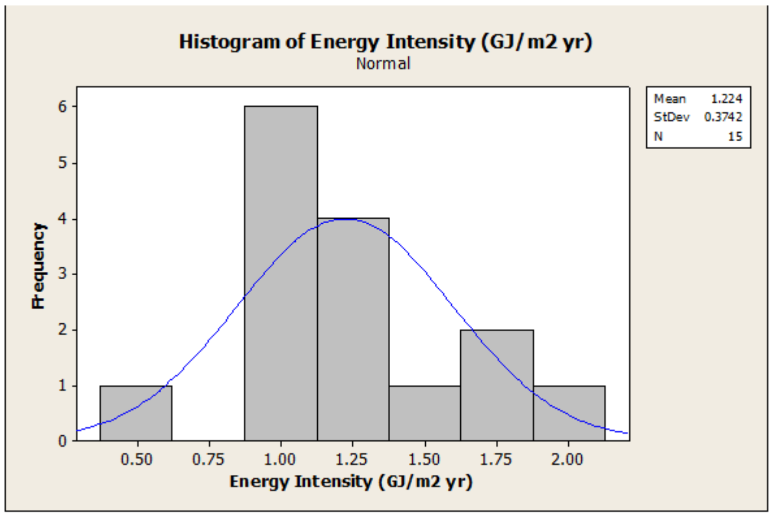


Figure 3.23: Energy Intensity Value Frequency

Figures 3.24, 3.25 and 3.26 provide boxplot analysis of all three buildings categories (shape, height and age)

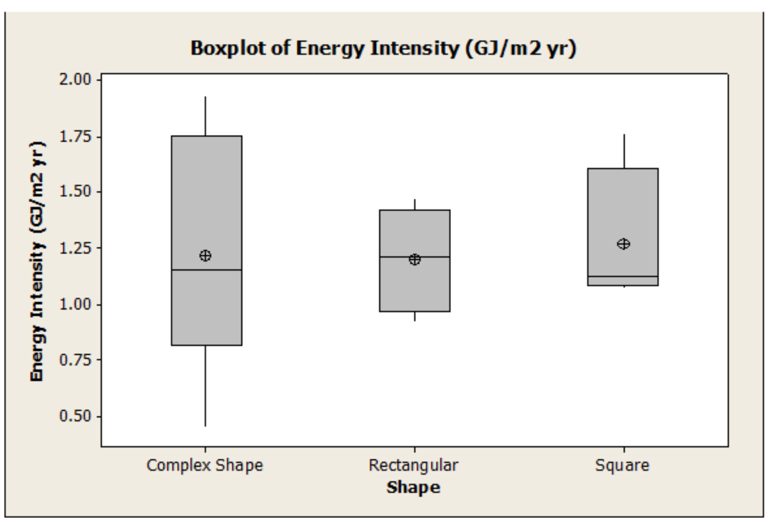


Figure 3.24: Boxplot Analysis of Buildings' Shape

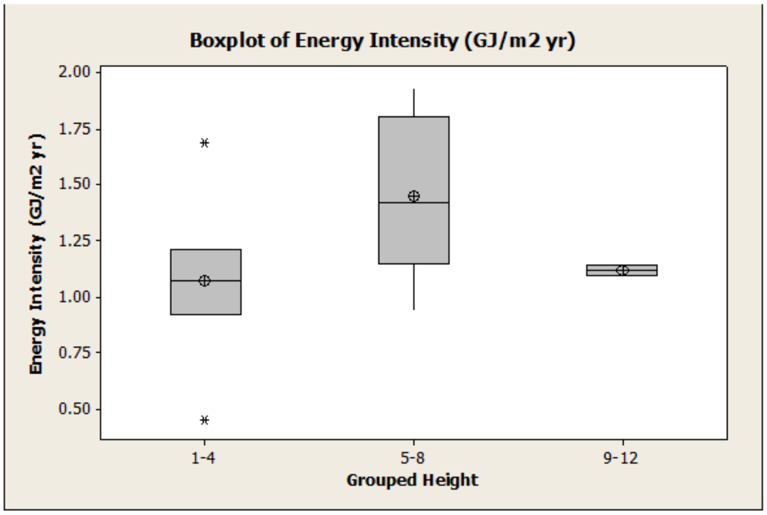


Figure 3.25: Boxplot Analysis of Buildings' Age

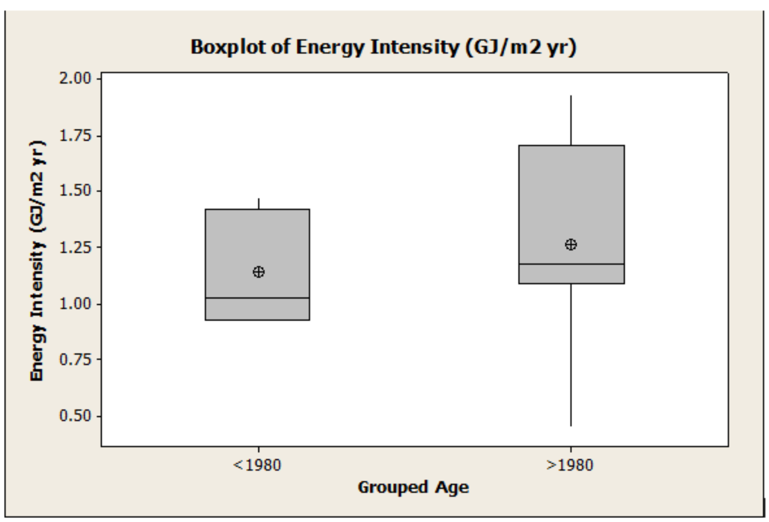


Figure 3.26: Boxplot Analysis of Buildings' Age

Case-study buildings with more complex shape and mid-rise buildings have very wide range of energy intensity data.

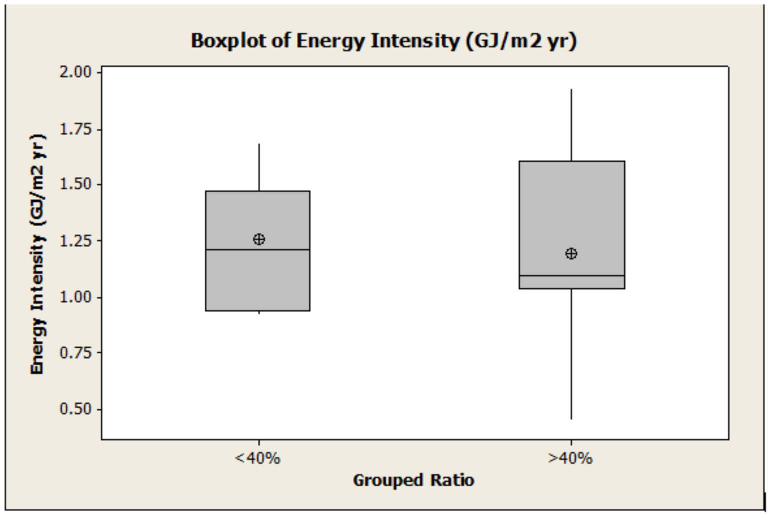


Figure 3.27: Boxplot Analysis of WWR to Energy Intensity

In addition boxplot analyses were completed to compare window-to-wall energy consumption to WWR. Essentially, Figure 31 is showing that the WWR doesn't have direct impact on the energy intensity (EI). The boxes (which are actually 2 quartiles) are almost the same size and line up almost perfectly well. This means that the middle 50% of each data set are very similar. The horizontal line inside the box is the median, or the middle value of the entire data set for each group, here they are very close to being lined up, which means the medians are very similar. The little crosshair sign at the middle is an average value; again these are lined up pretty well, so the average of each group is almost the same. Lastly, the vertical lines extending above and below the boxes each represent 25% of the data points (the lowest and highest quartile). The fact that the top lines are roughly the same size means that they upper 25% of each data set look very similar. Data ¿40% has a much longer lower quartile line, this means that there is one value that reaches all the way down to 0.50, while the first box has a min value closer to 0.9 (there's only a little stub of a line on the first box). From boxplot analysis of energy intensity versus WWR can be concluded that regardless how inconsistent and spread-out data is, buildings with WWR of more than 40% did not show higher results in terms of energy intensity.

Following two steps, energy consumption related to WWR was analyzed in comparison to overall building energy consumption. Here data from energy balance calculations was utilized.

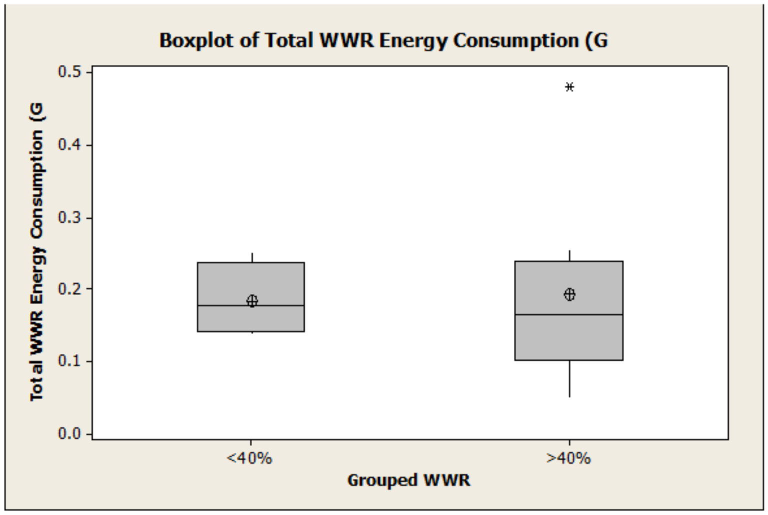


Figure 3.28: Boxplot Analysis of WWR Energy Consumption (GJ/m^2/year) to WWR

As seen above in Figure 3.28, there is no significant difference when comparing WWR Consumption to WWR%. Note that the boxes are roughly centered and are approximately equally sized. However, there is a little more variation in energy intensity when the WWR% is greater than 40%.

Also energy intensity was analysed in regards to WWR. As seen below in Figure 3.29, there is also no significant difference when comparing WWR Consumption to WWR%. The same trend of more variation in the data is seen with a WWR 40%, but the boxes are still centered and the same size.

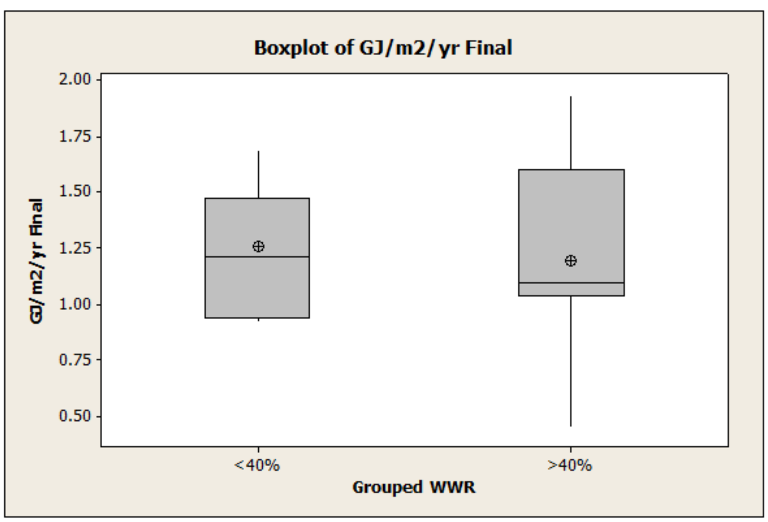


Figure 3.29: Boxplot Analysis of Energy Intensity to WWR

Lastly comparison analysis of overall buildings energy intensity to WWR energy consumption, which was calculated through energy balance, was performed. As shown in Figure 3.30, there is a slight positive correlation between the Overall Energy Intensity and the WWR Energy Consumption, as noted by the R2 value of 0.61. This means that 61% of the variation in the data (the distance above and below the line) can be explained by normal variation. This implies that there may be other external parameters that may be affecting the data, either by themselves, or in conjunction with one another. The bubbles size shows the relative value of the WWR%. There isn't a discernible pattern to the distribution of bubble size along the trend line. This further emphasizes the above analysis that shows WWR% has very little correlation with either the Energy Intensity or the WWR Energy Consumption.

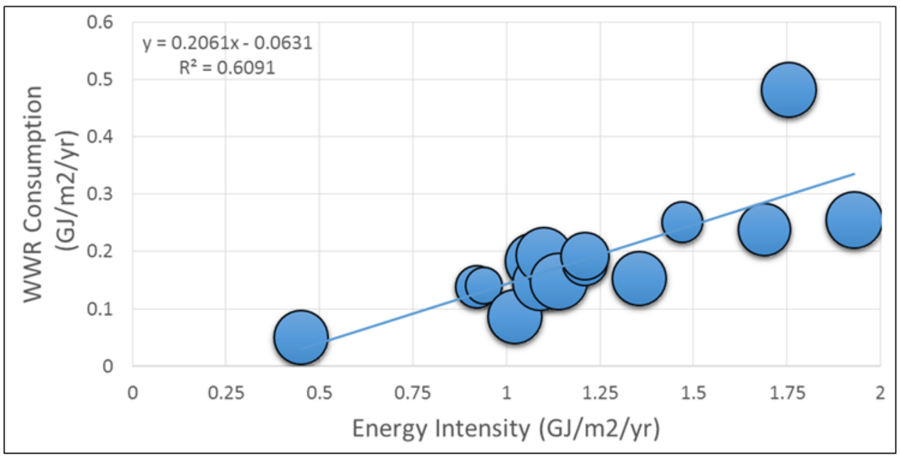


Figure 3.30: Overall Energy Intensity vs. WWR Energy Intensity

3.9 Conclusions

WWR is directly related to energy intensity of existing building, fifteen case-study buildings were analysed to calculate how energy intensity of existing case-study office buildings compare with averages for similar buildings, and those that would be resulting from the application of current standards. As for the energy intensity benchmark value BOMA average energy use intensity for certified Office Buildings (1.05GJ/m^2/yr) was selected, and for minimum WWR benchmark SB-10 for building envelope prescriptive requirement (below 40%). Calculations for case-study buildings showed that the building shape didnt directly influence energy intensity, however analysis based on the age of the building showed that the newer buildings are more energy efficient, and analysis on buildings height concluded that taller case study buildings have higher energy intensity, therefore energy consumption. Energy balance exercise was completed to analyse the impact of five architectural features such as number of stories, building orientation, WWR, building thermal performance and opaque wall thermal performance on energy consumption, based on energy distribution. This helped to determine the potential for energy savings in existing case-study buildings through envelope upgrades. Calculations showed that based on energy balance and energy loads distribution (as per architectural features indicators), WWR impacts on average 15% of overall energy consumption. By evaluation, using the energy audit (Level One) report, it is believed that it would be extremely beneficial to introduce the analysis of WWR into energy audit procedure.

However prescriptive requirements of SB-10, which is based on 40% WWR, are aiming for energy efficient design, but the possibility is that building's energy consumption could be even increased. If the shape of the building is complex, it is not feasible to fit it under the same standards. Energy intensity of the buildings cannot be directly related to its WWR; although 15% of energy consumption could be linked to percentage of fenestration area in relationship to wall area.

Appendix 1

Appendix A

Building #1 – Utility Bills Analysis

Actual data used for calculations (year with highest energy consumption):

ADDRESS:	**Building A - Toronto, Ontario**
BUILDING #	1
Year - Highest Energy Consumption:	2013
AREA:	**25,424**
USAGE INDEX:	**1.20**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	2013/01/31	2013/02/28	2013/03/31	2013/04/30	2013/05/31	2013/06/30	2013/07/31	2013/08/31	2013/09/30	2013/10/31	2013/11/30	2013/12/31
Electric Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
Gas Billing Date	2013/01/31	2013/02/28	2013/03/31	2013/04/30	2013/05/31	2013/06/30	2013/07/31	2013/08/31	2013/09/30	2013/10/31	2013/11/30	2013/12/31
Gas Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	0	23	59	121	94	28	0	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	0	1	2	4	3	1	0	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	624	632	555	359	109	33	1	4	83	209	478	661
Daily Htg. D.D. Avg. (Highest Year)	20	23	18	12	4	1	0	0	3	7	16	21
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	444,710	400,060	439,963	440,310	485,292	490,785	524,947	512,849	457,158	434,681	405,161	390,256
Daily kWh Avg.	14,345	14,288	14,192	14,677	15,655	16,359	16,934	16,544	15,239	14,022	13,505	12,589
Demand kW/RkVA Used	921	916	915	930	1,099	1,320	1,212	1,189	1,212	1,082	882	899
Load Factor (Highest Year)	65%	65%	65%	66%	59%	52%	58%	58%	52%	54%	64%	58%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	49,498	49,937	45,461	20,660	5,017	0	0	0	76	12,895	37,843	73,539
Daily m^3 Avg.	1,597	1,783	1,466	689	162	0	0	0	3	416	1,261	2,372
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	649,471	622,540	617,707	442,421	361,975	330,164	353,146	345,008	308,080	383,681	540,381	782,978
S02 (kgs) (Highest Year)	7,017	6,726	6,674	4,780	3,911	3,567	3,815	3,727	3,329	4,145	5,838	8,459
N0x (kgs) (Highest Year)	3,076	2,949	2,926	2,096	1,714	1,564	1,673	1,634	1,459	1,817	2,560	3,709
USAGE DATA												
kWh to GJ	1600.96	1440.22	1583.87	1585.12	1747.05	1766.83	1889.81	1846.26	1645.77	1564.85	1458.58	1404.92
GJ/m2/Day ELECTRIC (Highest Year)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
GJ/m2/Month (Highest Year)	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06
m3 to GJ	1841.33	1857.66	1691.15	768.55	186.63	0.00	0.00	0.00	2.83	479.69	1407.76	2735.65
GJ/m2/Day GAS (Highest Year)	0.002	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003
GJ/m2/Month	0.07	0.07	0.07	0.03	0.01	0.00	0.00	0.00	0.00	0.02	0.06	0.11
m3/m2/Month	1.95	1.96	1.79	0.81	0.20	0.00	0.00	0.00	0.00	0.51	1.49	2.89
GJ/m2/Day ENERGY (Highest Year)	0.004	0.005	0.004	0.003	0.002	0.002	0.002	0.002	0.002	0.003	0.004	0.005
GJ/m2/Month (Highest Consumption Year)	0.135	0.130	0.129	0.093	0.076	0.069	0.074	0.073	0.065	0.080	0.113	0.163

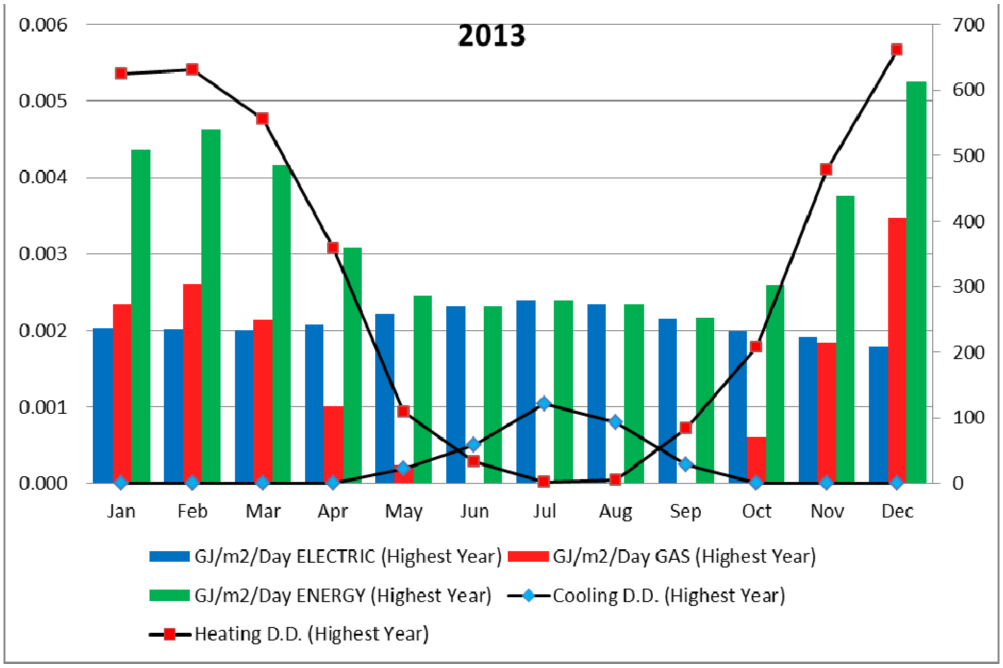
Energy Usage per Month (Electricity + Gas)	3442	3298	3275	2354	1934	1767	1890	1846	1649	2045	2866	4141
Degree Days	624	632	555	359	132	92	122	98	111	209	478	661

Actual data used for calculations (year with lowest energy consumption):

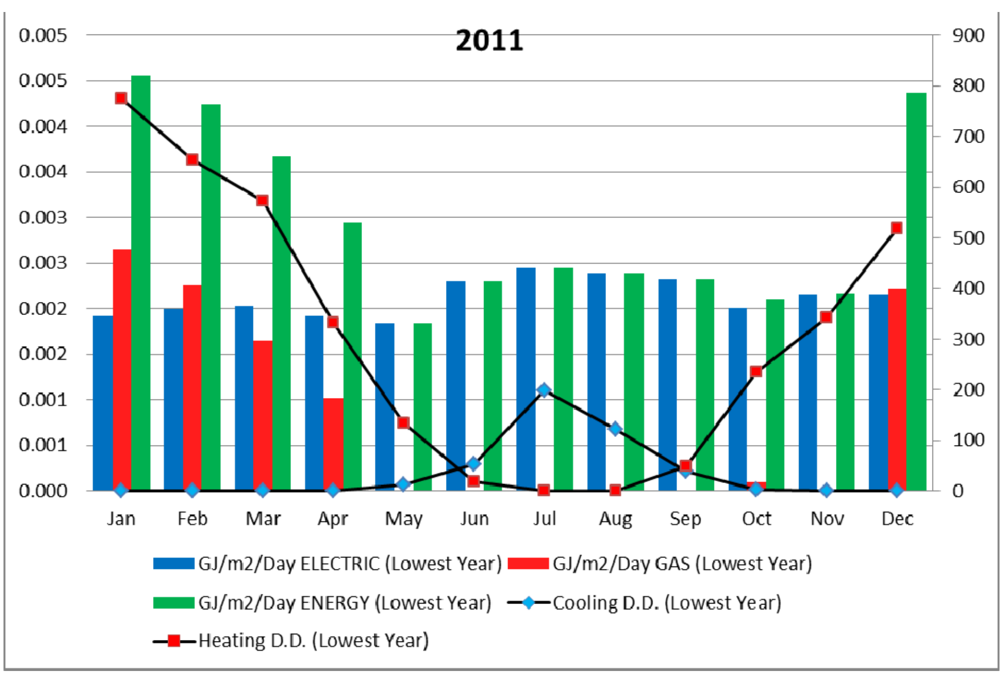
ADDRESS:	Building A - Toronto, Ontario			
BUILDING #	1			
Year - Lowest Energy Consumption:	2011			
AREA:	25,424			
USAGE INDEX:	1.08	AVERAGE:	1.14006	1.13999

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	2011/01/31	2011/02/28	2011/03/31	2011/04/30	2011/05/31	2011/06/30	2011/07/31	2011/08/31	2011/09/30	2011/10/31	2011/11/30	2011/12/31
Electric Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
Gas Billing Date	2011/02/01	2011/03/02	2011/04/05	2011/05/03	2011/06/03	2011/07/03	2011/08/02	2011/09/02	2011/10/02	2011/11/02	2011/12/02	2012/01/03
Gas Billing Days	31	29	34	28	31	30	30	31	30	31	30	32
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	0	13	52	199	122	39	2	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	0	0	2	6	4	1	0	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	775	654	573	332	134	19	0	0	48	235	342	518
Daily Htg. D.D. Avg. (Lowest Year)	25	23	17	12	4	1	0	0	2	8	11	16
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	419,798	394,149	443,891	405,758	402,198	487,192	534,864	522,070	492,117	439,272	456,542	470,760
Daily kWh Avg.	13,542	13,591	13,056	14,491	12,974	16,240	17,829	16,841	16,404	14,170	15,218	14,711
Demand kW/RkVA Used	943	976	960	1,053	1,211	1,279	1,371	1,227	1,166	1,135	1,126	1,000
Load Factor (Lowest Year)	60%	60%	62%	54%	45%	53%	52%	57%	59%	52%	56%	63%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	56,050	44,600	38,217	19,569	0	0	0	0	0	1,972	164	48,498
Daily m^3 Avg.	1,808	1,538	1,124	699	0	0	0	0	0	64	5	1,516
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	679,081	580,793	569,083	411,456	270,570	327,748	359,818	351,211	331,061	309,466	308,289	659,918
S02 (kgs) (Lowest Year)	7,337	6,275	6,148	4,445	2,923	3,541	3,887	3,794	3,577	3,343	3,331	7,130
N0x (kgs) (Lowest Year)	3,216	2,751	2,695	1,949	1,282	1,552	1,704	1,664	1,568	1,466	1,460	3,126
USAGE DATA												
kWh to GJ	1511.27	1418.94	1598.01	1460.73	1447.91	1753.89	1925.51	1879.45	1771.62	1581.38	1643.55	1694.74
GJ/m2/Day ELECTRIC (Lowest Year)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
GJ/m2/Month (Lowest Year)	0.06	0.06	0.06	0.06	0.06	0.07	0.08	0.07	0.07	0.06	0.06	0.07
m3 to GJ	2085.06	1659.12	1421.67	727.97	0.00	0.00	0.00	0.00	0.00	73.36	6.10	1804.13
GJ/m2/Day GAS (Lowest Year)	0.003	0.002	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
GJ/m2/Month	0.08	0.07	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
m3/m2/Month	2.20	1.75	1.50	0.77	0.00	0.00	0.00	0.00	0.00	0.08	0.01	1.91
GJ/m2/Day ENERGY (Lowest Year)	0.005	0.004	0.004	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.004
GJ/m2/Month (Lowest Consumption Year)	0.141	0.121	0.119	0.086	0.057	0.069	0.076	0.074	0.070	0.065	0.065	0.138
Average Highest Year to Lowest Year	0.138	0.125	0.124	0.089	0.067	0.069	0.075	0.073	0.067	0.073	0.089	0.150
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Gas)	3596	3078	3020	2189	1448	1754	1926	1879	1772	1655	1650	3499
Degree Days	775	654	573	332	147	71	199	122	87	238	342	518
Normalized Data (Average Degree Days)	700	643	564	345	140	82	160	110	99	223	410	589
Normalized Data (Av Energy Consumption)	3561	3380	3129	2436	1783	1599	1849	1690	1655	2049	2641	3210
Normalized Data (Av Energy Index / month)	0.140	0.133	0.123	0.096	0.070	0.063	0.073	0.066	0.065	0.081	0.104	0.126

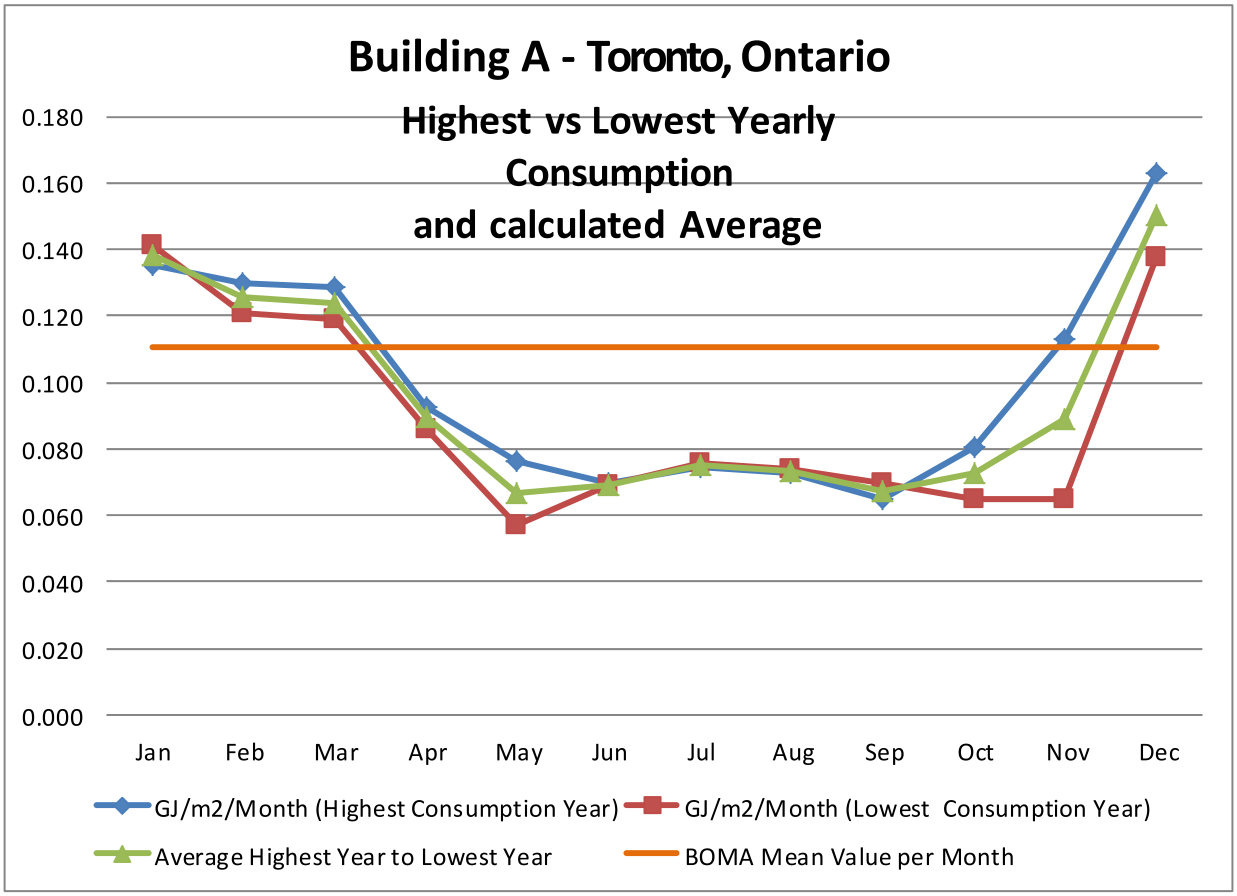
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Building #2 – Utility Bills Analysis

Calculations for Energy Index for Building #2

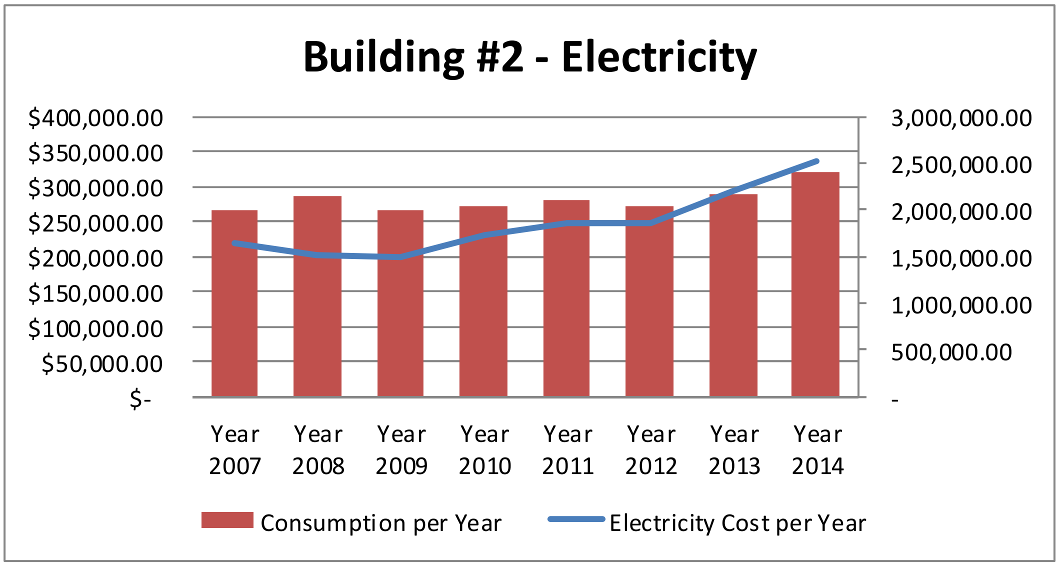
Similar procedure as was utilized for Building #1 was done for Building #2. Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity and gas. For Building #2 utility bills were provided from December 2006 to March 2015. Summarized yearly data showed relatively consistent values except gas consumption for 2014 year, this is could have been due to additional equipment installation after energy audit proposal. Therefore 2014 total energy consumption was not included in average energy index calculations. By having total floor area of 8,225 m^2 energy index was calculated in $GJ/m^2/yr$.

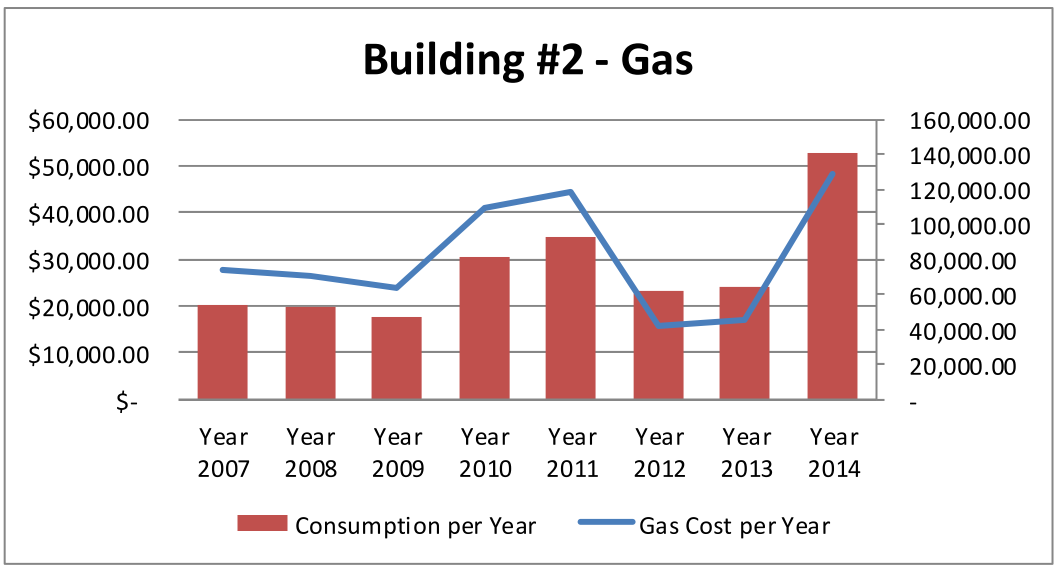
Utility bills analysis showed following:

Building B - Mississauga, Ontario						
		kWh		m^3-ngas	Total GJ/yr	8,225.00
Row Labels	**Sum of Ele Total Cost / Year**	**Sum of Ele Consumption / Year**	**Sum of Gas Total Cost / Year**	**Sum of Gas Consumption / Year**	**Total**	**GJ/m2/yr**
Year 2006	$ 20,177.03	190,800.00	$ 2,536.39	4,853.00		
Year 2007	$ 220,341.47	1,992,960.00	$ 27,691.10	54,442.00	9,199.90	1.12
Year 2008	$ 202,864.43	2,147,040.00	$ 26,571.55	52,367.00	9,677.40	1.18
Year 2009	$ 198,438.54	1,992,960.00	$ 23,774.25	47,032.00	8,924.25	1.09
Year 2010	$ 230,118.15	2,039,760.00	$ 40,845.86	81,291.00	10,367.16	1.26
Year 2011	$ 246,250.71	2,095,217.28	$ 44,531.43	92,998.00	11,002.31	1.34
Year 2012	$ 248,670.86	2,033,280.00	$ 15,918.09	62,255.00	9,635.69	1.17
Year 2013	$ 292,958.48	2,157,840.00	$ 16,921.91	64,682.00	10,174.39	1.24
Year 2014	$ 336,096.60	2,412,000.00	$ 48,195.47	141,235.00	13,937.14	1.69
Year 2015	$ 86,020.69	606,240.00	$ 24,990.54	70,886.00		
Average	**$ 246,967.41**	**2,121,842.88**	**$ 30,556.21**	**82,817.17**		**1.20**

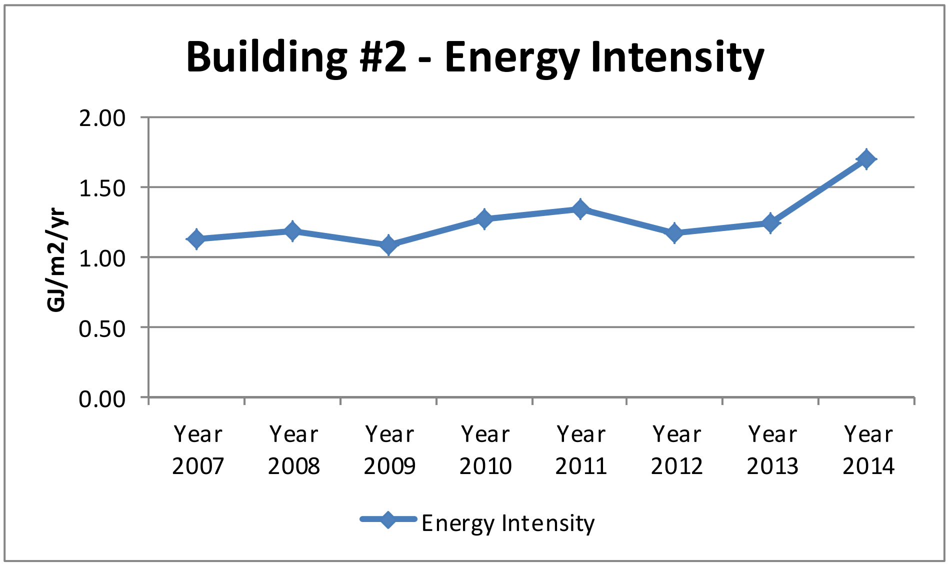
Similarly to energy audit conclusion that energy consumption of the building is moderately high in comparison to similar office buildings in same region; energy index value showed high results as well in comparison to BOMA energy efficient building value of 1.05 $GJ/m^2/yr$ or but lower than average National Resources Canada value of 1.43 $GJ/m^2/yr$.

Two charts below show electricity and gas consumption per year for Building #2. Electricity consumption chart demonstrates steady but not very prominent increase in energy usage; however 2014 shows the highest value. But because 2014 will not be used for further calculations due to inconsistency, therefore 2013 considered as the highest value. Gas consumption chart show values that vary a lot from year to year, there is prominent decrease in gas consumption in 2012 and 2013, but because 2014 data is very inconsistent it's not reasonable to conclude that gas consumption of the Building #2 decreasing and more efficient. Another assumption can be made that 2014 gas utility bills data actually contains partial gas consumption from 2012 and 2013, but from utility bills information this cannot be confirmed.





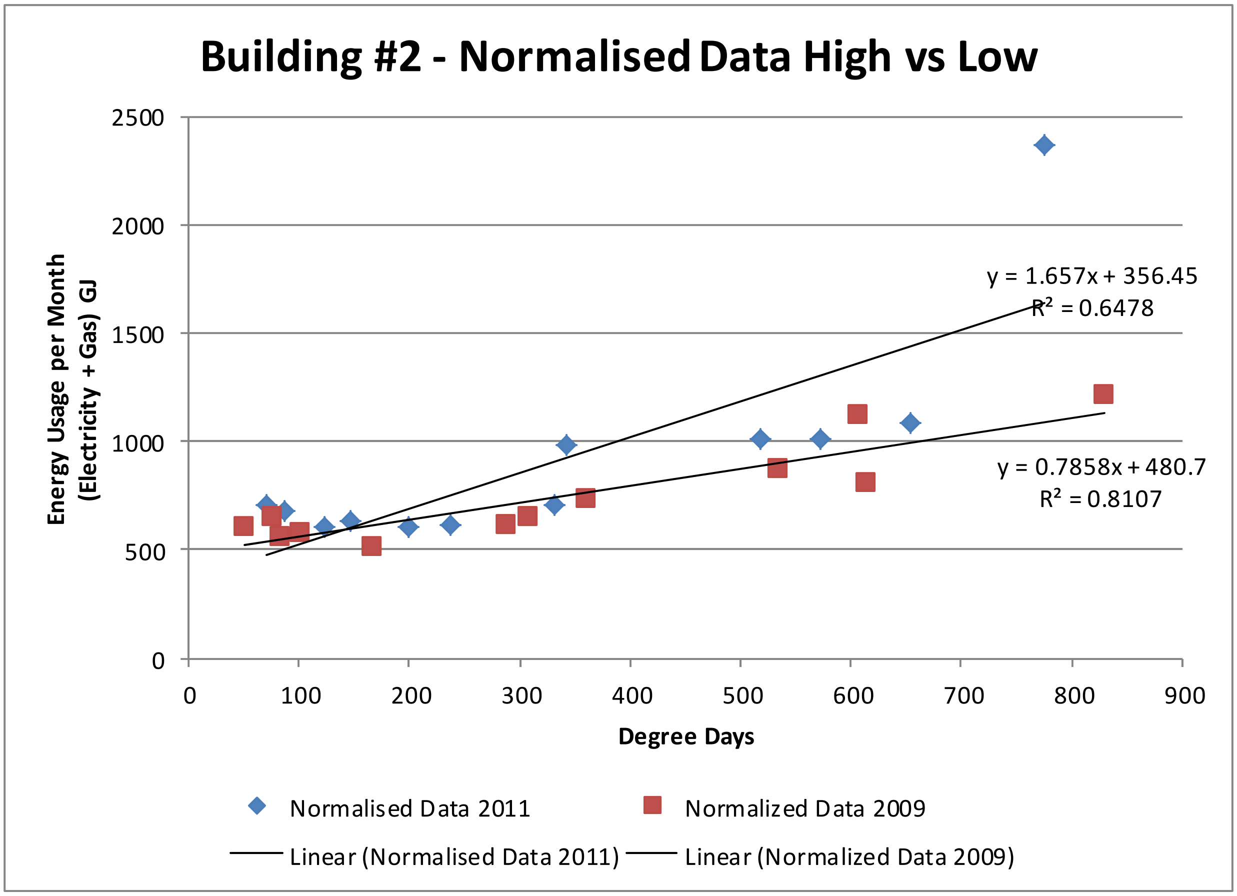
Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. Chart below shows that energy index value is fluctuating. The lowest energy index was in 2009 and highest in 2011. These two years' data will be used for further calculations and comparisons.



Normalized total energy consumption was calculated for Building #2 for 2011 and 2009 as they represent highest and lowest energy consumption respectively. Based on plotted results, shown below in the chart, it can be concluded that energy consumption for 2011 is higher than for 2009. This proves that regardless of weather conditions 2011 has higher energy consumptions than in 2009. Implementing trendline equations, average equation was calculated:

$$y = 1.2214x + 418.575$$

From above equation normalized average energy index was calculated as 1.21 GJ/m^2/yr, this value is slightly higher than average for 2007 to 2014 years range. Calculated value will be used for further case-study buildings comparison.


Building #2 - Normalised Data High vs Low
Energy Usage per Month (Electricity + Gas) GJ
Degree Days
y = 1.657x + 356.45
R² = 0.6478
y = 0.7858x + 480.7
R² = 0.8107
0
500
1000
1500
2000
2500
0
100
200
300
400
500
600
700
800
900
Normalised Data 2011
Normalized Data 2009
Linear (Normalised Data 2011)
Linear (Normalized Data 2009)

Actual data used for calculations (year with highest energy consumption):

ADDRESS:	**Building B - Mississauga, Ontario**
BUILDING #	2
Year - Highest Energy Consumption:	2011
AREA:	**8,225**
USAGE INDEX:	**1.34**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	2011/02/03	2011/03/03	2011/04/01	2011/05/03	2011/06/02	2011/07/06	2011/08/04	2011/09/01	2011/10/04	2011/11/02	2011/12/02	2012/01/03
Electric Billing Days	31	28	29	32	30	34	29	28	33	29	30	32
Gas Billing Date	2011/02/04	2011/03/03	2011/04/04	2011/05/04	2011/06/06	2011/07/06	2011/08/05	2011/09/06	2011/10/04	2011/11/02	2011/12/05	2012/01/03
Gas Billing Days	31	27	32	30	33	30	30	32	28	29	33	29
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	0	13	52	199	122	39	2	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	0	0	2	7	4	1	0	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	775	654	573	332	134	19	0	0	48	235	342	518
Daily Htg. D.D. Avg. (Highest Year)	25	24	18	11	4	1	0	0	2	8	10	18
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	216,000	184,320	163,440	163,440	154,405	193,193	169,324	152,168	177,529	151,422	173,799	196,177
Daily kWh Avg.	6,968	6,827	5,108	5,448	4,679	6,440	5,644	4,755	6,340	5,221	5,267	6,765
Demand kW/RkVA Used	396	401	335	335	330	338	354	354	354	315	401	412
Load Factor (Highest Year)	73%	68%	70%	64%	65%	70%	69%	64%	63%	69%	60%	62%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	42,616	11,280	11,273	3,215	2,157	182	0	1,510	1,027	1,870	9,699	8,169
Daily m^3 Avg.	1,375	418	352	107	65	6	0	47	37	64	294	282
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	446,906	203,827	189,731	132,703	119,138	131,254	113,909	113,054	126,697	115,100	185,560	189,786
S02 (kgs) (Highest Year)	4,828	2,202	2,050	1,434	1,287	1,418	1,231	1,221	1,369	1,244	2,005	2,050
N0x (kgs) (Highest Year)	2,117	965	899	629	564	622	540	535	600	545	879	899
USAGE DATA												
kWh to GJ	777.60	663.55	588.38	588.38	555.86	695.50	609.57	547.80	639.10	545.12	625.68	706.24
GJ/m2/Day ELECTRIC (Highest Year)	0.003	0.003	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.003	0.003
GJ/m2/Month (Highest Year)	0.09	0.08	0.07	0.07	0.07	0.08	0.07	0.07	0.08	0.07	0.08	0.09
m3 to GJ	1585.32	419.62	419.36	119.60	80.24	6.77	0.00	56.17	38.20	69.56	360.80	303.89
GJ/m2/Day GAS (Highest Year)	0.006	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
GJ/m2/Month	0.19	0.05	0.05	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.04	0.04
m3/m2/Month	5.18	1.37	1.37	0.39	0.26	0.02	0.00	0.18	0.12	0.23	1.18	0.99
GJ/m2/Day ENERGY (Highest Year)	0.009	0.005	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.004
GJ/m2/Month (Highest Consumption Year)	0.287	0.132	0.123	0.086	0.077	0.085	0.074	0.073	0.082	0.075	0.120	0.123

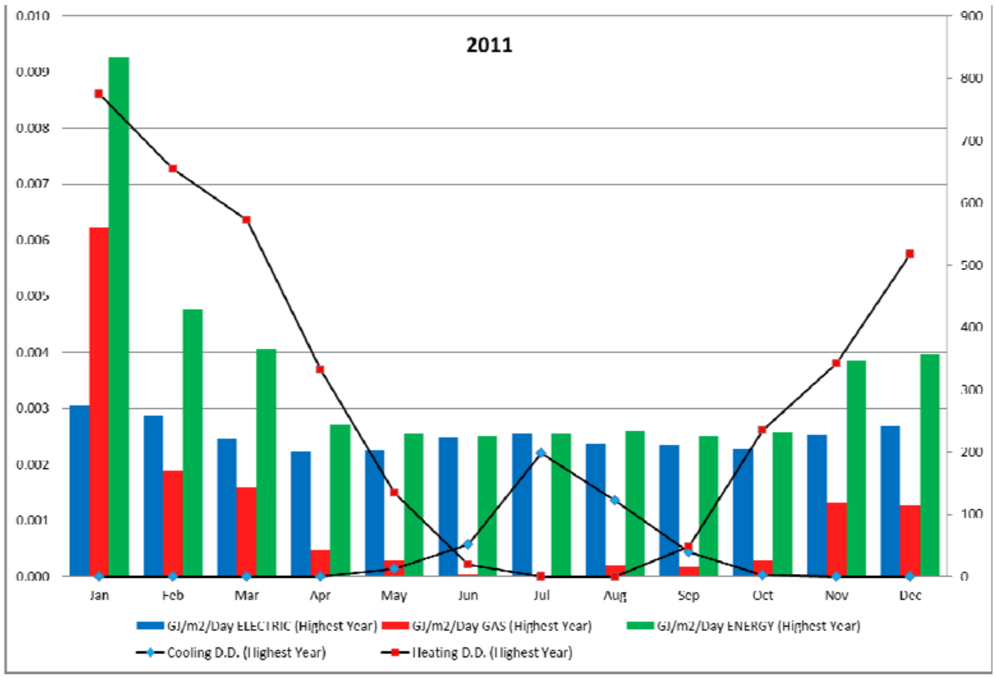
Energy Usage per Month (Electricity + Gas)	2363	1083	1008	708	636	702	610	604	677	615	986	1010
Degree Days	775	654	573	332	147	71	199	122	87	238	342	518

Actual data used for calculations (year with lowest energy consumption):

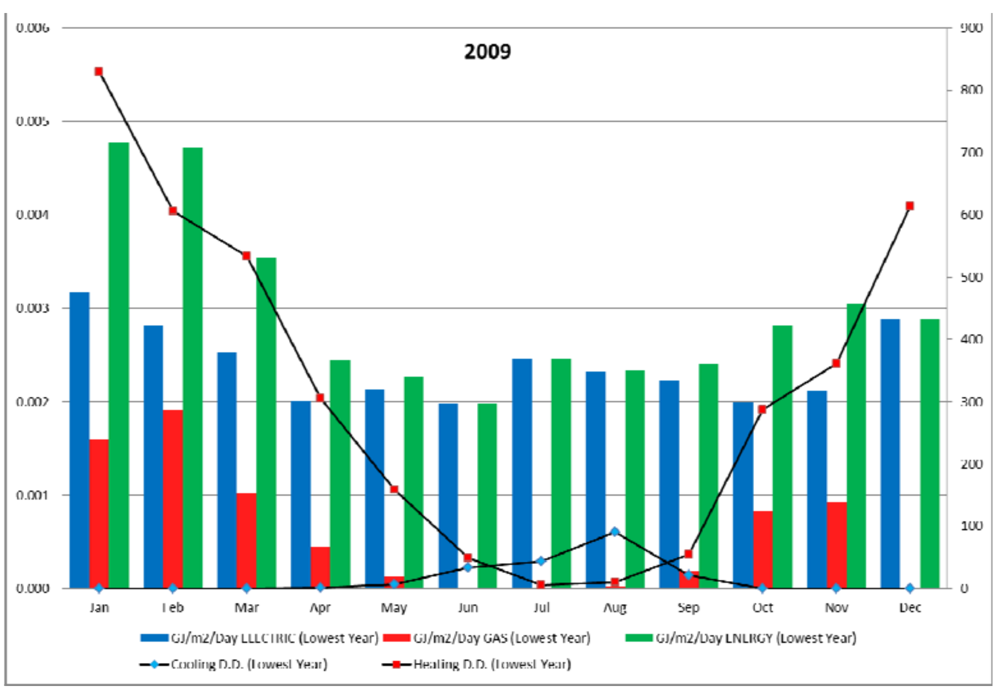
ADDRESS:	Building B - Mississauga, Ontario			
BUILDING #	2			
Year - Lowest Energy Consumption:	2009			
AREA:	8,225			
USAGE INDEX:	1.09	AVERAGE:	1.21134	1.21130

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	2009/02/04	2009/03/05	2009/04/03	2009/05/06	2009/06/02	2009/07/06	2009/08/05	2009/09/04	2009/10/07	2009/11/02	2009/12/01	2010/01/04
Electric Billing Days	31	29	29	33	27	34	30	30	33	26	29	34
Gas Billing Date	2009/02/05	2009/03/06	2009/04/07	2009/05/07	2009/06/08	2009/07/06	2009/08/10	2009/09/04	2009/10/07	2009/11/04	2009/12/04	2010/01/04
Gas Billing Days	31	29	32	30	32	28	35	25	33	28	30	31
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	1	7	34	44	91	21	0	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	0	0	1	1	3	1	0	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	830	606	534	306	159	49	6	10	55	288	361	614
Daily Htg. D.D. Avg. (Lowest Year)	27	21	17	10	5	2	0	0	2	10	12	20
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	224,640	186,480	167,040	151,200	131,760	154,080	168,480	159,120	167,760	118,080	140,400	223,920
Daily kWh Avg.	7,246	6,430	5,220	5,040	4,118	5,503	4,814	6,365	5,084	4,217	4,680	7,223
Demand kW/RkVA Used	867	909	914	1,051	1,028	1,306	1,263	1,171	1,110	1,081	941	902
Load Factor (Lowest Year)	35%	29%	26%	18%	20%	14%	19%	19%	19%	18%	21%	30%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	10,970	12,224	7,213	2,934	942	0	0	111	1,339	5,119	6,180	0
Daily m^3 Avg.	354	422	225	98	29	0	0	4	41	183	206	0
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	228,757	211,961	163,419	122,481	95,305	103,654	113,341	107,830	122,333	115,663	138,187	150,637
S02 (kgs) (Lowest Year)	2,472	2,290	1,766	1,323	1,030	1,120	1,225	1,165	1,322	1,250	1,493	1,627
N0x (kgs) (Lowest Year)	1,084	1,004	774	580	451	491	537	511	579	548	655	713
USAGE DATA												
kWh to GJ	808.70	671.33	601.34	544.32	474.34	554.69	606.53	572.83	603.94	425.09	505.44	806.11
GJ/m2/Day ELECTRIC (Lowest Year)	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003
GJ/m2/Month (Lowest Year)	0.10	0.08	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.05	0.06	0.10
m3 to GJ	408.08	454.73	268.32	109.14	35.04	0.00	0.00	4.13	49.81	190.43	229.90	0.00
GJ/m2/Day GAS (Lowest Year)	0.002	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000
GJ/m2/Month	0.05	0.06	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.00
m3/m2/Month	1.33	1.49	0.88	0.36	0.11	0.00	0.00	0.01	0.16	0.62	0.75	0.00
GJ/m2/Day ENERGY (Lowest Year)	0.005	0.005	0.004	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003
GJ/m2/Month (Lowest Consumption Year)	0.148	0.137	0.106	0.079	0.062	0.067	0.074	0.070	0.079	0.075	0.089	0.098
Average Highest Year to Lowest Year	0.218	0.134	0.114	0.083	0.070	0.076	0.074	0.072	0.081	0.075	0.105	0.110
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Gas)	1217	1126	870	653	509	555	607	577	654	616	735	806
Degree Days	830	606	534	307	166	84	50	101	76	288	361	614
Normalized Data (Average Degree Days)	727	619	544	333	149	88	86	100	94	248	420	637
Normalized Data (Av Energy Consumption)	1307	1175	1083	825	601	526	524	540	533	722	931	1197
Normalized Data (Av Energy Index / month)	0.159	0.143	0.132	0.100	0.073	0.064	0.064	0.066	0.065	0.088	0.113	0.146

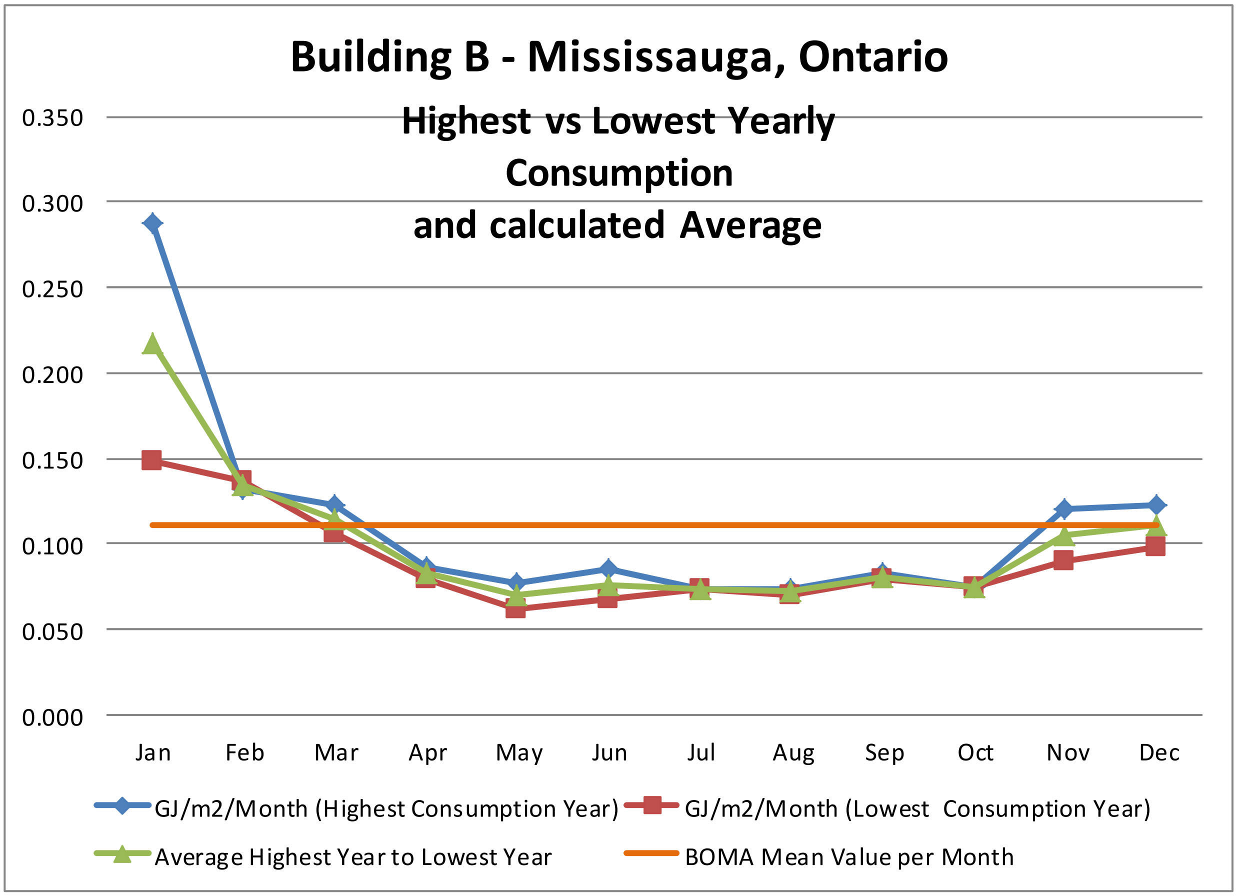
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Building #3 – Utility Bills Analysis

Calculations of Energy Index for Building #3

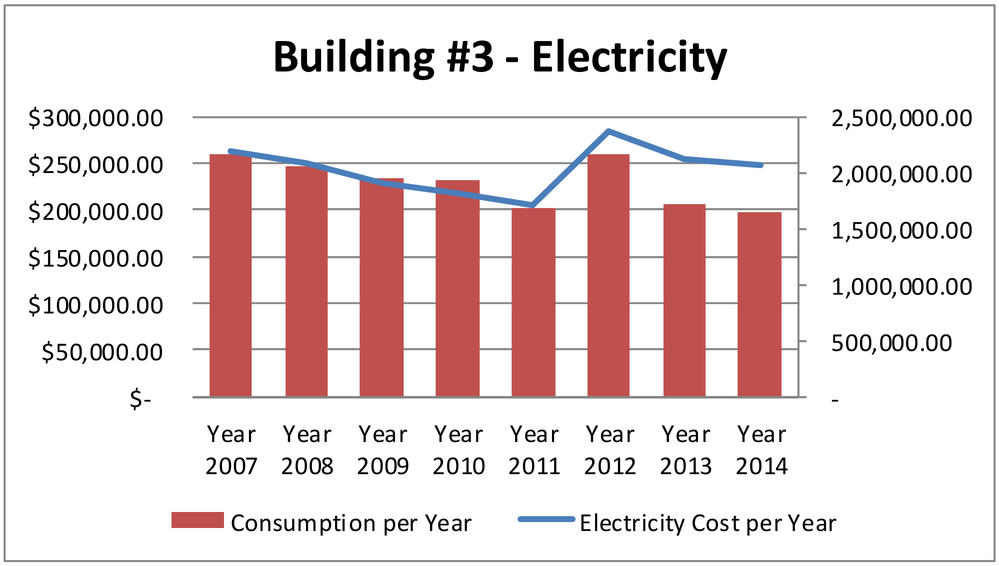
Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity and gas. For Building #3 utility bills were provided from December 2006 to March 2015. To complete most accurate analysis utility bills for 2007 to 2014 were only analyzed because 2006 and 2015 has incomplete data. By having total floor area of 9,240 m^2 energy intensity was calculated. From calculations it was noticed that electricity and gas utility bills provided relatively consistent data, therefore all years' data from 2007 to 2014 were included in calculations.

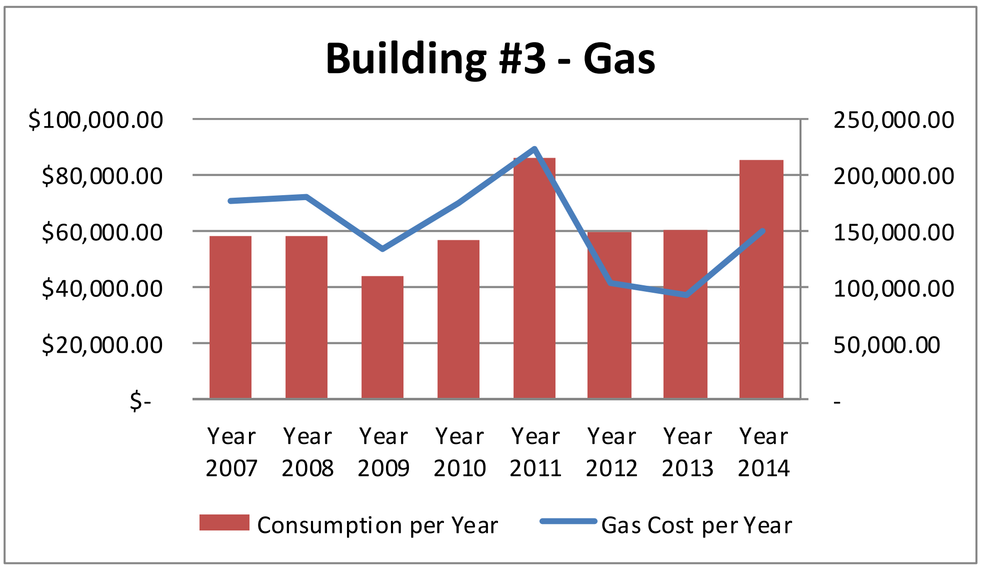
Utility bills analysis showed following:

Building C - Toronto, Ontario						
		kWh		m³-ngas	Total GJ/yr	9,240.00
Row Labels	**Sum of Ele Total Cost / Year**	**Sum of Ele Consumption / Year**	**Sum of Gas Total Cost / Year**	**Sum of Gas Consumption / Year**	**Total**	**GJ/m2/yr**
Year 2006	$ 14,358.63	118,800.00	$ 8,151.68	16,423.00		
Year 2007	$ 262,384.36	2,160,600.00	$ 70,497.72	145,115.00	13,176.44	1.43
Year 2008	$ 250,075.96	2,056,800.00	$ 71,866.39	145,774.00	12,827.27	1.39
Year 2009	$ 227,687.84	1,939,800.00	$ 53,508.79	108,747.00	11,028.67	1.19
Year 2010	$ 216,924.34	1,924,200.00	$ 69,973.69	141,814.00	12,202.60	1.32
Year 2011	$ 205,533.78	1,682,878.08	$ 89,164.96	214,286.00	14,029.80	1.52
Year 2012	$ 284,302.26	2,166,600.00	$ 41,423.33	148,280.00	13,315.78	1.44
Year 2013	$ 254,088.22	1,717,800.00	$ 37,043.42	150,897.00	11,797.45	1.28
Year 2014	$ 248,333.15	1,650,600.00	$ 59,593.20	211,988.00	13,828.11	1.50
Year 2015	$ 58,395.57	399,000.00	$ 40,053.85	114,724.00		
Average	**$ 243,666.24**	**1,912,409.76**	**$ 61,633.94**	**158,362.63**		**1.38**

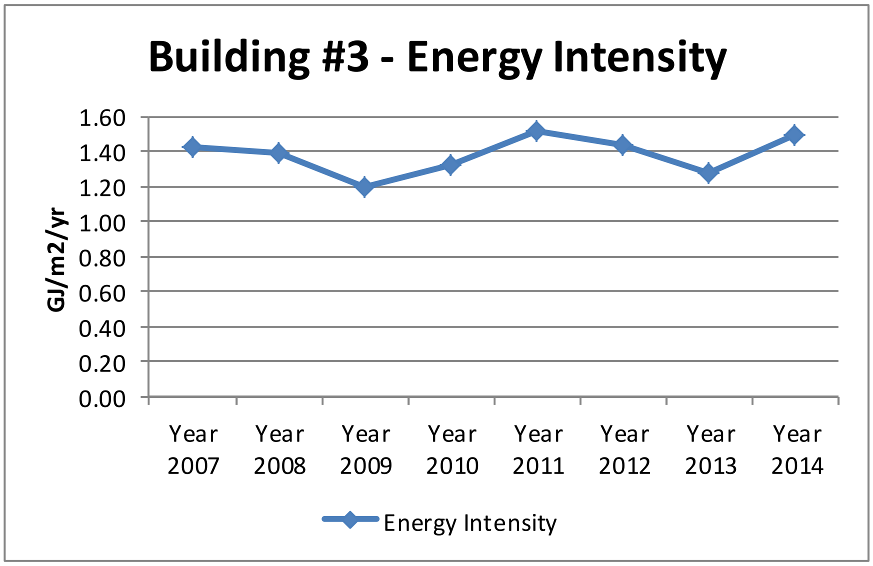
As it was specified in energy audit, energy consumption of the Building #3 is moderately high in comparison to similar office buildings in same region; and therefore average energy index which equals to 1.38 GJ/m^2/yr is also high in comparison to benchmark values of BOMA energy efficient building value of 1.05 GJ/m^2/yr and around average value of National Resources Canada value of 01.43 GJ/m^2/yr.

Two charts below show electricity and gas consumption per year. Electricity consumption chart demonstrates prominent decrease in consumption from 2007 to 2011, and although 2012 shows higher value, overall electricity consumption is decreasing. Gas consumption chart doesn't show such results, 2011 shows slightly inconsistent gas consumption result, but fluctuation of consumption is prominent through entire yearly range.





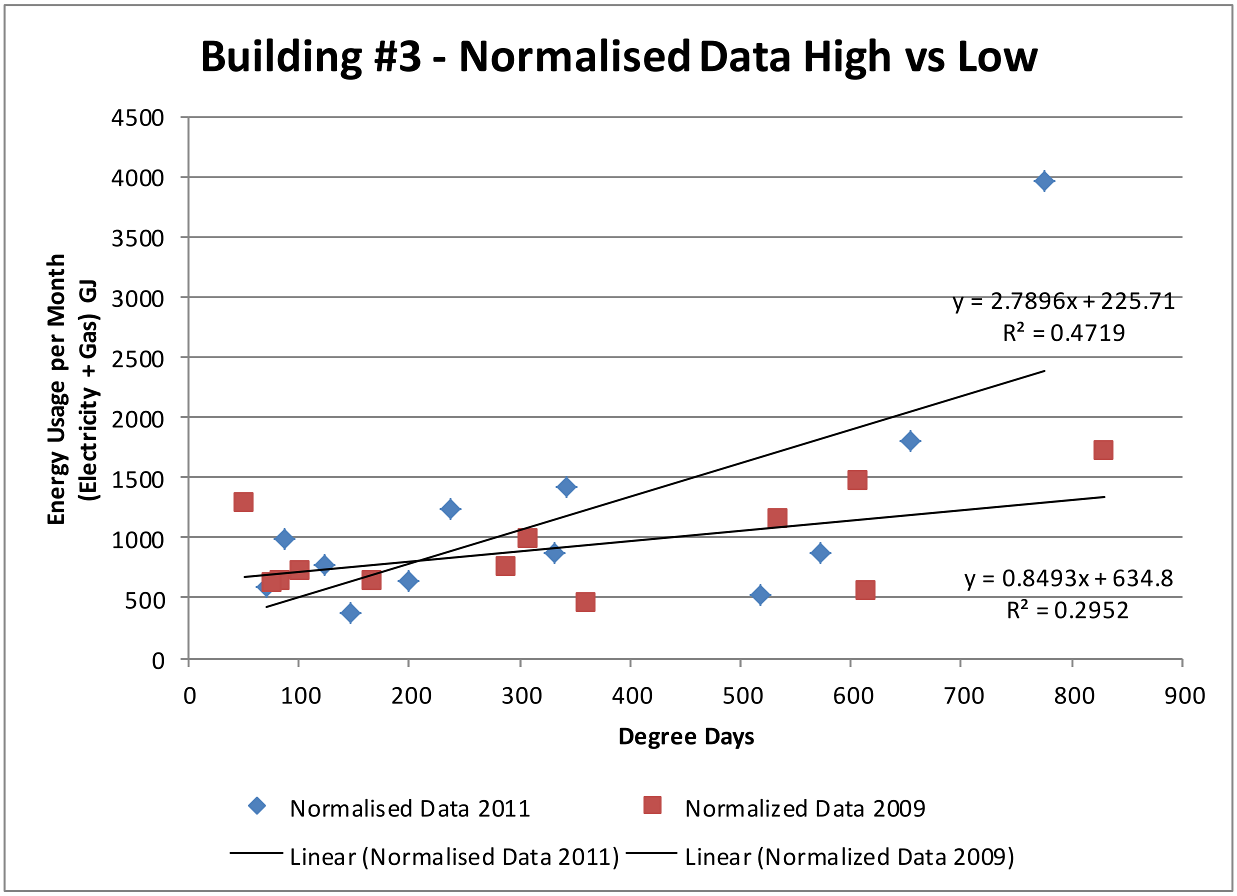
Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. Chart below shows that energy index value fluctuating over years it's calculated, and 2011 and 2014 show very similar results. The lowest energy index was in 2009 and highest in 2011. These two years' data will be used for further calculations and comparisons.



Normalized total energy consumption was calculated for Building #3. Based on plotted results, shown below in the chart, it can be concluded that energy consumption for 2011 at some point is intersecting with 2009, but nevertheless shows higher results. Regardless of weather conditions 2011 has higher energy consumptions than in 2009. Implementing trendline equations, average equation was calculated:

$$y = 1.8194x + 430.26$$

From above equation normalized average energy index was calculated as 1.36 GJ/m^2/yr, this value is slightly higher than average for 2007 to 2014 years range. Calculated value will be used for further case-study buildings comparison.


Building #3 - Normalised Data High vs Low
Energy Usage per Month (Electricity + Gas) GJ
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
600
700
800
900
Degree Days
y = 2.7896x + 225.71
R² = 0.4719
y = 0.8493x + 634.8
R² = 0.2952
Normalised Data 2011
Normalized Data 2009
Linear (Normalised Data 2011)
Linear (Normalized Data 2009)

Actual data used for calculations (year with highest energy consumption):

ADDRESS:	**Building C - Toronto, Ontario**
BUILDING #	3
Year - Highest Energy Consumption:	2011
AREA:	**9,240**
USAGE INDEX:	**1.52**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	2011/01/26	2011/03/01	2011/03/29	2011/05/02	2011/06/01	2011/06/30	2011/08/03	2011/08/31	2011/09/30	2011/11/01	2011/11/30	2012/01/03
Electric Billing Days	31	34	28	34	30	29	34	28	30	32	29	34
Gas Billing Date	2011/02/24	2011/03/23	2011/04/25	2011/05/26	2011/07/23	2011/08/25	2011/09/24	2011/10/25	2011/11/23	2011/12/22	2012/01/23	2012/12/21
Gas Billing Days	31	27	33	31	58	33	30	31	29	29	32	333
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	0	13	52	199	122	39	2	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	0	0	2	6	4	1	0	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	775	654	573	332	134	19	0	0	48	235	342	518
Daily Htg. D.D. Avg. (Highest Year)	25	24	17	11	2	1	0	0	2	8	11	2
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	119,532	188,013	63,501	175,562	90,894	159,375	173,694	167,469	142,566	126,380	129,492	146,400
Daily kWh Avg.	3,856	6,963	1,924	5,663	1,567	4,830	5,790	5,402	4,916	4,358	4,047	440
Demand kW/RkVA Used	273	413	272	356	401	422	451	470	440	470	287	287
Load Factor (Highest Year)	59%	56%	35%	60%	31%	54%	47%	53%	45%	35%	65%	63%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	94,962	30,109	17,216	6,358	1,191	435	278	4,429	12,722	20,919	25,667	0
Daily m^3 Avg.	3,063	1,115	522	205	21	13	9	143	439	721	802	0
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	752,467	339,566	164,558	163,101	69,576	110,295	118,816	144,005	185,943	233,065	268,761	98,487
S02 (kgs) (Highest Year)	8,130	3,669	1,778	1,762	752	1,192	1,284	1,556	2,009	2,518	2,904	1,064
N0x (kgs) (Highest Year)	3,564	1,608	779	773	330	522	563	682	881	1,104	1,273	466
USAGE DATA												
kWh to GJ	430.31	676.85	228.60	632.02	327.22	573.75	625.30	602.89	513.24	454.97	466.17	527.04
GJ/m2/Day ELECTRIC (Highest Year)	0.002	0.002	0.001	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002
GJ/m2/Month (Highest Year)	0.05	0.07	0.02	0.07	0.04	0.06	0.07	0.07	0.06	0.05	0.05	0.06
m3 to GJ	3532.59	1120.05	640.44	236.52	44.31	16.18	10.34	164.76	473.26	778.19	954.81	0.00
GJ/m2/Day GAS (Highest Year)	0.012	0.004	0.002	0.001	0.000	0.000	0.000	0.001	0.002	0.003	0.003	0.000
GJ/m2/Month	0.38	0.12	0.07	0.03	0.00	0.00	0.00	0.02	0.05	0.08	0.10	0.00
m3/m2/Month	10.28	3.26	1.86	0.69	0.13	0.05	0.03	0.48	1.38	2.26	2.78	0.00
GJ/m2/Day ENERGY (Highest Year)	0.014	0.007	0.003	0.003	0.001	0.002	0.002	0.003	0.004	0.004	0.005	0.002
GJ/m2/Month (Highest Consumption Year)	0.429	0.194	0.094	0.094	0.040	0.064	0.069	0.083	0.107	0.133	0.154	0.057

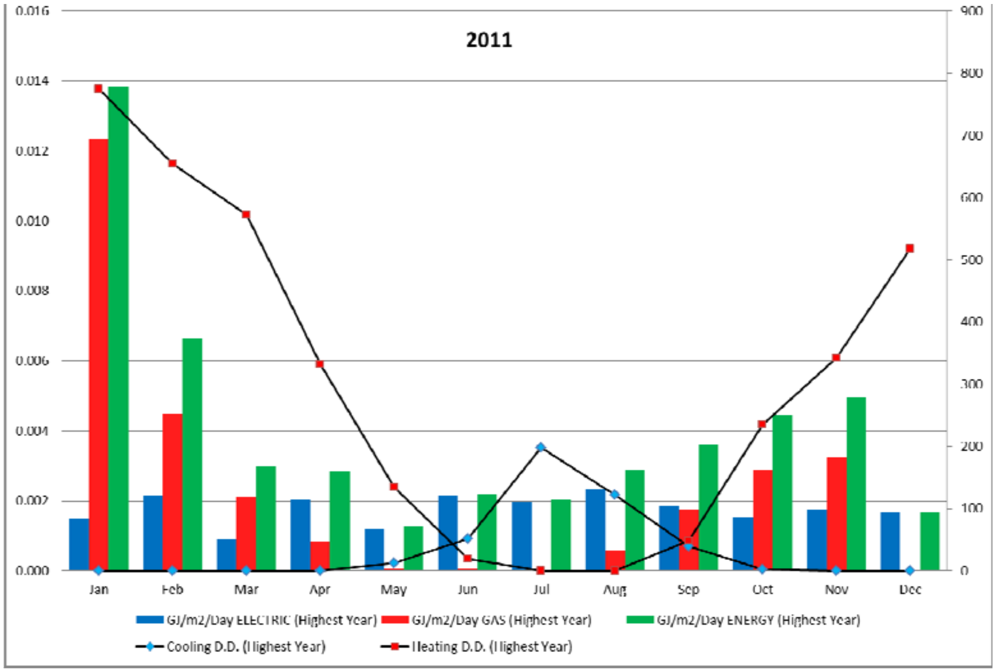
Energy Usage per Month (Electricity + Gas)	3963	1797	869	869	372	590	636	768	986	1233	1421	527
Degree Days	775	654	573	332	147	71	199	122	87	238	342	518

Actual data used for calculations (year with lowest energy consumption):

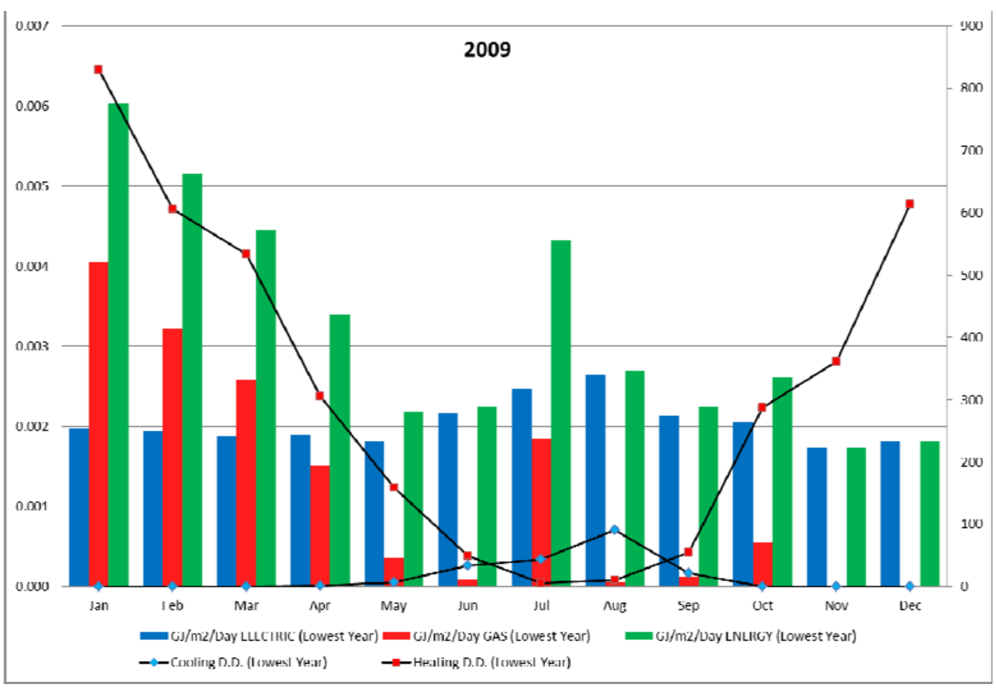
ADDRESS:	Building C - Toronto, Ontario			
BUILDING #	3			
Year - Lowest Energy Consumption:	2009			
AREA:	9,240			
USAGE INDEX:	1.19	AVERAGE:	1.3560	1.35520

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	2009/01/30	2009/03/03	2009/03/30	2009/04/30	2009/06/01	2009/07/02	2009/08/04	2009/09/02	2009/10/02	2009/11/03	2009/12/02	2010/01/04
Electric Billing Days	31	32	27	31	32	31	33	29	30	32	29	33
Gas Billing Date	2009/01/27	2009/02/26	2009/03/27	2009/04/28	2009/05/28	2009/06/26	2009/07/27	2009/08/28	2009/09/28	2009/10/28	2009/12/04	2010/01/04
Gas Billing Days	31	30	29	32	30	29	31	32	31	30	37	31
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	1	7	34	44	91	21	0	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	0	0	1	1	3	1	0	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	830	606	534	306	159	49	6	10	55	288	361	614
Daily Htg. D.D. Avg. (Lowest Year)	27	20	18	10	5	2	0	0	2	10	10	20
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	157,200	159,600	130,200	150,600	148,800	172,800	208,800	196,800	163,800	169,200	128,400	153,600
Daily kWh Avg.	5,071	5,320	4,490	4,706	4,960	5,959	6,735	6,150	5,284	5,640	3,470	4,955
Demand kW/RkVA Used	316	320	314	316	499	467	438	493	371	419	475	319
Load Factor (Lowest Year)	67%	65%	64%	64%	39%	50%	60%	57%	61%	53%	39%	61%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	31,223	23,981	18,580	11,989	2,714	585	14,252	381	918	4,124	0	0
Daily m^3 Avg.	1,007	799	641	375	90	20	460	12	30	137	0	0
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	326,721	277,083	219,081	186,160	119,309	120,387	241,328	135,089	116,689	143,011	86,378	103,331
S02 (kgs) (Lowest Year)	3,530	2,994	2,367	2,011	1,289	1,301	2,607	1,460	1,261	1,545	933	1,116
N0x (kgs) (Lowest Year)	1,548	1,312	1,038	882	565	570	1,143	640	553	677	409	489
USAGE DATA												
kWh to GJ	565.92	574.56	468.72	542.16	535.68	622.08	751.68	708.48	589.68	609.12	462.24	552.96
GJ/m2/Day ELECTRIC (Lowest Year)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.002
GJ/m2/Month (Lowest Year)	0.06	0.06	0.05	0.06	0.06	0.07	0.08	0.08	0.06	0.07	0.05	0.06
m3 to GJ	1161.50	892.09	691.18	445.99	100.96	21.76	530.17	14.17	34.15	153.41	0.00	0.00
GJ/m2/Day GAS (Lowest Year)	0.004	0.003	0.003	0.002	0.000	0.000	0.002	0.000	0.000	0.001	0.000	0.000
GJ/m2/Month	0.13	0.10	0.07	0.05	0.01	0.00	0.06	0.00	0.00	0.02	0.00	0.00
m3/m2/Month	3.38	2.60	2.01	1.30	0.29	0.06	1.54	0.04	0.10	0.45	0.00	0.00
GJ/m2/Day ENERGY (Lowest Year)	0.006	0.005	0.004	0.003	0.002	0.002	0.004	0.003	0.002	0.003	0.002	0.002
GJ/m2/Month (Lowest Consumption Year)	0.187	0.159	0.126	0.107	0.069	0.070	0.139	0.078	0.068	0.083	0.050	0.060
Average Highest Year to Lowest Year	0.308	0.177	0.110	0.100	0.055	0.067	0.104	0.081	0.087	0.108	0.102	0.058
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Ga	1727	1467	1160	988	637	644	1282	723	624	763	462	553
Degree Days	830	606	534	307	166	84	50	101	76	288	361	614
Normalized Data (Average Degree Days)	727	619	544	333	149	88	86	100	94	248	420	637
Normalized Data (Av Energy Consumptio	1754	1556	1421	1036	701	590	587	611	601	882	1194	1590
Normalized Data (Av Energy Index / mon	0.190	0.168	0.154	0.112	0.076	0.064	0.063	0.066	0.065	0.095	0.129	0.172

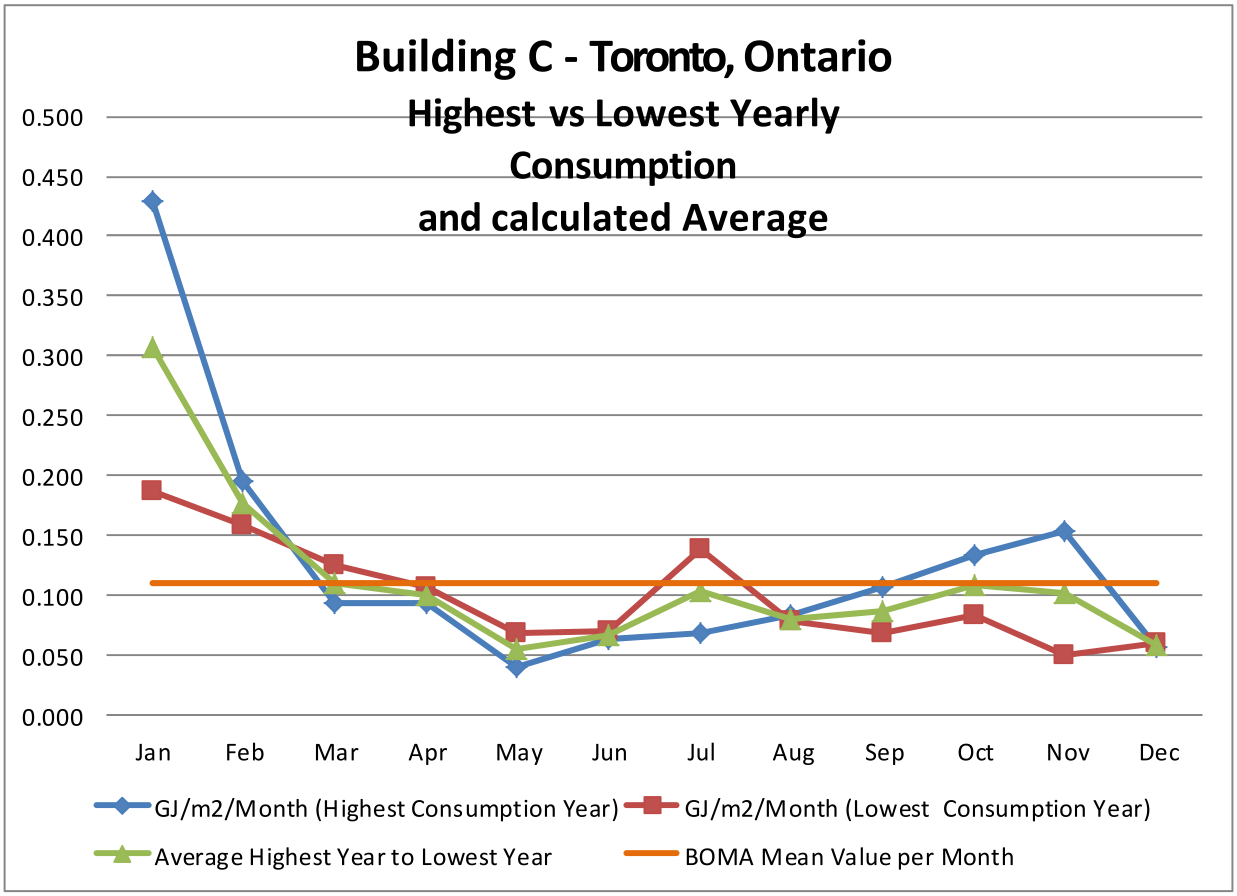
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Building #4 – Utility Bills Analysis

Calculations of Energy Index for Building #4

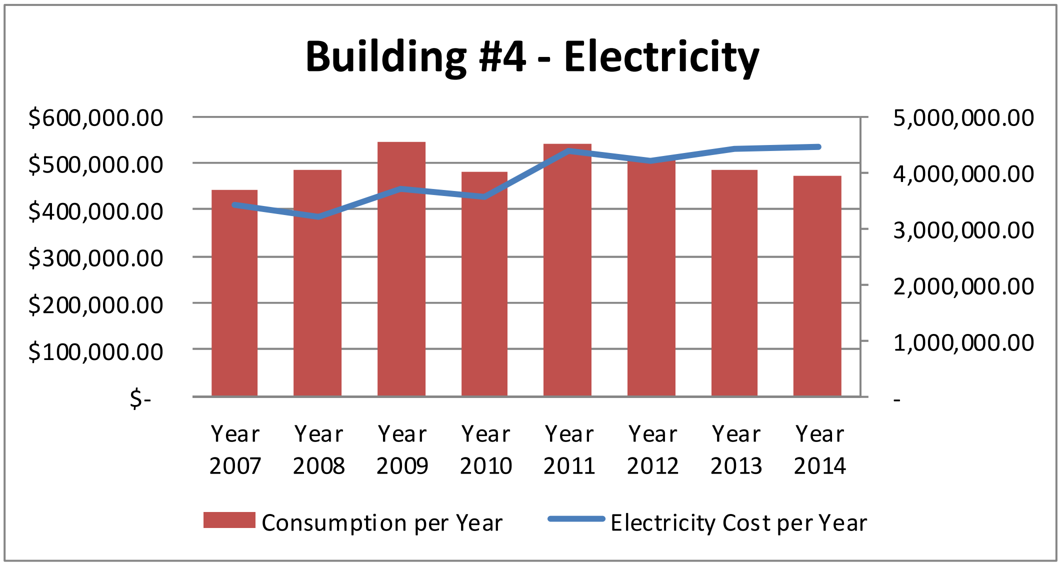
Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity and gas. For Building #4 utility bills were provided from December 2006 to March 2015. To complete most accurate analysis utility bills for 2007 to 2014 were only analyzed because 2006 and 2015 has incomplete data. By having total floor area for entire building of 15,712 m^2, energy index in GJ/m^2/year was calculated. From calculations it was noticed that gas consumption in 2012 is lower than other years, but this year was included in calculations.

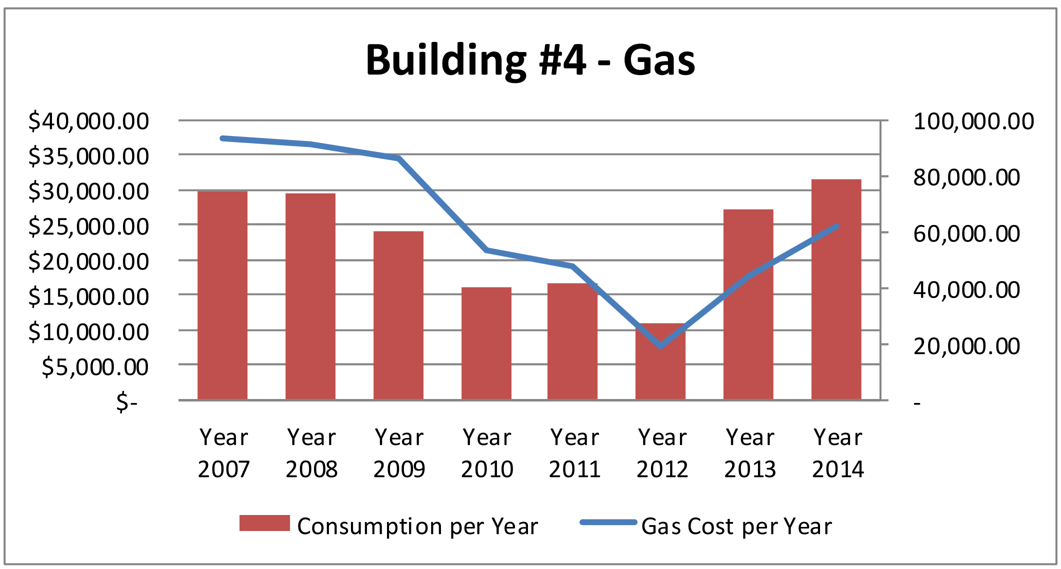
Utility bills analysis showed following:

Building D - Mississauga, Ontario						
		kWh		m^3-ngas	Total GJ/yr	15,712.00
Row Labels	**Sum of Ele Total Cost / Year**	**Sum of Ele Consumption / Year**	**Sum of Gas Total Cost / Year**	**Sum of Gas Consumption / Year**	**Total**	**GJ/m2/yr**
Year 2006	$ 37,785.45	334,800.00				
Year 2007	$ 410,537.45	3,680,400.00	$ 37,382.66	74,712.00	16,028.73	1.02
Year 2008	$ 382,770.41	4,057,200.00	$ 36,450.36	73,660.00	17,346.07	1.10
Year 2009	$ 443,793.78	4,525,401.60	$ 34,358.18	60,446.00	18,540.04	1.18
Year 2010	$ 428,198.70	3,995,644.20	$ 21,306.10	40,093.00	15,875.78	1.01
Year 2011	$ 526,856.96	4,521,619.20	$ 19,058.84	41,305.00	17,814.38	1.13
Year 2012	$ 505,052.00	4,231,608.00	$ 7,665.44	27,266.00	16,248.08	1.03
Year 2013	$ 529,230.33	4,026,000.00	$ 17,580.83	67,617.00	17,008.95	1.08
Year 2014	$ 535,652.84	3,918,000.00	$ 24,764.77	78,886.00	17,039.36	1.08
Year 2015	$ 134,893.74	928,800.00	$ 22,223.44	63,019.00		
Average	**$ 393,477.17**	**3,421,947.30**	**$ 24,532.29**	**58,556.00**		**1.08**

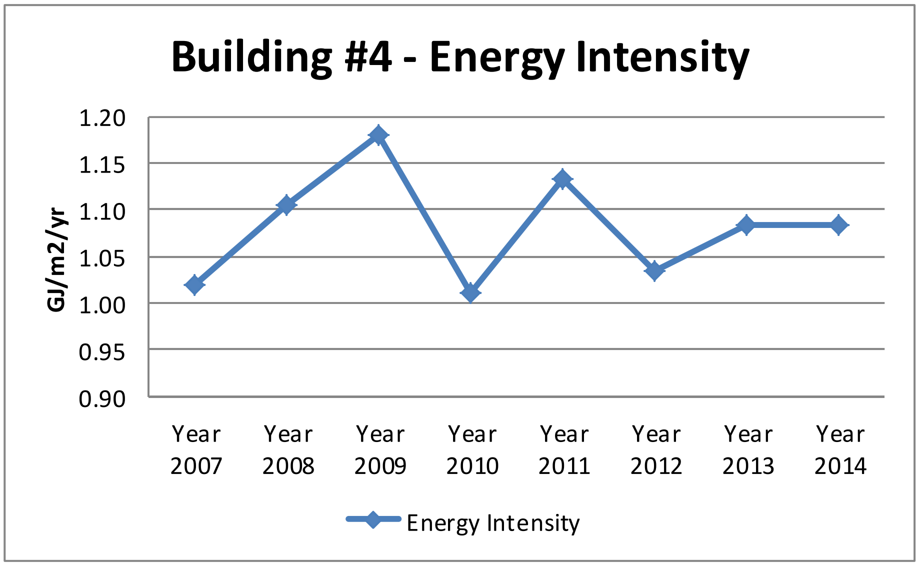
As it was specified in energy audit, energy consumption of the Building #4 is average in comparison to similar office buildings in same region; and therefore average energy index which equals to 1.08 GJ/m^2/yr is also average in comparison to benchmark values of BOMA energy efficient building value of 1.05 GJ/m^2/yr, however value is much lower than average National Resources Canada value of 1.43GJ/m2/year.

Two charts below show electricity and gas consumption per year. Electricity consumption chart fluctuating throughout years but doesn't show any significant improvement or degradation. On the other hand gas consumption show very low value in 2012, this could be due to the fact that some of the gas utility bills were carried into 2013, however by analyzing billing information it was not possible to come to such conclusion certainly.





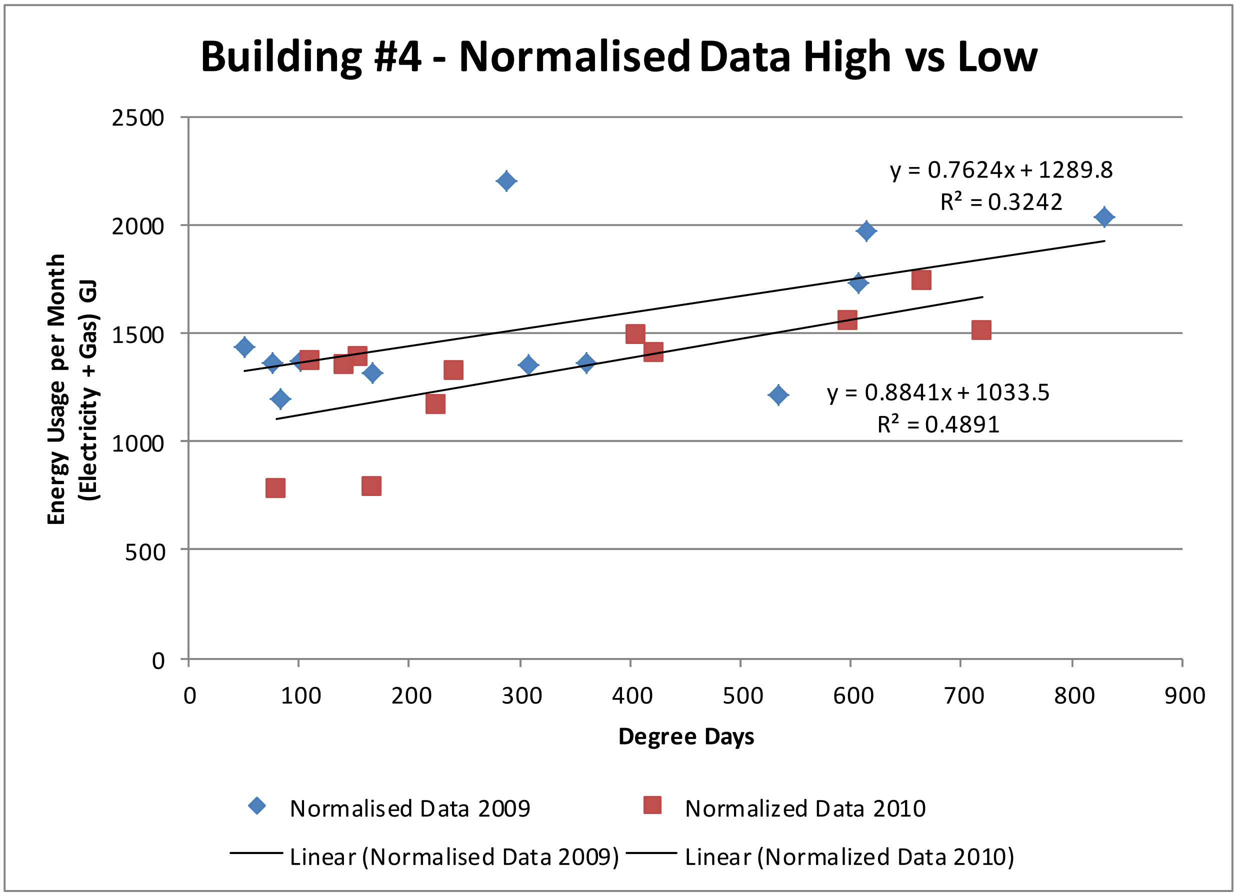
Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. Chart below shows that energy index value is fluctuation through given year range, and in recent years is even lower than in 2010 or 2007. The lowest energy index was in 2010 and highest in 2009. These two years' data will be used for further calculations and comparisons.



Normalized total energy consumption was calculated for Building #4. Based on plotted results, shown below in the chart, it can be concluded that energy consumption for 2009 is higher than for 2010. This proves that regardless of weather conditions 2009 has higher energy consumptions than in 2010. Implementing trendline equations, average equation was calculated:

$$y = 0.8234x + 1161.65$$

From above equation normalized average energy index was calculated as 1.09 GJ/m^2/yr, this value is slightly higher than average for 2007 to 2014 years range. Calculated value will be used for further case-study buildings comparison.


Building #4 - Normalised Data High vs Low
y = 0.7624x + 1289.8
R² = 0.3242
y = 0.8841x + 1033.5
R² = 0.4891
Energy Usage per Month (Electricity + Gas) GJ
Degree Days
0
500
1000
1500
2000
2500
0
100
200
300
400
500
600
700
800
900
Normalised Data 2009
Normalized Data 2010
Linear (Normalised Data 2009)
Linear (Normalized Data 2010)

Actual data used for calculations (year with highest energy consumption):

ADDRESS:	**Building D -Mississauga, Ontario**
BUILDING #	4
Year - Highest Energy Consumption:	2009
AREA:	**15,712**
USAGE INDEX:	**1.18**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	2009/01/21	2009/02/20	2009/03/18	2009/04/21	2009/05/21	2009/06/19	2009/07/21	2009/08/21	2009/09/23	2009/11/18	2009/12/15	2010/01/20
Electric Billing Days	31	30	26	34	30	29	32	31	33	56	27	36
Gas Billing Date	2009/01/21	2009/02/20	2009/03/18	2009/04/21	2009/05/21	2009/06/19	2009/07/21	2009/08/21	2009/09/23	2009/11/18	2009/12/15	2010/01/20
Gas Billing Days	31	30	26	34	30	29	32	31	33	56	27	36
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	1	7	34	44	91	21	0	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	0	0	1	1	3	1	0	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	830	606	534	306	159	49	6	10	55	288	361	614
Daily Htg. D.D. Avg. (Highest Year)	27	20	21	9	5	2	0	0	2	5	13	17
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	326,400	343,200	300,000	373,200	366,000	331,200	398,400	380,400	379,200	612,000	295,200	420,202
Daily kWh Avg.	10,529	11,440	11,538	10,976	12,200	11,421	12,450	12,271	11,491	10,929	10,933	11,672
Demand kW/RkVA Used	631	640	629	674	684	796	782	743	748	659	702	657
Load Factor (Highest Year)	70%	74%	76%	68%	74%	60%	66%	69%	64%	69%	65%	74%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	23,010	13,427	3,589	151	6	0	0	0	0	0	8,022	12,241
Daily m^3 Avg.	742	448	138	4	0	0	0	0	0	0	297	340
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	382,422	325,904	227,218	252,130	246,261	222,807	268,015	255,905	255,098	411,709	255,362	369,312
S02 (kgs) (Highest Year)	4,132	3,521	2,455	2,724	2,661	2,407	2,896	2,765	2,756	4,448	2,759	3,990
N0x (kgs) (Highest Year)	1,811	1,544	1,076	1,194	1,166	1,055	1,269	1,212	1,208	1,950	1,210	1,749
USAGE DATA												
kWh to GJ	1175.04	1235.52	1080.00	1343.52	1317.60	1192.32	1434.24	1369.44	1365.12	2203.20	1062.72	1512.73
GJ/m2/Day ELECTRIC (Highest Year)	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
GJ/m2/Month (Highest Year)	0.07	0.08	0.07	0.09	0.08	0.08	0.09	0.09	0.09	0.14	0.07	0.10
m3 to GJ	855.97	499.48	133.51	5.62	0.22	0.00	0.00	0.00	0.00	0.00	298.42	455.37
GJ/m2/Day GAS (Highest Year)	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
GJ/m2/Month	0.05	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03
m3/m2/Month	1.46	0.85	0.23	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.78
GJ/m2/Day ENERGY (Highest Year)	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
GJ/m2/Month (Highest Consumption Year)	0.129	0.110	0.077	0.086	0.084	0.076	0.091	0.087	0.087	0.140	0.087	0.125

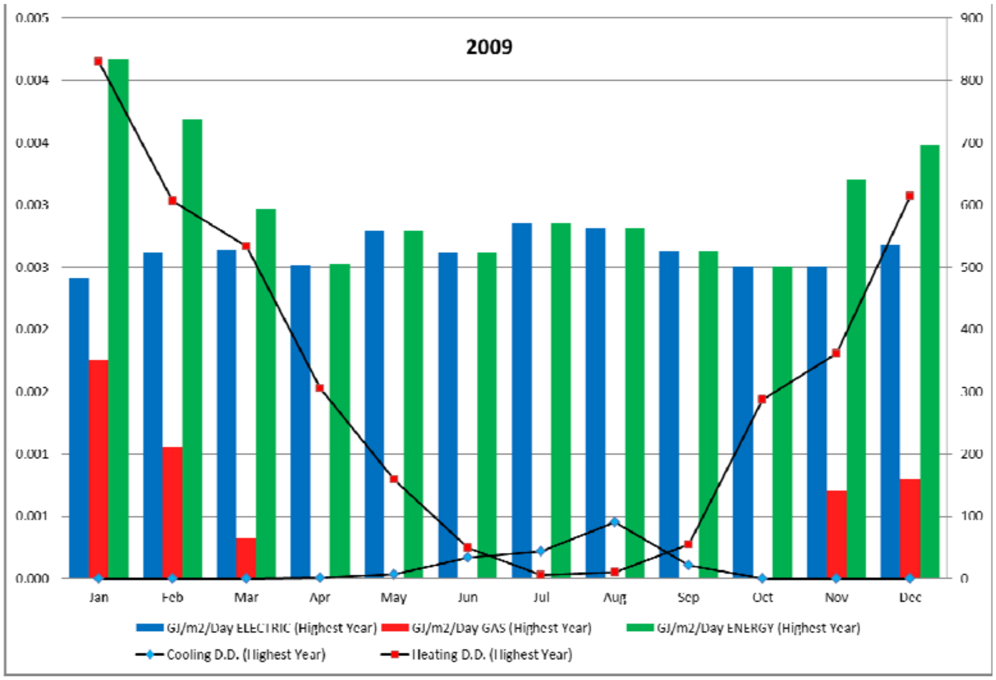
Energy Usage per Month (Electricity + Gas)	2031	1735	1214	1349	1318	1192	1434	1369	1365	2203	1361	1968
Degree Days	830	606	534	307	166	84	50	101	76	288	361	614

Actual data used for calculations (year with lowest energy consumption):

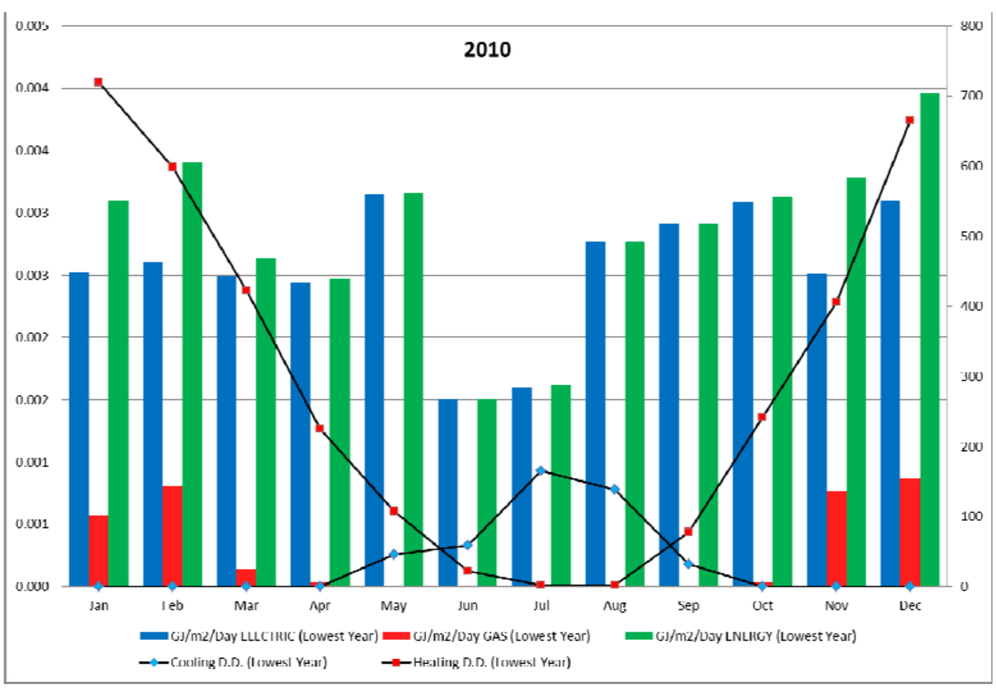
ADDRESS:	Building D -Mississauga, Ontario			
BUILDING #	4			
Year - Lowest Energy Consumption:	2010			
AREA:	15,712			
USAGE INDEX:	1.01	AVERAGE:	1.0952	1.09685

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	2010/02/09	2010/03/10	2010/04/13	2010/05/13	2010/06/10	2010/07/13	2010/08/13	2010/09/13	2010/10/13	2010/11/09	2010/12/08	2011/01/05
Electric Billing Days	31	29	34	30	28	33	31	31	30	27	29	28
Gas Billing Date	2010/02/09	2010/03/10	2010/04/13	2010/05/13	2010/06/10	2010/07/13	2010/08/13	2010/09/13	2010/10/13	2010/11/09	2010/12/08	2011/01/05
Gas Billing Days	31	29	34	30	28	33	31	31	30	27	29	28
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	0	46	59	165	139	32	0	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	0	2	2	5	4	1	0	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	720	598	423	225	108	22	2	2	78	242	405	665
Daily Htg. D.D. Avg. (Lowest Year)	23	21	12	8	4	1	0	0	3	9	14	24
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	341,880	329,448	370,474	319,502	385,392	216,317	216,317	374,203	381,662	364,257	318,259	377,933
Daily kWh Avg.	11,028	11,360	10,896	10,650	13,764	6,555	6,978	12,071	12,722	13,491	10,974	13,498
Demand kW/RkVA Used	658	664	618	654	688	746	683	712	690	617	664	606
Load Factor (Lowest Year)	70%	71%	73%	68%	83%	37%	43%	71%	77%	91%	69%	93%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	7,434	9,857	2,043	439	15	0	184	26	3	437	9,378	10,277
Daily m^3 Avg.	240	340	60	15	1	0	6	1	0	16	323	367
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	282,603	291,388	263,686	218,045	259,370	145,522	146,824	251,921	256,776	248,138	280,471	326,977
S02 (kgs) (Lowest Year)	3,053	3,148	2,849	2,356	2,802	1,572	1,586	2,722	2,774	2,681	3,030	3,533
N0x (kgs) (Lowest Year)	1,339	1,380	1,249	1,033	1,229	689	695	1,193	1,216	1,175	1,328	1,549
USAGE DATA												
kWh to GJ	1230.77	1186.01	1333.70	1150.21	1387.41	778.74	778.74	1347.13	1373.98	1311.33	1145.73	1360.56
GJ/m2/Day ELECTRIC (Lowest Year)	0.003	0.003	0.002	0.002	0.003	0.002	0.002	0.003	0.003	0.003	0.003	0.003
GJ/m2/Month (Lowest Year)	0.08	0.08	0.08	0.07	0.09	0.05	0.05	0.09	0.09	0.08	0.07	0.09
m3 to GJ	276.54	366.68	76.00	16.33	0.56	0.00	6.84	0.97	0.11	16.26	348.86	382.30
GJ/m2/Day GAS (Lowest Year)	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
GJ/m2/Month	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
m3/m2/Month	0.47	0.63	0.13	0.03	0.00	0.00	0.01	0.00	0.00	0.03	0.60	0.65
GJ/m2/Day ENERGY (Lowest Year)	0.003	0.003	0.003	0.002	0.003	0.002	0.002	0.003	0.003	0.003	0.003	0.004
GJ/m2/Month (Lowest Consumption Year)	0.096	0.099	0.090	0.074	0.088	0.050	0.050	0.086	0.087	0.084	0.095	0.111
Average Highest Year to Lowest Year	0.113	0.105	0.083	0.080	0.086	0.063	0.071	0.086	0.087	0.112	0.091	0.118
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Ga	1507	1553	1410	1167	1388	779	786	1348	1374	1328	1495	1743
Degree Days	720	598	423	225	154	80	167	141	110	242	405	665
Normalized Data (Average Degree Days)	672	615	489	292	143	86	144	120	110	225	442	663
Normalized Data (Av Energy Consumptio	1715	1668	1564	1402	1279	1233	1281	1260	1252	1347	1525	1707
Normalized Data (Av Energy Index / mon	0.109	0.106	0.100	0.089	0.081	0.078	0.081	0.080	0.080	0.086	0.097	0.109

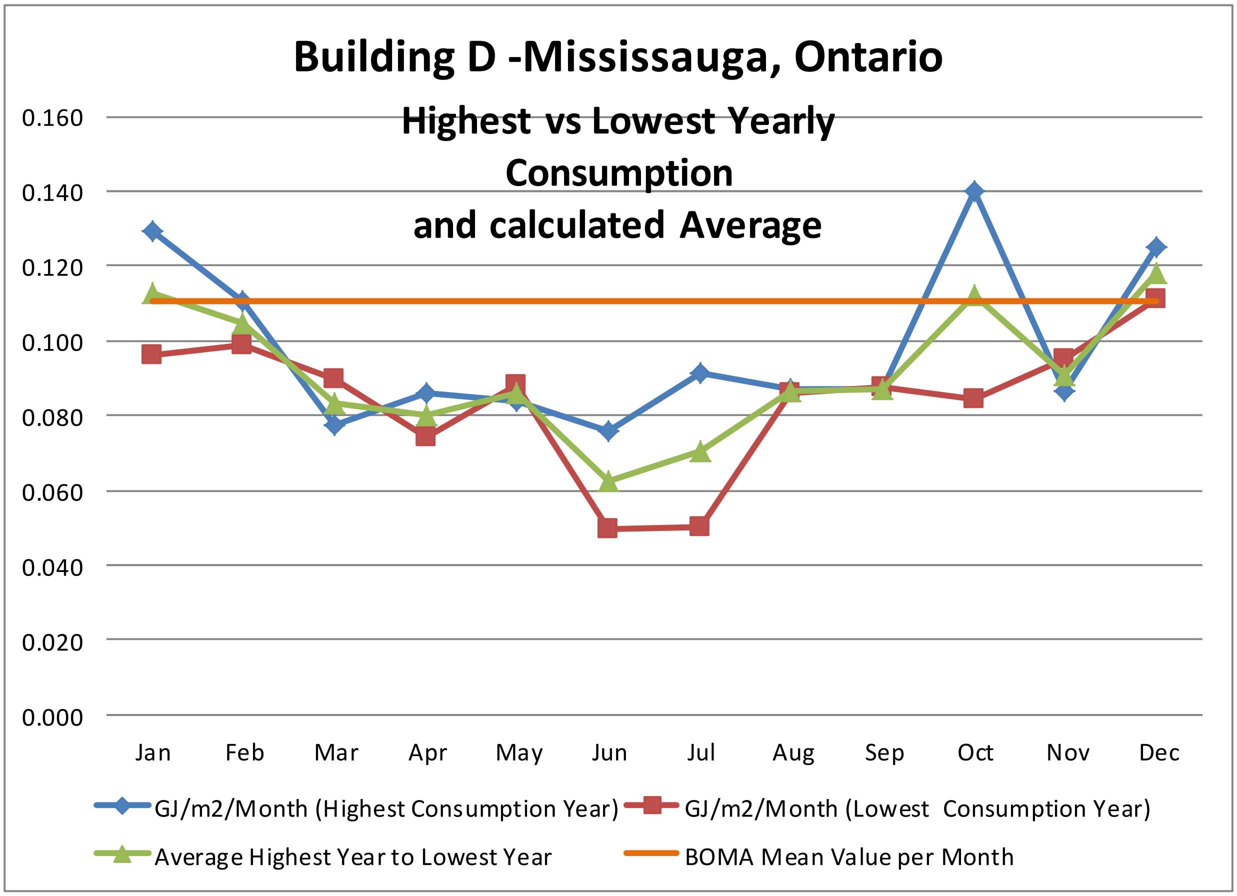
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Building #5 – Utility Bills Analysis

Calculations of Energy Index for Building #5

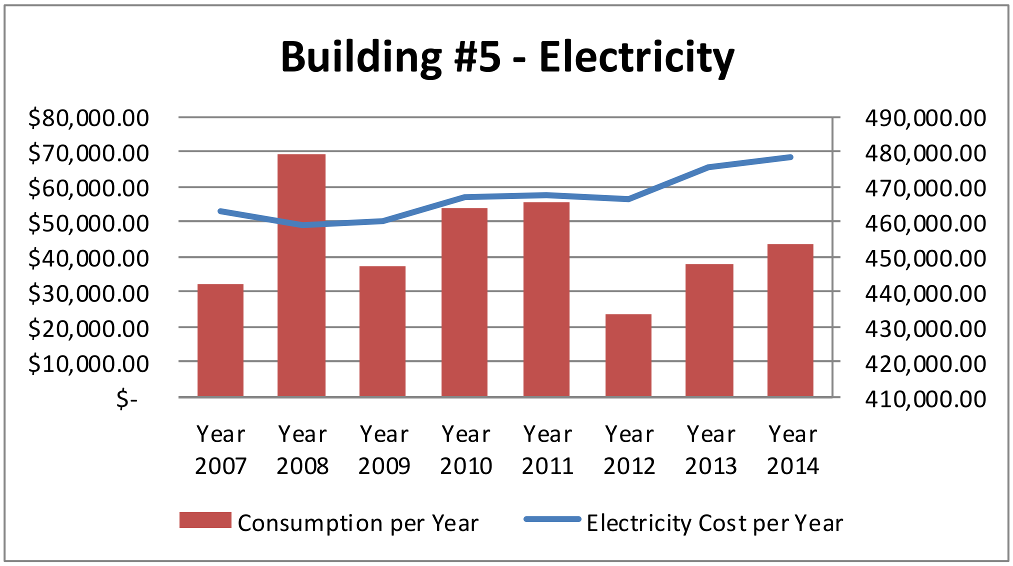
Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity and gas. For Building #5 utility bills were provided from December 2006 to March 2015. To complete most accurate analysis utility bills for 2007 to 2014 were only analyzed because 2006 and 2015 has incomplete data. By having total floor area for entire building of 6,332 m^2, energy index in GJ/m^2/year was calculated. Calculations didn't show very significant inconsistency; therefore all years' data was included for calculations.

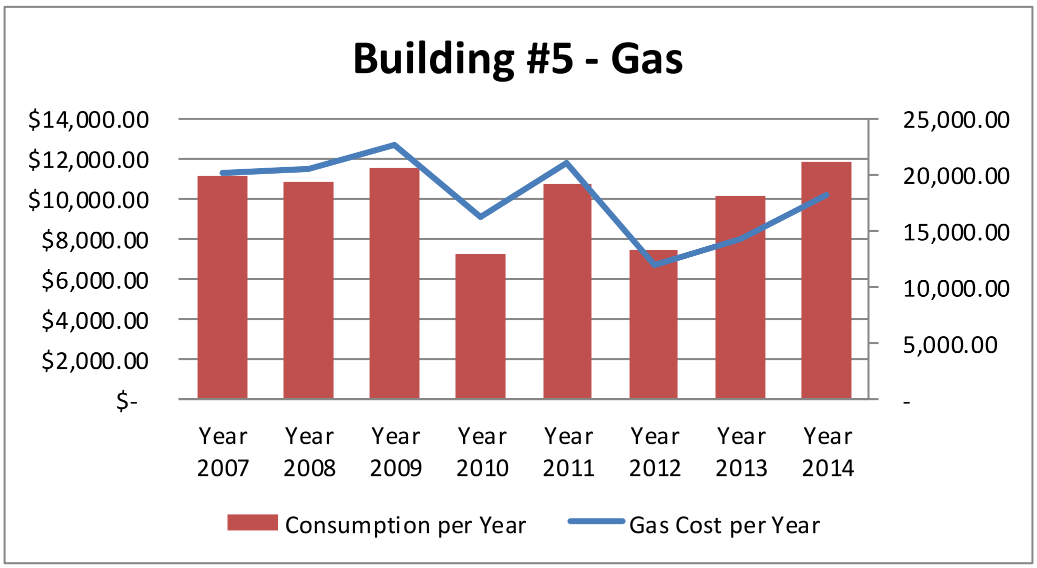
Utility bills analysis showed following:

Building E - Mississauga, Ontario						
		kWh		m³-ngas	Total GJ/yr	6,332.00
Row Labels	**Sum of Ele Total Cost / Year**	**Sum of Ele Consumption / Year**	**Sum of Gas Total Cost / Year**	**Sum of Gas Consumption / Year**	**Total**	**GJ/m2/yr**
Year 2006	$ 5,353.49	48,476.00				
Year 2007	$ 52,977.78	442,250.00	$ 11,279.06	19,789.00	2,328.25	0.37
Year 2008	$ 48,956.14	479,483.00	$ 11,506.41	19,377.00	2,446.96	0.39
Year 2009	$ 50,152.04	447,142.00	$ 12,667.30	20,483.00	2,371.68	0.37
Year 2010	$ 56,722.71	463,824.00	$ 9,042.09	12,824.00	2,146.82	0.34
Year 2011	$ 57,419.84	465,251.37	$ 11,742.19	19,125.00	2,386.35	0.38
Year 2012	$ 56,389.25	433,337.78	$ 6,694.88	13,250.00	2,052.92	0.32
Year 2013	$ 65,225.17	447,643.00	$ 7,931.53	17,992.00	2,280.82	0.36
Year 2014	$ 68,385.92	453,619.00	$ 10,132.16	21,121.00	2,418.73	0.38
Year 2015	$ 18,855.43	125,819.00	$ 5,575.48	12,854.00		
Average	**$ 57,028.61**	**454,068.77**	**$ 10,124.45**	**17,995.13**		**0.36**

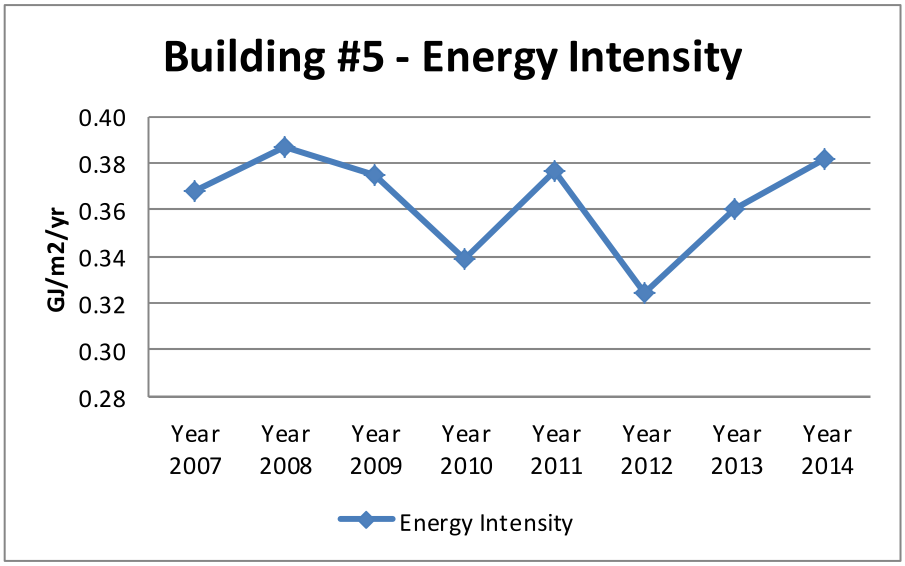
As it was specified in energy audit, energy consumption of the Building #5 is very low in comparison to similar office buildings in same region; and therefore average energy index which equals to 0.36 GJ/m^2/yr is also very low in comparison to benchmark values of BOMA energy efficient building value of 1.05 GJ/m^2/yr, however value is much lower than average National Resources Canada value of 1.43GJ/m2/year.

Two charts below show electricity and gas consumption per year. Electricity consumption chart doesn't demonstrate prominent increase or decrease in energy usage. Electricity utility bills data show 2008 having much higher consumption than other years. Gas utility bills data evenly fluctuating throughout range of years without prominent increase or decrease trend; but 2014 is approaching the highest value.





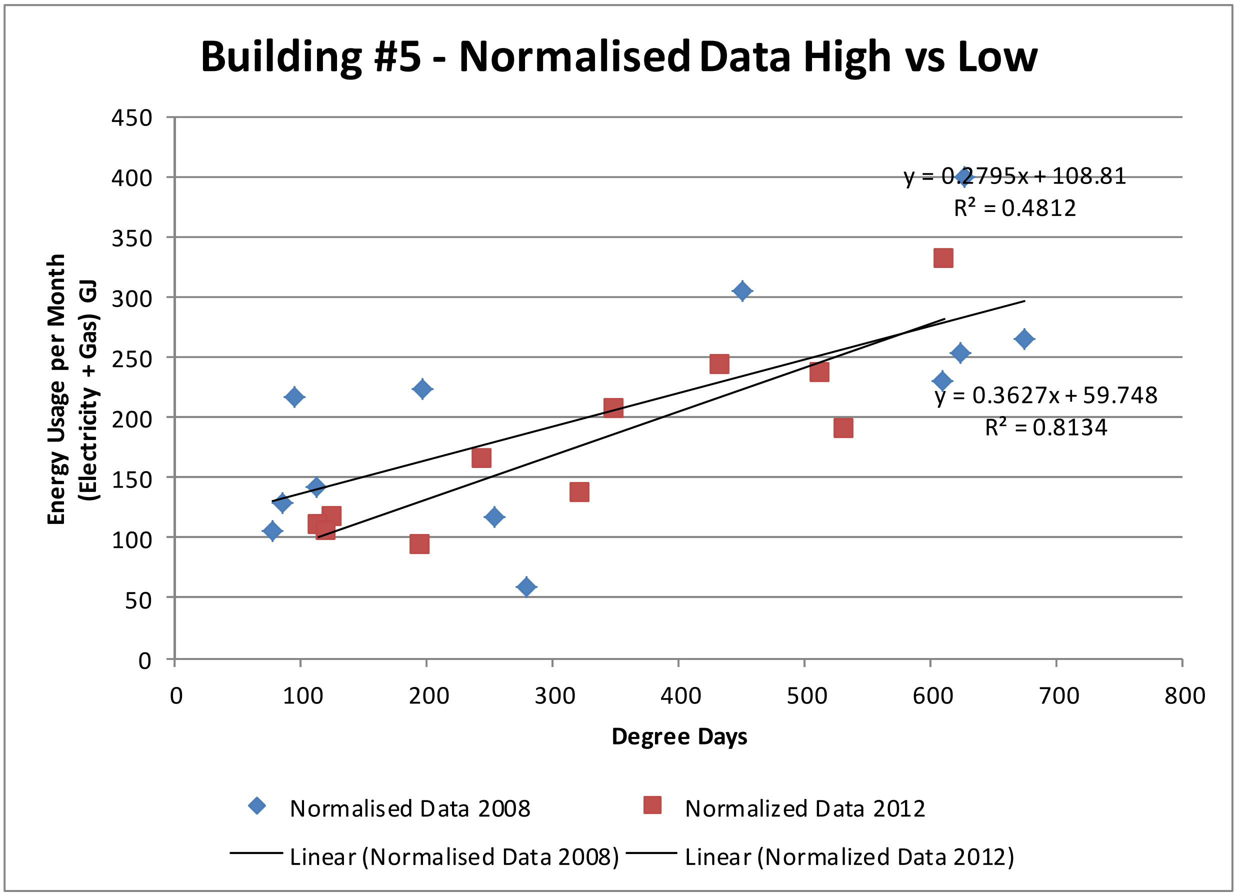
Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. Chart below shows that energy index value is fluctuating through yearly range given. The lowest energy index was in 2012 and highest in 2008. These two years' data will be used for further calculations and comparisons.



Normalized total energy consumption was calculated for Building #5. Based on plotted results, shown below in the chart, it can be concluded that normalized energy consumption for 2008 and 2012 approaching similar alignment therefore have very close values. This proves that weather conditions could impact energy consumptions for these two years. Implementing trendline equations, average equation was calculated:

$$y = 0.3211x + 84.279$$

From above equation normalized average energy index was calculated as 0.36 GJ/m^2/yr, this value is the same as average for 2007 to 2014 years range. As it was mentioned before energy consumption will be increased by 20% to provide more accurate evaluations. Therefore new energy intensity index 0.45 GJ/m^2/yr; this value will be used for further case-study buildings comparison.


Building #5 - Normalised Data High vs Low
Energy Usage per Month (Electricity + Gas) GJ
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
Degree Days
y = 0.2795x + 108.81
R² = 0.4812
y = 0.3627x + 59.748
R² = 0.8134
Normalised Data 2008
Normalized Data 2012
Linear (Normalised Data 2008)
Linear (Normalized Data 2012)

Actual data used for calculations (year with highest energy consumption):

ADDRESS:	**Building E - Mississauga, Ontario**
BUILDING #	5
Year - Highest Energy Consumption:	2008
AREA:	**6,332**
USAGE INDEX:	**0.39**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	2008/02/06	2008/03/07	2008/04/07	2008/05/06	2008/06/05	2008/07/04	2008/08/06	2008/09/04	2008/10/06	2008/11/04	2008/12/04	2009/01/06
Electric Billing Days	31	30	31	29	30	29	33	29	32	29	30	33
Gas Billing Date	2008/02/06	2008/03/07	2008/04/07	2008/05/06	2008/06/05	2008/07/04	2008/08/06	2008/09/04	2008/10/06	2008/11/04	2008/12/04	2009/01/06
Gas Billing Days	31	30	31	29	30	29	33	29	32	29	30	33
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	0	3	72	111	64	27	0	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	0	0	2	3	2	1	0	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	624	675	610	254	194	23	1	13	59	279	452	627
Daily Htg. D.D. Avg. (Highest Year)	20	22	20	9	6	1	0	0	2	10	15	19
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	53,760	52,920	46,610	18,000	40,080	29,080	30,710	27,540	34,130	14,790	55,251	76,612
Daily kWh Avg.	1,734	1,764	1,504	621	1,336	1,003	931	950	1,067	510	1,842	2,322
Demand kW/RkVA Used	103	103	97	54	93	126	88	88	85	38	103	101
Load Factor (Highest Year)	70%	71%	65%	48%	60%	33%	44%	45%	52%	56%	75%	96%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	1,606	2,011	1,660	1,408	2,142	3,025	834	176	143	179	2,862	3,331
Daily m^3 Avg.	52	67	54	49	71	104	25	6	4	6	95	101
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	47,532	49,833	43,104	22,074	42,122	40,971	26,562	19,772	23,972	11,216	57,423	75,113
S02 (kgs) (Highest Year)	514	538	466	238	455	443	287	214	259	121	620	812
N0x (kgs) (Highest Year)	225	236	204	105	200	194	126	94	114	53	272	356
USAGE DATA												
kWh to GJ	193.54	190.51	167.80	64.80	144.29	104.69	110.56	99.14	122.87	53.24	198.90	275.80
GJ/m2/Day ELECTRIC (Highest Year)	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
GJ/m2/Month (Highest Year)	0.03	0.03	0.03	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.03	0.04
m3 to GJ	59.74	74.81	61.75	52.38	79.68	112.53	31.02	6.55	5.32	6.66	106.47	123.91
GJ/m2/Day GAS (Highest Year)	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.001
GJ/m2/Month	0.01	0.01	0.01	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.02	0.02
m3/m2/Month	0.25	0.32	0.26	0.22	0.34	0.48	0.13	0.03	0.02	0.03	0.45	0.53
GJ/m2/Day ENERGY (Highest Year)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.002	0.002
GJ/m2/Month (Highest Consumption Year)	0.040	0.042	0.036	0.019	0.035	0.034	0.022	0.017	0.020	0.009	0.048	0.063

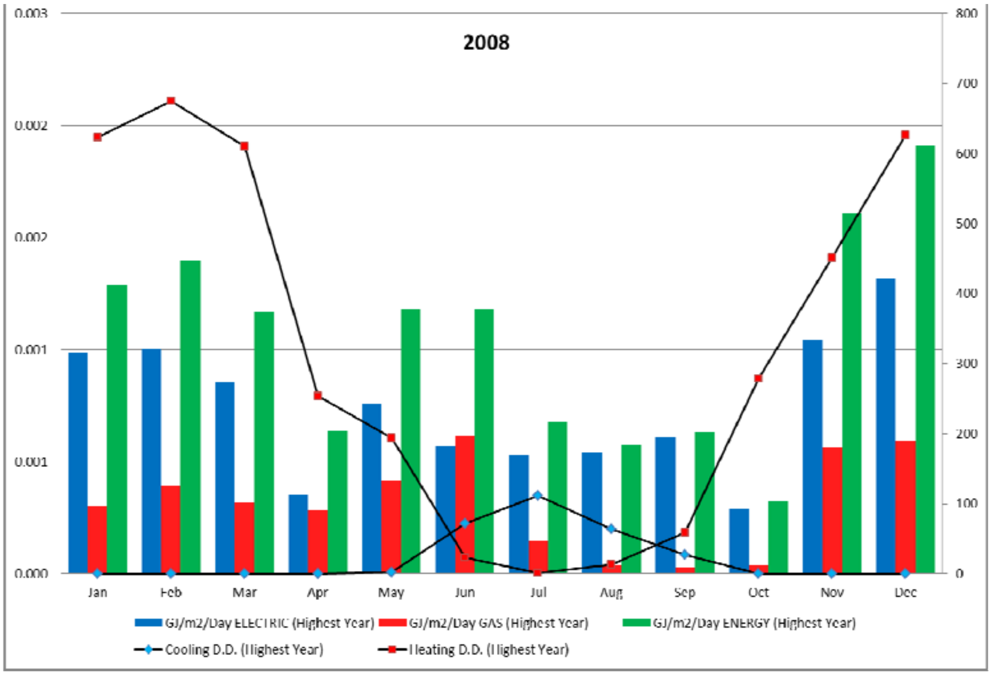
Energy Usage per Month (Electricity + Gas)	253	265	230	117	224	217	142	106	128	60	305	400
Degree Days	624	675	610	254	196	94	112	77	86	279	452	627

Actual data used for calculations (year with lowest energy consumption):

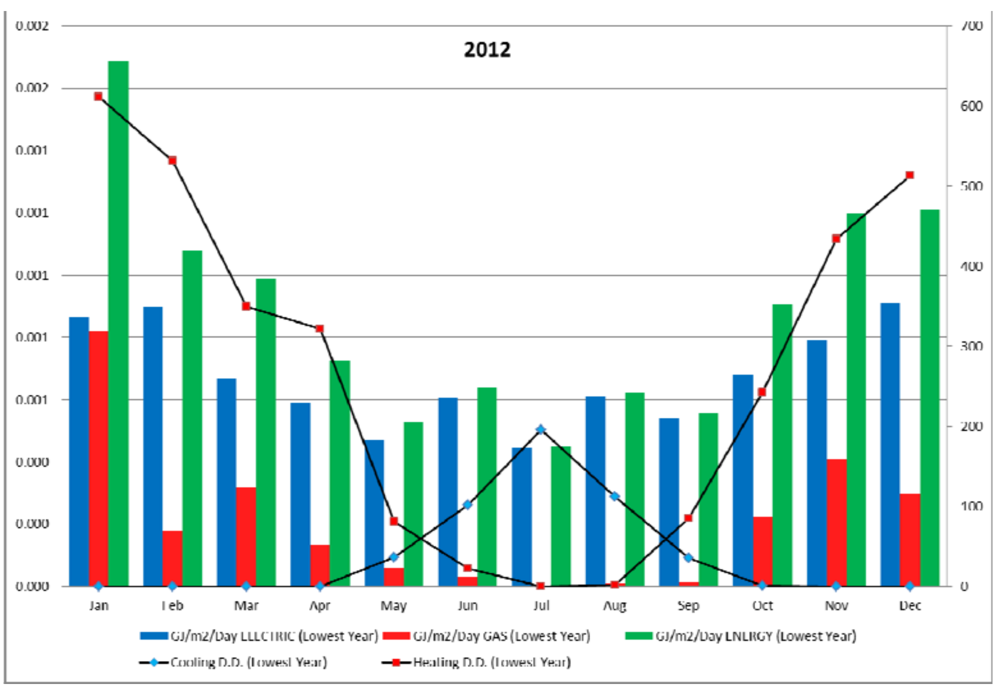
ADDRESS:	Building E - Mississauga, Ontario				
BUILDING #	5				
Year - Lowest Energy Consumption:	2012				
AREA:	6,332				
USAGE INDEX:	0.32	AVERAGE:	0.355	0.35623	

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	2012/02/03	2012/03/02	2012/04/04	2012/05/04	2012/06/06	2012/07/05	2012/08/07	2012/09/04	2012/10/04	2012/11/02	2012/12/04	2013/01/04
Electric Billing Days	31	28	33	30	33	29	33	28	30	29	32	31
Gas Billing Date	2012/02/03	2012/03/02	2012/04/04	2012/05/04	2012/06/06	2012/07/05	2012/08/07	2012/09/04	2012/10/04	2012/11/02	2012/12/04	2013/01/04
Gas Billing Days	31	28	33	30	33	29	33	28	30	29	32	31
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	0	37	102	195	112	36	1	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	0	1	4	6	4	1	0	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	611	532	349	322	81	23	0	2	85	243	434	513
Daily Htg. D.D. Avg. (Lowest Year)	20	19	11	11	2	1	0	0	3	8	14	17
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	47,164	44,236	38,941	31,064	27,357	31,033	25,812	30,144	28,601	34,782	44,577	49,627
Daily kWh Avg.	1,521	1,580	1,180	1,035	829	1,070	782	1,077	953	1,199	1,393	1,601
Demand kW/RkVA Used	63	61	59	52	47	48	50	49	55	57	61	61
Load Factor (Lowest Year)	101%	108%	83%	84%	73%	93%	65%	92%	72%	88%	95%	109%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	4,333	854	1,786	690	330	148	26	51	72	1,100	2,220	1,578
Daily m^3 Avg.	140	31	54	23	10	5	1	2	2	38	69	51
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	62,394	35,803	38,836	25,781	20,739	21,924	17,548	20,640	19,750	31,184	45,699	44,553
S02 (kgs) (Lowest Year)	674	387	420	279	224	237	190	223	213	337	494	481
N0x (kgs) (Lowest Year)	296	170	184	122	98	104	83	98	94	148	216	211
USAGE DATA												
kWh to GJ	169.79	159.25	140.19	111.83	98.48	111.72	92.92	108.52	102.96	125.22	160.48	178.66
GJ/m2/Day ELECTRIC (Lowest Year)	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.001	0.001	0.001	0.001	0.001
GJ/m2/Month (Lowest Year)	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.03	0.03
m3 to GJ	161.19	31.77	66.44	25.67	12.28	5.51	0.97	1.90	2.68	40.92	82.58	58.70
GJ/m2/Day GAS (Lowest Year)	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GJ/m2/Month	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
m3/m2/Month	0.68	0.13	0.28	0.11	0.05	0.02	0.00	0.01	0.01	0.17	0.35	0.25
GJ/m2/Day ENERGY (Lowest Year)	0.002	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001
GJ/m2/Month (Lowest Consumption Year)	0.052	0.030	0.033	0.022	0.017	0.019	0.015	0.017	0.017	0.026	0.038	0.037
Average Highest Year to Lowest Year	0.046	0.036	0.034	0.020	0.026	0.026	0.019	0.017	0.018	0.018	0.043	0.050
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Ga	331	191	207	137	111	117	94	110	106	166	243	237
Degree Days	611	532	350	322	117	125	195	114	121	244	434	513
Normalized Data (Average Degree Days)	618	582	452	340	125	108	159	106	116	226	456	587
Normalized Data (Av Energy Consumptio	283	271	229	194	124	119	135	118	121	157	231	273
Normalized Data (Av Energy Index / mon	0.045	0.043	0.036	0.031	0.020	0.019	0.021	0.019	0.019	0.025	0.036	0.043

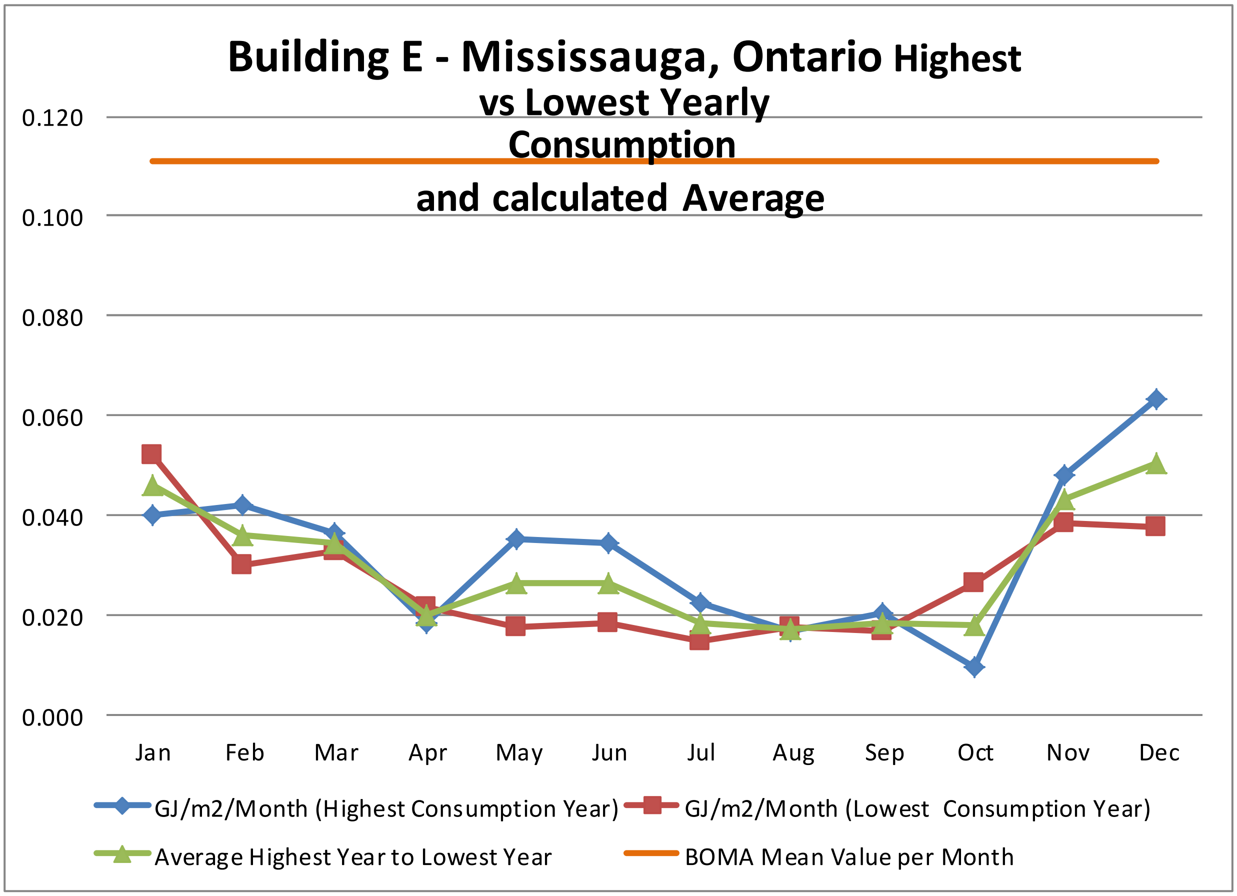
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Building #6 – Utility Bills Analysis

Calculations of Energy Index for Building #6

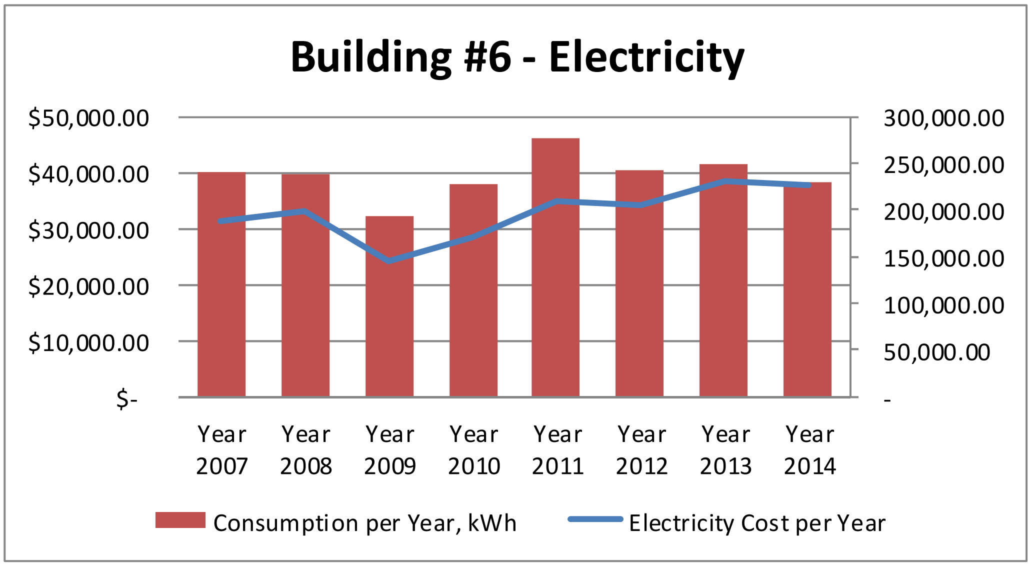
Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity and gas. For Building #1 utility bills were provided from December 2006 to March 2015. To complete most accurate analysis utility bills for 2007 to 2014 were only analyzed because 2006 and 2015 has incomplete data. By having total floor area for entire building of 2,130 m^2, energy index in GJ/m^2/year was calculated. From calculations it was noticed that yearly data is relatively consistent, therefore all years values were included in calculations.

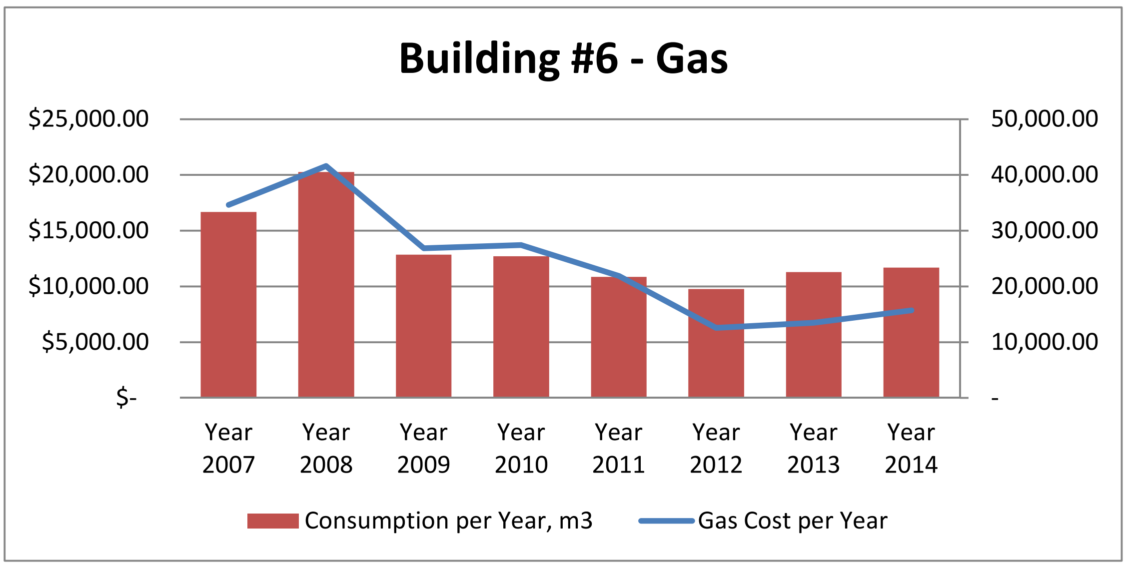
Utility bills analysis showed following:

Building F - Scarborough, Ontario						
		kWh		m³-ngas	Total GJ/yr	2,130.00
Row Labels	Sum of Ele Total Cost / Year	Sum of Ele Consumption / Year	Sum of Gas Total Cost / Year	Sum of Gas Consumption / Year	Total	GJ/m2/yr
Year 2006	$ 5,287.22	42,840.00	$ 1,974.35	3,846.00		
Year 2007	$ 31,149.19	240,150.60	$ 17,306.80	33,358.00	2,105.46	0.99
Year 2008	$ 33,140.73	238,644.90	$ 20,779.73	40,484.00	2,365.13	1.11
Year 2009	$ 24,245.33	193,655.90	$ 13,433.47	25,699.00	1,653.16	0.78
Year 2010	$ 28,324.31	228,129.84	$ 13,700.88	25,401.00	1,766.18	0.83
Year 2011	$ 34,954.77	276,990.83	$ 10,956.97	21,737.00	1,805.78	0.85
Year 2012	$ 34,142.03	242,659.97	$ 6,281.61	19,558.00	1,601.13	0.75
Year 2013	$ 38,332.15	249,357.20	$ 6,748.71	22,593.00	1,738.15	0.82
Year 2014	$ 37,658.14	230,587.05	$ 7,852.37	23,348.00	1,698.66	0.80
Year 2015	$ 13,415.96	88,861.30	$ 3,666.59	9,599.00		
Average	**$ 32,743.33**	**237,522.04**	**$ 12,132.57**	**26,522.25**		**0.86**

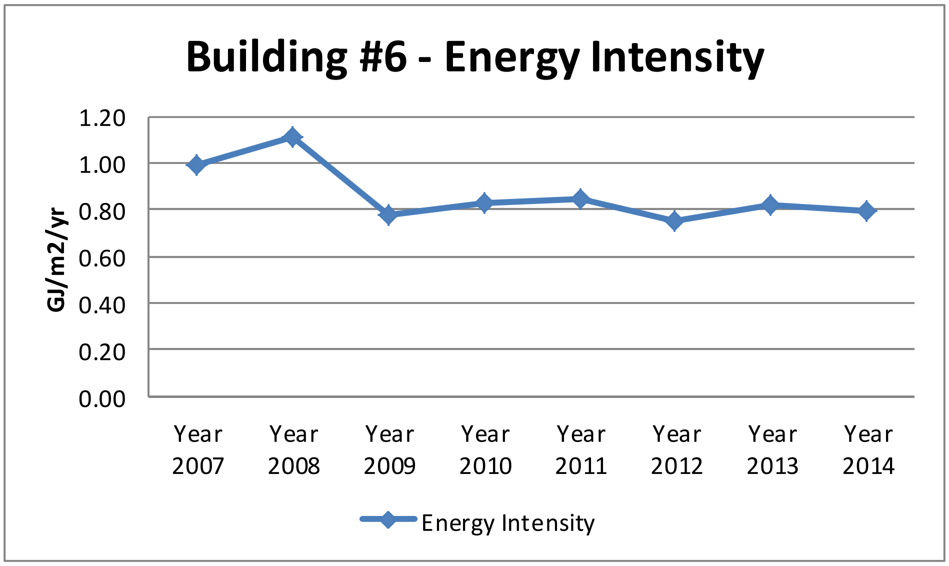
As it was specified in energy audit, energy consumption of the Building #6 is relatively low in comparison to similar office buildings in same region; and therefore average energy index which equals to 0.86 GJ/m^2/yr is also low in comparison to benchmark values of BOMA energy efficient building value of 1.05 GJ/m^2/yr, however value is much lower than average National Resources Canada value of 1.43GJ/m2/year.

Two charts below show electricity and gas consumption per year. Electricity consumption chart fluctuates throughout the year range without any prominent increase or decrease. But gas consumption chart shows prominent decrease in values, however from utility bills analysis there is no obvious reason why this occurred.





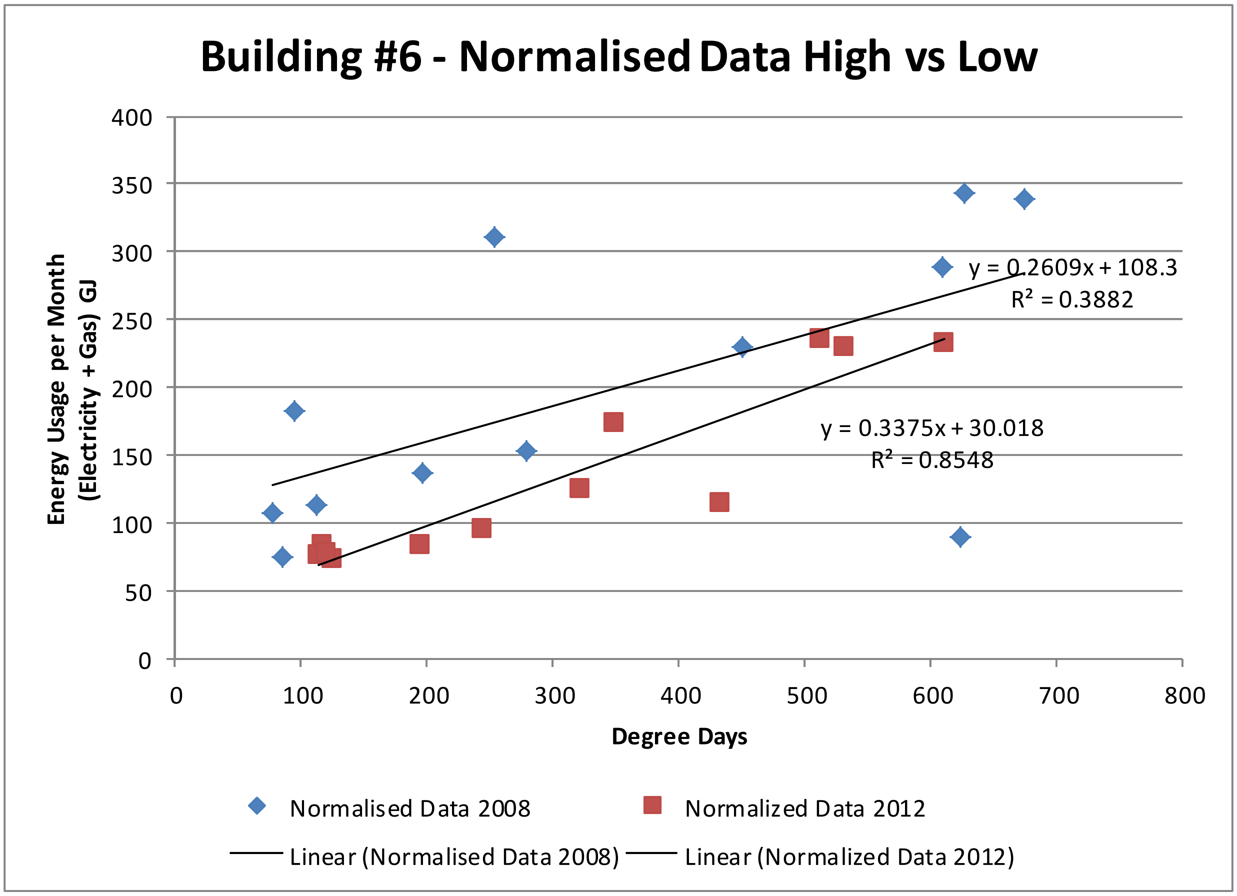
Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. Chart below shows that energy index value is gradually decreasing and currently around 0.80 GJ/m^2/yr and much lower than in 2007 of 1.11 GJ/m^2/yr. The lowest energy index was in 2012 and highest in 2008. These two years' data will be used for further calculations and comparisons.



Normalized total energy consumption was calculated for Building #6. Based on plotted results, shown below in the chart, it can be concluded that energy consumption for 2008 is higher than for 2012. This proves that regardless of weather conditions 2008 has higher energy consumptions than in 2012. Implementing trendline equations, average equation was calculated:

$$y = 0.2992x + 69.159$$

From above equation normalized average energy index was calculated as 0.93 GJ/m^2/yr, this value is significantly higher than average for 2007 to 2014 years range. As it was discussed previously, to reflect more accurate energy consumption it should be multiplied by 10%, therefore new value is 1.02 GJ/m^2/yr. This value will be used for further case-study buildings comparison.



Building #6 - Normalised Data High vs Low
Energy Usage per Month (Electricity + Gas) GJ
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
Degree Days
y = 0.2609x + 108.3
R² = 0.3882
y = 0.3375x + 30.018
R² = 0.8548
Normalised Data 2008
Normalized Data 2012
Linear (Normalised Data 2008)
Linear (Normalized Data 2012)

Actual data used for calculations (year with highest energy consumption):

ADDRESS:	**Building F - Scarborough, Ontario**	
BUILDING #	6	
Year - Highest Energy Consumption:	2008	
AREA:	**2,130**	**1,375**
USAGE INDEX:	**1.11**	**2,365.13**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	2008/02/06	2008/03/07	2008/04/07	2008/05/06	2008/06/05	2008/07/04	2008/08/06	2008/09/04	2008/10/06	2008/11/04	2008/12/04	2009/01/06
Electric Billing Days	31	30	31	29	30	29	33	29	32	29	30	33
Gas Billing Date	2008/02/06	2008/03/07	2008/04/07	2008/05/06	2008/06/05	2008/07/04	2008/08/06	2008/09/04	2008/10/06	2008/11/04	2008/12/04	2009/01/06
Gas Billing Days	31	30	31	29	30	29	33	29	32	29	30	33
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	0	3	72	111	64	27	0	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	0	0	2	3	2	1	0	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	624	675	610	254	194	23	1	13	59	279	452	627
Daily Htg. D.D. Avg. (Highest Year)	20	22	20	9	6	1	0	0	2	10	15	19
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	24,689	19,823	20,116	17,199	17,095	21,084	23,393	19,013	17,421	15,265	16,821	26,726
Daily kWh Avg.	796	661	649	593	570	727	709	656	544	526	561	810
Demand kW/RkVA Used	40	37	43	43	61	61	61	58	54	43	36	36
Load Factor (Highest Year)	84%	74%	63%	57%	39%	49%	48%	47%	42%	51%	65%	94%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	0	7,202	5,797	6,700	2,038	2,865	761	1,022	306	2,617	4,530	6,646
Daily m^3 Avg.	0	240	187	231	68	99	23	35	10	90	151	201
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	16,609	64,305	54,558	58,986	25,923	34,460	21,123	20,024	13,885	28,790	43,375	65,014
S02 (kgs) (Highest Year)	179	695	589	637	280	372	228	216	150	311	469	702
N0x (kgs) (Highest Year)	79	305	258	279	123	163	100	95	66	136	205	308
USAGE DATA												
kWh to GJ	88.88	71.36	72.42	61.91	61.54	75.90	84.21	68.45	62.72	54.96	60.55	96.22
GJ/m2/Day ELECTRIC (Highest Year)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
GJ/m2/Month (Highest Year)	0.04	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.05
m3 to GJ	0.00	267.91	215.65	249.24	75.81	106.58	28.31	38.02	11.38	97.35	168.52	247.23
GJ/m2/Day GAS (Highest Year)	0.000	0.004	0.003	0.004	0.001	0.002	0.000	0.001	0.000	0.002	0.003	0.004
GJ/m2/Month	0.00	0.13	0.10	0.12	0.04	0.05	0.01	0.02	0.01	0.05	0.08	0.12
m3/m2/Month	0.00	3.38	2.72	3.15	0.96	1.35	0.36	0.48	0.14	1.23	2.13	3.12
GJ/m2/Day ENERGY (Highest Year)	0.001	0.005	0.004	0.005	0.002	0.003	0.002	0.002	0.001	0.002	0.004	0.005
GJ/m2/Month (Highest Consumption Year)	0.042	0.159	0.135	0.146	0.064	0.086	0.053	0.050	0.035	0.072	0.108	0.161

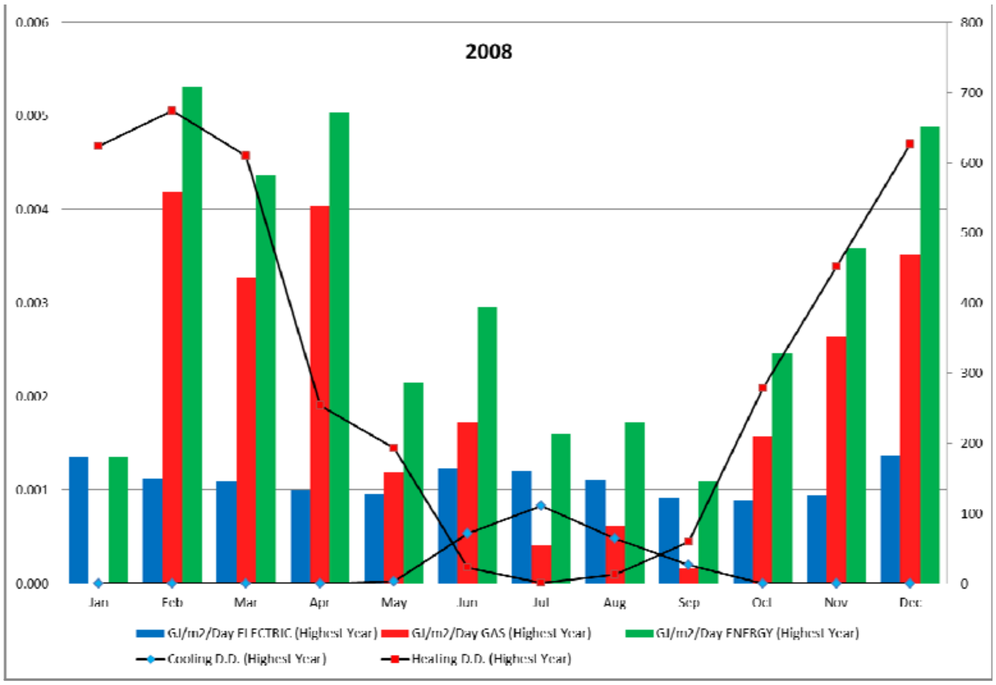
Energy Usage per Month (Electricity + Gas)	89	339	288	311	137	182	113	106	74	152	229	343
Degree Days	624	675	610	254	196	94	112	77	86	279	452	627

Actual data used for calculations (year with lowest energy consumption):

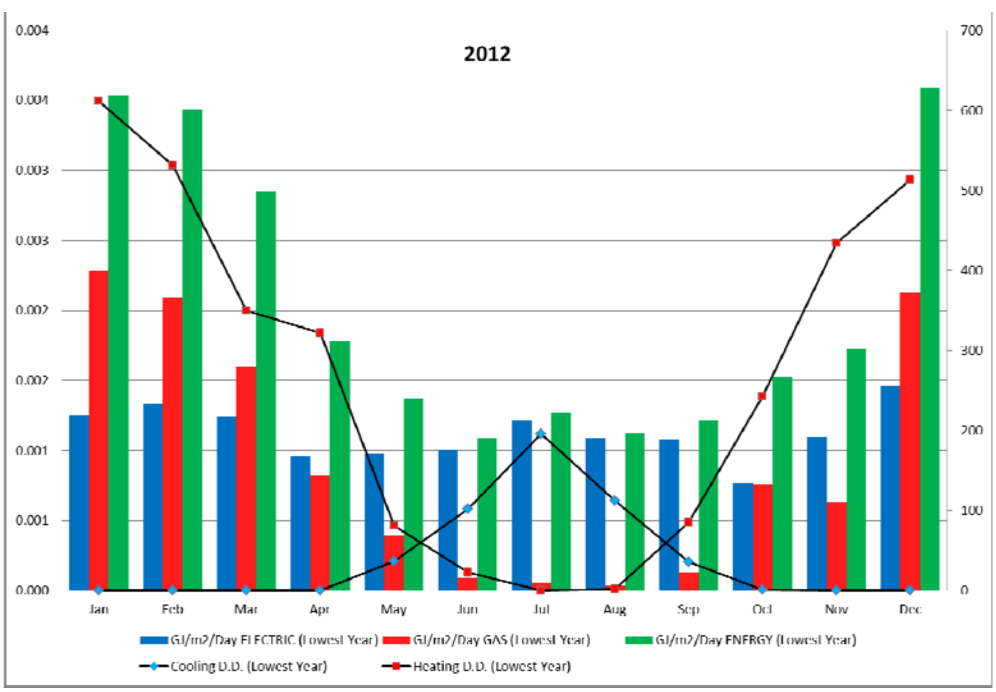
ADDRESS:	Building F - Scarborough, Ontario			
BUILDING #	6			
Year - Lowest Energy Consumption:	2012			
AREA:	2,130			
USAGE INDEX:	0.75	AVERAGE:	0.9310	0.93396

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	2012/01/19	2012/02/17	2012/03/19	2012/04/20	2012/05/18	2012/06/18	2012/07/19	2012/08/20	2012/09/19	2012/10/18	2012/11/19	2012/12/18
Electric Billing Days	31	29	31	32	28	31	31	32	30	29	32	29
Gas Billing Date	2012/01/28	2012/03/01	2012/03/28	2012/05/01	2012/05/31	2012/07/03	2012/07/31	2012/08/31	2012/10/01	2012/10/31	2012/11/29	2012/12/31
Gas Billing Days	31	33	27	34	30	33	28	31	31	30	29	32
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	0	37	102	195	112	36	1	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	0	1	3	6	4	1	0	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	611	532	349	322	81	23	0	2	85	243	434	513
Daily Htg. D.D. Avg. (Lowest Year)	20	16	13	9	3	1	0	0	3	8	15	16
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	22,934	22,949	22,877	18,211	16,228	18,384	22,334	20,616	19,199	13,128	20,756	25,046
Daily kWh Avg.	740	695	847	536	541	557	798	665	619	438	716	783
Demand kW/RkVA Used	45	51	46	52	49	59	69	66	66	52	55	61
Load Factor (Lowest Year)	68%	65%	66%	46%	49%	42%	43%	41%	41%	37%	49%	59%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	4,052	3,954	2,469	1,592	679	173	86	69	232	1,300	1,052	3,900
Daily m^3 Avg.	131	120	91	47	23	5	3	2	7	43	36	122
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	44,105	43,421	32,863	23,518	15,722	13,592	15,633	14,357	14,558	18,032	21,408	44,450
S02 (kgs) (Lowest Year)	477	469	355	254	170	147	169	155	157	195	231	480
N0x (kgs) (Lowest Year)	209	206	156	111	74	64	74	68	69	85	101	211
USAGE DATA												
kWh to GJ	82.56	82.61	82.36	65.56	58.42	66.18	80.40	74.22	69.12	47.26	74.72	90.17
GJ/m2/Day ELECTRIC (Lowest Year)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
GJ/m2/Month (Lowest Year)	0.04	0.04	0.04	0.03	0.03	0.03	0.04	0.03	0.03	0.02	0.04	0.04
m3 to GJ	150.73	147.09	91.85	59.22	25.26	6.44	3.20	2.57	8.63	48.36	39.13	145.08
GJ/m2/Day GAS (Lowest Year)	0.002	0.002	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002
GJ/m2/Month	0.07	0.07	0.04	0.03	0.01	0.00	0.00	0.00	0.00	0.02	0.02	0.07
m3/m2/Month	1.90	1.86	1.16	0.75	0.32	0.08	0.04	0.03	0.11	0.61	0.49	1.83
GJ/m2/Day ENERGY (Lowest Year)	0.004	0.003	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.004
GJ/m2/Month (Lowest Consumption Year)	0.110	0.108	0.082	0.059	0.039	0.034	0.039	0.036	0.037	0.045	0.053	0.110
Average Highest Year to Lowest Year	0.076	0.134	0.109	0.102	0.052	0.060	0.046	0.043	0.036	0.058	0.080	0.136
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Gas)	233	230	174	125	84	73	84	77	78	96	114	235
Degree Days	611	532	350	322	117	125	195	114	121	244	434	513
Normalized Data (Average Degree Days)	618	582	452	340	125	108	159	106	116	226	456	587
Normalized Data (Av Energy Consumption)	254	243	204	171	106	102	117	101	104	137	206	245
Normalized Data (Av Energy Index / month)	0.119	0.114	0.096	0.080	0.050	0.048	0.055	0.047	0.049	0.064	0.097	0.115

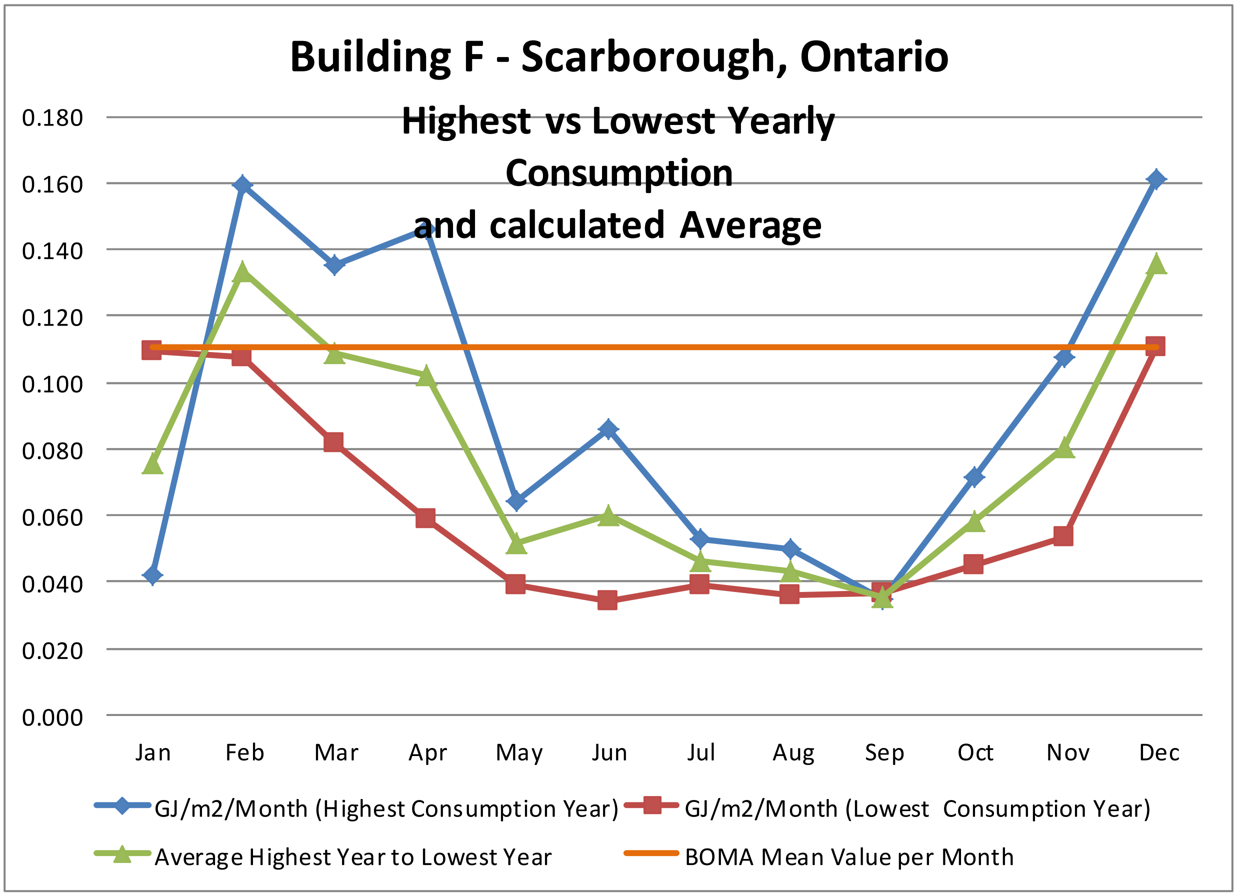
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Building #7 – Utility Bills Analysis

Calculations of Energy Index for Building #7

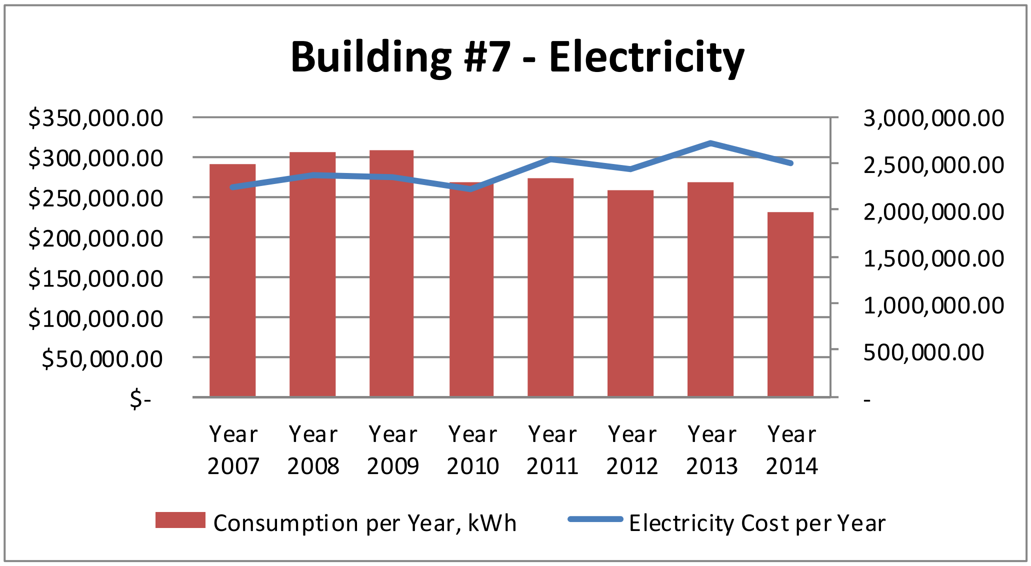
Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity and gas. For Building #7 utility bills were provided from December 2006 to March 2015. To complete most accurate analysis utility bills for 2007 to 2014 were only analyzed because 2006 and 2015 has incomplete data. By having total floor area for entire building of 8,180 m^2, energy index in GJ/m^2/year was calculated. From calculations it was noticed that utility bills data provided consistent information and therefore all years were included for calculations.

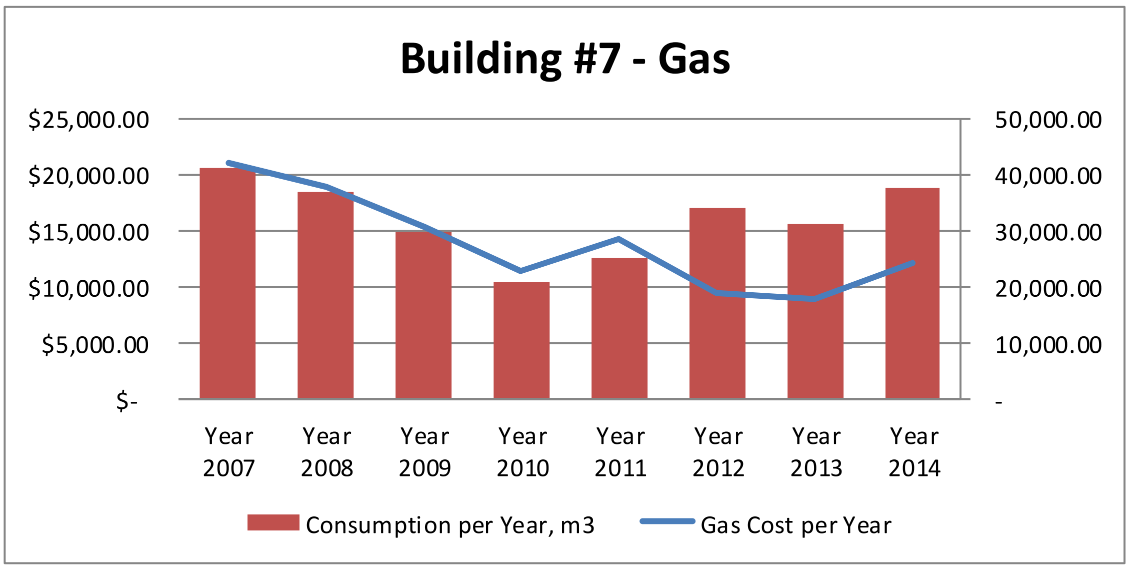
Utility bills analysis showed following:

Building G - Ottawa, Ontario						
		kWh		m^3-ngas	Total GJ/yr	8,180.00
Row Labels	**Sum of Ele Total Cost / Year**	**Sum of Ele Consumption / Year**	**Sum of Gas Total Cost / Year**	**Sum of Gas Consumption / Year**	**Total**	**GJ/m2/yr**
Year 2006	$ 77,017.04	718,425.00	$ 468.19	842.00		
Year 2007	$ 261,537.40	2,492,279.00	$ 20,995.34	40,955.00	10,495.73	1.28
Year 2008	$ 275,706.85	2,620,408.00	$ 18,855.84	36,871.00	10,805.07	1.32
Year 2009	$ 275,088.80	2,628,606.71	$ 15,240.91	29,529.00	10,561.46	1.29
Year 2010	$ 259,308.67	2,301,725.00	$ 11,312.18	20,917.00	9,064.32	1.11
Year 2011	$ 297,341.73	2,339,181.16	$ 14,159.67	25,159.00	9,356.97	1.14
Year 2012	$ 283,483.13	2,205,540.61	$ 9,378.44	33,887.00	9,200.54	1.12
Year 2013	$ 317,637.06	2,298,816.16	$ 8,844.17	30,965.00	9,427.64	1.15
Year 2014	$ 291,286.42	1,980,949.16	$ 12,013.35	37,409.00	8,523.03	1.04
Year 2015	$ 107,912.33	719,858.65	$ 10,795.49	29,685.00		
Average	**$ 282,673.76**	**2,358,438.23**	**$ 13,849.99**	**31,961.50**		**1.18**

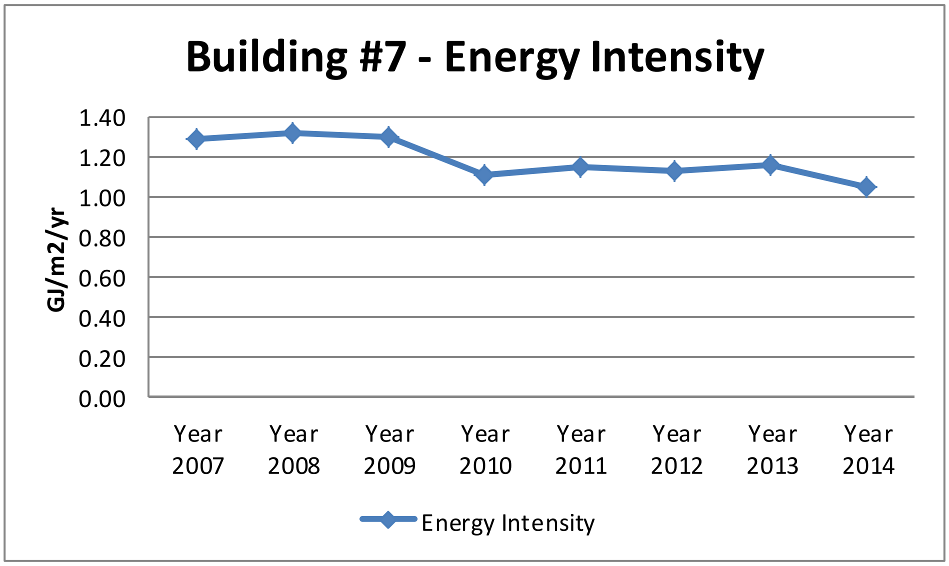
As it was specified in energy audit, energy consumption of the Building #7 is high in comparison to similar office buildings in same region; and therefore average energy index which equals to 1.18 GJ/m^2/yr is also high in comparison to benchmark values of BOMA energy efficient building value of 1.05 GJ/m^2/yr, however value is much lower than average National Resources Canada value of 1.43GJ/m2/year.

Two charts below show electricity and gas consumption per year. Electricity consumption chart demonstrates decrease in energy usage, with lowest usage in 2014. However gas consumption chart doesn't show values that prominently increasing or decreasing, but more recent years are approaching better efficiency.





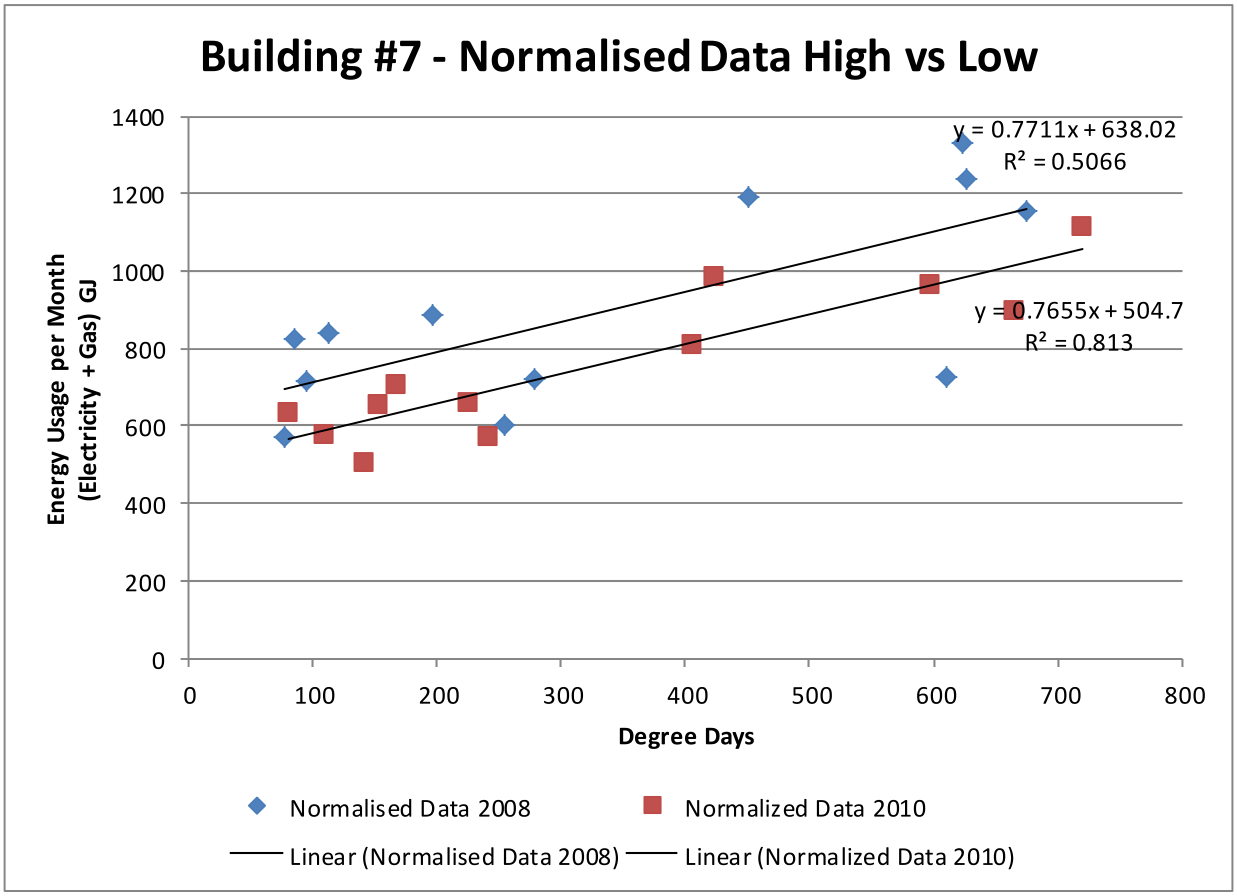
Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. Chart below shows that energy index value is decreasing and currently has the lowest value of 1.04 GJ/m^2/yr. The lowest energy index was in 2014, but due to utility bills inconsistency in 2014 for normalization calculation 2010 will be used. The highest energy consumption is in 2008. These two years' data will be used for further calculations and comparisons.



Normalized total energy consumption was calculated for Building #7. Based on plotted results, shown below in the chart, it can be concluded that energy consumption for 2008 is higher than for 2010. This proves that regardless of weather conditions 2008 has higher energy consumptions than in 2010. Implementing trendline equations, average equation was calculated:

$$y = 0.7683x + 571.36$$

From above equation normalized average energy index was calculated as 1.21 GJ/m^2/yr, this value is higher than average for 2007 to 2014 years range. Calculated value will be used for further case-study buildings comparison.


Building #7 - Normalised Data High vs Low
y = 0.7711x + 638.02
R² = 0.5066
y = 0.7655x + 504.7
R² = 0.813
Energy Usage per Month (Electricity + Gas) GJ
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
600
700
800
Degree Days
Normalised Data 2008
Normalized Data 2010
Linear (Normalised Data 2008)
Linear (Normalized Data 2010)

Actual data used for calculations (year with highest energy consumption):

ADDRESS:	**Building G - Ottawa, Ontario**
BUILDING #	7
Year - Highest Energy Consumption:	2008
AREA:	**8,180**
USAGE INDEX:	**1.32**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	11/02/2008	12/03/2008	11/04/2008	09/05/2008	11/06/2008	14/07/2008	13/08/2008	10/09/2008	09/10/2008	12/11/2008	11/12/2008	13/01/2009
Electric Billing Days	31	30	30	28	33	33	30	28	29	34	29	33
Gas Billing Date	29/01/2008	28/02/2008	28/04/2008	25/06/2008	26/06/2008	04/07/2008	06/08/2008	04/09/2008	06/10/2008	28/10/2008	26/11/2008	29/12/2008
Gas Billing Days	31	30	60	58	1	8	33	29	32	22	29	33
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	0	3	72	111	64	27	0	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	0	0	2	4	2	1	0	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	624	675	610	254	194	23	1	13	59	279	452	627
Daily Htg. D.D. Avg. (Highest Year)	20	22	10	4	194	3	0	0	2	13	16	19
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	280,330	227,400	154,421	167,160	245,625	199,560	233,218	158,880	229,177	197,760	280,517	246,360
Daily kWh Avg.	9,043	7,580	2,574	2,882	245,625	24,945	7,067	5,479	7,162	8,989	9,673	7,465
Demand kW/RkVA Used	410	456	180	365	380	412	375	387	375	362	444	419
Load Factor (Highest Year)	92%	69%	119%	68%	82%	61%	86%	61%	88%	67%	91%	74%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	8,594	9,101	4,573	42	0	0	0	0	0	250	4,943	9,368
Daily m^3 Avg.	277	303	76	1	0	0	0	0	0	11	170	284
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	249,406	217,387	136,247	112,750	165,239	134,249	156,892	106,883	154,174	134,808	223,693	232,031
S02 (kgs) (Highest Year)	2,695	2,349	1,472	1,218	1,785	1,450	1,695	1,155	1,666	1,456	2,417	2,507
N0x (kgs) (Highest Year)	1,181	1,030	645	534	783	636	743	506	730	639	1,060	1,099
USAGE DATA												
kWh to GJ	1009.19	818.64	555.92	601.78	884.25	718.42	839.58	571.97	825.04	711.94	1009.86	886.90
GJ/m2/Day ELECTRIC (Highest Year)	0.004	0.003	0.002	0.003	0.003	0.003	0.003	0.002	0.003	0.003	0.004	0.003
GJ/m2/Month (Highest Year)	0.12	0.10	0.07	0.07	0.11	0.09	0.10	0.07	0.10	0.09	0.12	0.11
m3 to GJ	319.70	338.56	170.12	1.56	0.00	0.00	0.00	0.00	0.00	9.30	183.88	348.49
GJ/m2/Day GAS (Highest Year)	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
GJ/m2/Month	0.04	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04
m3/m2/Month	1.05	1.11	0.56	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.60	1.15
GJ/m2/Day ENERGY (Highest Year)	0.005	0.005	0.003	0.003	0.003	0.003	0.003	0.002	0.003	0.003	0.005	0.005
GJ/m2/Month (Highest Consumption Year)	0.162	0.141	0.089	0.074	0.108	0.088	0.103	0.070	0.101	0.088	0.146	0.151

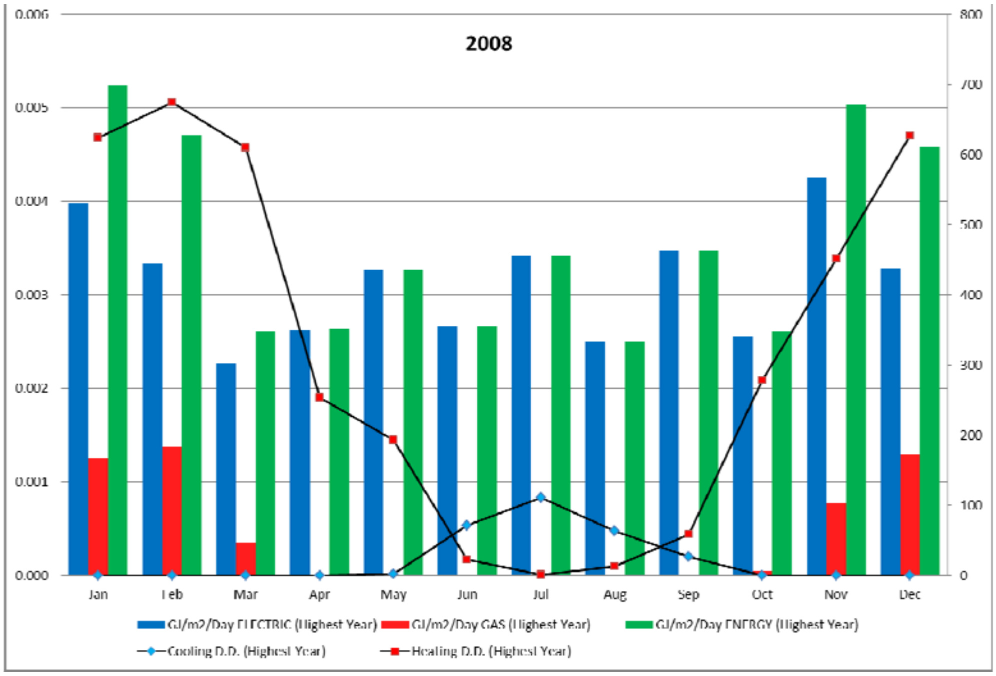
Energy Usage per Month (Electricity + Gas)	1329	1157	726	603	884	718	840	572	825	721	1194	1235
Degree Days	624	675	610	254	196	94	112	77	86	279	452	627

Actual data used for calculations (year with lowest energy consumption):

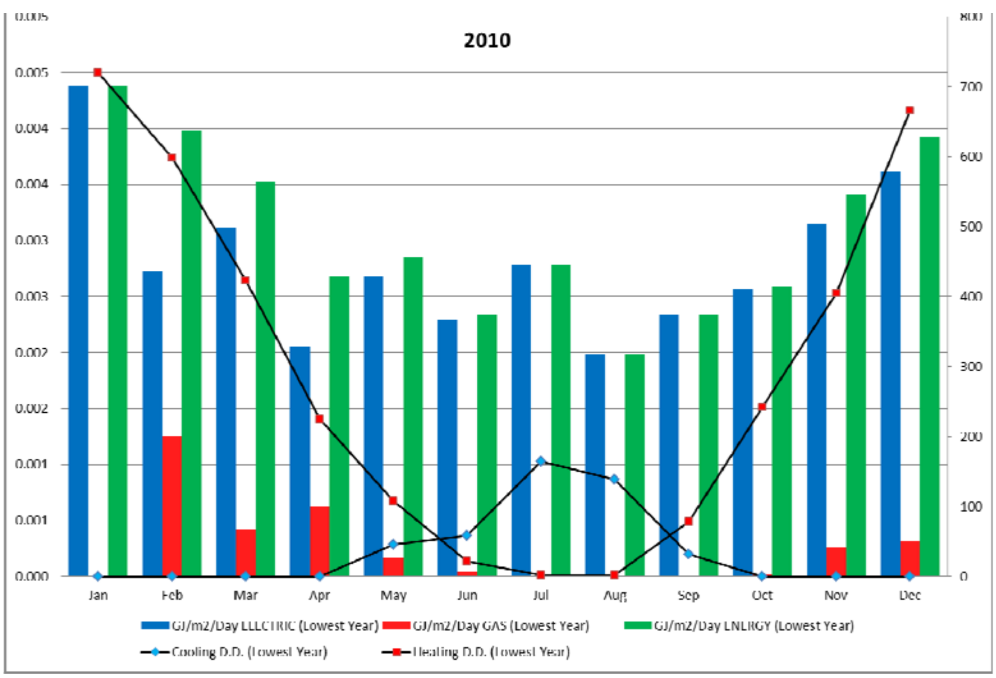
ADDRESS:	**Building G - Ottawa, Ontario**			
BUILDING #	7			
Year - Lowest Energy Consumption:	2010			
AREA:	**8,180**			
USAGE INDEX:	**1.11**	AVERAGE:	**1.2145**	**1.21399**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	09/02/2010	10/03/2010	13/04/2010	13/05/2010	10/06/2010	13/07/2010	13/08/2010	13/09/2010	13/10/2010	09/11/2010	08/12/2010	05/01/2011
Electric Billing Days	31	29	34	30	28	33	31	31	30	27	29	28
Gas Billing Date	09/02/2010	10/03/2010	13/04/2010	13/05/2010	10/06/2010	13/07/2010	13/08/2010	13/09/2010	13/10/2010	09/11/2010	08/12/2010	05/01/2011
Gas Billing Days	31	31	34	30	28	33	31	31	30	27	29	28
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	0	46	59	165	139	32	0	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	0	2	2	5	4	1	0	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	720	598	423	225	108	22	2	2	78	242	405	665
Daily Htg. D.D. Avg. (Lowest Year)	23	19	12	8	4	1	0	0	3	9	14	24
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	308,961	179,520	240,330	140,136	170,798	171,720	196,219	139,680	159,358	157,392	207,811	229,800
Daily kWh Avg.	9,966	5,791	7,069	4,671	6,100	5,204	6,330	4,506	5,312	5,829	7,166	8,207
Demand kW/RkVA Used	407	355	345	352	410	416	400	398	343	340	435	347
Load Factor (Lowest Year)	102%	73%	85%	55%	62%	52%	66%	47%	65%	71%	69%	99%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	0	8,544	3,149	4,099	1,060	341	3	17	17	134	1,637	1,916
Daily m^3 Avg.	0	276	93	137	38	10	0	1	1	5	56	68
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	207,846	181,235	183,962	123,282	122,402	117,934	132,023	94,087	107,325	106,830	151,385	168,152
S02 (kgs) (Lowest Year)	2,246	1,958	1,988	1,332	1,322	1,274	1,426	1,017	1,160	1,154	1,636	1,817
N0x (kgs) (Lowest Year)	984	858	871	584	580	559	625	446	508	506	717	796
USAGE DATA												
kWh to GJ	1112.26	646.27	865.19	504.49	614.87	618.19	706.39	502.85	573.69	566.61	748.12	827.28
GJ/m2/Day ELECTRIC (Lowest Year)	0.004	0.003	0.003	0.002	0.003	0.002	0.003	0.002	0.002	0.003	0.003	0.004
GJ/m2/Month (Lowest Year)	0.14	0.08	0.11	0.06	0.08	0.08	0.09	0.06	0.07	0.07	0.09	0.10
m3 to GJ	0.00	317.84	117.14	152.48	39.43	12.69	0.11	0.63	0.63	4.98	60.90	71.28
GJ/m2/Day GAS (Lowest Year)	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GJ/m2/Month	0.00	0.04	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
m3/m2/Month	0.00	1.04	0.38	0.50	0.13	0.04	0.00	0.00	0.00	0.02	0.20	0.23
GJ/m2/Day ENERGY (Lowest Year)	0.004	0.004	0.004	0.003	0.003	0.002	0.003	0.002	0.002	0.003	0.003	0.004
GJ/m2/Month (Lowest Consumption Year)	0.136	0.118	0.120	0.080	0.080	0.077	0.086	0.062	0.070	0.070	0.099	0.110
Average Highest Year to Lowest Year	0.149	0.130	0.104	0.077	0.094	0.082	0.095	0.066	0.086	0.079	0.122	0.130
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Gas)	1112	964	982	657	654	631	707	503	574	572	809	899
Degree Days	720	598	423	225	154	80	167	141	110	242	405	665
Normalized Data (Average Degree Days)	672	615	489	292	143	86	144	120	110	225	442	663
Normalized Data (Av Energy Consumption)	1088	1044	947	796	681	638	682	663	656	744	911	1081
Normalized Data (Av Energy Index / month)	0.133	0.128	0.116	0.097	0.083	0.078	0.083	0.081	0.080	0.091	0.111	0.132

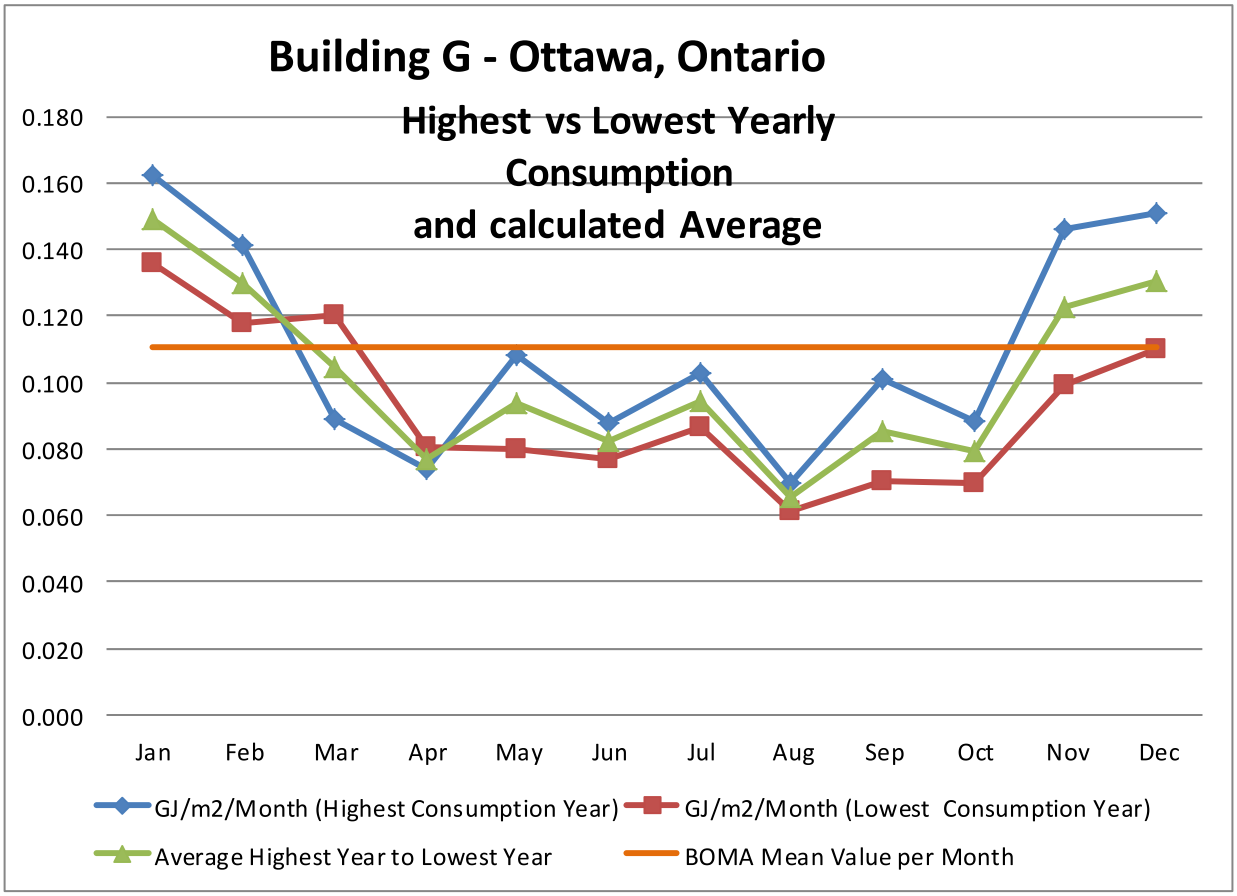
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Building #8 – Utility Bills Analysis

Calculations of Energy Index for Building #8

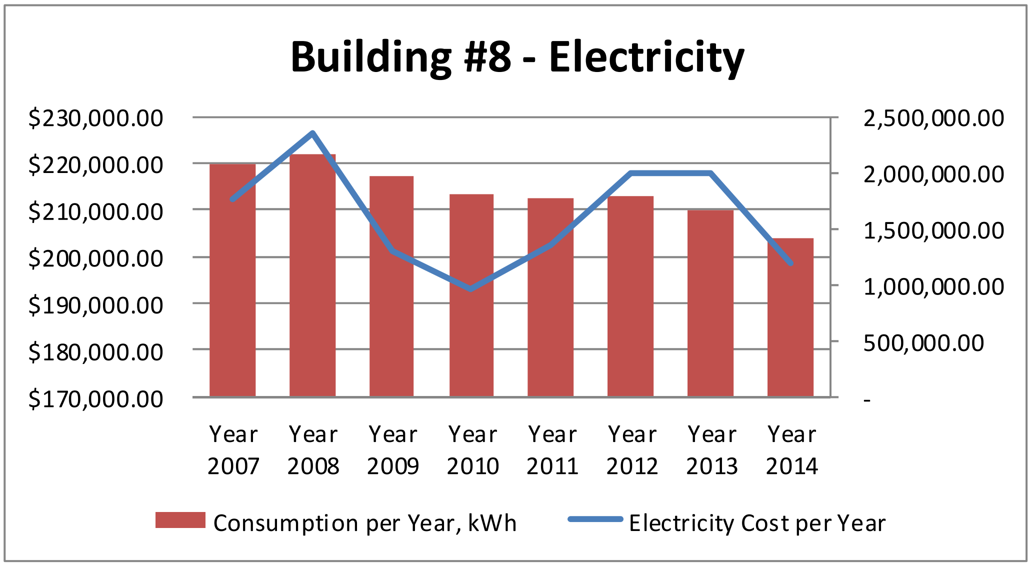
Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity and gas. For Building #1 utility bills were provided from December 2006 to March 2015. To complete most accurate analysis utility bills for 2007 to 2014 were only analyzed because 2006 and 2015 has incomplete data. By having total floor area for entire building of 5,020 m^2, energy index in GJ/m^2/year was calculated. From calculations it was noticed that 2011 gas consumption show very inconsistent value in comparison to other years, but overall 2011 data wasn't excluded from calculations. After analysing gas utility bills in more details, was concluded that this inconsistency could be due to some of the bills transferred from 2010 to 2011.

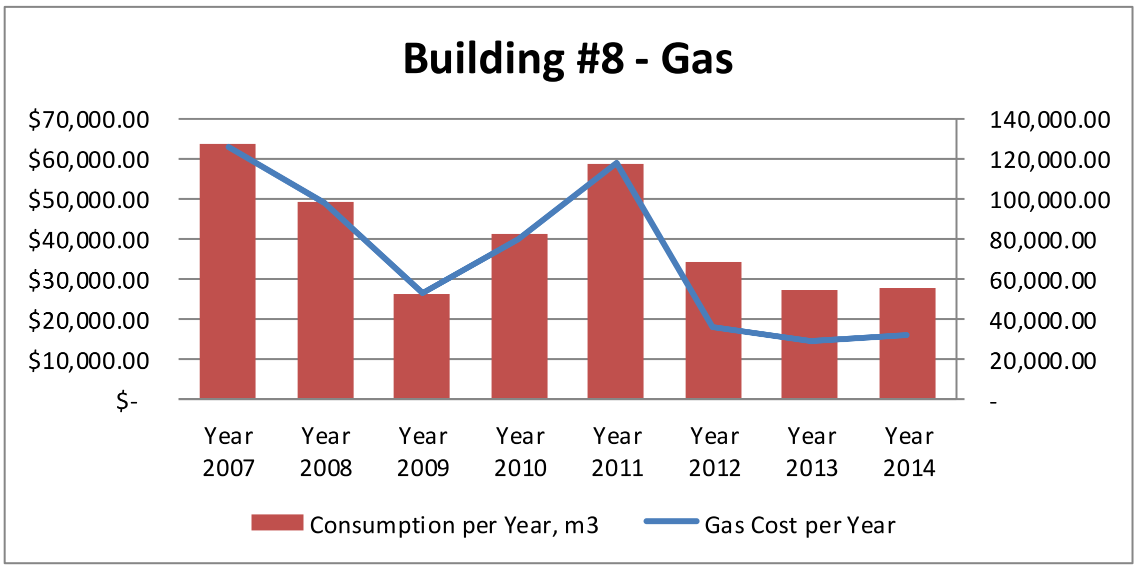
Utility bills analysis showed following:

Building H - Ottawa, Ontario						
		kWh		m^3-ngas	Total GJ/yr	5,020.00
Row Labels	**Sum of Ele Total Cost / Year**	**Sum of Ele Consumption / Year**	**Sum of Gas Total Cost / Year**	**Sum of Gas Consumption / Year**	**Total**	**GJ/m2/yr**
Year 2006	$ 34,814.04	355,368.00				
Year 2007	$ 212,376.79	2,073,600.00	$ 62,908.21	127,080.00	12,192.34	2.43
Year 2008	$ 226,555.91	2,167,200.00	$ 48,932.17	98,374.00	11,461.43	2.28
Year 2009	$ 201,310.10	1,964,088.00	$ 26,371.51	52,369.00	9,018.84	1.80
Year 2010	$ 192,938.69	1,808,712.00	$ 39,954.34	81,685.00	9,550.05	1.90
Year 2011	$ 202,353.88	1,761,923.81	$ 58,867.11	116,830.00	10,689.00	2.13
Year 2012	$ 217,899.83	1,779,480.00	$ 17,781.31	68,518.00	8,955.00	1.78
Year 2013	$ 217,769.31	1,664,280.00	$ 14,301.85	54,087.00	8,003.44	1.59
Year 2014	$ 198,561.19	1,419,480.00	$ 16,008.26	55,175.00	7,162.64	1.43
Year 2015	$ 70,723.43	494,400.00	$ 15,813.63	44,422.00		
Average	**$ 208,720.71**	**1,829,845.48**	**$ 35,640.60**	**81,764.75**		**1.92**

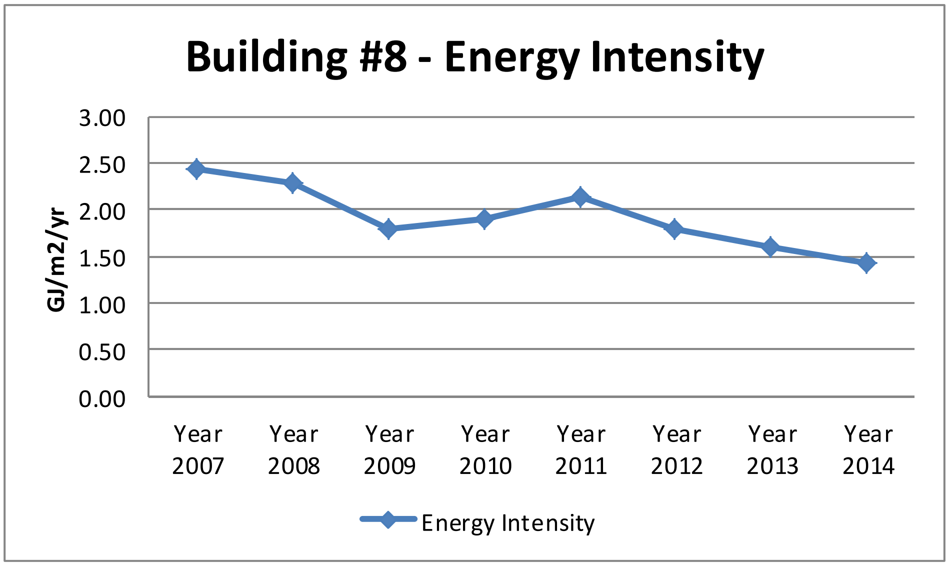
As it was specified in energy audit, energy consumption of the Building #8 is very high in comparison to similar office buildings in same region; and therefore average energy index which equals to 1.92 GJ/m^2/yr is also high in comparison to benchmark values of BOMA energy efficient building value of 1.05 GJ/m^2/yr and then average National Resources Canada value of 1.43GJ/m2/year..

Two charts below show electricity and gas consumption per year. Electricity consumption chart demonstrates prominent decrease in energy usage, 2013 and 2014 have the lowest energy consumption values. Gas consumption chart shows big jump in 2011, but at it was discussed earlier this could be due to gas bills.





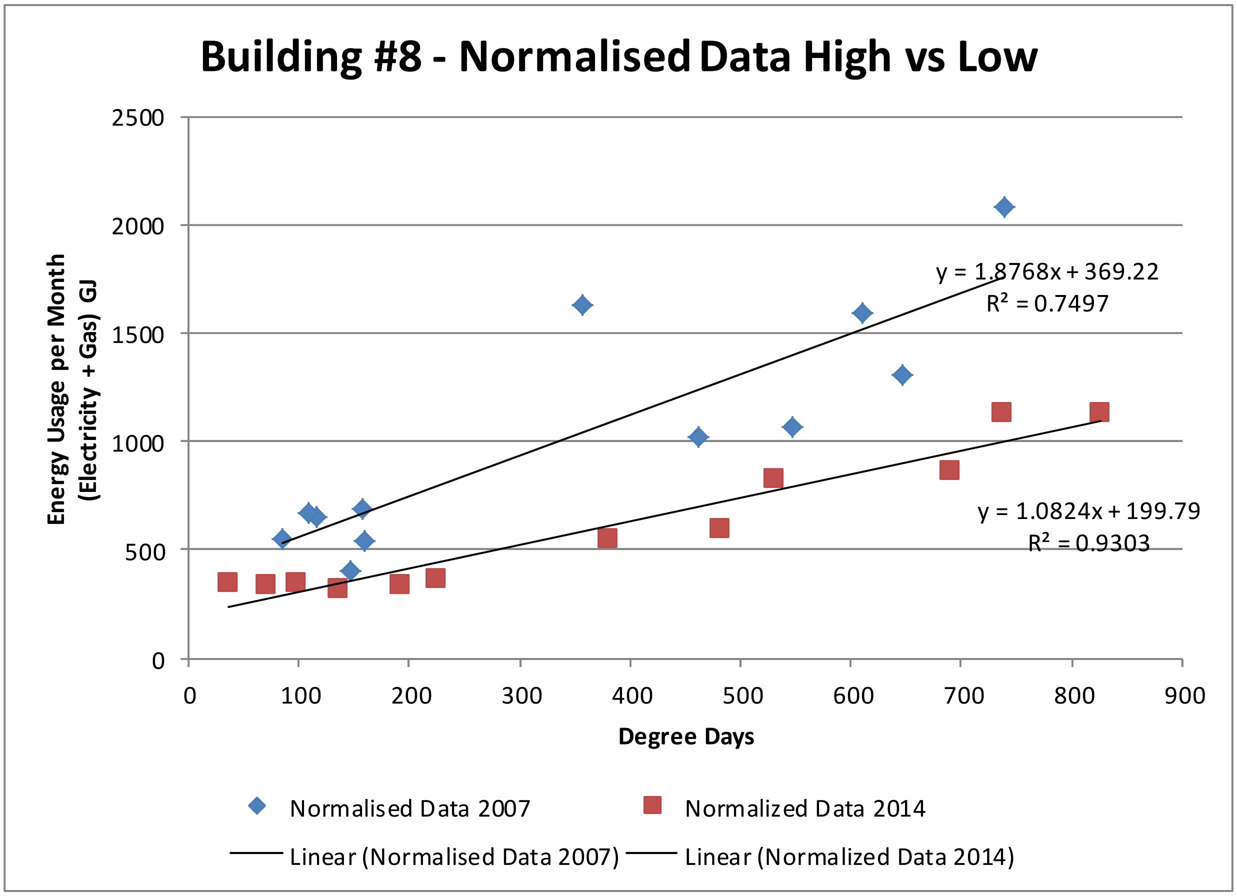
Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. Chart below shows that energy index value is gradually decreasing, and the lowest energy intensity value is in 2014 and highest in 2007. These two years' data will be used for further calculations and comparisons.



Normalized total energy consumption was calculated for Building #8. Based on plotted results, shown below in the chart, it can be concluded that energy consumption for 2007 is higher than for 2014. This proves that regardless of weather conditions 2007 has higher energy consumptions than in 2014. Implementing trendline equations, average equation was calculated:

$$y = 1.4796x + 284.505$$

From above equation normalized average energy index was calculated as 1.93 GJ/m^2/yr, this value is slightly higher than average for 2007 to 2014 years range. Calculated value will be used for further case-study buildings comparison.



Building #8 - Normalised Data High vs Low
Energy Usage per Month (Electricity + Gas) GJ
2500
2000
1500
1000
500
0
0
100
200
300
400
500
600
700
800
900
Degree Days
y = 1.8768x + 369.22
R² = 0.7497
y = 1.0824x + 199.79
R² = 0.9303
Normalised Data 2007
Normalized Data 2014
Linear (Normalised Data 2007)
Linear (Normalized Data 2014)

Actual data used for calculations (year with highest energy consumption):

ADDRESS:	**Building H - Ottawa, Ontario**
BUILDING #	8
Year - Highest Energy Consumption:	2007
AREA:	**5,020**
USAGE INDEX:	**2.43**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	14/02/2007	13/03/2007	13/04/2007	14/05/2007	13/06/2007	13/07/2007	15/08/2007	13/09/2007	12/10/2007	13/11/2007	11/12/2007	11/01/2008
Electric Billing Days	31	27	31	31	30	30	33	29	29	32	28	31
Gas Billing Date	29/01/2007	26/02/2007	27/03/2007	26/04/2007	29/05/2007	25/06/2007	27/07/2007	28/08/2007	27/09/2007	25/10/2007	27/11/2007	29/12/2007
Gas Billing Days	31	28	29	30	33	27	32	32	30	28	33	32
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	0	22	99	106	141	48	20	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	0	1	3	3	5	2	1	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	647	740	547	356	136	17	3	5	37	138	463	611
Daily Htg. D.D. Avg. (Highest Year)	21	26	19	12	4	1	0	0	1	5	14	19
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	222,840	170,640	188,280	141,480	135,360	150,480	185,040	112,320	153,720	186,840	196,200	230,400
Daily kWh Avg.	7,188	6,094	6,492	4,716	4,102	5,573	5,783	3,510	5,124	6,673	5,945	7,200
Demand kW/RkVA Used	354	366	357	0	343	343	323	301	311	323	365	380
Load Factor (Highest Year)	85%	72%	71%	#DIV/0!	55%	61%	72%	54%	71%	75%	80%	82%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	13,526	39,355	10,409	29,983	1,458	3,033	0	0	0	398	8,397	20,521
Daily m^3 Avg.	436	1,406	359	999	44	112	0	0	0	14	254	641
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	245,635	393,313	200,327	307,370	101,379	122,697	124,481	75,561	103,412	128,509	191,415	300,225
S02 (kgs) (Highest Year)	2,654	4,249	2,164	3,321	1,095	1,326	1,345	816	1,117	1,388	2,068	3,244
N0x (kgs) (Highest Year)	1,163	1,863	949	1,456	480	581	590	358	490	609	907	1,422
USAGE DATA												
kWh to GJ	802.22	614.30	677.81	509.33	487.30	541.73	666.14	404.35	553.39	672.62	706.32	829.44
GJ/m2/Day ELECTRIC (Highest Year)	0.005	0.005	0.004	0.003	0.003	0.004	0.004	0.003	0.004	0.004	0.005	0.005
GJ/m2/Month (Highest Year)	0.16	0.12	0.14	0.10	0.10	0.11	0.13	0.08	0.11	0.13	0.14	0.17
m3 to GJ	503.17	1464.01	387.21	1115.37	54.24	112.83	0.00	0.00	0.00	14.81	312.37	763.38
GJ/m2/Day GAS (Highest Year)	0.003	0.010	0.003	0.007	0.000	0.001	0.000	0.000	0.000	0.000	0.002	0.005
GJ/m2/Month	0.10	0.29	0.08	0.22	0.01	0.02	0.00	0.00	0.00	0.00	0.06	0.15
m3/m2/Month	2.69	7.84	2.07	5.97	0.29	0.60	0.00	0.00	0.00	0.08	1.67	4.09
GJ/m2/Day ENERGY (Highest Year)	0.008	0.015	0.007	0.011	0.004	0.004	0.004	0.003	0.004	0.004	0.007	0.010
GJ/m2/Month (Highest Consumption Year)	0.260	0.414	0.212	0.324	0.108	0.130	0.133	0.081	0.110	0.137	0.203	0.317

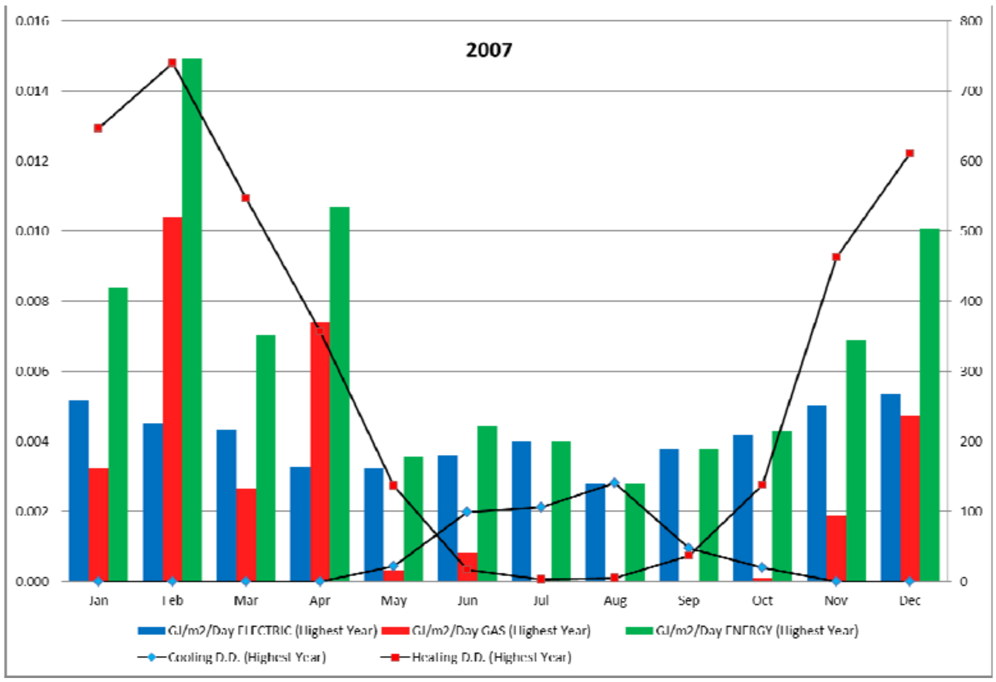
Energy Usage per Month (Electricity + Gas)	1305	2078	1065	1625	542	655	666	404	553	687	1019	1593
Degree Days	647	740	547	356	159	116	109	146	84	158	463	611

Actual data used for calculations (year with lowest energy consumption):

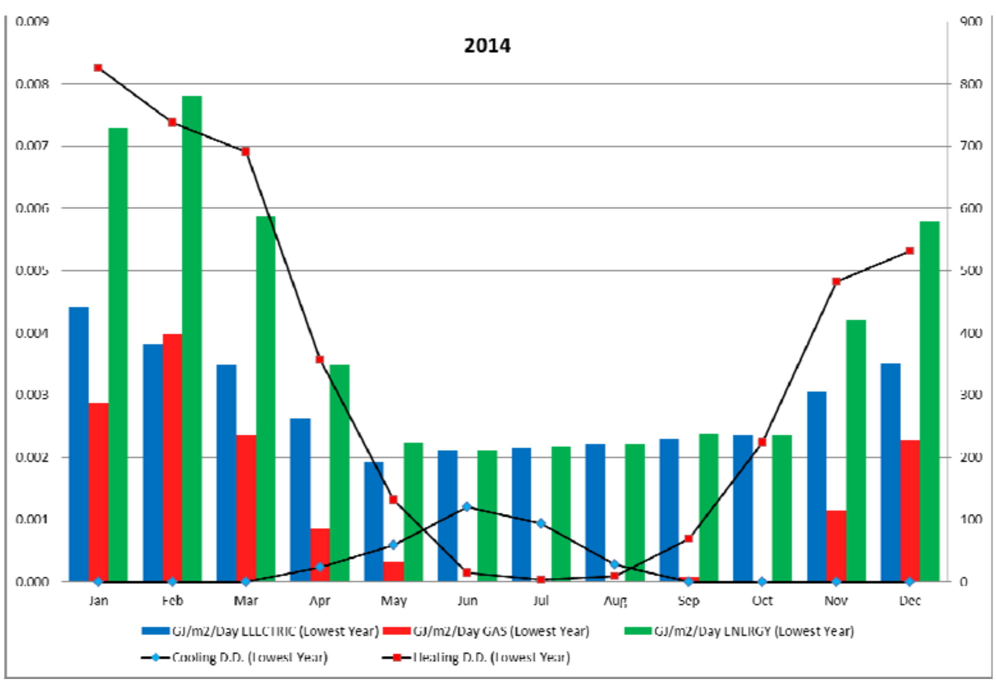
ADDRESS:	Building H - Ottawa, Ontario			
BUILDING #	8			
Year - Lowest Energy Consumption:	2014			
AREA:	5,020			
USAGE INDEX:	1.43	AVERAGE:	1.9278	1.92910

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	02/02/2014	04/03/2014	02/04/2014	04/05/2014	03/06/2014	03/07/2014	04/08/2014	04/09/2014	02/10/2014	02/11/2014	30/11/2014	28/12/2014
Electric Billing Days	31	30	29	32	30	30	32	31	28	31	28	28
Gas Billing Date	27/01/2014	24/02/2014	26/03/2014	25/04/2014	27/05/2014	24/06/2014	28/07/2014	25/08/2014	25/09/2014	27/10/2014	25/11/2014	24/12/2014
Gas Billing Days	31	28	30	30	32	28	34	28	31	32	29	29
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	23	59	121	94	28	0	0	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	1	2	4	3	1	0	0	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	826	737	691	357	132	14	4	9	70	224	482	532
Daily Htg. D.D. Avg. (Lowest Year)	27	26	23	12	4	1	0	0	2	7	17	18
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	191,160	159,840	141,480	117,360	80,640	88,200	96,120	96,120	90,000	102,240	119,520	136,800
Daily kWh Avg.	6,166	5,709	4,716	3,912	2,520	3,150	2,827	3,433	2,903	3,195	4,121	4,717
Demand kW/RkVA Used	356	309	309	276	256	258	252	239	235	247	297	326
Load Factor (Lowest Year)	72%	72%	66%	55%	44%	47%	50%	54%	57%	56%	60%	62%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	11,989	15,033	9,570	3,439	1,393	0	51	0	307	3	4,465	8,925
Daily m^3 Avg.	387	537	319	115	44	0	2	0	10	0	154	308
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	213,446	213,919	162,905	103,289	64,107	59,335	65,023	64,663	62,718	68,801	112,004	155,192
S02 (kgs) (Lowest Year)	2,306	2,311	1,760	1,116	693	641	703	699	678	743	1,210	1,677
N0x (kgs) (Lowest Year)	1,011	1,013	772	489	304	281	308	306	297	326	531	735
USAGE DATA												
kWh to GJ	688.18	575.42	509.33	422.50	290.30	317.52	346.03	346.03	324.00	368.06	430.27	492.48
GJ/m2/Day ELECTRIC (Lowest Year)	0.004	0.004	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.004
GJ/m2/Month (Lowest Year)	0.14	0.11	0.10	0.08	0.06	0.06	0.07	0.07	0.06	0.07	0.09	0.10
m3 to GJ	445.99	559.23	356.00	127.93	51.82	0.00	1.90	0.00	11.42	0.11	166.10	332.01
GJ/m2/Day GAS (Lowest Year)	0.003	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002
GJ/m2/Month	0.09	0.11	0.07	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.07
m3/m2/Month	2.39	2.99	1.91	0.69	0.28	0.00	0.01	0.00	0.06	0.00	0.89	1.78
GJ/m2/Day ENERGY (Lowest Year)	0.007	0.008	0.006	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.004	0.006
GJ/m2/Month (Lowest Consumption Year)	0.226	0.226	0.172	0.110	0.068	0.063	0.069	0.069	0.067	0.073	0.119	0.164
Average Highest Year to Lowest Year	0.243	0.320	0.192	0.217	0.088	0.097	0.101	0.075	0.089	0.105	0.161	0.241
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Gas)	1134	1135	865	550	342	318	348	346	335	368	596	824
Degree Days	826	737	691	380	191	135	98	37	70	224	482	532
Normalized Data (Average Degree Days)	725	684	623	369	162	114	110	68	91	217	480	596
Normalized Data (Av Energy Consumption)	1357	1297	1206	831	524	452	447	384	419	605	995	1167
Normalized Data (Av Energy Index / month)	0.270	0.258	0.240	0.166	0.104	0.090	0.089	0.077	0.083	0.121	0.198	0.232

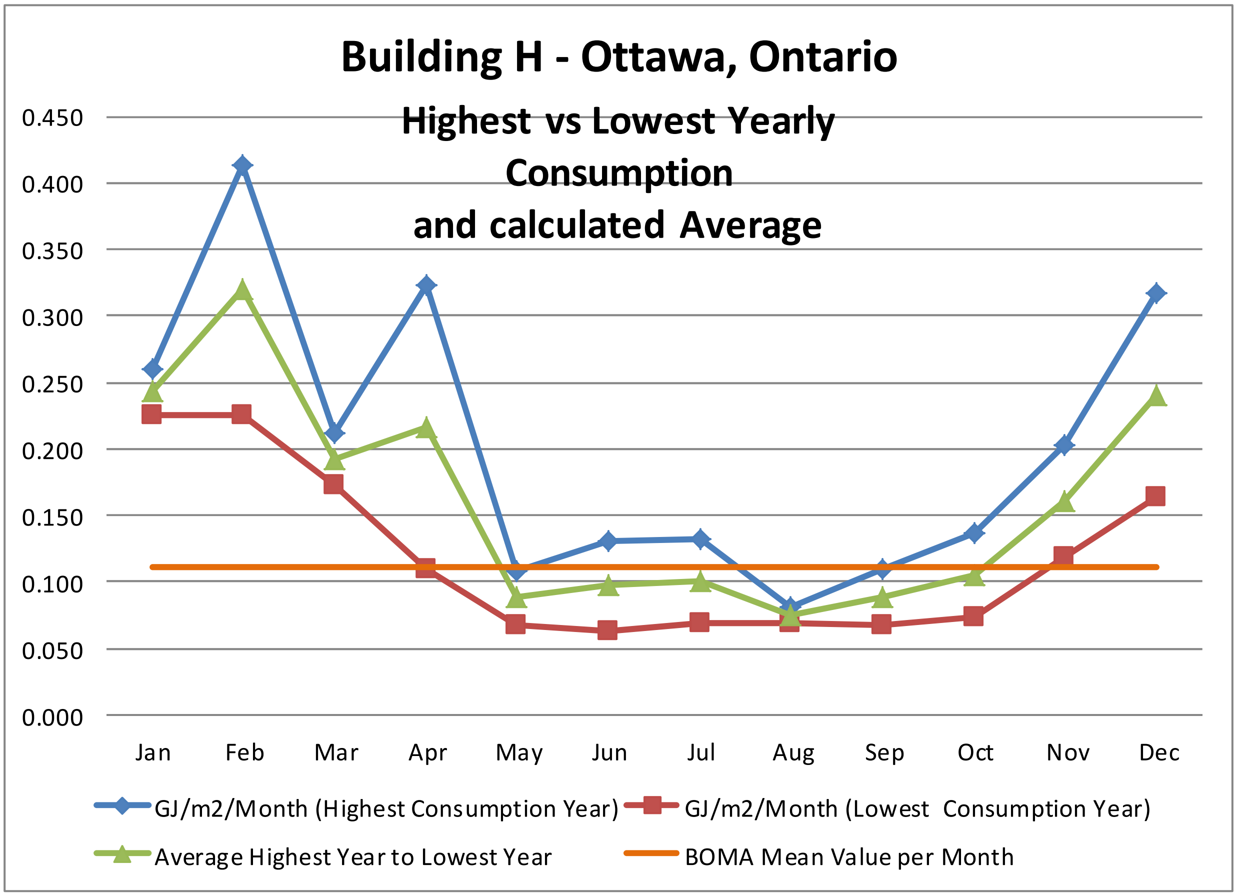
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Building #9 – Utility Bills Analysis

Calculations of Energy Index for Building #9

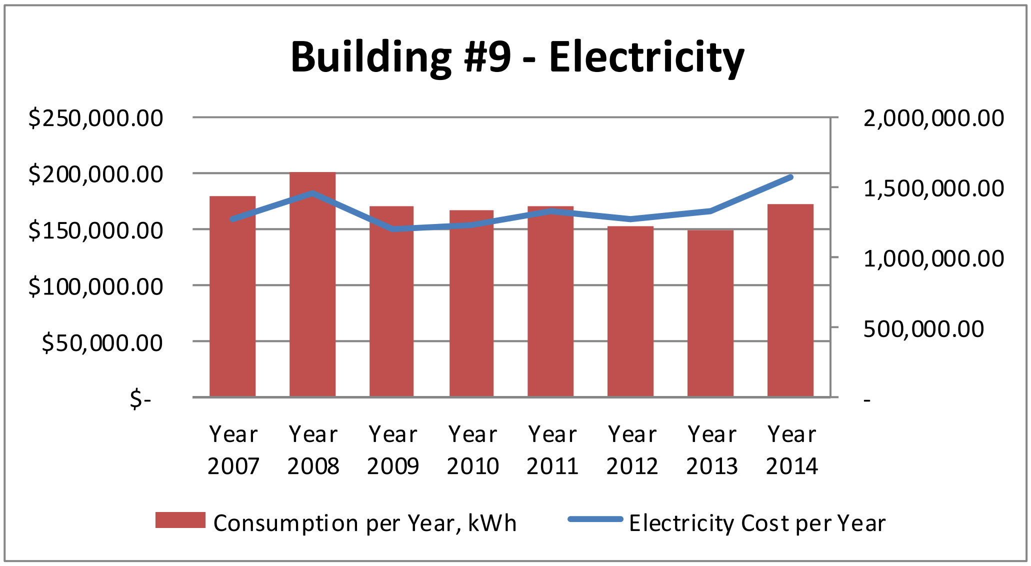
Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity and gas. For Building #9 utility bills were provided from December 2006 to March 2015. To complete most accurate analysis utility bills for 2007 to 2014 were only analyzed because 2006 and 2015 has incomplete data. By having total floor area for entire building of 4,854 m^2, energy index in GJ/m^2/year was calculated. From calculations it was noticed that energy bills provided very consistent data therefore all years data was included in calculations.

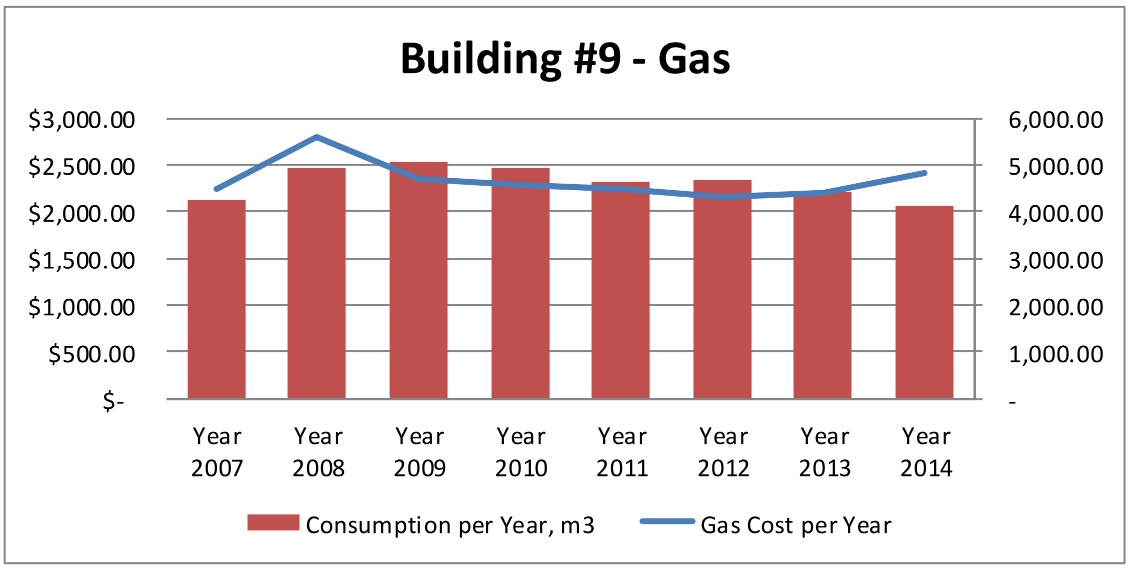
Utility bills analysis showed following:

Building I - Ontario, Tower C						
		kWh		m³-ngas	Total GJ/yr	4,854.00
Row Labels	**Sum of Ele Total Cost / Year**	**Sum of Ele Consumption / Year**	**Sum of Gas Total Cost / Year**	**Sum of Gas Consumption / Year**	**Total**	**GJ/m2/yr**
Year 2006	$ 31,318.60	311,000.00	$ 374.09	842.00		
Year 2007	$ 158,746.02	1,426,920.00	$ 2,243.37	4,249.00	5,294.97	1.09
Year 2008	$ 181,699.80	1,608,132.76	$ 2,797.49	4,931.00	5,972.71	1.23
Year 2009	$ 150,245.56	1,360,798.52	$ 2,358.21	5,048.00	5,086.66	1.05
Year 2010	$ 152,691.50	1,323,680.93	$ 2,277.44	4,952.00	4,949.47	1.02
Year 2011	$ 165,110.74	1,364,871.04	$ 2,237.54	4,619.00	5,085.36	1.05
Year 2012	$ 158,838.82	1,222,999.21	$ 2,161.27	4,656.00	4,576.00	0.94
Year 2013	$ 165,048.43	1,184,278.26	$ 2,190.31	4,405.00	4,427.27	0.91
Year 2014	$ 195,255.26	1,372,687.83	$ 2,418.11	4,116.00	5,094.79	1.05
Year 2015	$ 57,634.67	387,763.83	$ 573.35	886.00		
Average	**$ 165,954.52**	**1,358,046.07**	**$ 2,335.47**	**4,622.00**		**1.04**

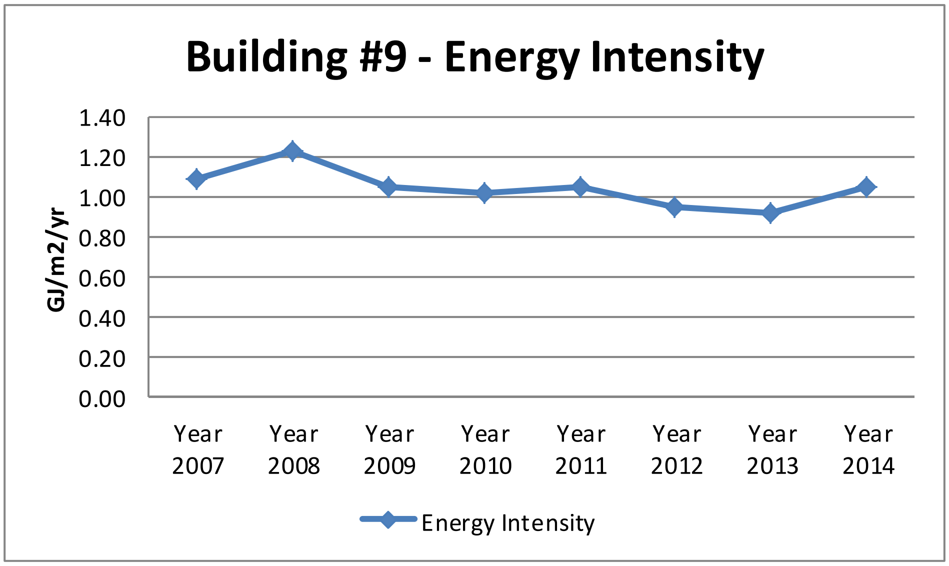
As it was specified in energy audit, energy consumption of the Building #9 is average in comparison to similar office buildings in same region; and therefore average energy index which equals to 1.04 GJ/m^2/yr is also high in comparison to benchmark values of BOMA energy efficient building value of 1.05 GJ/m^2/yr, however value is much lower than average National Resources Canada value of 1.43GJ/m2/year.

Two charts below show electricity and gas consumption per year. Electricity consumption chart shows data that fluctuation throughout years range. However on the other side gas consumption chart demonstrates decrease in gas usage.





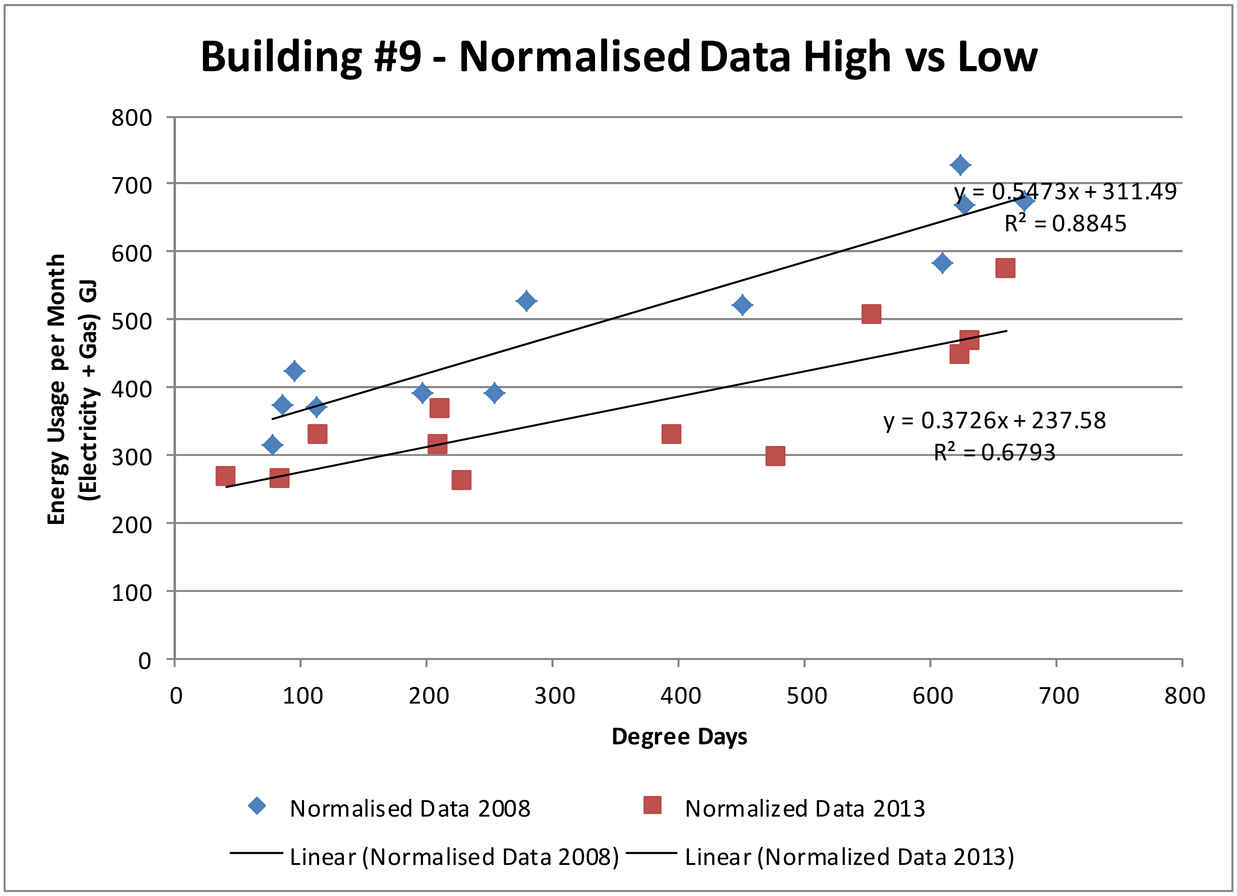
Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. Chart below shows that energy index value is gradually decreasing. The lowest energy index was in 2013 and highest in 2008. These two years' data will be used for further calculations and comparisons.



Normalized total energy consumption was calculated for Building #9. Based on plotted results, shown below in the chart, it can be concluded that energy consumption for 2008 is higher than for 2013. This proves that regardless of weather conditions 2008 has higher energy consumptions than in 2013. Implementing trendline equations, average equation was calculated:

$$y = 0.4599x + 274.535$$

From above equation normalized average energy index was calculated as 1.07 $GJ/m^2/yr$, this value is slightly higher than average for 2007 to 2014 years range. Calculated value will be used for further case-study buildings comparison.


Building #9 - Normalised Data High vs Low
Energy Usage per Month (Electricity + Gas) GJ
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
Degree Days
y = 0.5473x + 311.49
R² = 0.8845
y = 0.3726x + 237.58
R² = 0.6793
Normalised Data 2008
Normalized Data 2013
Linear (Normalised Data 2008)
Linear (Normalized Data 2013)

Actual data used for calculations (year with highest energy consumption):

ADDRESS:	Building I - Ottawa, Ontario, Tower C
BUILDING #	9
Year - Highest Energy Consumption:	2008
AREA:	4,854
USAGE INDEX:	1.23

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	12/02/2008	12/03/2008	11/04/2008	12/05/2008	10/06/2008	14/07/2008	12/08/2008	10/09/2008	09/10/2008	12/11/2008	10/12/2008	12/01/2009
Electric Billing Days	31	29	30	31	29	34	29	29	29	34	28	33
Gas Billing Date	15/02/2008	18/03/2008	16/04/2008	15/05/2008	16/06/2008	16/07/2008	15/08/2008	16/09/2008	15/10/2008	14/11/2008	15/12/2008	16/01/2009
Gas Billing Days	31	32	29	29	32	30	30	32	29	30	31	32
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	0	3	72	111	64	27	0	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	0	0	2	4	2	1	0	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	624	675	610	254	194	23	1	13	59	279	452	627
Daily Htg. D.D. Avg. (Highest Year)	20	21	21	9	6	1	0	0	2	9	15	20
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	198,314	183,475	158,389	103,775	104,357	113,675	99,592	82,775	100,276	142,803	139,759	180,941
Daily kWh Avg.	6,397	5,734	5,462	3,578	3,261	3,789	3,320	2,587	3,458	4,760	4,508	5,654
Demand kW/RkVA Used	373	372	340	336	272	260	244	263	255	310	361	360
Load Factor (Highest Year)	71%	71%	65%	41%	55%	54%	59%	45%	57%	56%	58%	64%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	384	424	384	468	429	402	352	431	344	380	482	451
Daily m^3 Avg.	12	13	13	16	13	13	12	13	12	13	16	14
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	136,129	126,429	109,270	73,124	73,240	79,317	69,489	58,735	69,893	98,757	97,431	124,916
S02 (kgs) (Highest Year)	1,471	1,366	1,181	790	791	857	751	635	755	1,067	1,053	1,350
N0x (kgs) (Highest Year)	645	599	518	346	347	376	329	278	331	468	461	592
USAGE DATA												
kWh to GJ	713.93	660.51	570.20	373.59	375.69	409.23	358.53	297.99	360.99	514.09	503.13	651.39
GJ/m2/Day ELECTRIC (Highest Year)	0.005	0.005	0.004	0.002	0.003	0.002	0.003	0.002	0.003	0.003	0.004	0.004
GJ/m2/Month (Highest Year)	0.15	0.14	0.12	0.08	0.08	0.08	0.07	0.06	0.07	0.11	0.10	0.13
m3 to GJ	14.28	15.77	14.28	17.41	15.96	14.95	13.09	16.03	12.80	14.14	17.93	16.78
GJ/m2/Day GAS (Highest Year)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GJ/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
m3/m2/Month	0.08	0.09	0.08	0.10	0.09	0.08	0.07	0.09	0.07	0.08	0.10	0.09
GJ/m2/Day ENERGY (Highest Year)	0.005	0.005	0.004	0.003	0.003	0.003	0.003	0.002	0.003	0.003	0.004	0.004
GJ/m2/Month (Highest Consumption Year)	0.150	0.139	0.120	0.081	0.081	0.087	0.077	0.065	0.077	0.109	0.107	0.138

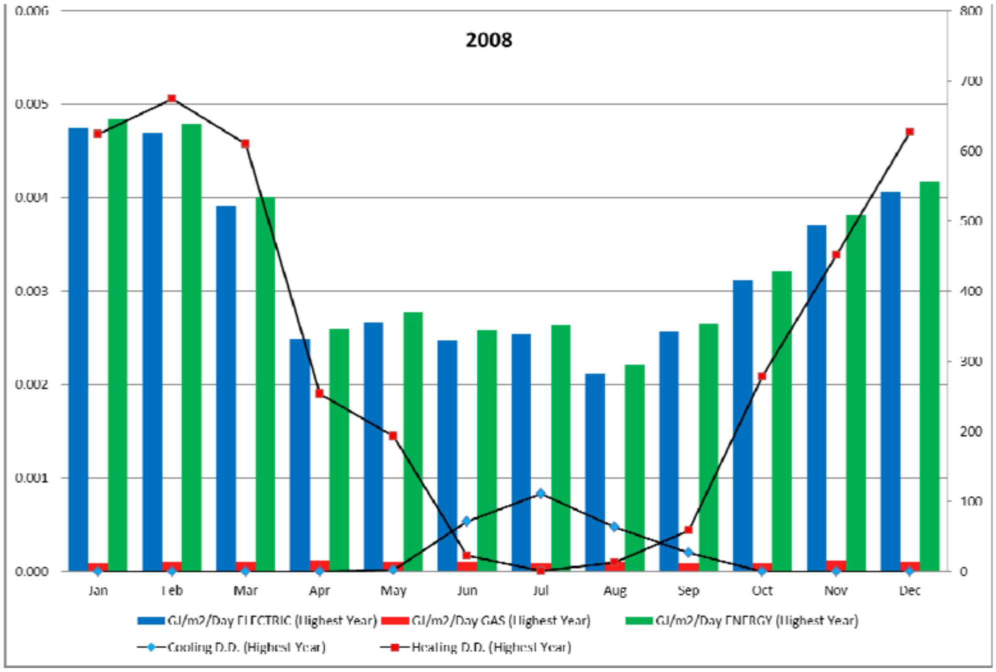
Energy Usage per Month (Electricity + Gas)	728	676	584	391	392	424	372	314	374	528	521	668
Degree Days	624	675	610	254	196	94	112	77	86	279	452	627

Actual data used for calculations (year with lowest energy consumption):

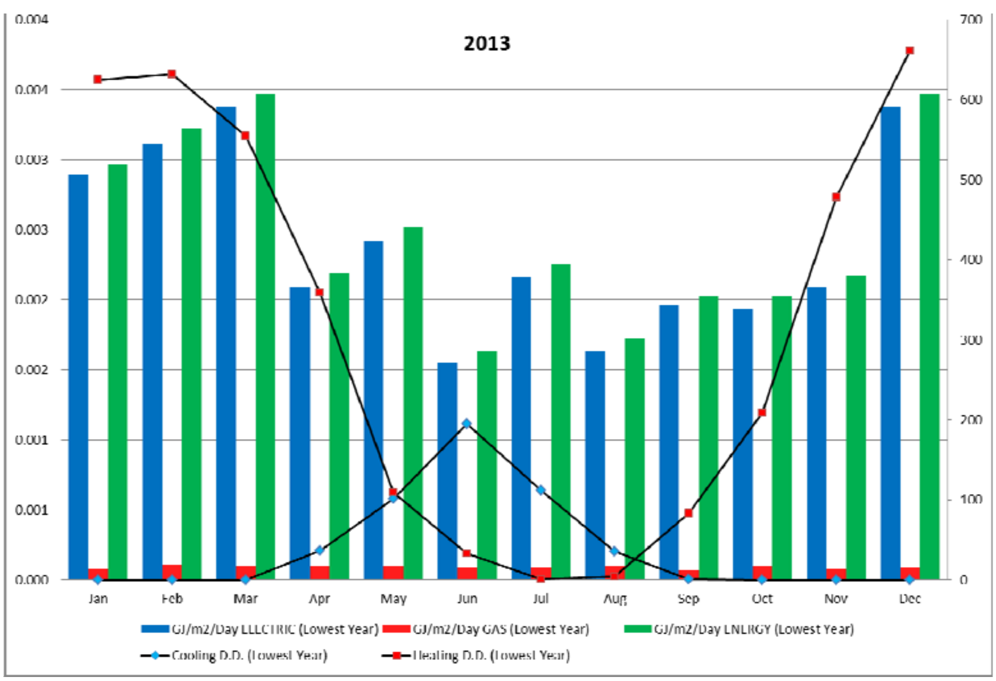
ADDRESS:	Building I - Ottawa, Ontario, Tower C			
BUILDING #	9			
Year - Lowest Energy Consumption:	2013			
AREA:	4,854			
USAGE INDEX:	0.91	AVERAGE:	1.0713	1.07209

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	12/02/2013	14/03/2013	13/04/2013	14/05/2013	13/06/2013	16/07/2013	15/08/2013	16/09/2013	13/10/2013	14/11/2013	12/12/2013	15/01/2014
Electric Billing Days	31	30	30	31	30	33	30	32	27	32	28	34
Gas Billing Date	12/02/2013	14/03/2013	13/04/2013	14/05/2013	13/06/2013	16/07/2013	15/08/2013	16/09/2013	13/10/2013	14/11/2013	12/12/2013	15/01/2014
Gas Billing Days	31	30	30	31	30	33	30	32	27	32	28	34
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	37	102	195	112	36	1	0	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	1	3	6	4	1	0	0	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	624	632	555	359	109	33	1	4	83	209	478	661
Daily Htg. D.D. Avg. (Lowest Year)	20	21	18	12	4	1	0	0	3	7	17	19
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	120,775	125,875	136,634	87,475	97,877	68,875	87,623	70,375	71,245	83,481	79,075	154,967
Daily kWh Avg.	3,896	4,196	4,554	2,822	3,263	2,087	2,921	2,199	2,639	2,609	2,824	4,558
Demand kW/RkVA Used	282	283	339	258	282	196	278	198	255	257	221	314
Load Factor (Lowest Year)	58%	62%	56%	46%	48%	44%	44%	46%	43%	42%	53%	61%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	306	443	382	403	377	384	349	398	242	398	306	417
Daily m^3 Avg.	10	15	13	13	13	12	12	12	9	12	11	12
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	83,414	87,815	94,621	61,699	68,512	49,052	61,416	50,160	49,641	58,977	55,362	107,202
S02 (kgs) (Lowest Year)	901	949	1,022	667	740	530	664	542	536	637	598	1,158
N0x (kgs) (Lowest Year)	395	416	448	292	325	232	291	238	235	279	262	508
USAGE DATA												
kWh to GJ	434.79	453.15	491.88	314.91	352.36	247.95	315.44	253.35	256.48	300.53	284.67	557.88
GJ/m2/Day ELECTRIC (Lowest Year)	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003
GJ/m2/Month (Lowest Year)	0.09	0.09	0.10	0.06	0.07	0.05	0.06	0.05	0.05	0.06	0.06	0.11
m3 to GJ	11.38	16.48	14.21	14.99	14.02	14.28	12.98	14.81	9.00	14.81	11.38	15.51
GJ/m2/Day GAS (Lowest Year)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GJ/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
m3/m2/Month	0.06	0.09	0.08	0.08	0.08	0.08	0.07	0.08	0.05	0.08	0.06	0.09
GJ/m2/Day ENERGY (Lowest Year)	0.003	0.003	0.003	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.003
GJ/m2/Month (Lowest Consumption Year)	0.092	0.097	0.104	0.068	0.075	0.054	0.068	0.055	0.055	0.065	0.061	0.118
Average Highest Year to Lowest Year	0.121	0.118	0.112	0.074	0.078	0.071	0.072	0.060	0.066	0.087	0.084	0.128
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Ga	446	470	506	330	366	262	328	268	265	315	296	573
Degree Days	624	632	555	395	211	228	113	40	84	209	478	661
Normalized Data (Average Degree Days)	624	632	555	377	171	160	118	69	98	209	478	661
Normalized Data (Av Energy Consumptio	562	565	530	448	353	348	329	306	319	371	494	578
Normalized Data (Av Energy Index / mon	0.116	0.116	0.109	0.092	0.073	0.072	0.068	0.063	0.066	0.076	0.102	0.119

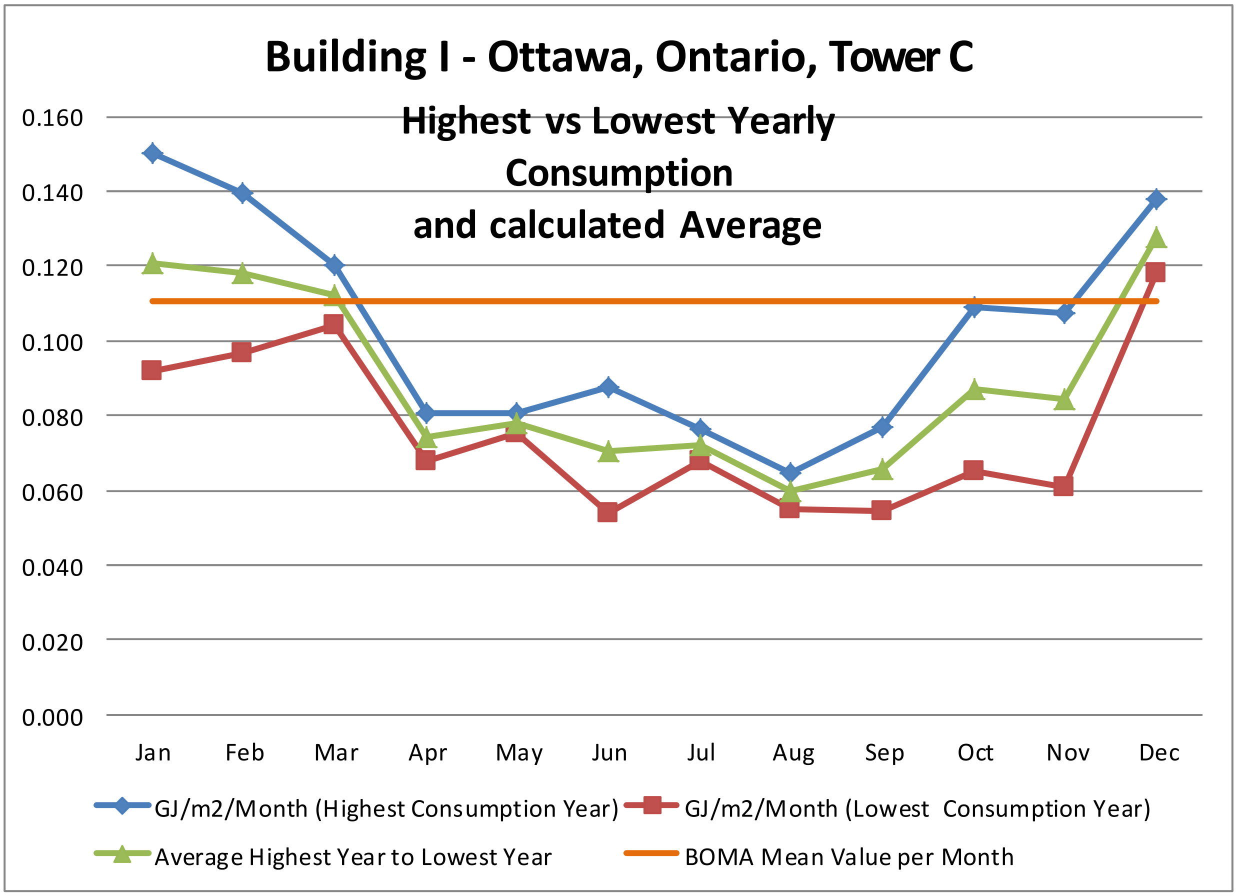
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Building #10 – Utility Bills Analysis

Calculations of Energy Index for Building #10

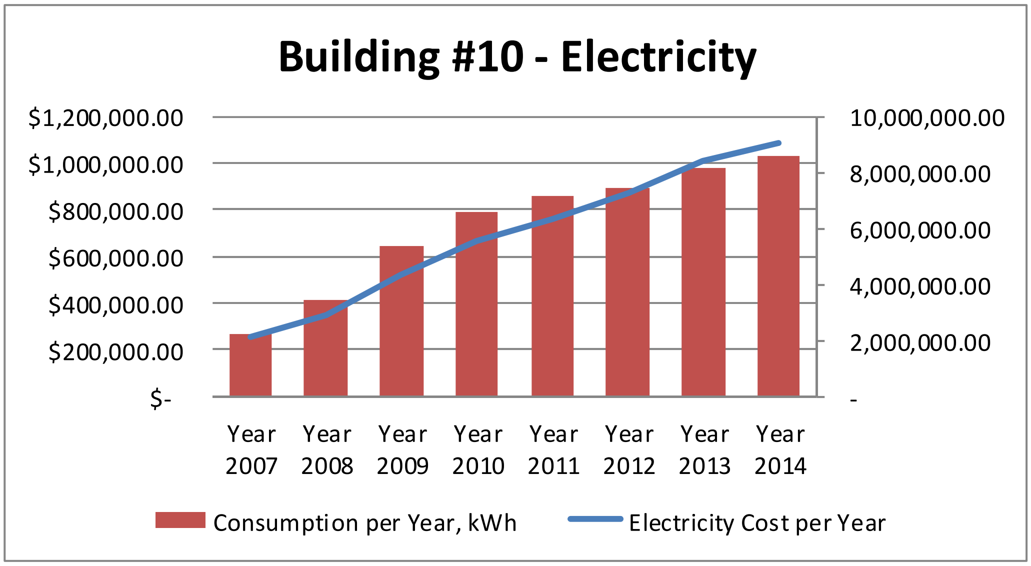
Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity. For Building #10 utility bills were provided from December 2006 to March 2015. To complete most accurate analysis utility bills for 2007 to 2014 were only analyzed because 2006 and 2015 has incomplete data. By having total floor area for entire building of 8,270 m^2, energy index in $GJ/m^2/year$ was calculated. From calculations it was noticed that electricity consumption is noticeably increasing.

Utility bills analysis showed following:

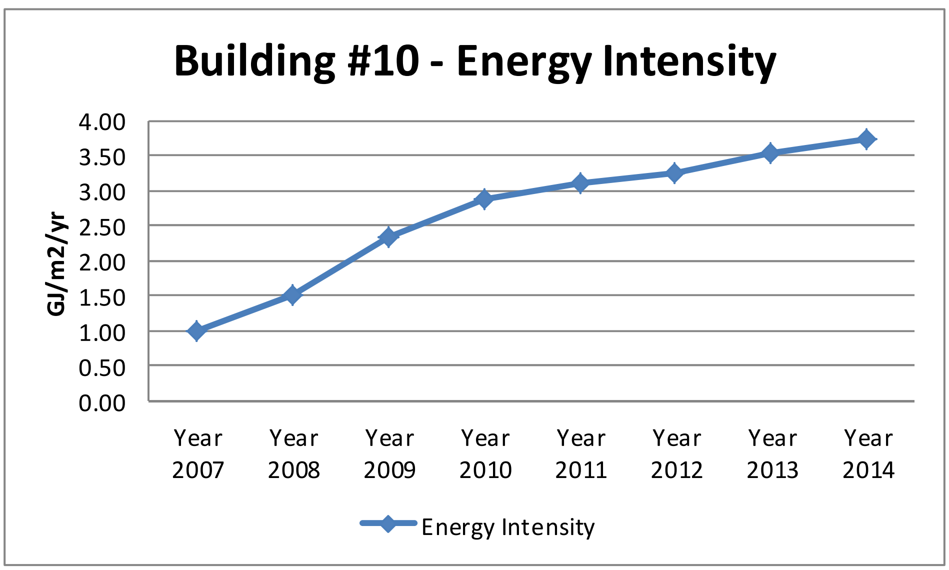
Building J - Ottawa, Ontario, Tower B						
		kWh		m^3-ngas	Total GJ/yr	8,270.00
Row Labels	**Sum of Ele Total Cost / Year**	**Sum of Ele Consumption / Year**	**Sum of Gas Total Cost / Year**	**Sum of Gas Consumption / Year**	**Total**	**GJ/m2/yr**
Year 2006	$ 42,147.20	395,066.52				
Year 2007	$ 257,457.26	2,244,904.38			8,081.66	0.98
Year 2008	$ 348,922.62	3,446,424.69			12,407.13	1.50
Year 2009	$ 518,992.42	5,380,956.18			19,371.44	2.34
Year 2010	$ 666,152.31	6,608,614.99			23,791.01	2.88
Year 2011	$ 760,441.78	7,158,754.60			25,771.52	3.12
Year 2012	$ 867,420.74	7,465,959.75			26,877.46	3.25
Year 2013	$ 1,009,936.95	8,117,404.05			29,222.65	3.53
Year 2014	$ 1,086,545.67	8,550,109.80			30,780.40	3.72
Year 2015	$ 292,627.19	2,223,623.79				
Average	**$ 689,483.72**	**6,121,641.06**				**2.66**

As it was specified in energy audit, energy consumption of the Building #10 is very high in comparison to similar office buildings in same region; and therefore average energy index which equals to 1.13 $GJ/m^2/yr$ is also high in comparison to benchmark values of BOMA energy efficient building value of 1.05 $GJ/m^2/yr$, and then average National Resources Canada value of 1.43GJ/m2/year..

Charts below show electricity consumption per year. Electricity consumption chart demonstrates prominent increase in energy usage.



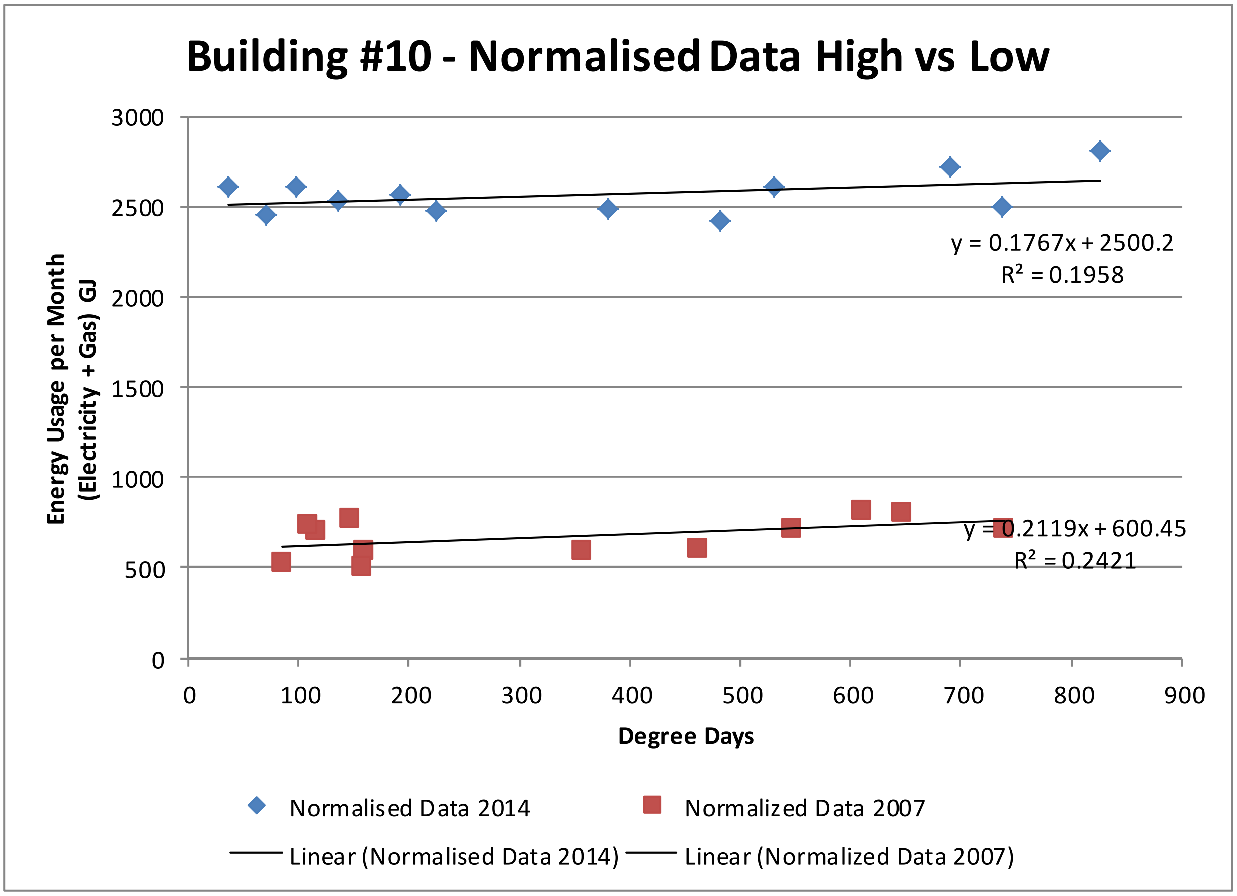
Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. Chart below shows that energy index value is gradually increasing and currently around 3.72 GJ/m^2/yr; this value is very high. The lowest energy index was in 2007 and highest in 2014. These two years' data will be used for further calculations and comparisons.



Normalized total energy consumption was calculated for Building #10. Based on plotted results, shown below in the chart, it can be concluded that energy consumption for 2014 is much higher than for 2007. This proves that regardless of weather conditions 2014 has higher energy consumptions than in 2007. Implementing trendline equations, average equation was calculated:

$y = 0.1943x + 1550.325$

From above equation normalized average energy index was calculated as 2.34 GJ/m^2/yr, this value is slightly lower than average for 2007 to 2014 years range. As it was discussed previously, to demonstrate more accurate energy consumption of the building, current value should be only 75%; therefore new energy intensity index value is 1.76 GJ/m^2/yr. This value will be used for further case-study buildings comparison.



Actual data used for calculations (year with highest energy consumption):

ADDRESS:	**Building J - Ottawa, Ontario, Tower B**
BUILDING #	10
Year - Highest Energy Consumption:	2014
AREA:	**8,270**
USAGE INDEX:	**3.72**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	31/01/2014	28/02/2014	31/03/2014	30/04/2014	31/05/2014	30/06/2014	31/07/2014	31/08/2014	30/09/2014	31/10/2014	30/11/2014	31/12/2014
Electric Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
Gas Billing Date	31/01/2014	28/02/2014	31/03/2014	30/04/2014	31/05/2014	30/06/2014	31/07/2014	31/08/2014	30/09/2014	31/10/2014	30/11/2014	31/12/2014
Gas Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	23	59	121	94	28	0	0	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	1	2	4	3	1	0	0	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	826	737	691	357	132	14	4	9	70	224	482	532
Daily Htg. D.D. Avg. (Highest Year)	27	26	22	12	4	0	0	0	2	7	16	17
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	779,591	693,374	754,671	691,542	713,452	703,583	723,955	723,047	682,004	687,047	673,248	724,597
Daily kWh Avg.	25,148	24,763	24,344	23,051	23,015	23,453	23,353	23,324	22,733	22,163	22,442	23,374
Demand kW/RkVA Used	1,237	1,245	1,155	1,111	1,097	1,115	1,085	1,089	1,075	1,046	1,070	1,115
Load Factor (Highest Year)	85%	83%	88%	86%	87%	88%	90%	89%	88%	88%	87%	87%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	0	0	0	0	0	0	0	0	0	0	0	0
Daily m^3 Avg.	0	0	0	0	0	0	0	0	0	0	0	0
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	524,452	466,451	507,688	465,219	479,959	473,320	487,024	486,413	458,803	462,195	452,912	487,456
S02 (kgs) (Highest Year)	5,666	5,040	5,485	5,026	5,186	5,114	5,262	5,255	4,957	4,994	4,893	5,266
N0x (kgs) (Highest Year)	2,484	2,209	2,405	2,204	2,273	2,242	2,307	2,304	2,173	2,189	2,145	2,309
USAGE DATA												
kWh to GJ	2806.53	2496.14	2716.82	2489.55	2568.43	2532.90	2606.24	2602.97	2455.22	2473.37	2423.69	2608.55
GJ/m2/Day ELECTRIC (Highest Year)	0.011	0.011	0.011	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
GJ/m2/Month (Highest Year)	0.34	0.30	0.33	0.30	0.31	0.31	0.32	0.31	0.30	0.30	0.29	0.32
m3 to GJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GJ/m2/Day GAS (Highest Year)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GJ/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
m3/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GJ/m2/Day ENERGY (Highest Year)	0.011	0.011	0.011	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
GJ/m2/Month (Highest Consumption Year)	0.339	0.302	0.329	0.301	0.311	0.306	0.315	0.315	0.297	0.299	0.293	0.315

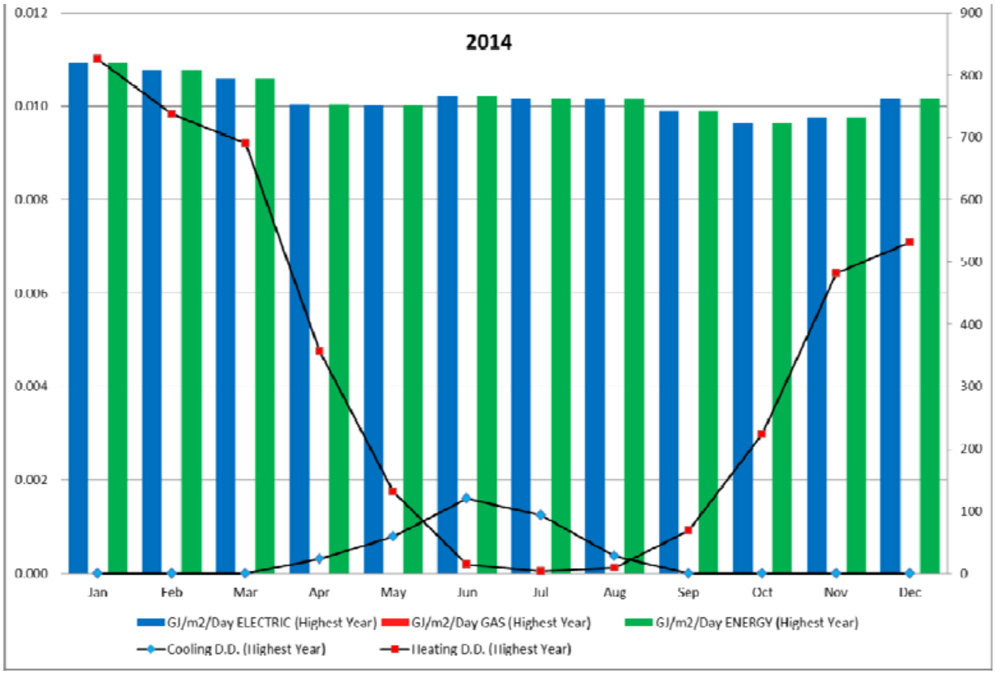
Energy Usage per Month (Electricity + Gas)	2807	2496	2717	2490	2568	2533	2606	2603	2455	2473	2424	2609
Degree Days	826	737	691	380	191	135	98	37	70	224	482	532

Actual data used for calculations (year with lowest energy consumption):

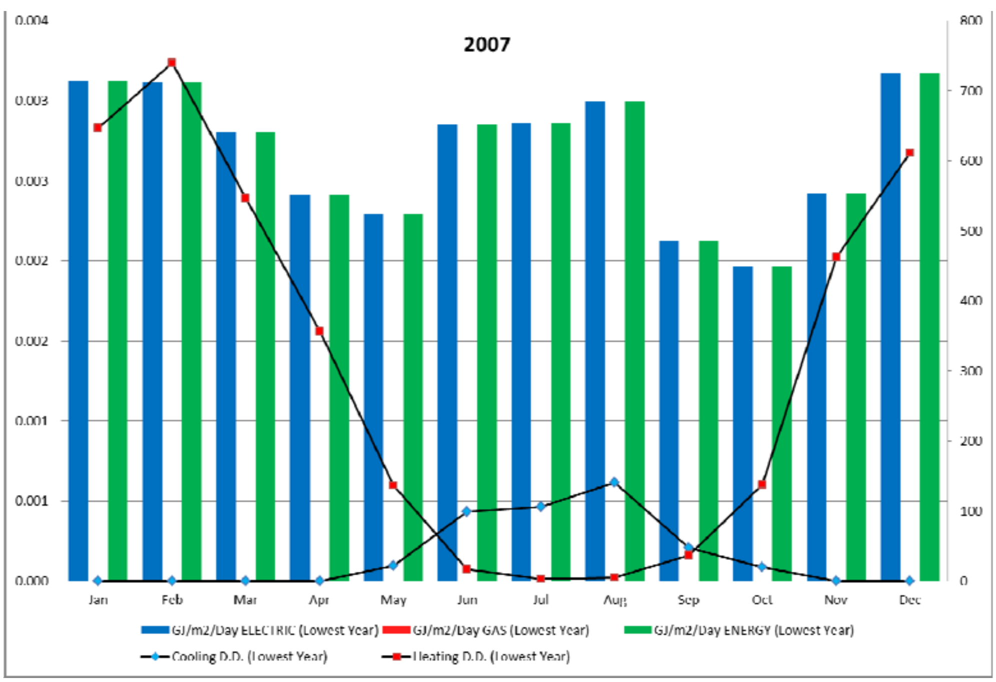
ADDRESS:	Building J - Ottawa, Ontario, Tower B			
BUILDING #	10			
Year - Lowest Energy Consumption:	2007			
AREA:	8,270			
USAGE INDEX:	0.98	AVERAGE:	2.3496	2.34599

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	31/01/2007	28/02/2007	31/03/2007	30/04/2007	31/05/2007	30/06/2007	31/07/2007	31/08/2007	30/09/2007	31/10/2007	30/11/2007	31/12/2007
Electric Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
Gas Billing Date	31/01/2007	28/02/2007	31/03/2007	30/04/2007	31/05/2007	30/06/2007	31/07/2007	31/08/2007	30/09/2007	31/10/2007	30/11/2007	31/12/2007
Gas Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	0	22	99	106	141	48	20	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	0	1	3	3	5	2	1	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	647	740	547	356	136	17	3	5	37	138	463	611
Daily Htg. D.D. Avg. (Lowest Year)	21	26	18	12	4	1	0	0	1	4	15	20
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	222,725	200,105	199,771	166,173	163,299	196,428	203,571	213,315	146,444	140,338	166,753	225,984
Daily kWh Avg.	7,185	7,147	6,444	5,539	5,268	6,548	6,567	6,881	4,881	4,527	5,558	7,290
Demand kW/RkVA Used	372	377	395	315	431	400	456	435	335	261	331	392
Load Factor (Lowest Year)	80%	79%	68%	73%	51%	68%	60%	66%	61%	72%	70%	78%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	0	0	0	0	0	0	0	0	0	0	0	0
Daily m^3 Avg.	0	0	0	0	0	0	0	0	0	0	0	0
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	149,833	134,616	134,391	111,789	109,856	132,142	136,948	143,503	98,517	94,409	112,179	152,025
S02 (kgs) (Lowest Year)	1,619	1,454	1,452	1,208	1,187	1,428	1,480	1,550	1,064	1,020	1,212	1,642
N0x (kgs) (Lowest Year)	710	638	637	529	520	626	649	680	467	447	531	720
USAGE DATA												
kWh to GJ	801.81	720.38	719.18	598.22	587.88	707.14	732.85	767.93	527.20	505.22	600.31	813.54
GJ/m2/Day ELECTRIC (Lowest Year)	0.003	0.003	0.003	0.002	0.002	0.003	0.003	0.003	0.002	0.002	0.002	0.003
GJ/m2/Month (Lowest Year)	0.10	0.09	0.09	0.07	0.07	0.09	0.09	0.09	0.06	0.06	0.07	0.10
m3 to GJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GJ/m2/Day GAS (Lowest Year)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GJ/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
m3/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GJ/m2/Day ENERGY (Lowest Year)	0.003	0.003	0.003	0.002	0.002	0.003	0.003	0.003	0.002	0.002	0.002	0.003
GJ/m2/Month (Lowest Consumption Year)	0.097	0.087	0.087	0.072	0.071	0.086	0.089	0.093	0.064	0.061	0.073	0.098
Average Highest Year to Lowest Year	0.218	0.194	0.208	0.187	0.191	0.196	0.202	0.204	0.180	0.180	0.183	0.207
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Gas)	802	720	719	598	588	707	733	768	527	505	600	814
Degree Days	647	740	547	356	159	116	109	146	84	158	463	611
Normalized Data (Average Degree Days)	636	686	551	358	146	104	116	122	98	183	470	636
Normalized Data (Av Energy Consumption)	1674	1684	1657	1620	1579	1571	1573	1574	1569	1586	1642	1674
Normalized Data (Av Energy Index / month)	0.202	0.204	0.200	0.196	0.191	0.190	0.190	0.190	0.190	0.192	0.199	0.202

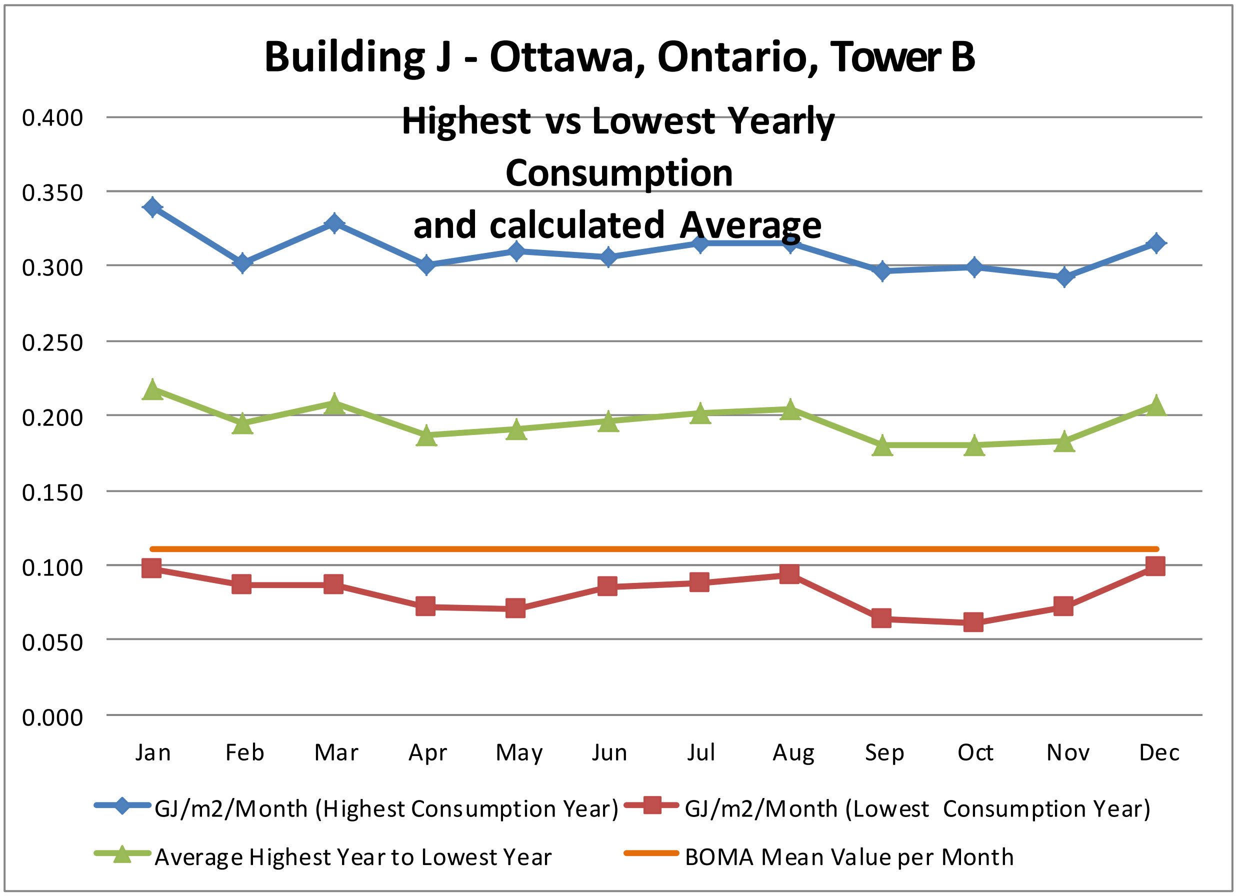
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Building #11 – Utility Bills Analysis

Calculations of Energy Index for Building #11

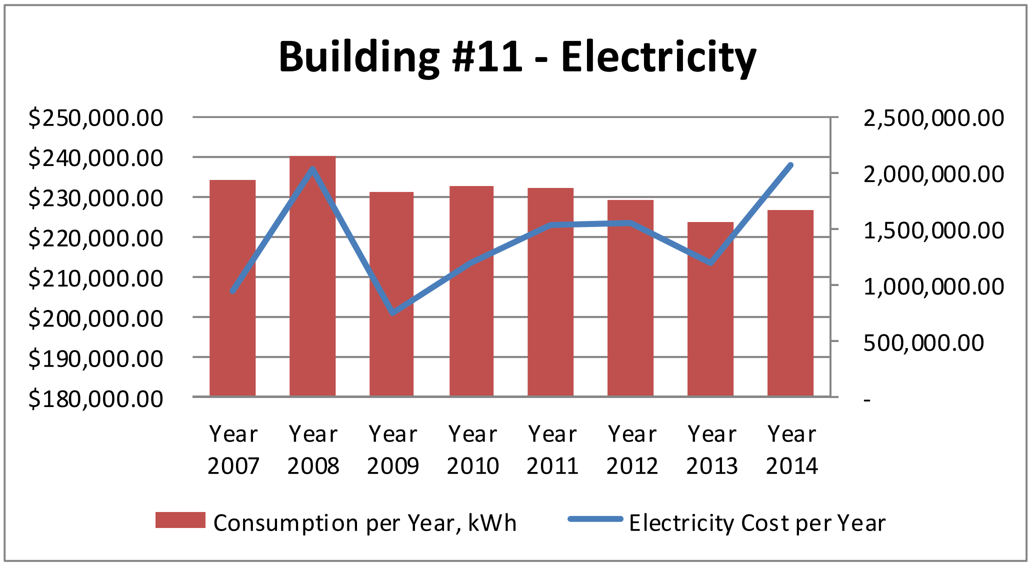
Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity only as gas is not used by this building. For Building #1 utility bills were provided from December 2006 to March 2015. To complete most accurate analysis utility bills for 2007 to 2014 were only analyzed because 2006 and 2015 has incomplete data. By having total floor area for entire building of 6,162 m^2, energy index in GJ/m^2/year was calculated. From calculations it was noticed that utility bills provide consistent data for all years, therefore all data will be used for calculations.

Utility bills analysis showed following:

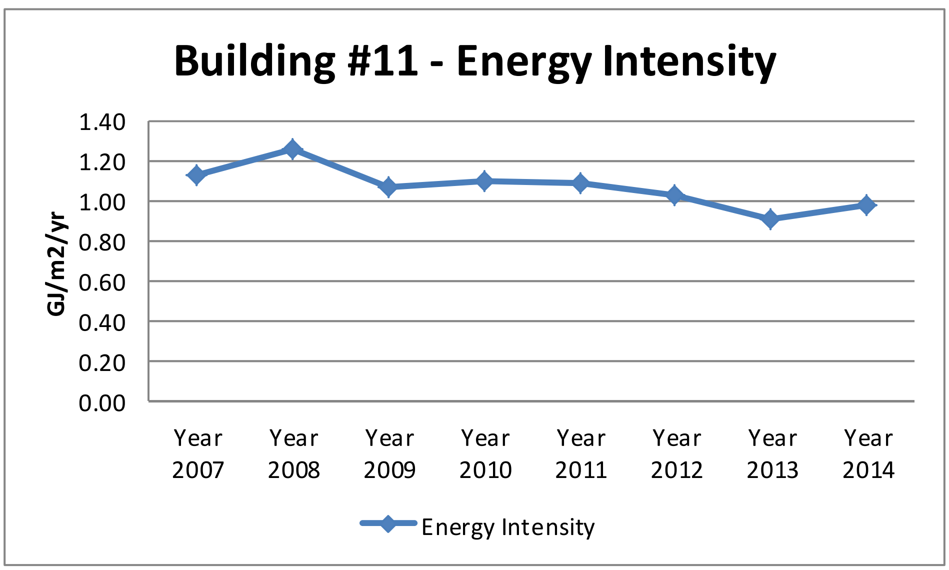
Building K - Ottawa, Ontario, Tower A						
		kWh		m³-ngas	Total GJ/yr	6,162.00
Row Labels	**Sum of Ele Total Cost / Year**	**Sum of Ele Consumption / Year**	**Sum of Gas Total Cost / Year**	**Sum of Gas Consumption / Year**	**Total**	**GJ/m2/yr**
Year 2006	$ 41,343.23	400,200.00				
Year 2007	$ 206,296.95	1,931,614.00			6,953.81	1.13
Year 2008	$ 236,996.59	2,151,971.49			7,747.10	1.26
Year 2009	$ 200,639.58	1,818,159.88			6,545.38	1.06
Year 2010	$ 213,361.37	1,884,751.63			6,785.11	1.10
Year 2011	$ 222,630.28	1,865,555.72			6,716.00	1.09
Year 2012	$ 223,175.74	1,748,425.41			6,294.33	1.02
Year 2013	$ 213,226.93	1,559,654.90			5,614.76	0.91
Year 2014	$ 237,831.31	1,662,740.74			5,985.87	0.97
Year 2015	$ 72,022.73	491,179.84				
Average	**$ 219,269.84**	**1,827,859.22**				**1.07**

As it was specified in energy audit, energy consumption of the Building #11 is average in comparison to similar office buildings in same region; and therefore average energy index which equals to 1.07 GJ/m^2/yr is also average in comparison to benchmark values of BOMA energy efficient building value of 1.05 GJ/m^2/yr, however value is much lower than average National Resources Canada value of 1.43GJ/m2/year..

Electricity consumption chart below shows consumption per year; it doesn't demonstrate prominent increase or decrease in consumption, however recent years shows lower values therefore improvement.



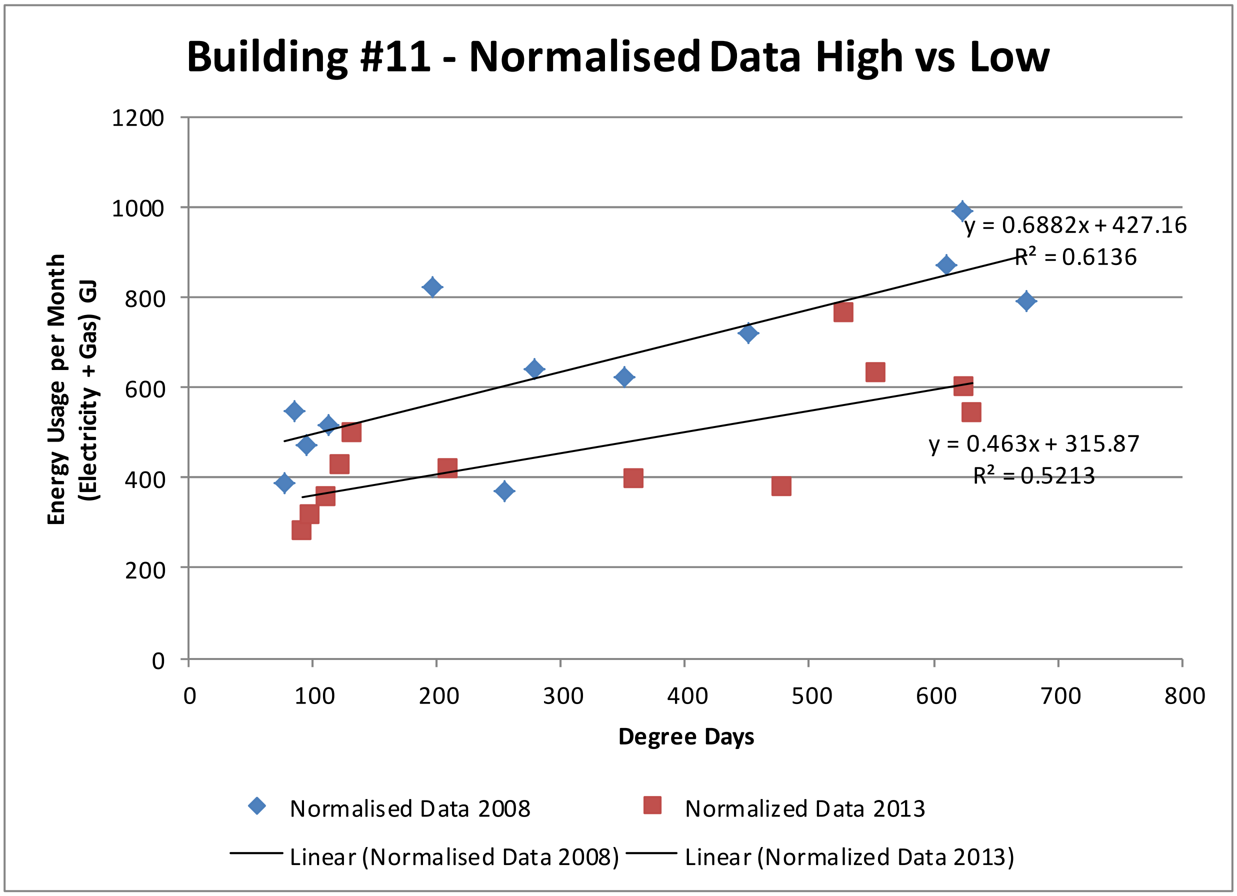
Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. Chart below shows that energy index value is gradually decreasing and currently around 0.97 $GJ/m^2/yr$. The lowest energy index was in 2013 and highest in 2008. These two years' data will be used for further calculations and comparisons.



Normalized total energy consumption was calculated for Building #11. Based on plotted results, shown below in the chart, it can be concluded that energy consumption for 2008 is higher than for 2013. This proves that regardless of weather conditions 2008 has higher energy consumptions than in 2013. Implementing trendline equations, average equation was calculated:

$$y = 0.5756x + 371.515$$

From above equation normalized average energy index was calculated as 1.1 GJ/m^2/yr, this value is higher than average for 2007 to 2014 years range. Calculated value will be used for further case-study buildings comparison.



Actual data used for calculations (year with highest energy consumption):

ADDRESS:	**Building K - Ottawa, Ontario, Tower A**
BUILDING #	11
Year - Highest Energy Consumption:	2008
AREA:	**6,162**
USAGE INDEX:	**1.26**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	12/02/2008	12/03/2008	11/04/2008	12/05/2008	10/06/2008	14/07/2008	12/08/2008	10/09/2008	09/10/2008	12/11/2008	12/12/2008	12/01/2009
Electric Billing Days	31	29	30	31	29	34	29	29	29	34	30	31
Gas Billing Date	12/02/2008	12/03/2008	11/04/2008	12/05/2008	10/06/2008	14/07/2008	12/08/2008	10/09/2008	09/10/2008	12/11/2008	12/12/2008	12/01/2009
Gas Billing Days	31	29	30	31	29	34	29	29	29	34	30	31
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	0	3	72	111	64	27	0	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	0	0	2	4	2	1	0	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	624	675	610	254	194	23	1	13	59	279	452	352
Daily Htg. D.D. Avg. (Highest Year)	20	23	20	8	7	1	0	0	2	8	15	11
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	274,953	219,826	241,264	102,826	227,732	131,626	142,877	107,626	152,045	178,066	199,922	173,206
Daily kWh Avg.	8,869	7,580	8,042	3,317	7,853	3,871	4,927	3,711	5,243	5,237	6,664	5,587
Demand kW/RkVA Used	408	408	41	389	382	314	327	350	357	339	408	386
Load Factor (Highest Year)	91%	77%	821%	35%	86%	51%	63%	44%	61%	64%	68%	60%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	0	0	0	0	0	0	0	0	0	0	0	0
Daily m^3 Avg.	0	0	0	0	0	0	0	0	0	0	0	0
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	184,969	147,883	162,305	69,174	153,202	88,549	96,117	72,403	102,285	119,790	134,493	116,521
S02 (kgs) (Highest Year)	1,998	1,598	1,754	747	1,655	957	1,038	782	1,105	1,294	1,453	1,259
N0x (kgs) (Highest Year)	876	700	769	328	726	419	455	343	484	567	637	552
USAGE DATA												
kWh to GJ	989.83	791.37	868.55	370.17	819.84	473.85	514.36	387.45	547.36	641.04	719.72	623.54
GJ/m2/Day ELECTRIC (Highest Year)	0.005	0.004	0.005	0.002	0.005	0.002	0.003	0.002	0.003	0.003	0.004	0.003
GJ/m2/Month (Highest Year)	0.16	0.13	0.14	0.06	0.13	0.08	0.08	0.06	0.09	0.10	0.12	0.10
m3 to GJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GJ/m2/Day GAS (Highest Year)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GJ/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
m3/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GJ/m2/Day ENERGY (Highest Year)	0.005	0.004	0.005	0.002	0.005	0.002	0.003	0.002	0.003	0.003	0.004	0.003
GJ/m2/Month (Highest Consumption Year)	0.161	0.128	0.141	0.060	0.133	0.077	0.083	0.063	0.089	0.104	0.117	0.101

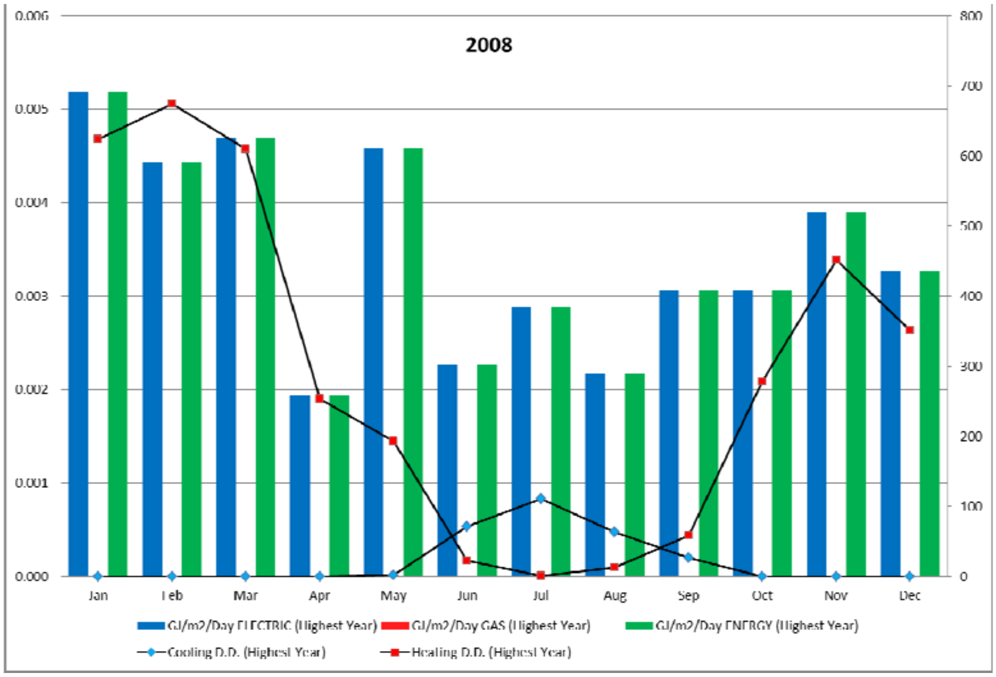
Energy Usage per Month (Electricity + Gas)	990	791	869	370	820	474	514	387	547	641	720	624
Degree Days	624	675	610	254	196	94	112	77	86	279	452	352

Actual data used for calculations (year with lowest energy consumption):

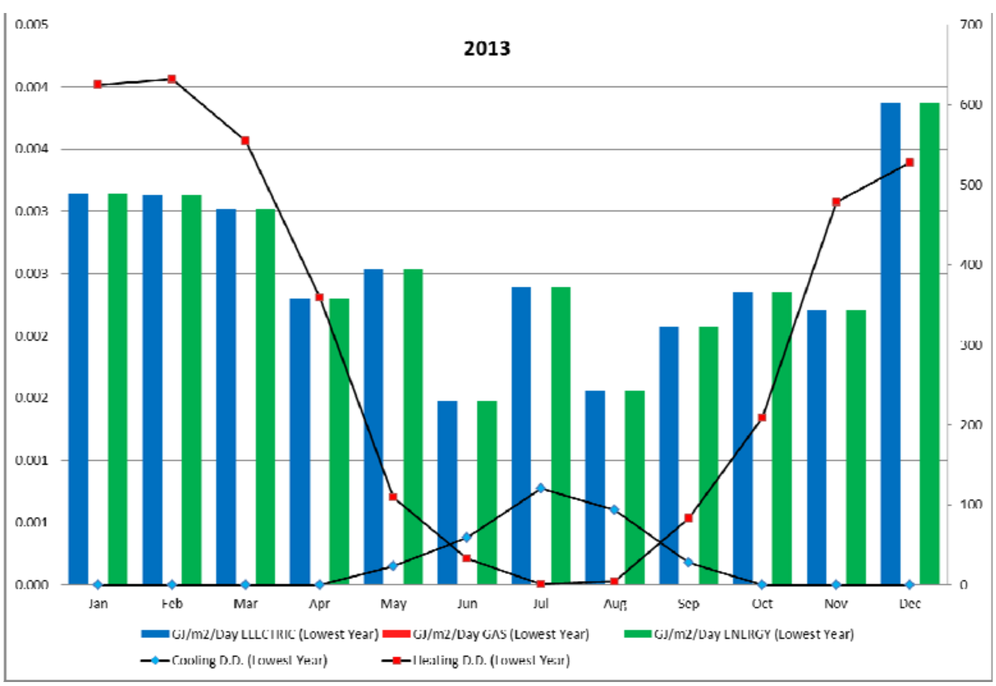
ADDRESS:	Building K - Ottawa, Ontario, Tower A			
BUILDING #	11			
Year - Lowest Energy Consumption:	2013			
AREA:	6,162			
USAGE INDEX:	0.91	AVERAGE:	1.0842	1.09773

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	31/01/2013	28/02/2013	03/04/2013	01/05/2013	02/06/2013	03/07/2013	01/08/2013	03/09/2013	01/10/2013	30/10/2013	27/11/2013	29/12/2013
Electric Billing Days	31	28	34	28	32	31	29	33	28	29	28	32
Gas Billing Date	31/01/2013	28/02/2013	03/04/2013	01/05/2013	02/06/2013	03/07/2013	01/08/2013	03/09/2013	01/10/2013	30/10/2013	27/11/2013	29/12/2013
Gas Billing Days	31	28	34	28	32	31	29	33	28	29	28	32
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	0	23	59	121	94	28	0	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	0	1	2	4	3	1	0	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	624	632	555	359	109	33	1	4	83	209	478	528
Daily Htg. D.D. Avg. (Lowest Year)	20	23	16	13	3	1	0	0	3	7	17	16
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	166,426	150,226	175,550	110,026	139,113	78,226	118,444	87,826	99,185	116,887	105,826	211,918
Daily kWh Avg.	5,369	5,365	5,163	3,930	4,347	2,523	4,084	2,661	3,542	4,031	3,780	6,622
Demand kW/RkVA Used	349	333	373	308	343	242	347	245	283	289	301	380
Load Factor (Lowest Year)	64%	67%	58%	53%	53%	43%	49%	45%	52%	58%	52%	73%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	0	0	0	0	0	0	0	0	0	0	0	0
Daily m^3 Avg.	0	0	0	0	0	0	0	0	0	0	0	0
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	111,960	101,061	118,098	74,018	93,585	52,625	79,681	59,083	66,724	78,633	71,192	142,563
S02 (kgs) (Lowest Year)	1,210	1,092	1,276	800	1,011	569	861	638	721	850	769	1,540
N0x (kgs) (Lowest Year)	530	479	559	351	443	249	377	280	316	372	337	675
USAGE DATA												
kWh to GJ	599.13	540.81	631.98	396.09	500.81	281.61	426.40	316.17	357.07	420.79	380.97	762.90
GJ/m2/Day ELECTRIC (Lowest Year)	0.003	0.003	0.003	0.002	0.003	0.001	0.002	0.002	0.002	0.002	0.002	0.004
GJ/m2/Month (Lowest Year)	0.10	0.09	0.10	0.06	0.08	0.05	0.07	0.05	0.06	0.07	0.06	0.12
m3 to GJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GJ/m2/Day GAS (Lowest Year)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GJ/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
m3/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GJ/m2/Day ENERGY (Lowest Year)	0.003	0.003	0.003	0.002	0.003	0.001	0.002	0.002	0.002	0.002	0.002	0.004
GJ/m2/Month (Lowest Consumption Year)	0.097	0.088	0.103	0.064	0.081	0.046	0.069	0.051	0.058	0.068	0.062	0.124
Average Highest Year to Lowest Year	0.129	0.108	0.122	0.062	0.107	0.061	0.076	0.057	0.073	0.086	0.089	0.112
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Gas)	599	541	632	396	501	282	426	316	357	421	381	763
Degree Days	624	632	555	359	132	92	122	98	111	209	478	528
Normalized Data (Average Degree Days)	624	632	555	359	132	92	122	98	111	209	478	594
Normalized Data (Av Energy Consumption)	731	735	691	578	448	425	442	428	435	492	647	714
Normalized Data (Av Energy Index / month)	0.119	0.119	0.112	0.094	0.073	0.069	0.072	0.069	0.071	0.080	0.105	0.116

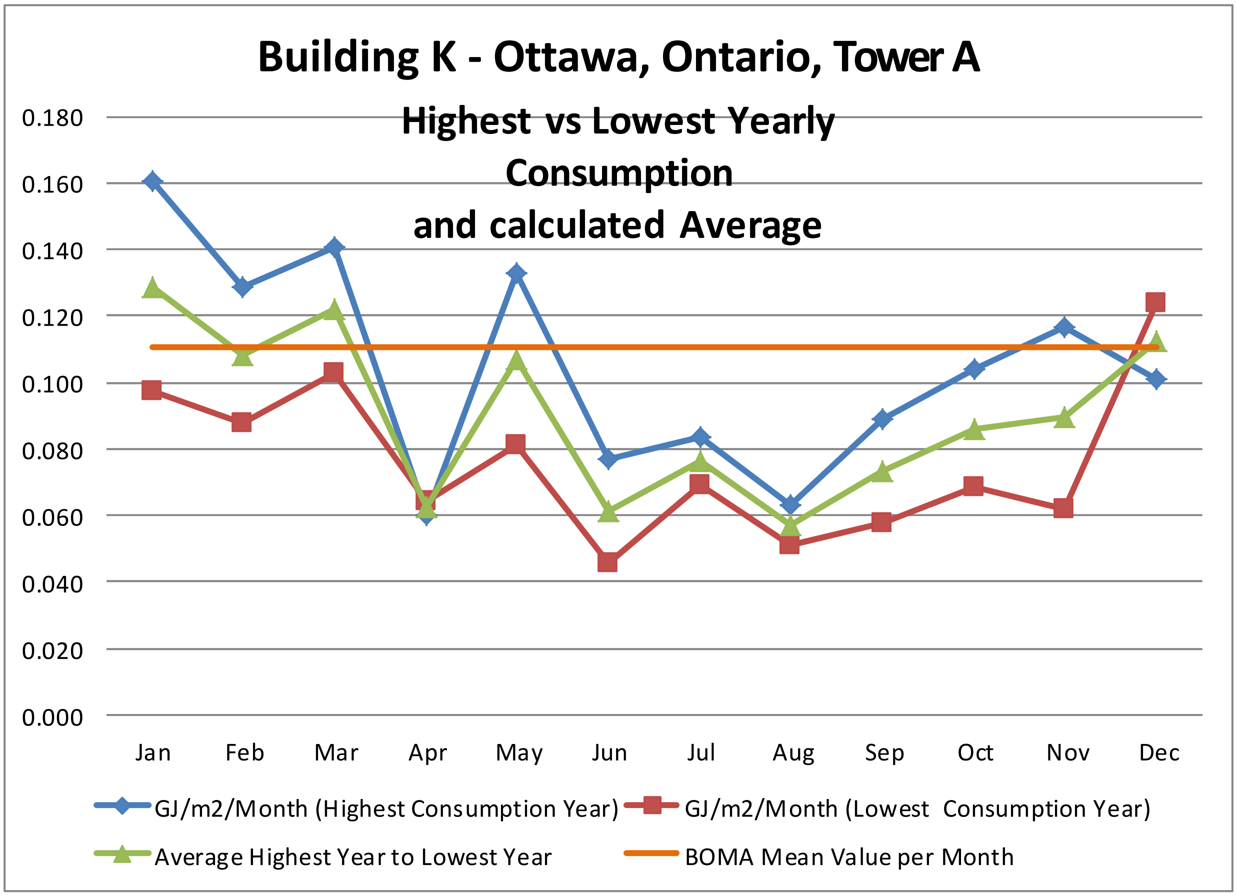
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Building #12 – Utility Bills Analysis

Calculations of Energy Index for Building #12

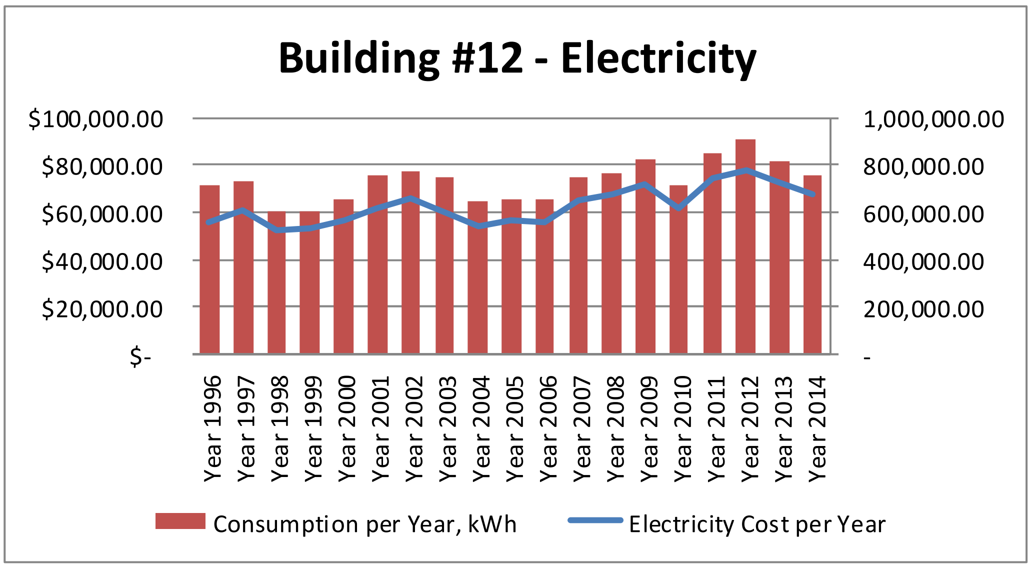
Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity and gas. For Building #12 utility bills were provided from December 1997 to March 2015. To complete most accurate analysis utility bills for 1998 to 2014 were only analyzed because 1997 and 2015 has incomplete data. By having total floor area for entire building of 3,518 m^2, energy index in GJ/m^2/year was calculated. From calculations it was noticed that 2006 provides not consistent values in comparison with the rest of years, therefore for calculations of average yearly energy index 2006 year was excluded.

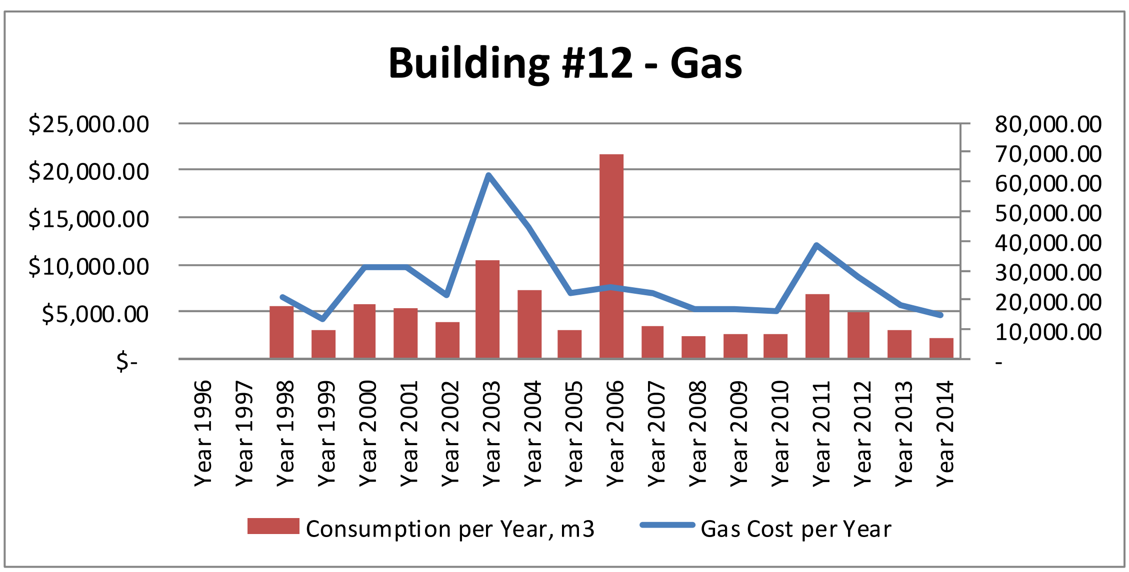
Utility bills analysis showed following:

Building L - Montreal, Quebec						
		kWh		m^3-ngas	Total GJ/yr	3,518.00
Row Labels	**Sum of Ele Total Cost / Year**	**Sum of Ele Consumption / Year**	**Sum of Gas Total Cost / Year**	**Sum of Gas Consumption / Year**	**Total**	**GJ/m2/yr**
Year 1995	$ 46,473.15	554,160.00				
Year 1996	$ 56,060.55	710,400.00				
Year 1997	$ 61,111.64	732,720.00				
Year 1998	$ 52,212.19	606,000.00	$ 6,655.83	18,059.00	2,853.39	0.81
Year 1999	$ 53,234.50	607,680.00	$ 4,222.68	9,920.00	2,556.67	0.73
Year 2000	$ 56,552.05	654,000.00	$ 9,641.38	18,495.00	3,042.41	0.86
Year 2001	$ 61,806.31	758,160.00	$ 9,798.80	17,112.00	3,365.94	0.96
Year 2002	$ 66,099.08	771,360.00	$ 6,687.77	12,296.00	3,234.31	0.92
Year 2003	$ 60,045.15	745,440.00	$ 19,456.55	33,708.00	3,937.52	1.12
Year 2004	$ 53,977.00	646,560.00	$ 13,964.67	23,521.00	3,202.60	0.91
Year 2005	$ 56,554.34	658,320.00	$ 6,914.06	10,084.00	2,745.08	0.78
Year 2006	$ 56,086.20	651,360.00	$ 7,696.09	69,246.00	4,920.85	1.40
Year 2007	$ 65,142.11	748,320.00	$ 6,967.83	11,391.00	3,117.70	0.89
Year 2008	$ 67,890.95	767,760.00	$ 5,373.33	8,004.00	3,061.68	0.87
Year 2009	$ 71,817.92	820,800.00	$ 5,314.92	8,245.00	3,261.59	0.93
Year 2010	$ 61,971.36	717,600.00	$ 5,079.91	8,234.00	2,889.66	0.82
Year 2011	$ 74,183.86	852,240.00	$ 12,102.73	22,108.00	3,890.48	1.11
Year 2012	$ 77,733.42	906,240.00	$ 8,703.32	16,058.00	3,859.82	1.10
Year 2013	$ 72,736.92	817,440.00	$ 5,750.34	10,018.00	3,315.45	0.94
Year 2014	$ 67,502.19	754,560.00	$ 4,695.00	7,356.00	2,990.06	0.85
Year 2015	$ 26,258.72	299,040.00	$ 2,799.50	4,676.00	1,250.49	0.36
Average	**$ 63,716.21**	**739,530.00**	**$ 8,208.07**	**14,663.06**		**0.91**

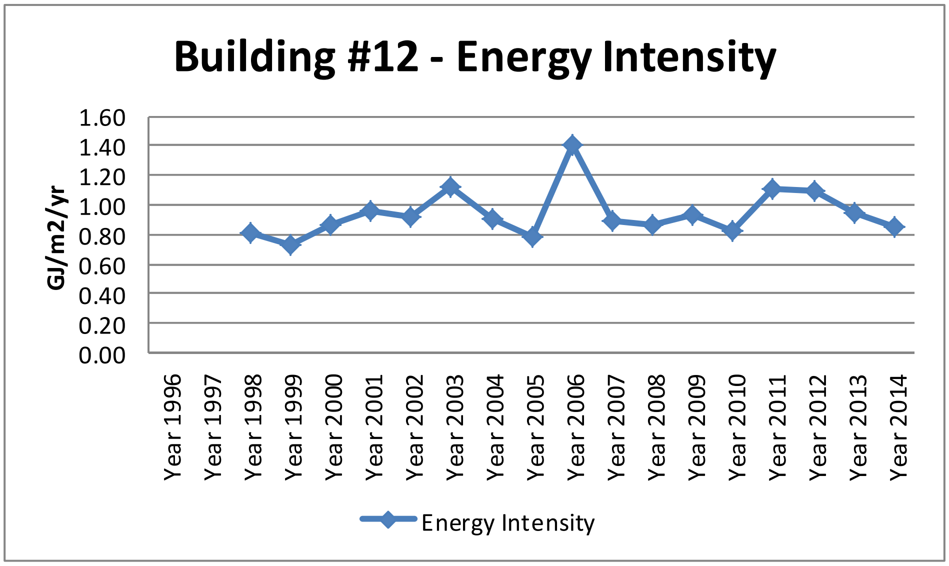
As it was specified in energy audit, energy consumption of the Building #12 is relatively low in comparison to similar office buildings in same region; and therefore average energy index which equals to 0.91 GJ/m^2/yr is also high in comparison to benchmark values of BOMA energy efficient building value of 1.05 GJ/m^2/yr, however value is much lower than average National Resources Canada value of 1.43GJ/m2/year.

Two charts below show electricity and gas consumption per year. Electricity consumption chart demonstrates prominent increase in energy usage. However gas consumption chart shows decrease in usage. As has been mentioned earlier 2006 shows very inconsistent gas consumption, energy bills for this year were analysed in details and showed that in November 2011 gas consumption was 60,347 m3-ngas. Utility bill didn't provide details on why such a high amount of gas consumption occurred; therefore whole 2006 year data was excluded from calculations.





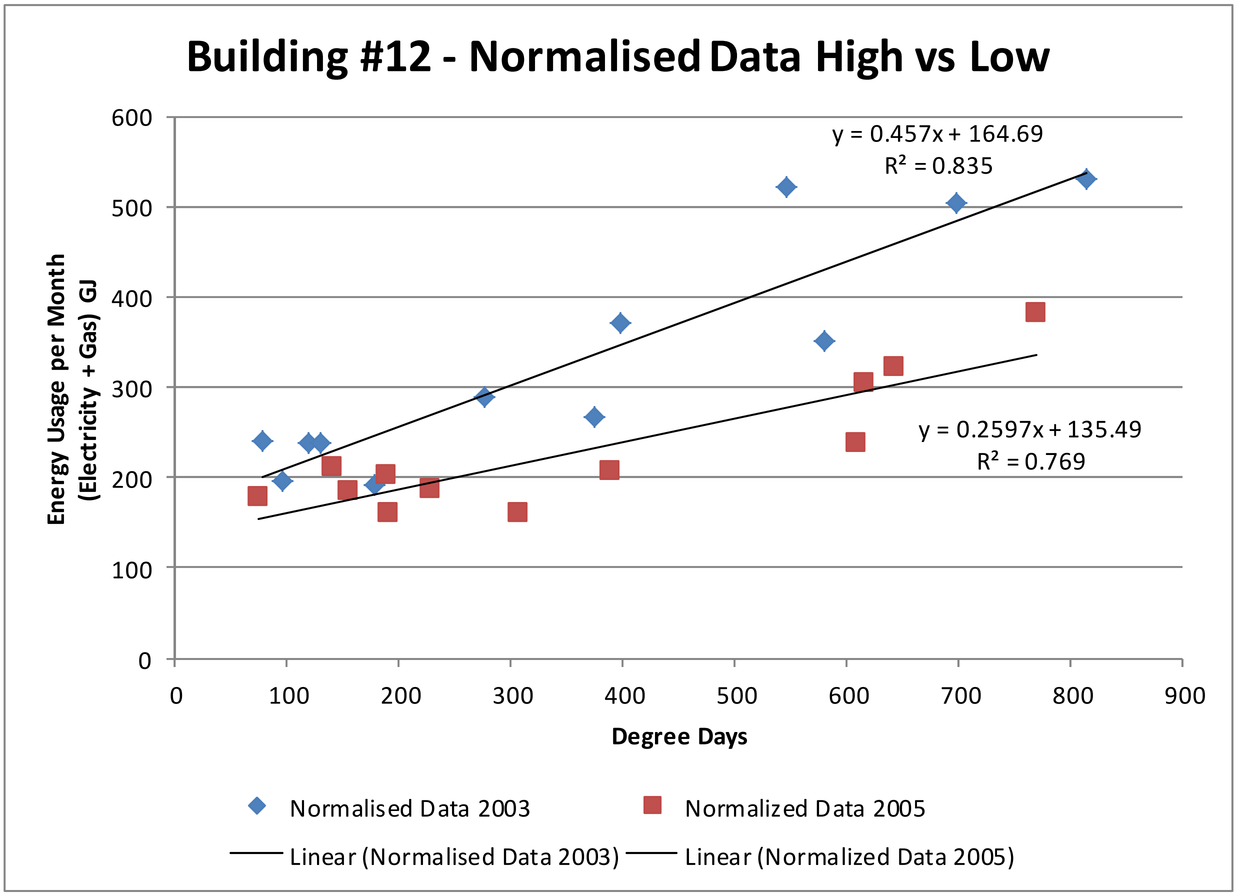
Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. Chart below shows that energy index value is gradually decreasing excluding high jump in 2006. The lowest energy index was in 1999 and highest in 2003, but 2005 and 2003 were used for further calculations and comparisons, to work with more recent data.



Normalized total energy consumption was calculated for Building #12. Based on plotted results, shown below in the chart, it can be concluded that energy consumption for 2003 is higher than for 2005. This proves that regardless of weather conditions 2003 has higher energy consumptions than in 2005. Implementing trendline equations, average equation was calculated:

$$y = 0.3584x + 150.09$$

From above equation normalized average energy index was calculated as 0.94 GJ/m^2/yr, this value is moderately higher than average for 1999 to 2014 years range. Calculated value will be used for further case-study buildings comparison.


Building #12 - Normalised Data High vs Low
y = 0.457x + 164.69
R² = 0.835
y = 0.2597x + 135.49
R² = 0.769
Energy Usage per Month (Electricity + Gas) GJ
0
100
200
300
400
500
600
0
100
200
300
400
500
600
700
800
900
Degree Days
Normalised Data 2003
Normalized Data 2005
Linear (Normalised Data 2003)
Linear (Normalized Data 2005)

Actual data used for calculations (year with highest energy consumption):

ADDRESS:	**Building L - Montreal, Quebec**
BUILDING #	12
Year - Highest Energy Consumption:	2003
AREA:	**3,518**
USAGE INDEX:	**1.12**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	31/01/2003	28/02/2003	31/03/2003	30/04/2003	31/05/2003	30/06/2003	31/07/2003	31/08/2003	30/09/2003	31/10/2003	30/11/2003	31/12/2003
Electric Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
Gas Billing Date	14/02/2003	17/03/2003	14/04/2003	16/05/2003	16/06/2003	18/07/2003	16/08/2003	18/09/2003	17/10/2003	15/11/2003	13/12/2003	17/01/2004
Gas Billing Days	31	31	28	32	31	32	29	33	29	29	28	35
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	2	0	53	118	128	24	0	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	0	0	2	4	4	1	0	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	815	699	581	373	178	43	0	2	55	276	399	546
Daily Htg. D.D. Avg. (Highest Year)	26	23	21	12	6	1	0	0	2	10	14	16
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	84,720	70,800	67,920	60,720	52,080	54,240	66,240	66,000	61,200	52,080	50,400	59,040
Daily kWh Avg.	2,733	2,284	2,426	1,898	1,680	1,695	2,284	2,000	2,110	1,796	1,800	1,687
Demand kW/RkVA Used	220	194	162	154	142	167	164	167	158	134	119	135
Load Factor (Highest Year)	52%	54%	57%	55%	49%	45%	54%	53%	54%	52%	59%	59%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	6,049	6,686	2,851	1,274	115	0	3	8	560	2,754	5,090	8,318
Daily m^3 Avg.	195	216	102	40	4	0	0	0	19	95	182	238
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	99,803	94,947	65,868	49,864	35,850	36,489	44,583	44,457	45,134	54,526	69,928	98,585
S02 (kgs) (Highest Year)	1,078	1,026	712	539	387	394	482	480	488	589	756	1,065
N0x (kgs) (Highest Year)	473	450	312	236	170	173	211	211	214	258	331	467
USAGE DATA												
kWh to GJ	304.99	254.88	244.51	218.59	187.49	195.26	238.46	237.60	220.32	187.49	181.44	212.54
GJ/m2/Day ELECTRIC (Highest Year)	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
GJ/m2/Month (Highest Year)	0.09	0.07	0.07	0.06	0.05	0.06	0.07	0.07	0.06	0.05	0.05	0.06
m3 to GJ	225.02	248.72	106.06	47.39	4.28	0.00	0.11	0.30	20.83	102.45	189.35	309.43
GJ/m2/Day GAS (Highest Year)	0.002	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003
GJ/m2/Month	0.06	0.07	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.05	0.09
m3/m2/Month	1.72	1.90	0.81	0.36	0.03	0.00	0.00	0.00	0.16	0.78	1.45	2.36
GJ/m2/Day ENERGY (Highest Year)	0.005	0.005	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.004	0.004
GJ/m2/Month (Highest Consumption Year)	0.151	0.143	0.100	0.076	0.055	0.056	0.068	0.068	0.069	0.082	0.105	0.148

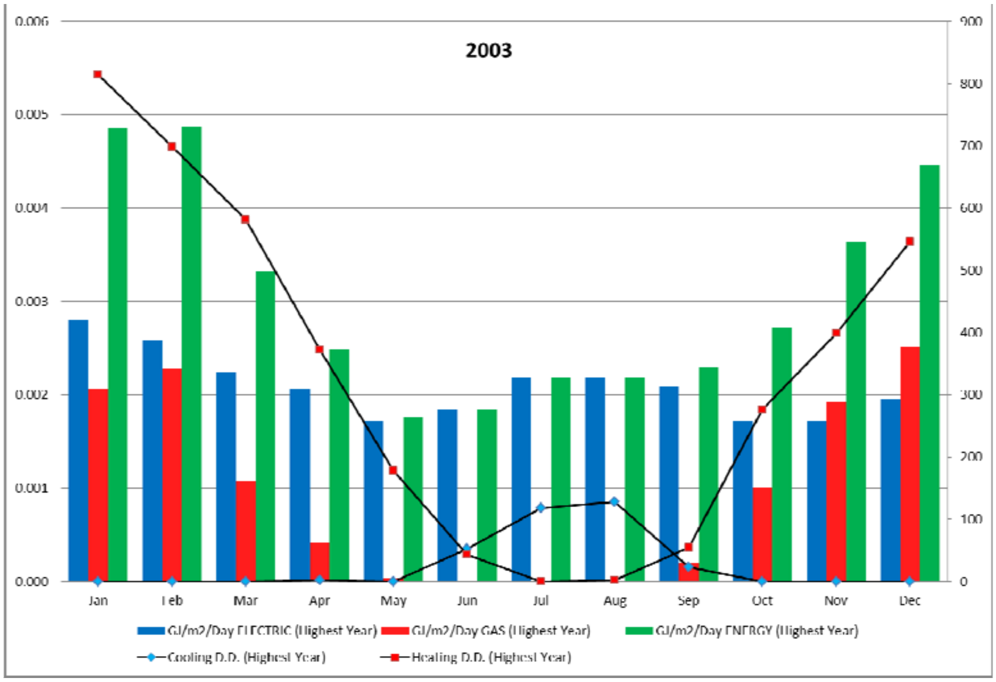
Energy Usage per Month (Electricity + Gas)	530	504	351	266	192	195	239	238	241	290	371	522
Degree Days	815	699	581	375	178	96	119	130	79	276	399	546

Actual data used for calculations (year with lowest energy consumption):

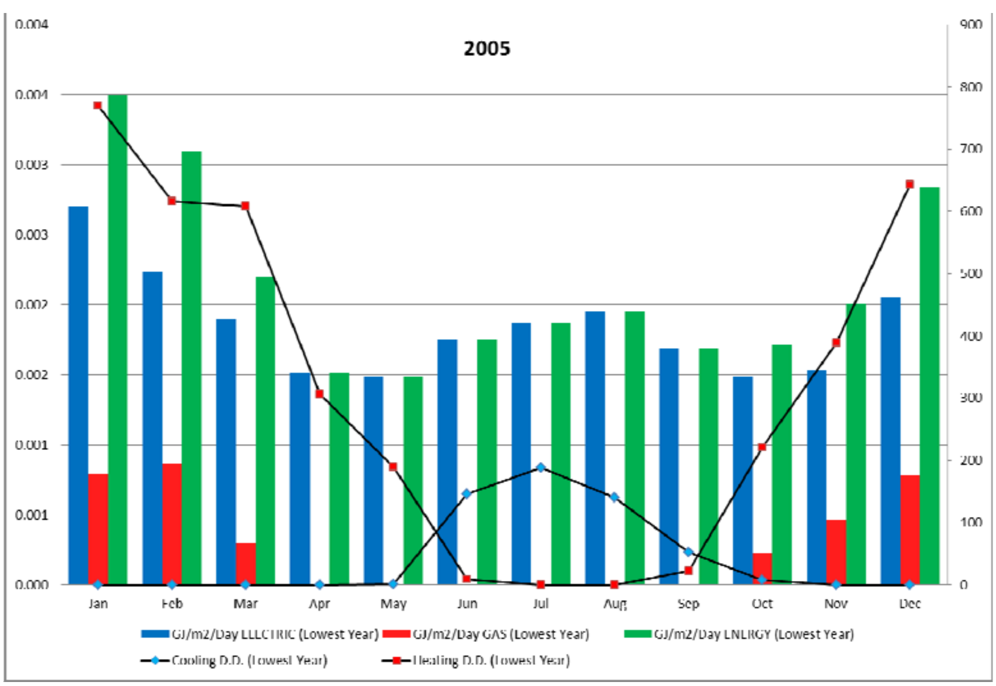
ADDRESS:	Building L - Montreal, Quebec			
BUILDING #	12			
Year - Lowest Energy Consumption:	2005			
AREA:	3,518			
USAGE INDEX:	0.78	AVERAGE:	0.9498	0.93894

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	31/01/2005	28/02/2005	31/03/2005	30/04/2005	31/05/2005	30/06/2005	31/07/2005	31/08/2005	30/09/2005	31/10/2005	30/11/2005	31/12/2005
Electric Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
Gas Billing Date	14/02/2005	14/03/2005	13/04/2005	13/05/2005	14/06/2005	15/07/2005	15/08/2005	14/09/2005	14/10/2005	15/11/2005	13/12/2005	18/01/2006
Gas Billing Days	31	28	30	30	32	31	31	30	30	32	28	36
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	0	1	146	189	141	52	8	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	0	0	5	6	5	2	0	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	770	616	609	307	189	9	0	0	23	220	388	643
Daily Htg. D.D. Avg. (Lowest Year)	25	22	20	10	6	0	0	0	1	7	14	18
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	81,840	61,200	57,600	44,400	44,880	51,360	56,640	59,040	49,440	44,880	44,880	62,160
Daily kWh Avg.	2,640	2,186	1,920	1,480	1,403	1,657	1,827	1,968	1,648	1,403	1,603	1,727
Demand kW/RkVA Used	185	164	160	129	117	132	137	141	133	136	135	160
Load Factor (Lowest Year)	60%	56%	49%	48%	52%	54%	55%	56%	52%	44%	46%	52%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	2,338	2,285	854	0	2	0	0	0	0	702	1,245	2,658
Daily m^3 Avg.	75	82	28	0	0	0	0	0	0	22	44	74
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	71,602	57,342	44,793	29,869	30,206	34,551	38,103	39,718	33,260	35,160	39,003	60,628
S02 (kgs) (Lowest Year)	774	620	484	323	326	373	412	429	359	380	421	655
N0x (kgs) (Lowest Year)	339	272	212	141	143	164	180	188	158	167	185	287
USAGE DATA												
kWh to GJ	294.62	220.32	207.36	159.84	161.57	184.90	203.90	212.54	177.98	161.57	161.57	223.78
GJ/m2/Day ELECTRIC (Lowest Year)	0.003	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.001	0.002	0.002
GJ/m2/Month (Lowest Year)	0.08	0.06	0.06	0.05	0.05	0.05	0.06	0.06	0.05	0.05	0.05	0.06
m3 to GJ	86.97	85.00	31.77	0.00	0.07	0.00	0.00	0.00	0.00	26.11	46.31	98.88
GJ/m2/Day GAS (Lowest Year)	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
GJ/m2/Month	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03
m3/m2/Month	0.66	0.65	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.35	0.76
GJ/m2/Day ENERGY (Lowest Year)	0.003	0.003	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.003
GJ/m2/Month (Lowest Consumption Year)	0.108	0.087	0.068	0.045	0.046	0.053	0.058	0.060	0.051	0.053	0.059	0.092
Average Highest Year to Lowest Year	0.130	0.115	0.084	0.061	0.050	0.054	0.063	0.064	0.060	0.068	0.082	0.120
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Gas)	382	305	239	160	162	185	204	213	178	188	208	323
Degree Days	770	616	609	307	190	155	189	141	75	228	388	643
Normalized Data (Average Degree Days)	697	624	582	333	161	124	155	120	93	218	433	652
Normalized Data (Av Energy Consumption)	400	374	359	269	208	194	206	193	183	228	305	384
Normalized Data (Av Energy Index / month)	0.114	0.106	0.102	0.077	0.059	0.055	0.058	0.055	0.052	0.065	0.087	0.109

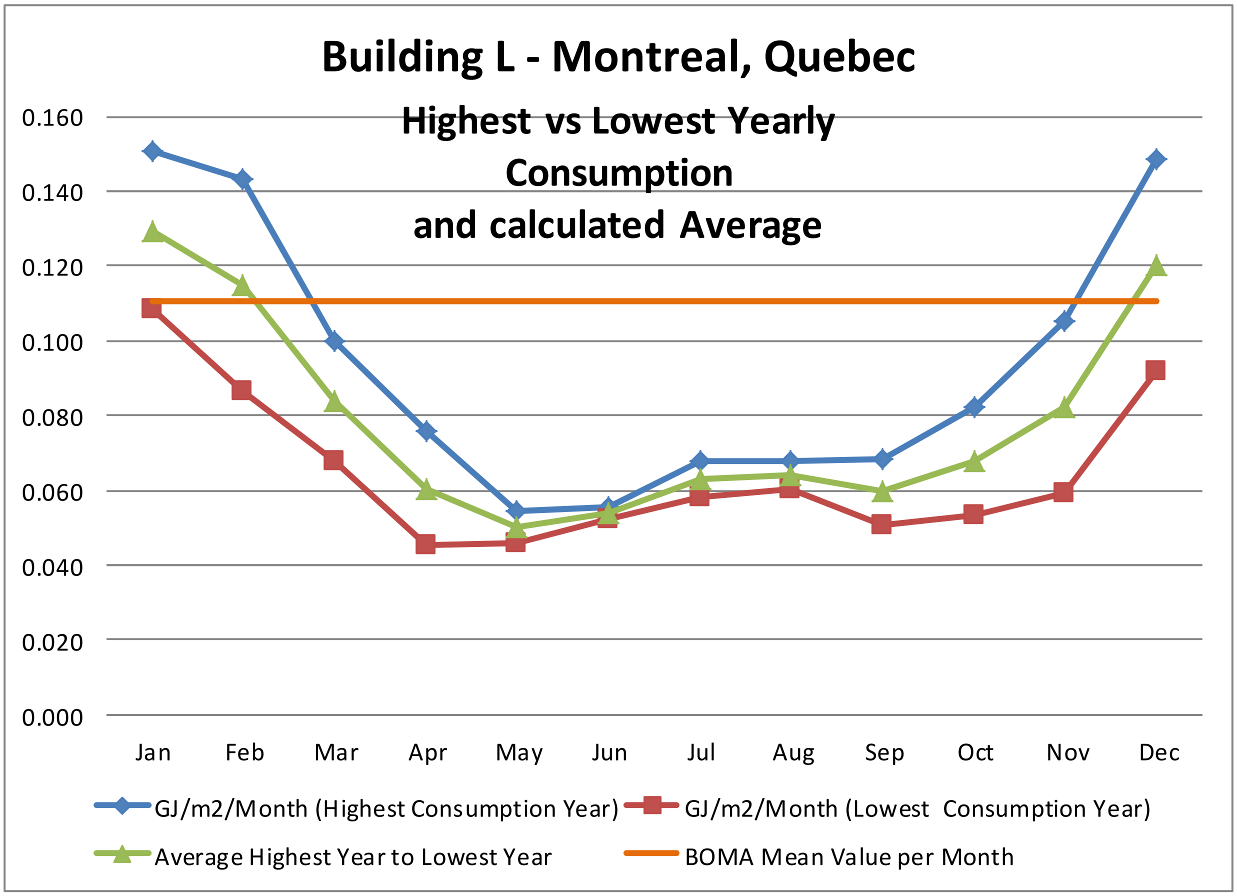
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Building #13 – Utility Bills Analysis

Calculations of Energy Index for Building #13

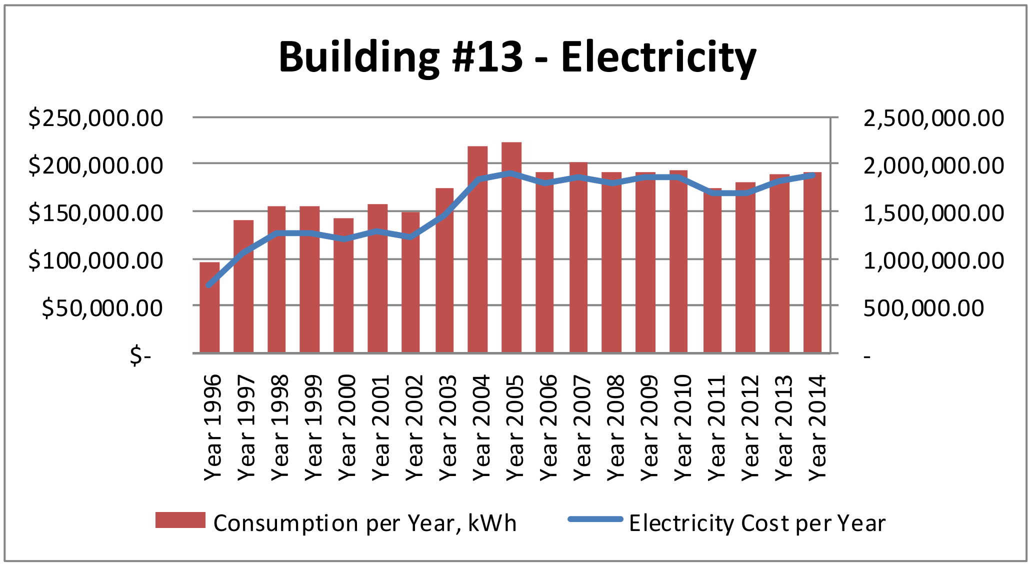
Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity and gas. For Building #13 electricity utility bills were provided from December 1995 to March 2015; gas utility bills were provided from January 2003 to March 2015. To complete most accurate analysis utility bills for 2003 to 2014 were only. By having total floor area for entire building of 8,022 m^2, energy index in GJ/m^2/year was calculated. From calculations it was noticed that gas utility bills for 2012 provides not consistent values in comparison with the rest of years, and afterwards gas consumption seems much higher than in years prior 2012. By analysing utility bills in more details it was not clear why such inconsistency occurred, therefore for further calculations all years data was included.

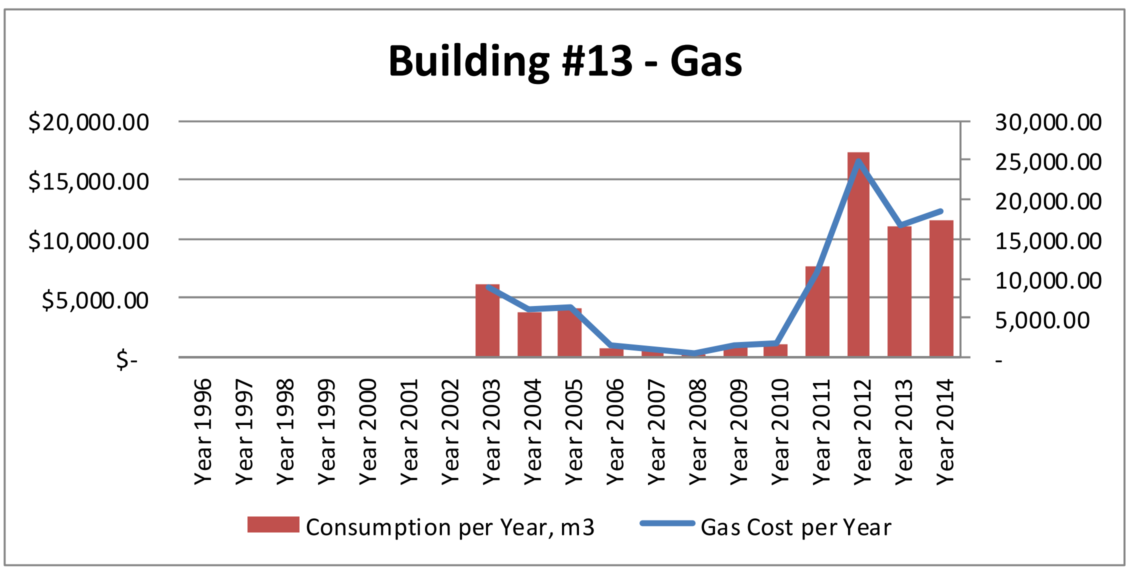
Utility bills analysis showed following:

Building M - Vaudreuil-Dorion, Quebec						
		kWh		m^3-ngas	Total GJ/yr	8,022.00
Row Labels	**Sum of Ele Total Cost / Year**	**Sum of Ele Consumption / Year**	**Sum of Gas Total Cost / Year**	**Sum of Gas Consumption / Year**	**Total**	**GJ/m2/yr**
Year 1995	$ 47,828.58	647,940.00				
Year 1996	$ 71,461.21	953,040.00			3,430.94	0.43
Year 1997	$ 105,261.37	1,405,080.00			5,058.29	0.63
Year 1998	$ 127,513.05	1,559,400.00			5,613.84	0.70
Year 1999	$ 126,240.32	1,551,000.00			5,583.60	0.70
Year 2000	$ 120,898.21	1,431,810.00			5,154.52	0.64
Year 2001	$ 128,418.77	1,577,150.00			5,677.74	0.71
Year 2002	$ 122,699.82	1,493,980.00			5,378.33	0.67
Year 2003	$ 146,374.27	1,747,330.00	$ 5,884.62	9,345.00	6,638.02	0.83
Year 2004	$ 184,302.66	2,193,660.00	$ 3,988.02	5,737.00	8,110.59	1.01
Year 2005	$ 190,976.08	2,219,820.00	$ 4,248.81	6,284.00	8,225.12	1.03
Year 2006	$ 178,663.73	1,912,140.00	$ 1,017.33	1,252.00	6,930.28	0.86
Year 2007	$ 186,555.40	2,024,430.00	$ 674.29	859.00	7,319.90	0.91
Year 2008	$ 180,115.50	1,915,680.00	$ 427.98	450.00	6,913.19	0.86
Year 2009	$ 185,402.53	1,917,160.00	$ 1,033.12	1,361.00	6,952.41	0.87
Year 2010	$ 185,396.49	1,936,200.00	$ 1,227.59	1,621.00	7,030.62	0.88
Year 2011	$ 168,687.72	1,735,650.00	$ 7,110.36	11,540.00	6,677.63	0.83
Year 2012	$ 169,972.48	1,807,020.00	$ 16,610.37	25,849.00	7,466.85	0.93
Year 2013	$ 180,878.36	1,896,000.00	$ 11,106.72	16,511.46	7,439.83	0.93
Year 2014	$ 188,104.76	1,919,520.00	$ 12,264.86	17,459.00	7,559.75	0.94
Year 2015	$ 66,981.63	706,920.00	$ 6,738.65	10,438.00	2,933.21	0.37
Average	**$ 149,787.57**	**1,692,200.50**	**$ 5,466.17**	**8,189.04**		**0.91**

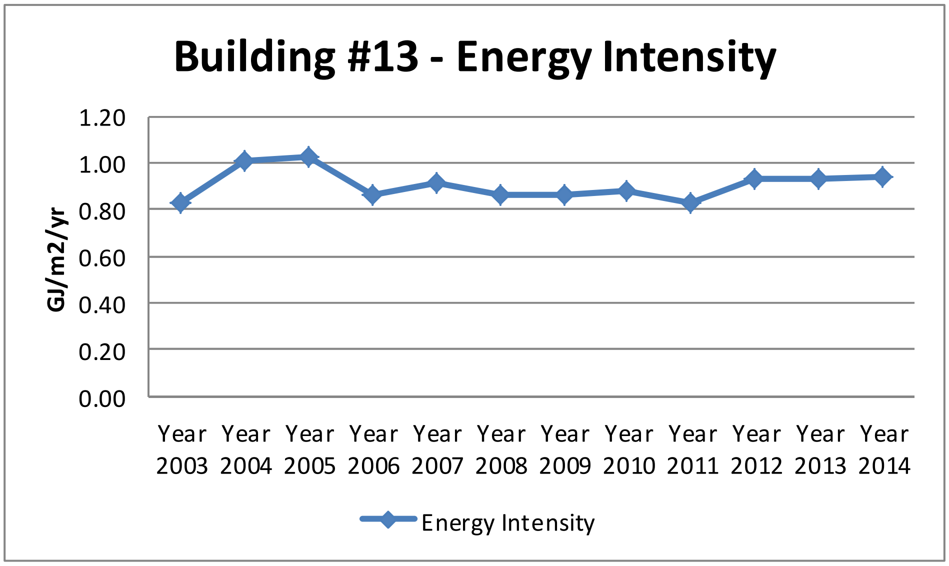
As it was specified in energy audit, energy consumption of the Building #13 is average in comparison to similar office buildings in same region; and therefore average energy index which equals to 0.91 $GJ/m^2/yr$ is also high in comparison to benchmark values of BOMA energy efficient building value of 1.05 $GJ/m^2/yr$, however value is much lower than average National Resources Canada value of 1.43GJ/m2/year.

Two charts below show electricity and gas consumption per year. Electricity consumption chart demonstrates prominent increase in energy usage. Gas consumption chart also shows increase in energy use with couple of high gas consumption values in 2004 and 2005.





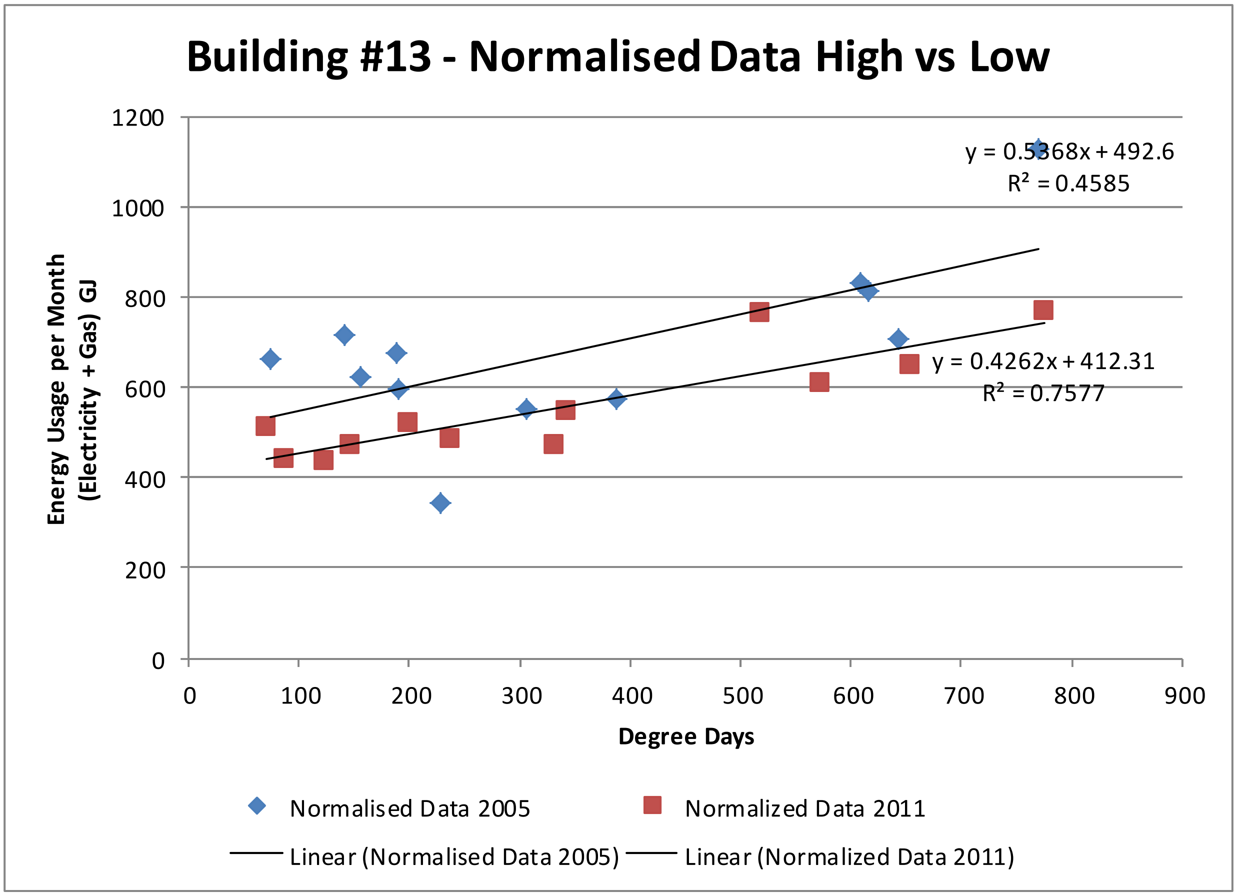
Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. Chart below shows that energy index value relatively steady starting in 2006. The lowest energy index was in 2011 and highest in 2005. These two years' data will be used for further calculations and comparisons.



Normalized total energy consumption was calculated for Building #13. Based on plotted results, shown below in the chart, it can be concluded that energy consumption for 2005 is higher than for 2011. This proves that regardless of weather conditions 2005 has higher energy consumptions than in 2011. Implementing trendline equations, average equation was calculated:

$$y = 0.4815x + 452.455$$

From above equation normalized average energy index was calculated as 0.92 $GJ/m^2/yr$, this value is slightly higher than average for 2003 to 2014 years range. Calculated value will be used for further case-study buildings comparison.



Building #13 - Normalised Data High vs Low
y = 0.5368x + 492.6
R² = 0.4585
y = 0.4262x + 412.31
R² = 0.7577
Energy Usage per Month (Electricity + Gas) GJ
1200
1000
800
600
400
200
0
0
100
200
300
400
500
600
700
800
900
Degree Days
Normalised Data 2005
Normalized Data 2011
Linear (Normalised Data 2005)
Linear (Normalized Data 2011)

Actual data used for calculations (year with highest energy consumption):

ADDRESS:	Building M - Vaudreuil-Dorion, Quebec
BUILDING #	13
Year - Highest Energy Consumption:	2005
AREA:	8,022
USAGE INDEX:	1.03

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	31/01/2005	28/02/2005	31/03/2005	30/04/2005	31/05/2005	30/06/2005	31/07/2005	31/08/2005	30/09/2005	31/10/2005	30/11/2005	31/12/2005
Electric Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
Gas Billing Date	31/01/2005	28/02/2005	31/03/2005	30/04/2005	31/05/2005	30/06/2005	31/07/2005	31/08/2005	30/09/2005	31/10/2005	30/11/2005	31/12/2005
Gas Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	0	1	146	189	141	52	8	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	0	0	5	6	5	2	0	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	770	616	609	307	189	9	0	0	23	220	388	643
Daily Htg. D.D. Avg. (Highest Year)	25	22	20	10	6	0	0	0	1	7	13	21
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	254,220	223,410	230,580	153,510	165,480	173,040	187,980	198,450	183,810	95,010	158,490	195,840
Daily kWh Avg.	8,201	7,979	7,438	5,117	5,338	5,768	6,064	6,402	6,127	3,065	5,283	6,317
Demand kW/RkVA Used	599	605	660	467	476	484	470	490	496	303	516	497
Load Factor (Highest Year)	57%	55%	47%	46%	47%	50%	54%	54%	51%	42%	43%	53%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	5,691	271	76	0	0	0	0	0	0	64	87	95
Daily m^3 Avg.	184	10	2	0	0	0	0	0	0	2	3	3
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	211,296	152,212	155,655	103,270	111,323	116,409	126,459	133,503	123,654	64,369	107,236	132,419
S02 (kgs) (Highest Year)	2,283	1,645	1,682	1,116	1,203	1,258	1,366	1,442	1,336	695	1,159	1,431
N0x (kgs) (Highest Year)	1,001	721	737	489	527	551	599	632	586	305	508	627
USAGE DATA												
kWh to GJ	915.19	804.28	830.09	552.64	595.73	622.94	676.73	714.42	661.72	342.04	570.56	705.02
GJ/m2/Day ELECTRIC (Highest Year)	0.004	0.004	0.003	0.002	0.002	0.003	0.003	0.003	0.003	0.001	0.002	0.003
GJ/m2/Month (Highest Year)	0.11	0.10	0.10	0.07	0.07	0.08	0.08	0.09	0.08	0.04	0.07	0.09
m3 to GJ	211.71	10.08	2.83	0.00	0.00	0.00	0.00	0.00	0.00	2.38	3.24	3.53
GJ/m2/Day GAS (Highest Year)	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GJ/m2/Month	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
m3/m2/Month	0.71	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
GJ/m2/Day ENERGY (Highest Year)	0.005	0.004	0.003	0.002	0.002	0.003	0.003	0.003	0.003	0.001	0.002	0.003
GJ/m2/Month (Highest Consumption Year)	0.140	0.102	0.104	0.069	0.074	0.078	0.084	0.089	0.082	0.043	0.072	0.088

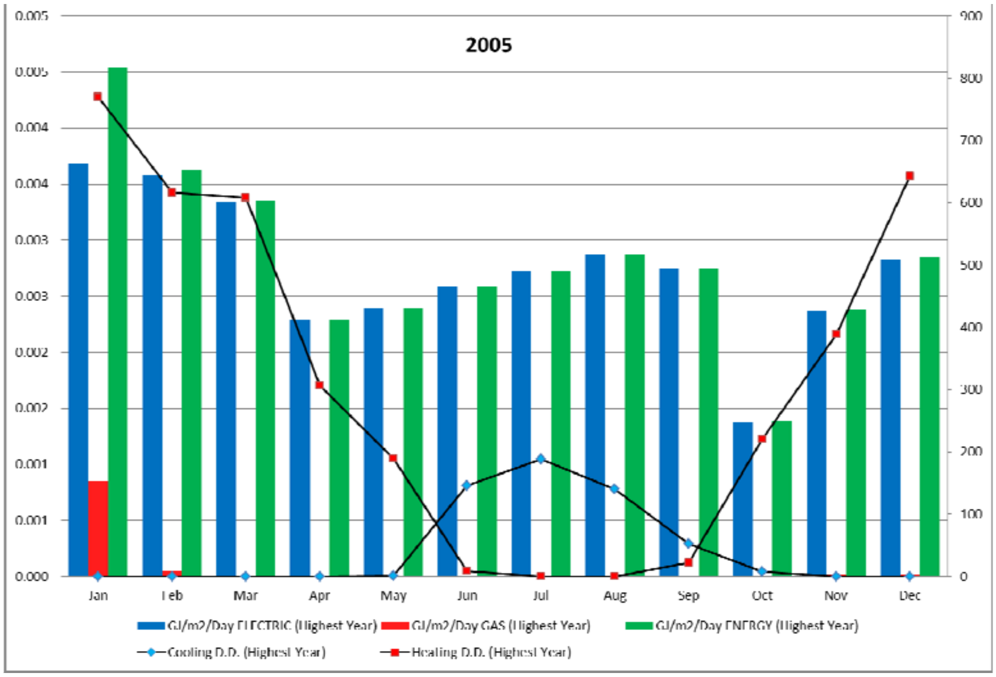
Energy Usage per Month (Electricity + Gas)	1127	814	833	553	596	623	677	714	662	344	574	709
Degree Days	770	616	609	307	190	155	189	141	75	228	388	643

Actual data used for calculations (year with lowest energy consumption):

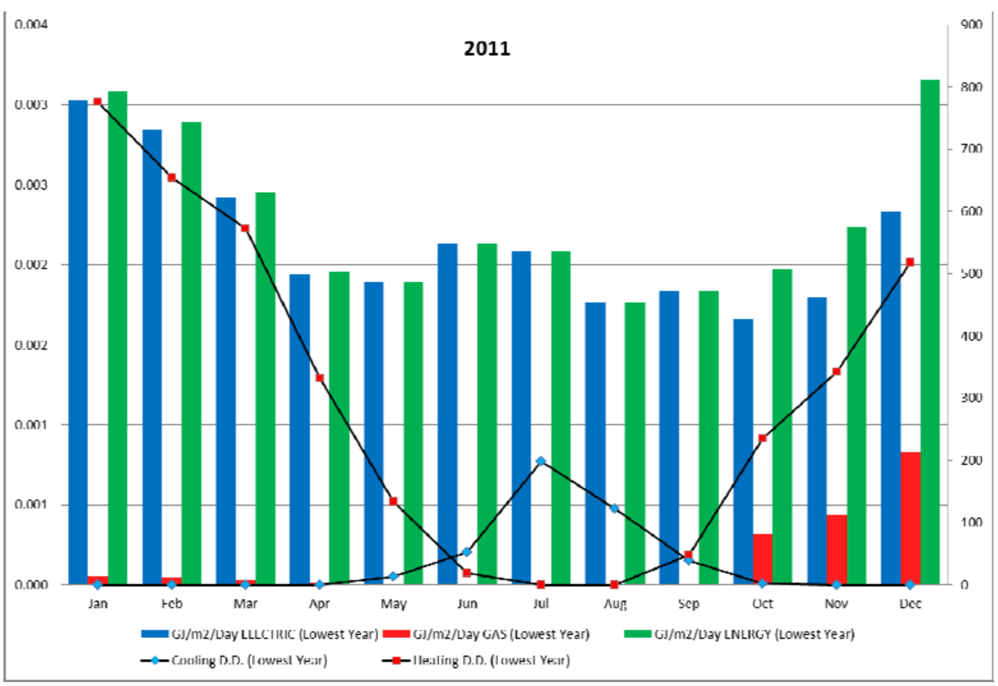
ADDRESS:	Building M - Vaudreuil-Dorion, Quebec			
BUILDING #	13			
Year - Lowest Energy Consumption:	2011			
AREA:	8,022			
USAGE INDEX:	0.83	AVERAGE:	0.9289	0.92085

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	31/01/2011	28/02/2011	31/03/2011	30/04/2011	31/05/2011	30/06/2011	31/07/2011	31/08/2011	30/09/2011	31/10/2011	30/11/2011	30/12/2011
Electric Billing Days	31	28	31	30	31	30	31	31	30	31	30	30
Gas Billing Date	03/02/2012	02/03/2012	04/04/2012	04/05/2012	06/06/2012	05/07/2012	07/08/2012	04/09/2012	04/10/2012	02/11/2012	04/12/2012	04/01/2013
Gas Billing Days	31	28	33	30	33	29	33	28	30	29	32	31
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	0	13	52	199	122	39	2	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	0	0	2	6	4	1	0	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	775	654	573	332	134	19	0	0	48	235	342	518
Daily Htg. D.D. Avg. (Lowest Year)	25	23	17	11	4	1	0	0	2	8	11	17
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	209,160	177,210	167,040	129,780	130,920	142,530	144,210	121,620	122,640	114,810	120,000	155,730
Daily kWh Avg.	6,747	6,329	5,062	4,326	3,967	4,915	4,370	4,344	4,088	3,959	3,750	5,024
Demand kW/RkVA Used	550	485	494	409	370	392	378	383	371	328	329	407
Load Factor (Lowest Year)	51%	54%	45%	44%	48%	51%	51%	43%	46%	47%	51%	53%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	374	303	224	102	0	0	0	0	0	1,957	3,051	5,529
Daily m^3 Avg.	12	11	7	3	0	0	0	0	0	67	95	178
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	143,354	121,358	113,958	88,028	88,073	95,884	97,014	81,817	82,503	91,086	102,319	143,893
S02 (kgs) (Lowest Year)	1,549	1,311	1,231	951	952	1,036	1,048	884	891	984	1,105	1,555
N0x (kgs) (Lowest Year)	679	575	540	417	417	454	460	388	391	431	485	682
USAGE DATA												
kWh to GJ	752.98	637.96	601.34	467.21	471.31	513.11	519.16	437.83	441.50	413.32	432.00	560.63
GJ/m2/Day ELECTRIC (Lowest Year)	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
GJ/m2/Month (Lowest Year)	0.09	0.08	0.07	0.06	0.06	0.06	0.06	0.05	0.06	0.05	0.05	0.07
m3 to GJ	13.91	11.27	8.33	3.79	0.00	0.00	0.00	0.00	0.00	72.80	113.50	205.68
GJ/m2/Day GAS (Lowest Year)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
GJ/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03
m3/m2/Month	0.05	0.04	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.24	0.38	0.69
GJ/m2/Day ENERGY (Lowest Year)	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003
GJ/m2/Month (Lowest Consumption Year)	0.096	0.081	0.076	0.059	0.059	0.064	0.065	0.055	0.055	0.061	0.068	0.096
Average Highest Year to Lowest Year	0.118	0.091	0.090	0.064	0.067	0.071	0.075	0.072	0.069	0.052	0.070	0.092
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Gas)	767	649	610	471	471	513	519	438	442	486	545	766
Degree Days	775	654	573	332	147	71	199	122	87	238	342	518
Normalized Data (Average Degree Days)	700	643	564	345	140	82	160	110	99	223	410	589
Normalized Data (Av Energy Consumption)	789	762	724	619	520	492	530	506	500	560	650	736
Normalized Data (Av Energy Index / month)	0.098	0.095	0.090	0.077	0.065	0.061	0.066	0.063	0.062	0.070	0.081	0.092

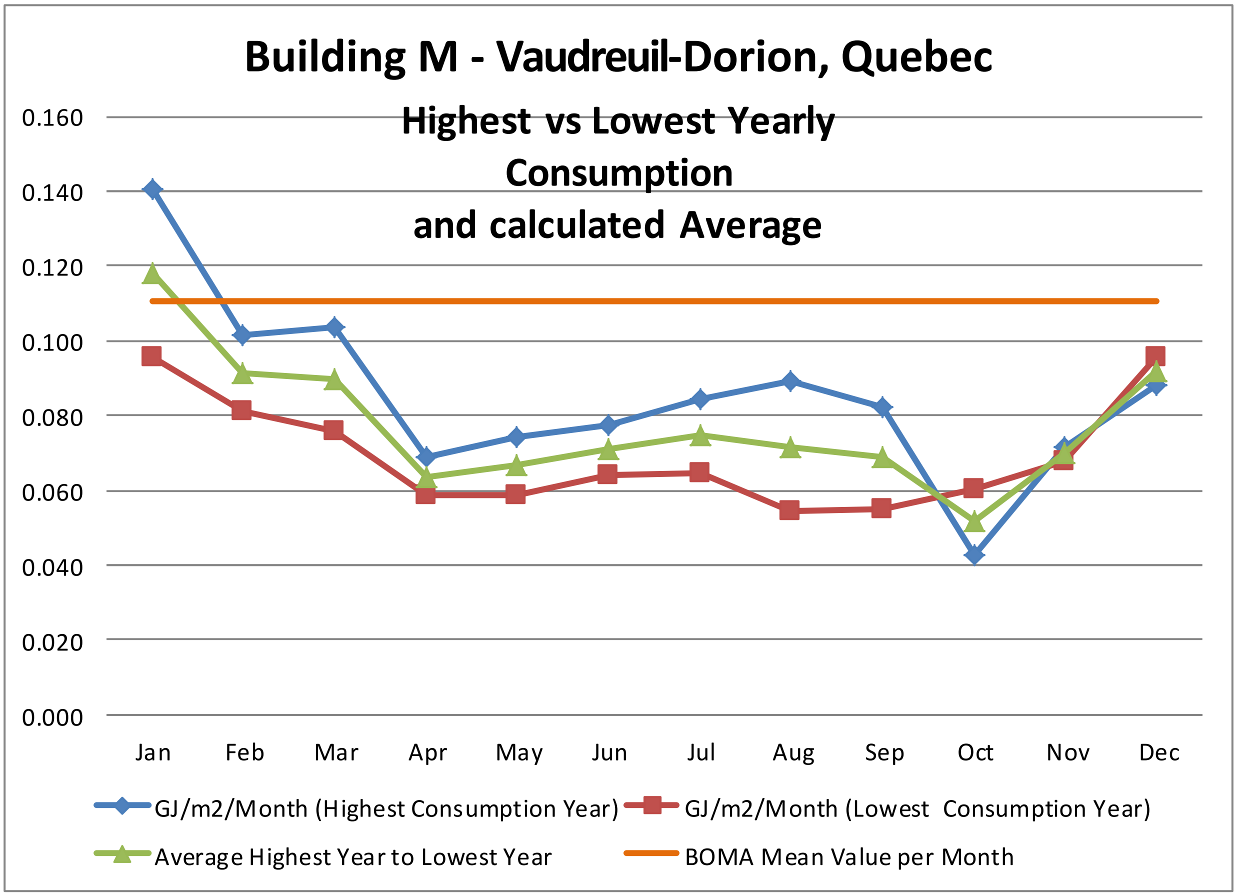
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Building #14 – Utility Bills Analysis

Calculations of Energy Index for Building #14

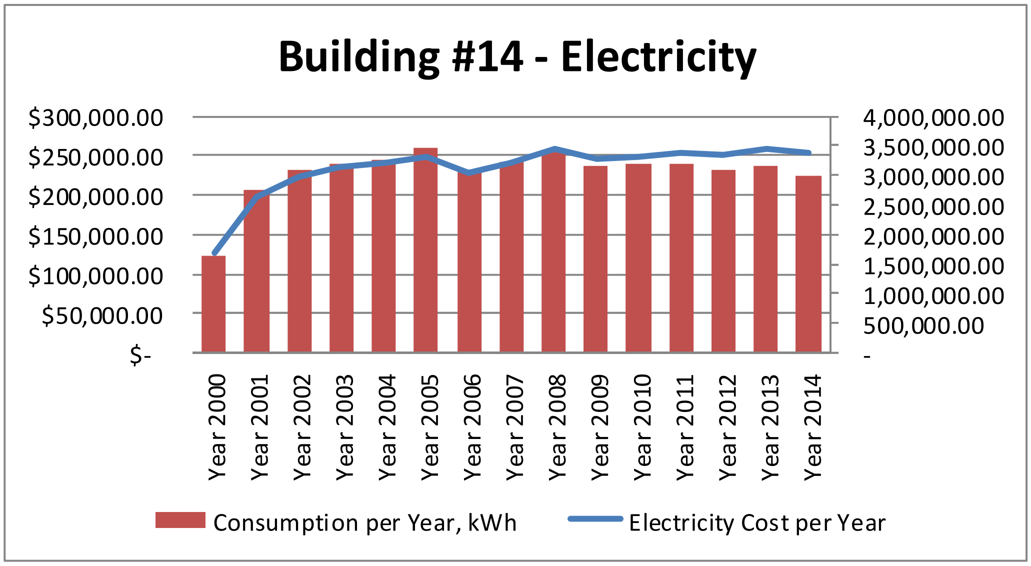
Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity only, as not gas is utilised in this building. For Building #14 utility bills were provided from December 1999 to March 2015. To complete most accurate analysis utility bills for 2000 to 2014 were only analyzed because 1999 and 2015 has incomplete data. By having total floor area for entire building of 7,943 m^2, energy index in GJ/m^2/year was calculated. From calculations it was noticed that yearly consumption provides consistent data throughout years, therefore all years will be used for calculations.

Utility bills analysis showed following:

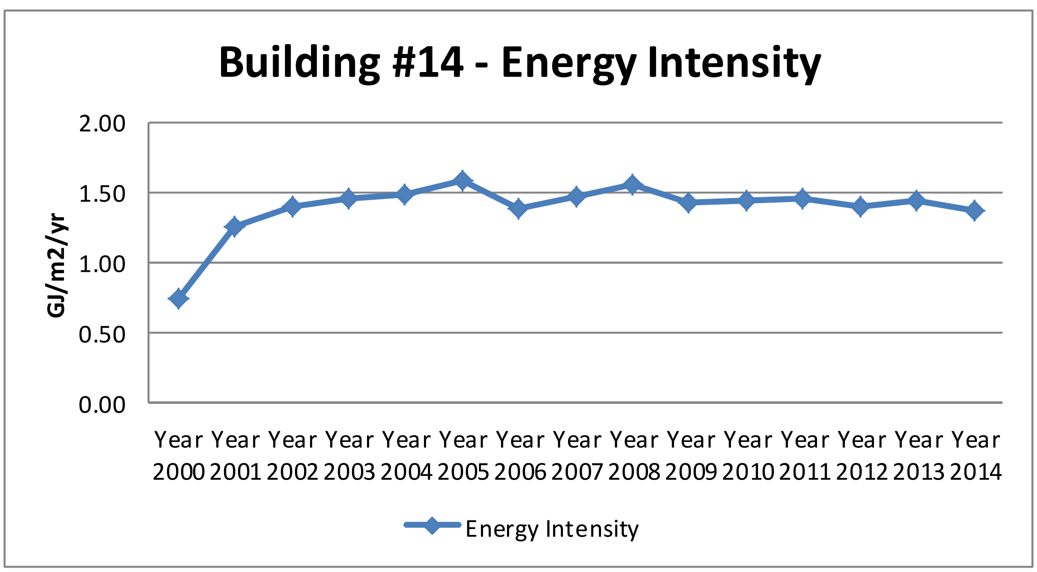
Building N - Côte-St-Luc, Quebec						
		kWh		m^3-ngas	Total GJ/yr	7,943.00
Row Labels	**Sum of Ele Total Cost / Year**	**Sum of Ele Consumption / Year**	**Sum of Gas Total Cost / Year**	**Sum of Gas Consumption / Year**	**Total**	**GJ/m2/yr**
Year 1999	$ 60,046.82	837,600.00				
Year 2000	$ 127,415.11	1,628,400.00			5,862.24	0.74
Year 2001	$ 198,171.97	2,769,600.00			9,970.56	1.26
Year 2002	$ 223,651.56	3,081,600.00			11,093.76	1.40
Year 2003	$ 235,667.15	3,191,600.00			11,489.76	1.45
Year 2004	$ 239,682.54	3,272,400.00			11,780.64	1.48
Year 2005	$ 248,677.25	3,472,800.00			12,502.08	1.57
Year 2006	$ 227,853.30	3,056,400.00			11,003.04	1.39
Year 2007	$ 240,558.36	3,236,400.00			11,651.04	1.47
Year 2008	$ 258,831.55	3,417,600.00			12,303.36	1.55
Year 2009	$ 245,117.35	3,153,600.00			11,352.96	1.43
Year 2010	$ 247,131.35	3,181,200.00			11,452.32	1.44
Year 2011	$ 252,991.18	3,201,600.00			11,525.76	1.45
Year 2012	$ 249,643.25	3,091,200.00			11,128.32	1.40
Year 2013	$ 258,750.26	3,157,200.00			11,365.92	1.43
Year 2014	$ 254,123.31	3,001,200.00			10,804.32	1.36
Year 2015	$ 113,645.04	1,338,600.00				
Average	**$ 233,884.37**	**3,060,853.33**				**1.39**

As it was specified in energy audit, energy consumption of the Building #14 is relatively high in comparison to similar office buildings in same region; and therefore average energy index which equals to 1.39 GJ/m^2/yr is also high in comparison to benchmark values of BOMA energy efficient building value of 1.05 GJ/m^2/yr, and then average National Resources Canada value of 1.43GJ/m2/year.

Charts below show electricity consumption per year. Electricity consumption chart demonstrates increase in energy usage.



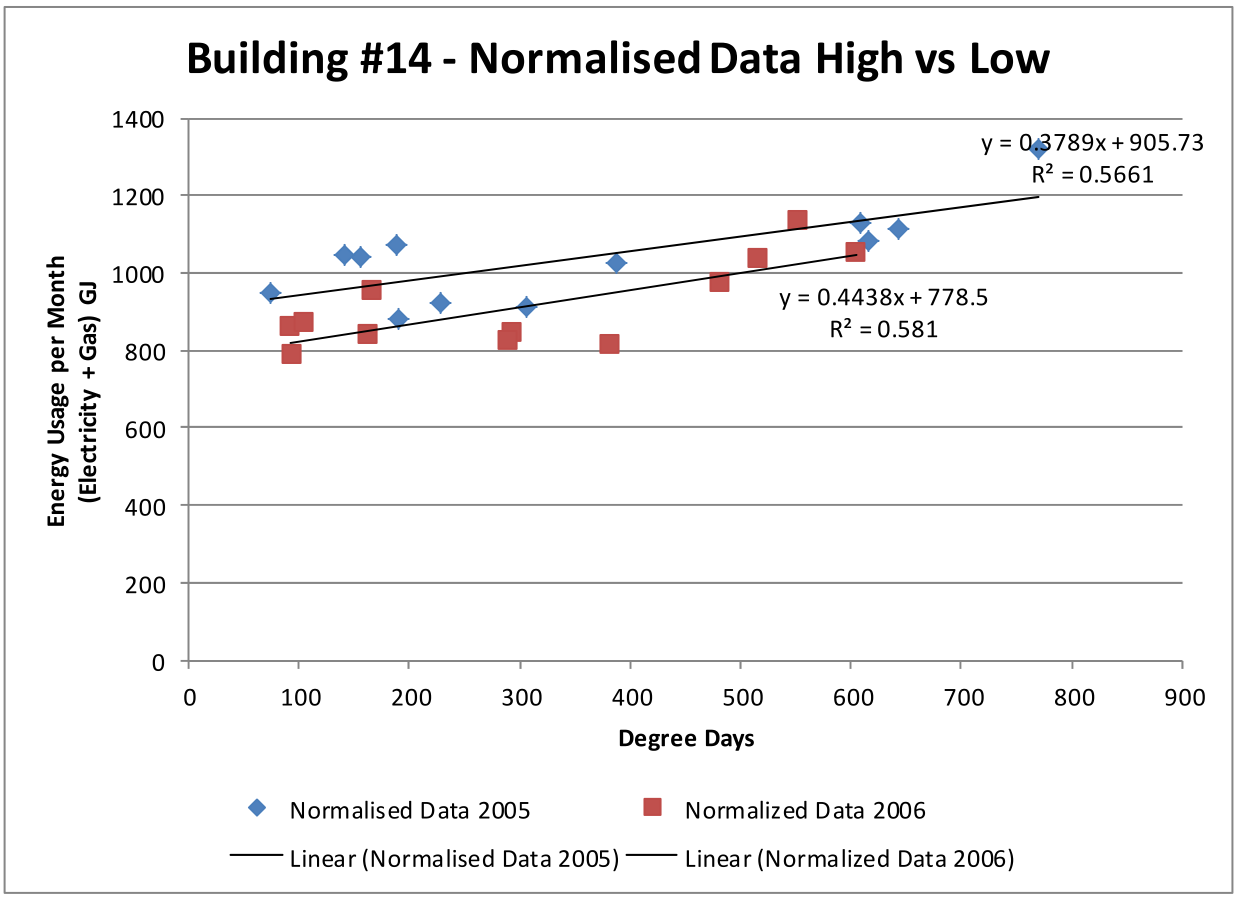
Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. Chart below shows that energy index value is very steady throughout years. The lowest energy index was in 2000 and highest in 2005, however 2006 and 2005 years will be used for further calculation to reflect more recent years' data. These two years' data will be used for further calculations and comparisons.



Normalized total energy consumption was calculated for Building #14. Based on plotted results, shown below in the chart, it can be concluded that energy consumption for 2013 is higher than for 2011. This proves that regardless of weather conditions 2013 has higher energy consumptions than in 2011. Implementing trendline equations, average equation was calculated:

$$y = 0.4114x + 842.115$$

From above equation normalized average energy index was calculated as 1.47 GJ/m^2/yr, this value is higher than average for 2000 to 2014 years range. Calculated value will be used for further case-study buildings comparison.



Actual data used for calculations (year with highest energy consumption):

ADDRESS:	**Building N - Côte-St-Luc, Quebec**
BUILDING #	14
Year - Highest Energy Consumption:	2005
AREA:	**7,943**
USAGE INDEX:	**1.57**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	31/01/2005	28/02/2005	31/03/2005	30/04/2005	31/05/2005	30/06/2005	31/07/2005	31/08/2005	30/09/2005	31/10/2005	30/11/2005	31/12/2005
Electric Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
Gas Billing Date	31/01/2005	28/02/2005	31/03/2005	30/04/2005	31/05/2005	30/06/2005	31/07/2005	31/08/2005	30/09/2005	31/10/2005	30/11/2005	31/12/2005
Gas Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	0	1	146	189	141	52	8	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	0	0	5	6	5	2	0	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	770	616	609	307	189	9	0	0	23	220	388	643
Daily Htg. D.D. Avg. (Highest Year)	25	22	20	10	6	0	0	0	1	7	13	21
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	367,200	301,200	313,200	253,200	244,800	289,200	297,600	290,400	264,000	256,800	285,600	309,600
Daily kWh Avg.	11,845	10,757	10,103	8,440	7,897	9,640	9,600	9,368	8,800	8,284	9,520	9,987
Demand kW/RkVA Used	682	614	610	475	452	572	570	508	511	487	574	566
Load Factor (Highest Year)	72%	73%	69%	74%	73%	70%	70%	77%	72%	71%	69%	73%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	0	0	0	0	0	0	0	0	0	0	0	0
Daily m^3 Avg.	0	0	0	0	0	0	0	0	0	0	0	0
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	247,025	202,625	210,698	170,335	164,684	194,553	200,204	195,360	177,600	172,756	192,131	208,276
S02 (kgs) (Highest Year)	2,669	2,189	2,276	1,840	1,779	2,102	2,163	2,111	1,919	1,866	2,076	2,250
N0x (kgs) (Highest Year)	1,170	960	998	807	780	921	948	925	841	818	910	986
USAGE DATA												
kWh to GJ	1321.92	1084.32	1127.52	911.52	881.28	1041.12	1071.36	1045.44	950.40	924.48	1028.16	1114.56
GJ/m2/Day ELECTRIC (Highest Year)	0.005	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005
GJ/m2/Month (Highest Year)	0.17	0.14	0.14	0.11	0.11	0.13	0.13	0.13	0.12	0.12	0.13	0.14
m3 to GJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GJ/m2/Day GAS (Highest Year)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GJ/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
m3/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GJ/m2/Day ENERGY (Highest Year)	0.005	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005
GJ/m2/Month (Highest Consumption Year)	0.166	0.137	0.142	0.115	0.111	0.131	0.135	0.132	0.120	0.116	0.129	0.140

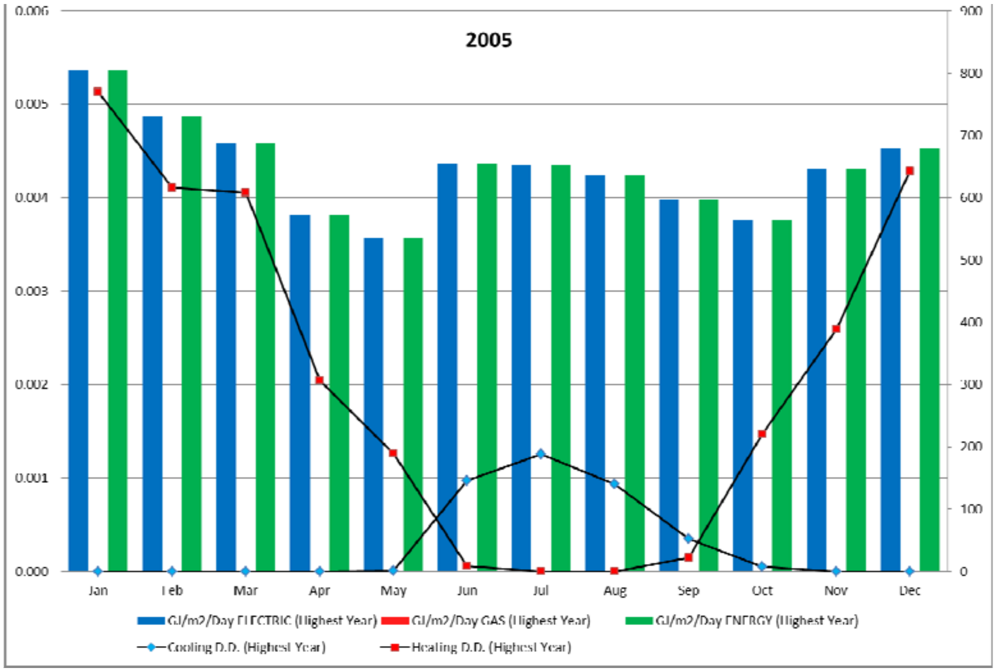
Energy Usage per Month (Electricity + Gas)	1322	1084	1128	912	881	1041	1071	1045	950	924	1028	1115
Degree Days	770	616	609	307	190	155	189	141	75	228	388	643

Actual data used for calculations (year with lowest energy consumption):

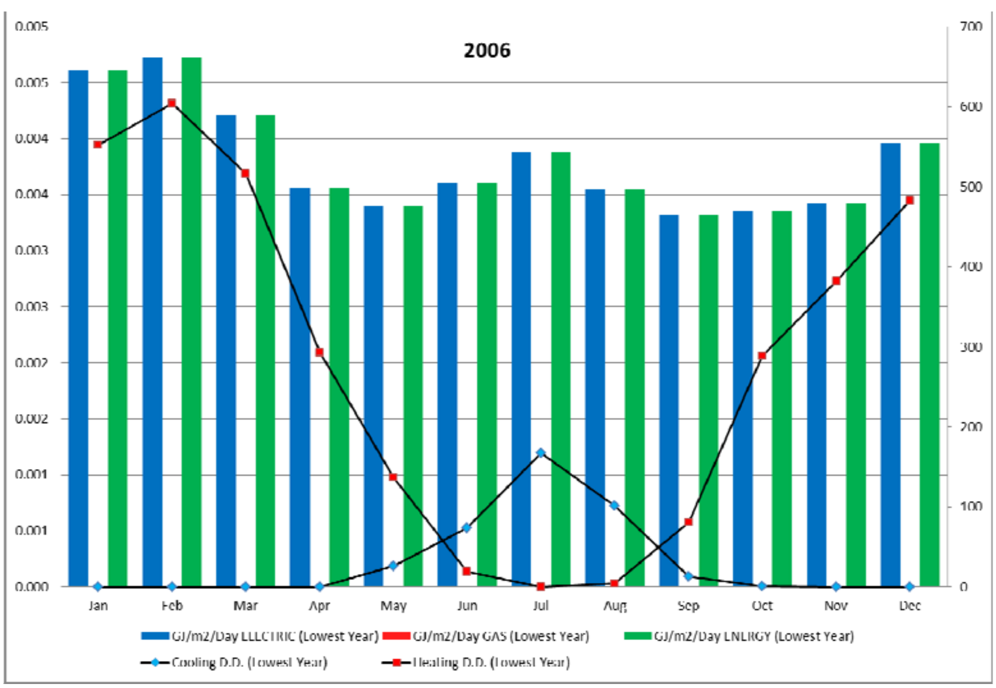
ADDRESS:	Building N - Côte-St-Luc, Quebec			
BUILDING #	14			
Year - Lowest Energy Consumption:	2006			
AREA:	7,943			
USAGE INDEX:	1.39	AVERAGE:	1.4796	1.47463

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	31/01/2006	28/02/2006	31/03/2006	30/04/2006	31/05/2006	30/06/2006	31/07/2006	31/08/2006	30/09/2006	31/10/2006	30/11/2006	31/12/2006
Electric Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
Gas Billing Date	31/01/2006	28/02/2006	31/03/2006	30/04/2006	31/05/2006	30/06/2006	31/07/2006	31/08/2006	30/09/2006	31/10/2006	30/11/2006	31/12/2006
Gas Billing Days	31	28	31	30	31	30	31	31	30	31	30	31
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	0	26	74	167	102	13	1	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	0	1	2	5	3	0	0	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	552	604	517	293	137	20	0	4	81	288	382	483
Daily Htg. D.D. Avg. (Lowest Year)	18	22	17	10	4	1	0	0	3	9	13	16
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	315,600	291,600	288,000	235,200	232,800	238,800	265,200	242,400	219,600	229,200	226,800	271,200
Daily kWh Avg.	10,181	10,414	9,290	7,840	7,510	7,960	8,555	7,819	7,320	7,394	7,560	8,748
Demand kW/RkVA Used	598	616	595	448	498	449	475	464	442	409	416	514
Load Factor (Lowest Year)	71%	70%	65%	73%	63%	74%	75%	70%	69%	75%	76%	71%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	0	0	0	0	0	0	0	0	0	0	0	0
Daily m^3 Avg.	0	0	0	0	0	0	0	0	0	0	0	0
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	212,313	196,167	193,745	158,225	156,611	160,647	178,407	163,069	147,731	154,189	152,575	182,444
S02 (kgs) (Lowest Year)	2,294	2,119	2,093	1,709	1,692	1,736	1,928	1,762	1,596	1,666	1,648	1,971
N0x (kgs) (Lowest Year)	1,006	929	918	749	742	761	845	772	700	730	723	864
USAGE DATA												
kWh to GJ	1136.16	1049.76	1036.80	846.72	838.08	859.68	954.72	872.64	790.56	825.12	816.48	976.32
GJ/m2/Day ELECTRIC (Lowest Year)	0.005	0.005	0.004	0.004	0.003	0.004	0.004	0.004	0.003	0.003	0.003	0.004
GJ/m2/Month (Lowest Year)	0.14	0.13	0.13	0.11	0.11	0.11	0.12	0.11	0.10	0.10	0.10	0.12
m3 to GJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GJ/m2/Day GAS (Lowest Year)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GJ/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
m3/m2/Month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GJ/m2/Day ENERGY (Lowest Year)	0.005	0.005	0.004	0.004	0.003	0.004	0.004	0.004	0.003	0.003	0.003	0.004
GJ/m2/Month (Lowest Consumption Year)	0.143	0.132	0.131	0.107	0.106	0.108	0.120	0.110	0.100	0.104	0.103	0.123
Average Highest Year to Lowest Year	0.155	0.134	0.136	0.111	0.108	0.120	0.128	0.121	0.110	0.110	0.116	0.132
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Gas)	1136	1050	1037	847	838	860	955	873	791	825	816	976
Degree Days	552	604	517	293	163	93	167	106	94	289	382	483
Normalized Data (Average Degree Days)	588	618	536	326	148	93	145	102	102	249	430	572
Normalized Data (Av Energy Consumption)	1084	1096	1062	976	903	880	902	884	884	945	1019	1077
Normalized Data (Av Energy Index / month)	0.136	0.138	0.134	0.123	0.114	0.111	0.114	0.111	0.111	0.119	0.128	0.136

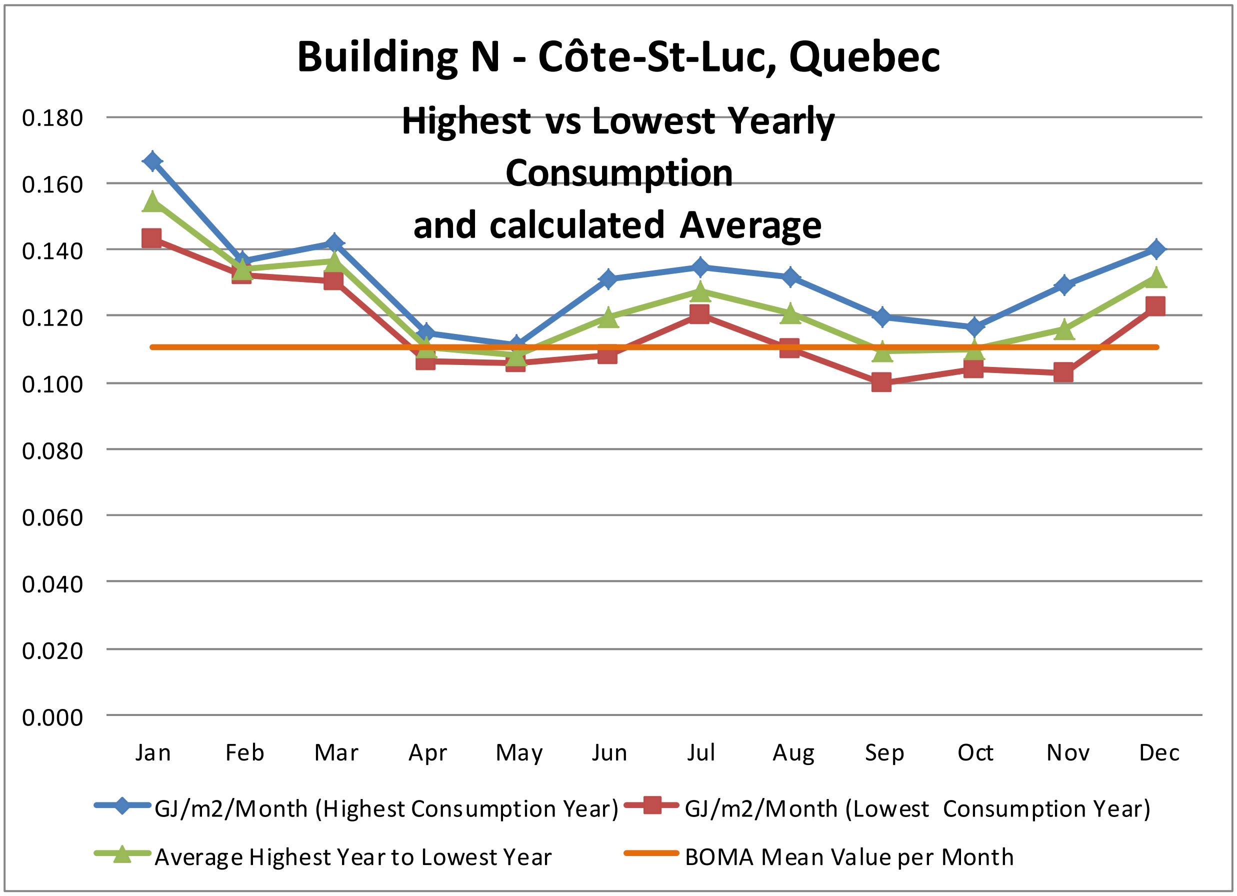
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Building #15 – Utility Bills Analysis

Calculations of Energy Index for Building #15

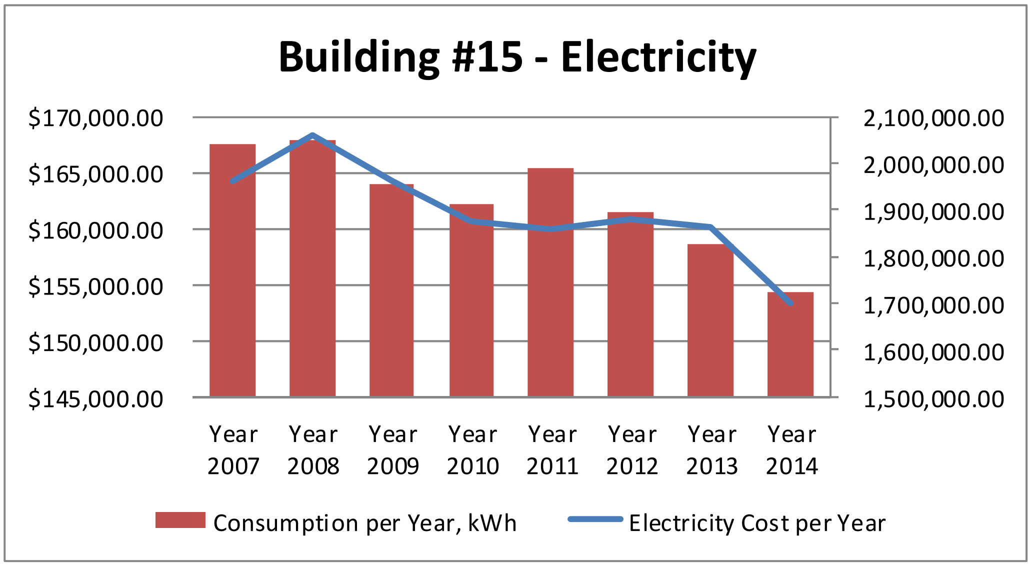
Energy CAP database was utilized to collect energy consumption information for the building. Energy consumption was provided by utility bills for electricity and gas. For Building #15 utility bills were provided from December 2006 to March 2015. To complete most accurate analysis utility bills for 2007 to 2014 were only analyzed because 2006 and 2015 has incomplete data. By having total floor area for entire building of 5,518 m^2, energy index in GJ/m^2/year was calculated. From calculations it was noticed that electrical utility bills data was consistent throughout years, however gas consumption in 2007 showed lower value in comparison to other years, after analysing utility bills in more details it was concluded that gas bills for 2007 provided incomplete information. Therefore 2007 was excluded from further calculations.

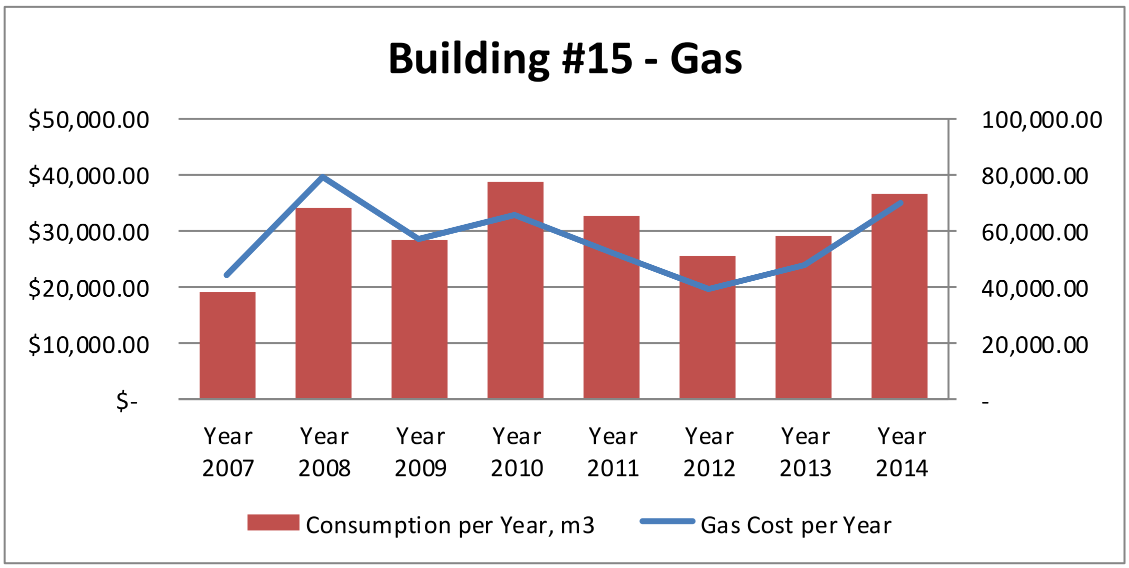
Utility bills analysis showed following:

Building O - Gatineau, Quebec						
		kWh		m³-ngas	Total GJ/yr	5,518.00
Row Labels	**Sum of Ele Total Cost / Year**	**Sum of Ele Consumption / Year**	**Sum of Gas Total Cost / Year**	**Sum of Gas Consumption / Year**	**Total**	**GJ/m2/yr**
Year 2006	$ 31,318.60	311,000.00	$ 374.09	842.00		
Year 2007	$ 164,142.20	2,039,760.00	$ 22,029.21	38,282.00	8,767.23	1.59
Year 2008	$ 168,291.14	2,050,800.00	$ 39,369.68	68,116.00	9,916.80	1.80
Year 2009	$ 164,229.61	1,953,360.00	$ 28,490.79	56,888.00	9,148.33	1.66
Year 2010	$ 160,678.74	1,911,120.00	$ 32,887.37	77,227.00	9,752.88	1.77
Year 2011	$ 159,909.60	1,989,600.00	$ 25,887.21	65,179.00	9,587.22	1.74
Year 2012	$ 160,769.69	1,895,280.00	$ 19,638.44	50,486.00	8,701.09	1.58
Year 2013	$ 160,200.71	1,826,160.00	$ 23,631.94	58,127.00	8,736.50	1.58
Year 2014	$ 153,304.00	1,725,600.00	$ 34,948.78	72,948.61	8,925.85	1.62
Year 2015	$ 69,009.91	751,320.00	$ 22,851.39	42,916.00		
Average	**$ 161,054.78**	**1,907,417.14**	**$ 29,264.89**	**64,138.80**		**1.68**

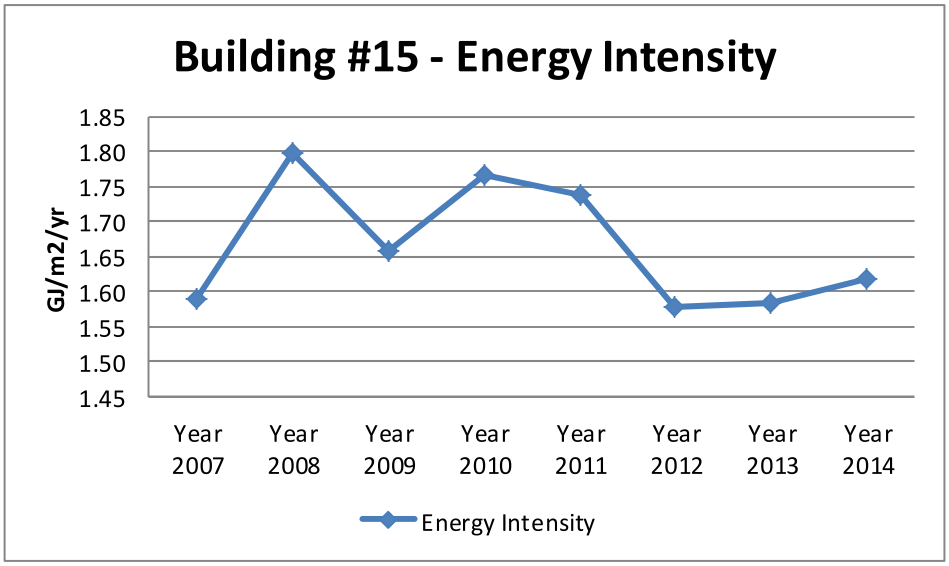
As it was specified in energy audit, energy consumption of the Building #15 is moderately high in comparison to similar office buildings in same region; and therefore average energy index which equals to 1.68 GJ/m^2/yr is also high in comparison to benchmark values of BOMA energy efficient building value of 1.05 GJ/m^2/yr, and then average National Resources Canada value of 1.43GJ/m2/year..

Two charts below show electricity and gas consumption per year. Electricity consumption chart demonstrates prominent decrease in energy usage, with 2013 and 2014 having the lowest values. On the other hand gas consumption chart show increase in energy consumption with 2014 much higher than previous years.





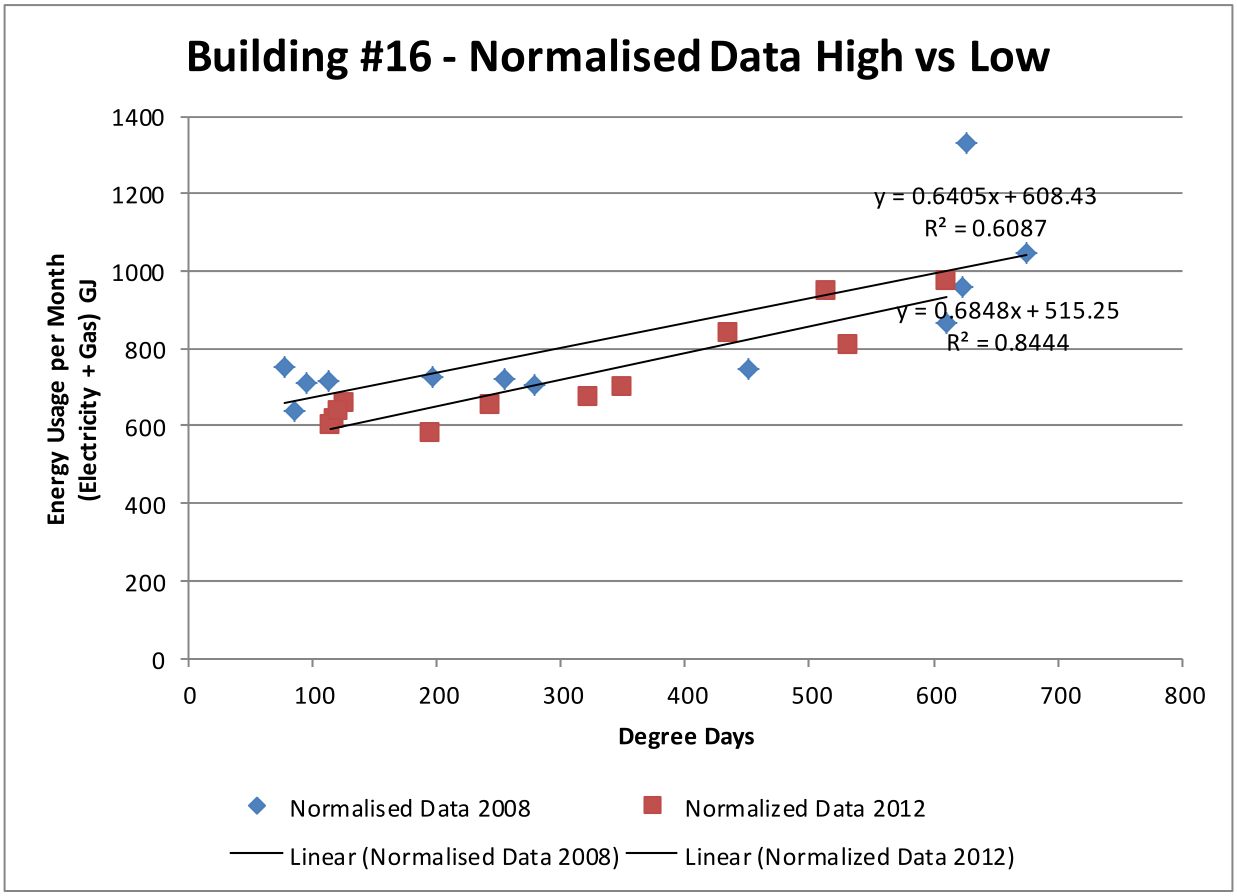
Yearly energy intensity (index) was also plotted to demonstrate increase or decrease over the range of years for which data is available. Chart below shows that energy index value is gradually decreasing with few jumps in 2008 and 2010. The lowest energy index was in 2012 and highest in 2008. These two years' data will be used for further calculations and comparisons.



Normalized total energy consumption was calculated for Building #15. Based on plotted results, shown below in the chart, it can be concluded that energy consumption for 2008 is higher than for 2012. This proves that regardless of weather conditions 2008 has higher energy consumptions than in 2012. Implementing trendline equations, average equation was calculated:

$$y = 0.6627x + 561.84$$

From above equation normalized average energy index was calculated as 1.69 GJ/m^2/yr, this value is slightly higher than average for 2007 to 2014 years range. Calculated value will be used for further case-study buildings comparison.


Building #16 - Normalised Data High vs Low
Energy Usage per Month (Electricity + Gas) GJ
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
600
700
800
Degree Days
y = 0.6405x + 608.43
R² = 0.6087
y = 0.6848x + 515.25
R² = 0.8444
Normalised Data 2008
Normalized Data 2012
Linear (Normalised Data 2008)
Linear (Normalized Data 2012)

Actual data used for calculations (year with highest energy consumption):

ADDRESS:	**Building O - Gatineau, Quebec**
BUILDING #	15
Year - Highest Energy Consumption:	2008
AREA:	**5,518**
USAGE INDEX:	**1.80**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	31/01/2008	03/03/2008	01/04/2008	01/05/2008	02/06/2008	03/07/2008	01/08/2008	02/09/2008	02/10/2008	03/11/2008	03/12/2008	06/01/2009
Electric Billing Days	31	32	29	30	32	31	29	32	30	32	30	34
Gas Billing Date	01/02/2008	04/03/2008	02/04/2008	01/05/2008	30/05/2008	02/07/2008	29/07/2008	02/09/2008	29/09/2008	31/10/2008	27/11/2008	02/01/2009
Gas Billing Days	31	32	29	29	29	33	27	35	27	32	27	36
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Highest Year)	0	0	0	0	3	72	111	64	27	0	0	0
Daily Clg D.D. Avg. (Highest Year)	0	0	0	0	0	2	4	2	1	0	0	0
Normal Cooling D.D. (Highest Year)												
Heating D.D. (Highest Year)	624	675	610	254	194	23	1	13	59	279	452	627
Daily Htg. D.D. Avg. (Highest Year)	20	21	21	9	7	1	0	0	2	9	17	17
Normal Heating D.D (Highest Year)												
ELECTRICAL USAGE & COST												
kWh Used	205,200	182,400	149,760	147,840	146,400	164,880	164,160	170,160	150,720	153,120	170,880	245,280
Daily kWh Avg.	6,619	5,700	5,164	5,098	5,048	4,996	6,080	4,862	5,582	4,785	6,329	6,813
Demand kW/RkVA Used	371	348	329	332	305	335	359	342	346	308	339	408
Load Factor (Highest Year)	74%	68%	66%	62%	63%	66%	66%	65%	61%	65%	70%	74%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	5,960	10,448	8,724	5,075	5,353	3,204	3,302	3,742	2,604	4,115	3,550	12,039
Daily m^3 Avg.	192	327	301	175	185	97	122	107	96	129	131	334
GREENHOUSE DATA												
C02 (kgs) (Highest Year)	180,223	196,647	162,488	135,372	136,371	133,594	133,803	140,954	119,822	132,130	140,079	250,208
S02 (kgs) (Highest Year)	1,947	2,125	1,756	1,463	1,473	1,443	1,446	1,523	1,295	1,428	1,513	2,703
N0x (kgs) (Highest Year)	854	931	770	641	646	633	634	668	568	626	663	1,185
USAGE DATA												
kWh to GJ	738.72	656.64	539.14	532.22	527.04	593.57	590.98	612.58	542.59	551.23	615.17	883.01
GJ/m2/Day ELECTRIC (Highest Year)	0.004	0.004	0.003	0.003	0.003	0.003	0.004	0.003	0.003	0.003	0.004	0.005
GJ/m2/Month (Highest Year)	0.13	0.12	0.10	0.10	0.10	0.11	0.11	0.11	0.10	0.10	0.11	0.16
m3 to GJ	221.71	388.67	324.53	188.79	199.13	119.19	122.83	139.20	96.87	153.08	132.06	447.85
GJ/m2/Day GAS (Highest Year)	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002
GJ/m2/Month	0.04	0.07	0.06	0.03	0.04	0.02	0.02	0.03	0.02	0.03	0.02	0.08
m3/m2/Month	1.08	1.89	1.58	0.92	0.97	0.58	0.60	0.68	0.47	0.75	0.64	2.18
GJ/m2/Day ENERGY (Highest Year)	0.006	0.006	0.005	0.004	0.004	0.004	0.005	0.004	0.004	0.004	0.005	0.007
GJ/m2/Month (Highest Consumption Year)	0.174	0.189	0.157	0.131	0.132	0.129	0.129	0.136	0.116	0.128	0.135	0.241

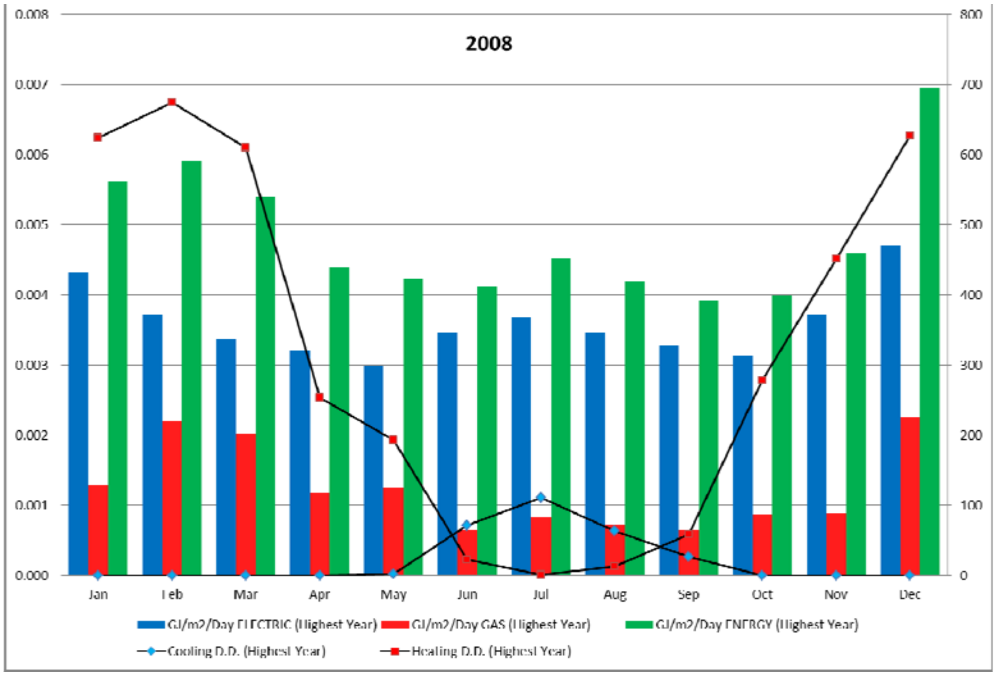
Energy Usage per Month (Electricity + Gas)	960	1045	864	721	726	713	714	752	639	704	747	1331
Degree Days	624	675	610	254	196	94	112	77	86	279	452	627

Actual data used for calculations (year with lowest energy consumption):

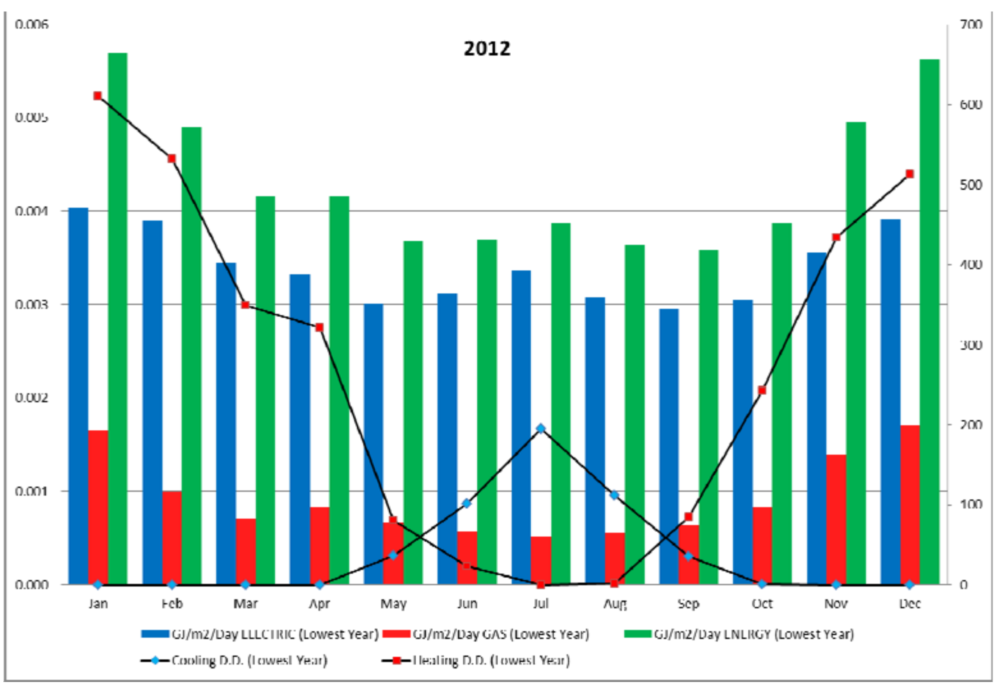
ADDRESS:	Building O - Gatineau, Quebec			
BUILDING #	15			
Year - Lowest Energy Consumption:	2012			
AREA:	5,518			
USAGE INDEX:	1.58	AVERAGE:	1.6870	1.68719

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Electric Billing Date	01/02/2012	02/03/2012	02/04/2012	01/05/2012	31/05/2012	02/07/2012	29/07/2012	28/08/2012	30/09/2012	30/10/2012	30/11/2012	30/12/2012
Electric Billing Days	31	30	31	29	30	32	27	30	33	30	31	30
Gas Billing Date	31/01/2012	01/03/2012	29/03/2012	29/04/2012	31/05/2012	03/07/2012	01/08/2012	30/08/2012	28/09/2012	30/10/2012	29/11/2012	31/12/2012
Gas Billing Days	31	30	28	31	32	33	29	29	29	32	30	32
COOLING & HEATING DEGREE DAYS												
Cooling D.D. (Lowest Year)	0	0	0	0	37	102	195	112	36	1	0	0
Daily Clg D.D. Avg. (Lowest Year)	0	0	0	0	1	3	7	4	1	0	0	0
Normal Cooling D.D. (Lowest Year)												
Heating D.D. (Lowest Year)	611	532	349	322	81	23	0	2	85	243	434	513
Daily Htg. D.D. Avg. (Lowest Year)	20	18	12	10	3	1	0	0	3	8	14	16
Normal Heating D.D (Lowest Year)												
ELECTRICAL USAGE & COST												
kWh Used	192,000	179,520	163,920	148,080	138,480	153,360	139,200	141,840	149,280	140,160	169,200	180,240
Daily kWh Avg.	6,194	5,984	5,854	4,777	4,328	4,647	4,800	4,891	5,148	4,380	5,640	5,633
Demand kW/RkVA Used	396	342	351	313	322	359	349	329	328	306	356	349
Load Factor (Lowest Year)	65%	73%	63%	68%	60%	56%	61%	60%	58%	64%	64%	72%
NATURAL GAS USAGE & COST												
CCF												
m^3 Used	7,588	4,442	2,962	3,811	3,190	2,817	2,221	2,413	2,769	3,957	6,218	8,098
Daily m^3 Avg.	245	148	106	123	100	85	77	83	95	124	207	253
GREENHOUSE DATA												
C02 (kgs) (Lowest Year)	182,865	152,204	131,236	126,588	115,735	123,106	109,362	112,497	120,021	122,294	157,831	178,563
S02 (kgs) (Lowest Year)	1,976	1,644	1,418	1,368	1,250	1,330	1,182	1,215	1,297	1,321	1,705	1,929
N0x (kgs) (Lowest Year)	866	721	622	600	548	583	518	533	568	579	748	846
USAGE DATA												
kWh to GJ	691.20	646.27	590.11	533.09	498.53	552.10	501.12	510.62	537.41	504.58	609.12	648.86
GJ/m2/Day ELECTRIC (Lowest Year)	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.004
GJ/m2/Month (Lowest Year)	0.13	0.12	0.11	0.10	0.09	0.10	0.09	0.09	0.10	0.09	0.11	0.12
m3 to GJ	282.27	165.24	110.19	141.77	118.67	104.79	82.62	89.76	103.01	147.20	231.31	301.25
GJ/m2/Day GAS (Lowest Year)	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002
GJ/m2/Month	0.05	0.03	0.02	0.03	0.02	0.02	0.01	0.02	0.02	0.03	0.04	0.05
m3/m2/Month	1.38	0.81	0.54	0.69	0.58	0.51	0.40	0.44	0.50	0.72	1.13	1.47
GJ/m2/Day ENERGY (Lowest Year)	0.006	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.006
GJ/m2/Month (Lowest Consumption Year)	0.176	0.147	0.127	0.122	0.112	0.119	0.106	0.109	0.116	0.118	0.152	0.172
Average Highest Year to Lowest Year	0.175	0.168	0.142	0.126	0.122	0.124	0.118	0.123	0.116	0.123	0.144	0.207
BOMA Mean Value per Month	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
Energy Usage per Month (Electricity + Gas)	973	812	700	675	617	657	584	600	640	652	840	950
Degree Days	611	532	350	322	117	125	195	114	121	244	434	513
Normalized Data (Average Degree Days)	618	582	452	340	125	108	159	106	116	226	456	587
Normalized Data (Av Energy Consumption)	971	947	861	787	645	634	667	632	639	712	864	951
Normalized Data (Av Energy Index / month)	0.176	0.172	0.156	0.143	0.117	0.115	0.121	0.115	0.116	0.129	0.157	0.172

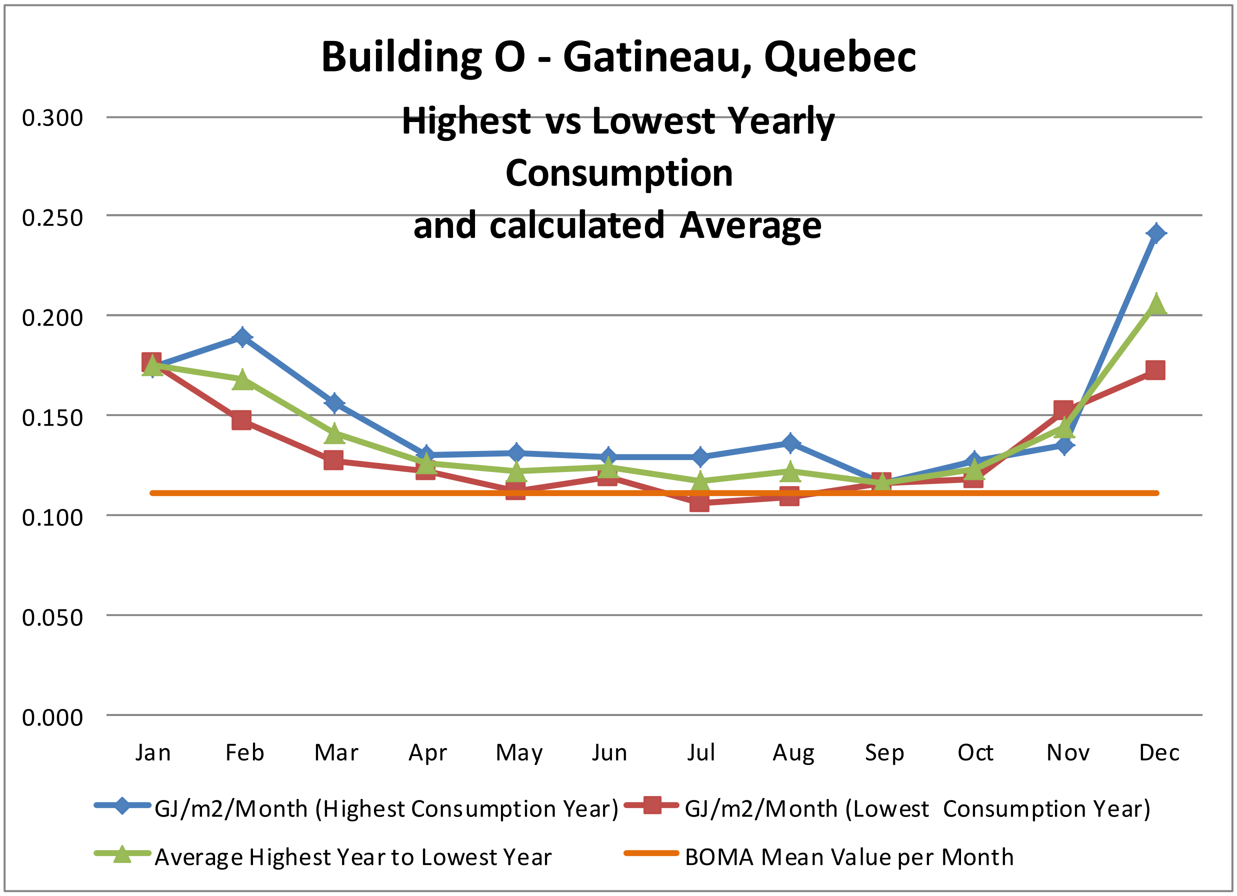
Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for highest energy consumption year):



Analysis on how electricity and gas consumption corresponds to heating and cooling periods (for lowest energy consumption year):



Monthly energy index comparison between highest energy consumption year, lowest, average and benchmark (BOMA) energy intensity:



Appendix 2

Appendix B

Window to Wall Ratio Calculations

“Assumption” 10-20% stands for mullions percentage assumption. WWR for each case-study building was calculated based on architectural drawings (for buildings #1, #2, #3 and #4). For those building where drawings weren’t available, vise visit was conducted or assumptions were made from building pictures available online (Google Earth).

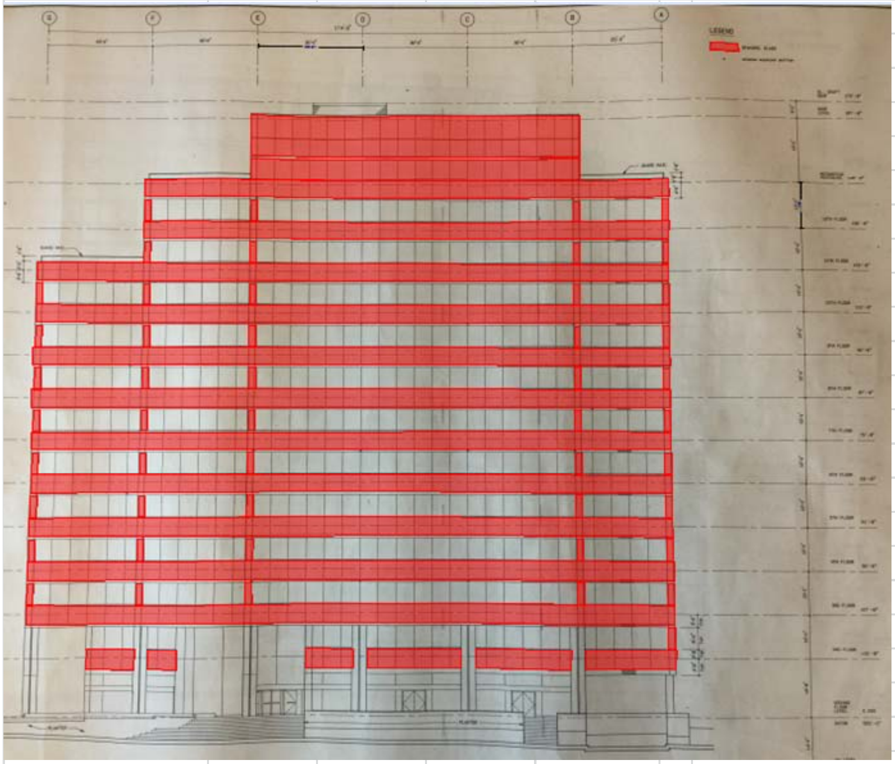
Building #1

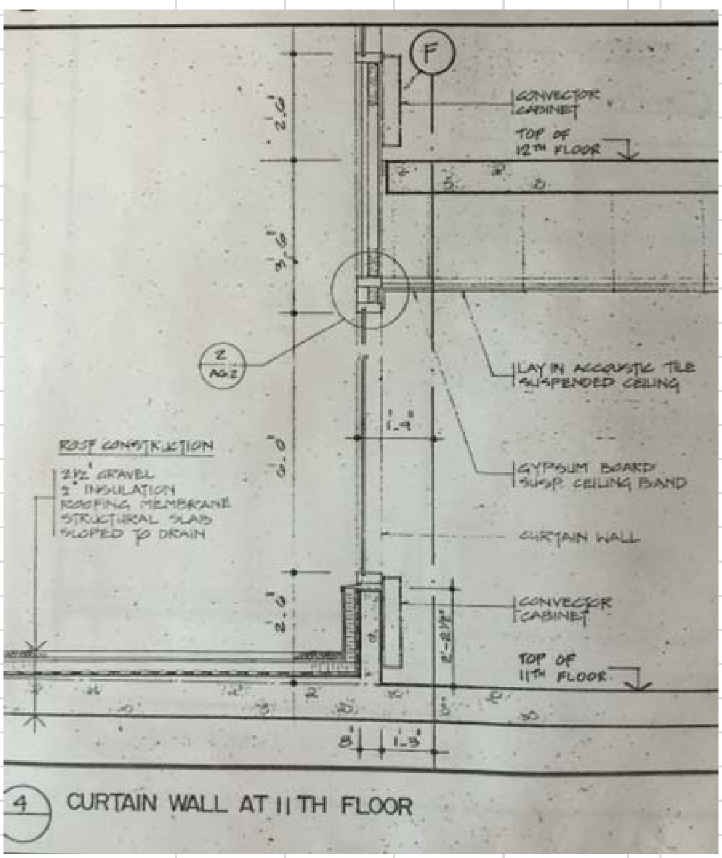
Building A - Toronto, Ontario				
43.76%	25,424			
South	sf	Units	sf	m2
Glazed Area				
Spandrell Glass	1,025.00	9	9,225.00	857.03
Spandrell Glass	186.00	1	186.00	17.28
Spandrell Glass	155.00	2	310.00	28.80
Spandrell Glass	79.00	2	158.00	14.68
Spandrell Glass	49.00	1	49.00	4.55
Spandrell Glass	769.00	2	1,538.00	142.88
Spandrell Glass	143.00	1	143.00	13.29
Spandrell Glass	1,532.00	1	1,532.00	142.33
Spandrell Glass	234.00	1	234.00	21.74
Spandrell Glass	12.00	48	576.00	53.51
Clear Glass	699.00	1	699.00	64.94
				1,224.93
Mullions and Framing				
	assumption value		14,650.00	**136.10**
Wall Area				
	30,475.00	1	30,475.00	2,831.22
			0.00	0.00
				2,831.22
WWR				
				43.26%

assamption	10%			
East	sf	Units	sf	m2
Glazed Area				
Spandrell Glass	1,024.00	9	9,216.00	856.19
Spandrell Glass	764.00	2	1,528.00	141.96
Spandrell Glass	1,151.00	1	1,151.00	106.93
Spandrell Glass	595.00	1	595.00	55.28
Spandrell Glass	82.00	1	82.00	7.62
Spandrell Glass	47.00	1	47.00	4.37
Spandrell Glass	143.00	1	143.00	13.29
Spandrell Glass	159.00	1	159.00	14.77
Spandrell Glass	149.00	1	149.00	13.84
Spandrell Glass	78.00	1	78.00	7.25
Spandrell Glass		1	0.00	0.00
				1,099.34
Mullions and Framing				
	assumption value		13,148.00	**122.15**
Wall Area				
	28,501.00	1	28,501.00	2,647.83
			0.00	0.00
				2,647.83
WWR				
				41.52%

assamption	10%			
North	sf	Units	sf	m2
Glazed Area				
Spandrell Glass	81.00	1	81.00	7.53
Spandrell Glass	53.00	1	53.00	4.92
Spandrell Glass	240.00	1	240.00	22.30
Spandrell Glass	587.00	1	587.00	54.53
Spandrell Glass	1,025.00	9	9,225.00	857.03
Spandrell Glass	793.00	2	1,586.00	147.34
Spandrell Glass	749.00	1	749.00	69.58
Spandrell Glass	1,496.00	1	1,496.00	138.98
Spandrell Glass	12.00	52	624.00	57.97
Spandrell Glass			0.00	0.00
Spandrell Glass			0.00	0.00
				1,224.17
Mullions and Framing				
	assumption value		14,641.00	**136.02**
Wall Area				
	29,303.00	1	29,303.00	2,722.34
			0.00	0.00
				2,722.34
WWR				
				44.97%

assamption	10%			
West	sf	Units	sf	m2
Glazed Area				
Spandrell Glass	1,025.00	9	9,225.00	857.03
Spandrell Glass	891.00	1	891.00	82.78
Spandrell Glass	857.00	2	1,714.00	159.24
Spandrell Glass	1,173.00	1	1,173.00	108.98
Spandrell Glass	600.00	1	600.00	55.74
Spandrell Glass	12.00	52	624.00	57.97
Spandrell Glass			0.00	0.00
Spandrell Glass			0.00	0.00
Spandrell Glass			0.00	0.00
Spandrell Glass			0.00	0.00
Spandrell Glass			0.00	0.00
				1,189.56
Mullions and Framing				
	assumption value		14,227.00	**132.17**
Wall Area				
	28,271.00	1	28,271.00	2,626.46
			0.00	0.00
				2,626.46
WWR				
				45.29%



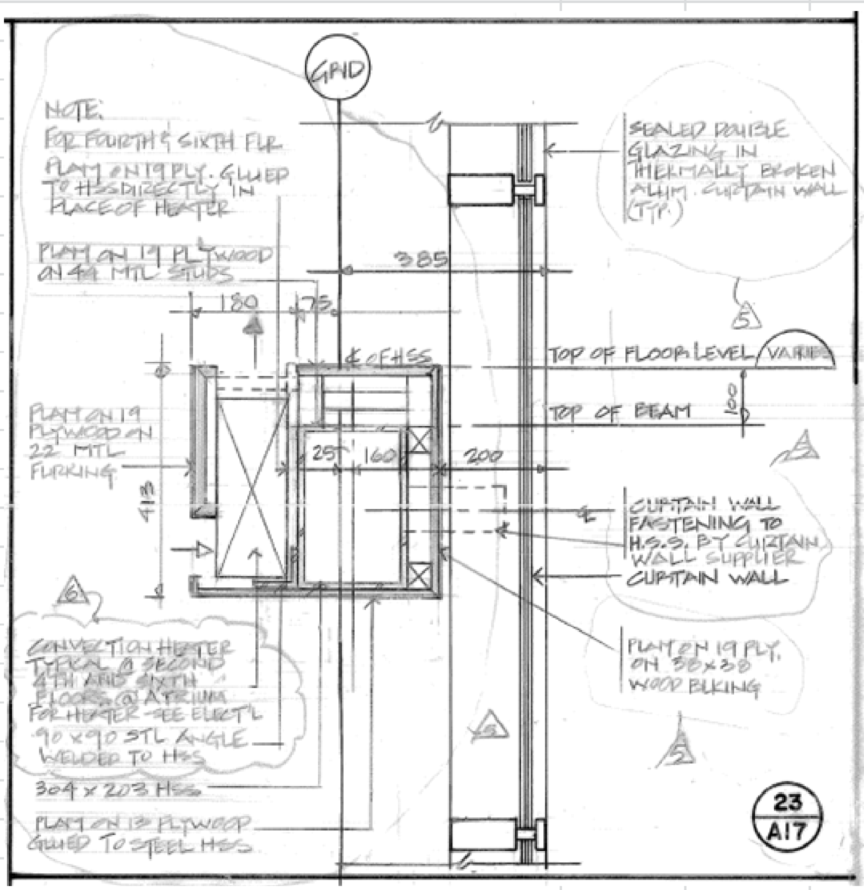

F
CONVECTOR CABINET
TOP OF 12TH FLOOR
LAY IN ACOUSTIC TILE SUSPENDED CEILING
GYPSUM BOARD SUSP. CEILING BAND
CURTAIN WALL
CONVECTOR CABINET
TOP OF 11TH FLOOR
ROOF CONSTRUCTION
2 1/2" GRAVEL
2" INSULATION
ROOFING MEMBRANE
STRUCTURAL SLAB
SLOPED TO DRAIN
4
CURTAIN WALL AT 11 TH FLOOR

Building #2

Building B - Mississauga, Ontario			20%	assamption	20%		
27.24%							
South	m2	Units	m2	East	m2	Units	m2
Glazed Area				Glazed Area			
Sealed Double Dlazing in Thermally Brocken Aluminum Frames	1.13	21	23.73	Sealed Double Dlazing in Thermally Brocken Aluminum Frames	1.13	121	136.73
Sealed Double Dlazing in Thermally Brocken Curtain Wall	5.88	38	223.55	Sealed Double Dlazing in Thermally Brocken Curtain Wall	10.54	4	42.16
	111.30	1	111.30		8.00	1	8.00
	4.20	2	8.40		8.60	1	8.60
	6.30	2	12.60		5.88	11	64.71
	6.00	2	12.00		13.50	1	13.50
	5.90	5	29.50		9.40	1	9.40
	14.50	1	14.50		19.10	1	19.10
	2.30	5	11.50		9.00	1	9.00
			0.00		9.50	1	9.50
			0.00				0.00
			357.67				**256.56**
Mullions and Framing				Mullions and Framing			
	assumption value		89.42		assumption value		64.14
Wall Area				Wall Area			
	1,030.00	1	1,030.00		1,294.00	1	1,294.00
			0.00				0.00
			1,030.00				**1,294.00**
WWR				WWR			
			34.72%				19.83%

assamption	20%			assamption	20%		
North	m2	Units	m2	West	m2	Units	m2
Glazed Area				Glazed Area			
Sealed Double Dlazing in Thermally Brocken Aluminum Frames	1.30	108	140.40	Sealed Double Dlazing in Thermally Brocken Aluminum Frames	1.30	25	32.50
Sealed Double Dlazing in Thermally Brocken Curtain Wall	44.00	1	44.00	Sealed Double Dlazing in Thermally Brocken Curtain Wall	9.50	8	76.00
	5.60	9	50.40		5.20	1	5.20
	6.50	1	6.50		5.70	4	22.80
	16.60	1	16.60		5.60	5	28.00
	5.80	1	5.80		9.30	1	9.30
			0.00		6.10	1	6.10
			0.00		5.60	38	212.80
			0.00		2.50	5	12.50
			0.00		122.00	1	122.00
			0.00				0.00
			210.96				**421.76**
Mullions and Framing				Mullions and Framing			
	assumption value		52.74		assumption value		105.44
Wall Area				Wall Area			
	1,030.00	1	1,030.00		1,243.00	1	1,243.00
			0.00				0.00
			1,030.00				**1,243.00**
WWR				WWR			
			20.48%				33.93%


NORTH ELEVATION


GRID
NOTE:
FOR FOURTH & SIXTH FLR.
PLAM ON 19 PLY. GLUED TO HSS DIRECTLY IN PLACE OF HEATER
PLAM ON 19 PLYWOOD
SEALED DOUBLE GLAZING IN THERMALLY BROKEN ALUM. CURTAIN WALL (TYP.)
385
180
75
℄ OF HSS
TOP OF FLOOR LEVEL VARIES
TOP OF BEAM
100
PLAM ON 19 PLYWOOD ON 22 MTL FURRING
413
25
160
200
CURTAIN WALL FASTENING TO H.S.S. BY CURTAIN WALL SUPPLIER
CURTAIN WALL
PLAM ON 19 PLY. ON 38x38 WOOD BLKING
CONVECTION HEATER TYPICAL @ SECOND 4TH AND SIXTH FLOORS, @ ATRIUM FOR HEATER SEE ELECT'L
90x90 STL ANGLE WELDED TO HSS
304 x 203 HSS
PLAM ON 19 PLYWOOD GLUED TO STEEL HSS
23
A17

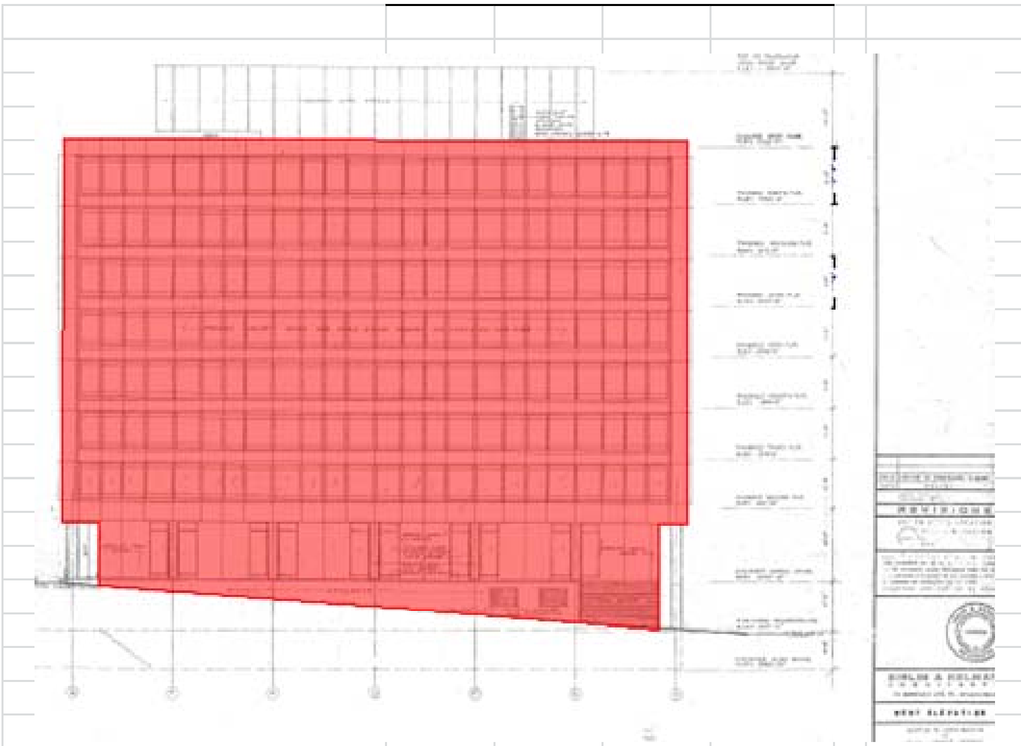
Building #3

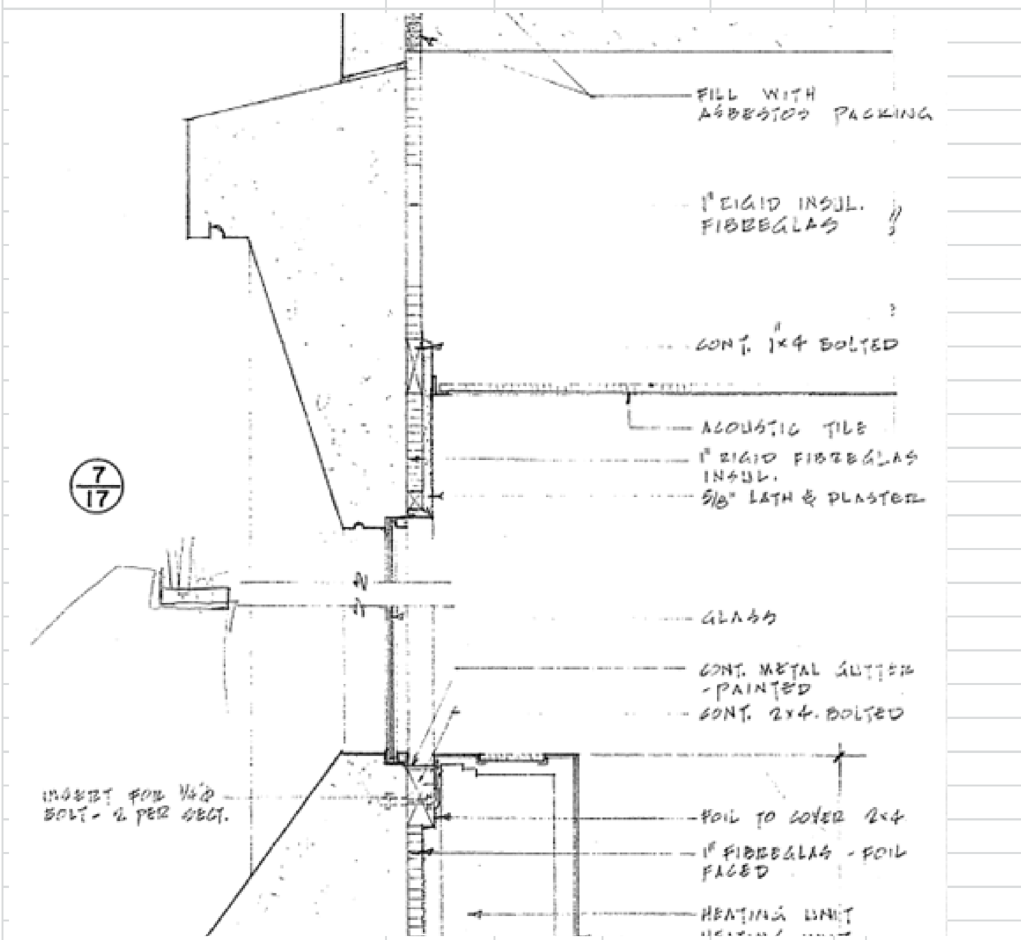
Building C - Toronto, Ontario				20%
38.89%				
South	sf	Units	sf	m2
Glazed Area				
Precast Panels with Tinted Glass	540.00	7	3,780.00	351.17
Clear Plate Glass	963.00	1	963.00	89.47
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
				352.51
Mullions and Framing				
assumption value			4,743.00	**88.13**
Wall Area				
	10,217.00	1	10,217.00	949.19
			0.00	0.00
				949.19
WWR				
				37.14%

assamption	20%			
East	sf	Units	sf	m2
Glazed Area				
Precast Panels with Tinted Glass	810.00	7	5,670.00	526.76
Clear Plate Glass	1,490.00	1	1,490.00	138.43
		1	0.00	0.00
		1	0.00	0.00
		1	0.00	0.00
		1	0.00	0.00
		1	0.00	0.00
		1	0.00	0.00
		1	0.00	0.00
		1	0.00	0.00
		1	0.00	0.00
				532.15
Mullions and Framing				
assumption value			7,160.00	**133.04**
Wall Area				
	14,700.00	1	14,700.00	1,365.67
			0.00	0.00
				1,365.67
WWR				
				38.97%

assamption	20%			
North	sf	Units	sf	m2
Glazed Area				
Precast Panels with Tinted Glass	540.00	7	3,780.00	351.17
Clear Plate Glass	915.00	1	915.00	85.01
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
				348.94
Mullions and Framing				
assumption value			4,695.00	**87.24**
Wall Area				
	9,416.00	1	9,416.00	874.77
			0.00	0.00
				874.77
WWR				
				39.89%

assamption	20%			
West	sf	Units	sf	m2
Glazed Area				
Precast Panels with Tinted Glass	856.00	7	5,992.00	556.67
Clear Plate Glass	1,291.00	1	1,291.00	119.94
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
				541.29
Mullions and Framing				
assumption value			7,283.00	**135.32**
Wall Area				
	14,731.00	1	14,731.00	1,368.55
			0.00	0.00
				1,368.55
WWR				
				39.55%




FILL WITH ASBESTOS PACKING
1" RIGID INSUL. FIBERGLAS
CONT. 1x4 BOLTED
ACOUSTIC TILE
1" RIGID FIBERGLAS INSUL.
5/8" LATH & PLASTER
7/17
GLASS
CONT. METAL GUTTER -PAINTED
CONT. 2x4. BOLTED
INSERT FOR 1/4"Ø BOLT - 2 PER SECT.
FOIL TO COVER 2x4
1" FIBERGLAS - FOIL FACED
HEATING UNIT

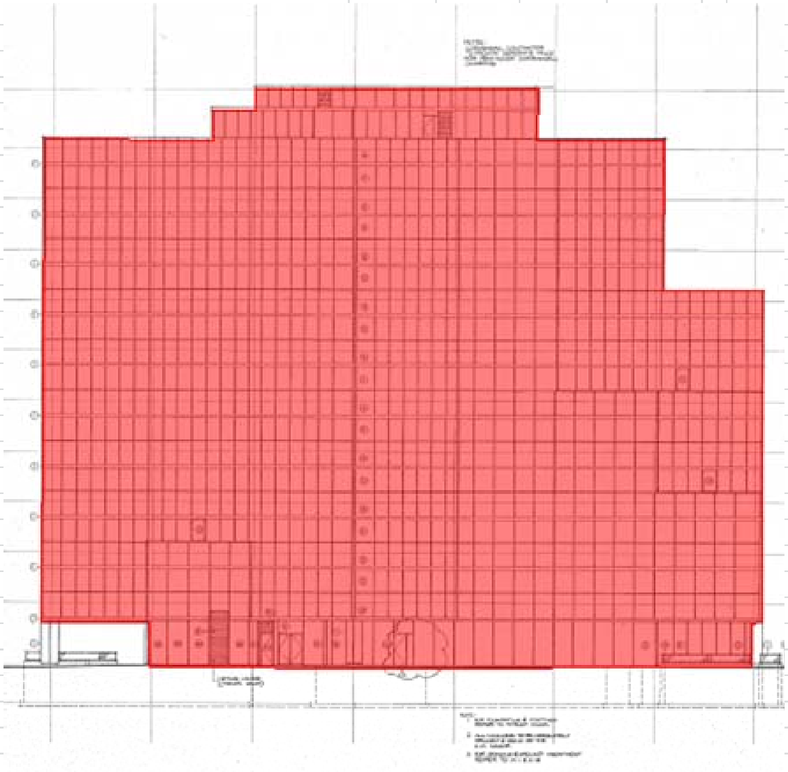
Building #4

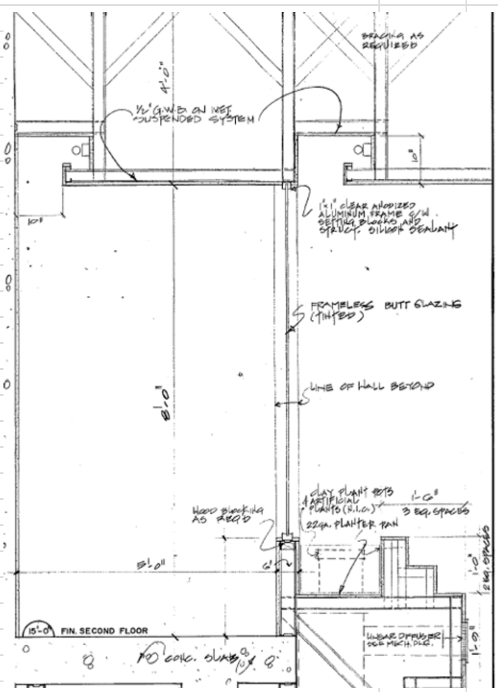
Building D - Mississauga, Ontario				10%
42.05%				
South	sf	Units	sf	m2
Glazed Area				
Hermetically Sealed Double Glazing Curtain Wa	1,034.00	6	6,204.00	576.37
Hermetically Sealed Double Glazing Curtain Wa	878.00	3	2,634.00	244.71
Penthouse Curtain Wall	795.00	1	795.00	73.86
Curtain wall with clear glass	1,396.00	1	1,396.00	129.69
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
				922.16
Mullions and Framing				
			11,029.00	**102.46**
Wall Area				
	23,239.00	1	23,239.00	2,158.97
			0.00	0.00
				2,158.97
WWR				
				42.71%

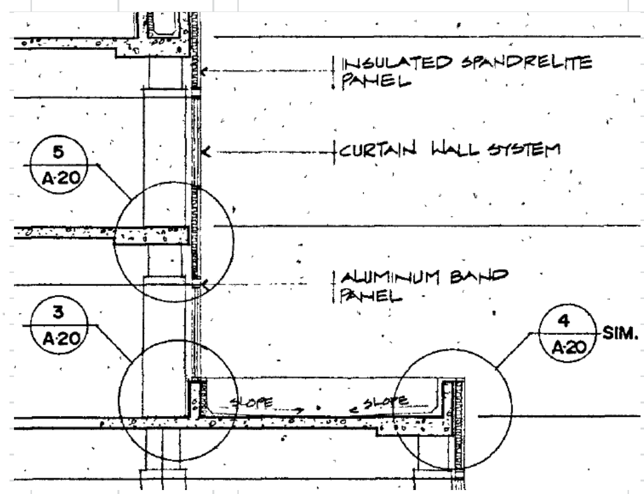
assamption	10%			
East	sf	Units	sf	m2
Glazed Area				
Hermetically Sealed Double Glazing Curtain Wa	1,035.00	6	6,210.00	576.93
Hermetically Sealed Double Glazing Curtain Wa	919.00	3	2,757.00	256.13
Penthouse Curtain Wall	775.00	1	775.00	72.00
Curtain wall with clear glass	1,351.00	1	1,351.00	125.51
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
				927.52
Mullions and Framing				
			11,093.00	**103.06**
Wall Area				
	23,247.00	1	23,247.00	2,159.72
			0.00	0.00
				2,159.72
WWR				
				42.95%

assamption	10%			
North	sf	Units	sf	m2
Glazed Area				
Hermetically Sealed Double Glazing Curtain Wa	1,035.00	6	6,210.00	576.93
Hermetically Sealed Double Glazing Curtain Wa	884.00	3	2,652.00	246.38
Penthouse Curtain Wall	841.00	1	841.00	78.13
Curtain wall with clear glass	1,100.00	1	1,100.00	102.19
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
				903.27
Mullions and Framing				
			10,803.00	**100.36**
Wall Area				
	23,337.00	1	23,337.00	2,168.08
			0.00	0.00
				2,168.08
WWR				
				41.66%

assamption	10%			
West	sf	Units	sf	m2
Glazed Area				
Hermetically Sealed Double Glazing Curtain Wa	1,035.00	6	6,210.00	576.93
Hermetically Sealed Double Glazing Curtain Wa	867.00	3	2,601.00	241.64
Penthouse Curtain Wall	842.00	1	842.00	78.22
Curtain wall with clear glass	900.00	1	900.00	83.61
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
			0.00	0.00
				882.36
Mullions and Framing				
			10,553.00	**98.04**
Wall Area				
	23,226.00	1	23,226.00	2,157.77
			0.00	0.00
				2,157.77
WWR				
				40.89%




FRAMELESS BUTT GLAZING (TINTED)
LINE OF WALL BEYOND
8'-0"
FIN. SECOND FLOOR


INSULATED SPANDRELITE PANEL
CURTAIN WALL SYSTEM
5
A-20
ALUMINUM BAND PANEL
3
A-20
4
A-20
SIM.
SLOPE
SLOPE

Building #5

Assumed WWR = 40% (based on the site visit)

Building #6 (based on the site visit)

Building E - Scarborough, Ontario				10%	Mullions assamption	10%			
39.82%									
South	m	m	Units	m2	East	m	m	Units	m2
Glazed Area					Glazed Area				
Glass Strip	61.00	1.50	1	91.50	Glass Strip	18.00	1.50	1	27.00
Glass first floor	5.60	3.20	10	179.20	Glass first floor	4.75	3.20	1	15.20
				0.00	Glass first floor	9.00	3.20	1	28.80
				0.00					0.00
				0.00					0.00
				243.63					**63.90**
Mullions and Framing					Mullions and Framing				
				27.07					7.10
Wall Area					Wall Area				
	61.00	8.70	1	530.70		18.00	8.70	1	156.60
				0.00					0.00
				530.70					**156.60**
WWR					WWR				
				45.91%					40.80%
assamption	10%				assamption	10%			
North	m	m	Units	m2	West	m	m	Units	m2
Glazed Area					Glazed Area				
Glass Strip	61.00	1.50	1	91.50	Glass Strip	8.00	1.50	1	12.00
Glass first floor	3.20	5.60	10	179.20	Glass Strip	0.50	1.28	1	0.64
				0.00	Glass first floor	7.50	4.50	1	33.75
				0.00					0.00
				0.00					0.00
				243.63					**41.75**
Mullions and Framing					Mullions and Framing				
				27.07					4.64
Wall Area					Wall Area				
	61.00	8.70	1	530.70		18.00	8.70	1	156.60
				0.00					0.00
				530.70					**156.60**
WWR					WWR				
				45.91%					26.66%

Building #7

Assumed WWR = 32% (based on Google Earth images)

Building #8

Building H - Ottawa, Ontario				10%
43.03%	5,020			
South	m	m	Units	m2
Glazed Area				
Curtain Wall	22.00	1.80	3	118.80
Curtain Wall	8.70	1.80	1	15.66
Glassed Area	5.20	2.80	3	43.68
Glassed Area				0.00
				160.33
Mullions and Framing				
				17.81
Wall Area				
	20.60	15.00	1	309.00
	9.00	3.80	1	34.20
				343.20
WWR				
				46.72%

assamption	10%			
South/East	m	m	Units	m2
Glazed Area				
Curtain Wall	16.00	1.80	3	86.40
Curtain Wall				0.00
Glassed Area	3.70	2.00	4	29.60
Glassed Area	6.00	4.60	1	27.60
				129.24
Mullions and Framing				
				14.36
Wall Area				
	20.00	16.00	1	320.00
				0.00
				320.00
WWR				
				40.39%

assamption	10%			
East	m	m	Units	m2
Glazed Area				
Curtain Wall	47.00	1.80	1	84.60
Curtain Wall	21.00	1.80	2	75.60
Curtain Wall	8.48	1.80	1	15.26
Glassed Area	3.00	5.50	3	49.50
Glassed Area	3.00	3.00	2	18.00
Glassed Area	3.00	15.50	1	46.50
				260.52
Mullions and Framing				
				28.95
Wall Area				
	47.00	8.00	1	376.00
	21.00	7.00	1	147.00
	8.00	4.00	1	32.00
				555.00
WWR				
				46.94%

assamption	10%			
North	m	m	Units	m2
Glazed Area				
				0.00
				0.00
				0.00
				0.00
				0.00
				0.00
				0.00
Mullions and Framing				
				0.00
Wall Area				
			1	0.00
				0.00
				0.00
WWR				
assumed				42.00%

assamption	10%			
West	m	m	Units	m2
Glazed Area				
Curtain Wall	47.00	1.80	1	84.60
Curtain Wall	21.00	1.80	2	75.60
Curtain Wall	8.48	1.80	1	15.26
Glassed Area	3.00	4.00	3	36.00
Glassed Area	3.00	3.00	2	18.00
Glassed Area	3.00	8.00	1	24.00
				0.00
				228.12
Mullions and Framing				
				25.35
Wall Area				
	47.00	8.00	1	376.00
	21.00	7.00	1	147.00
	8.00	4.00	1	32.00
				555.00
WWR				
				41.10%

Building #9

Assumed WWR = 42% (based on Google Earth images)

Building #10

Assumed WWR = 42% (based on Google Earth images)

Building #11

Assumed WWR = 42% (based on Google Earth images)

Building #12

Assumed WWR = 19% (based on Google Earth images)

Building #13

Building M - Montreal, Quebec				10%	assamption	10%			
18.61%									
South	m	m	Units	m2	East	m	m	Units	m2
Glazed Area					Glazed Area				
Punched Window	2.44	1.30	12	38.06	Punched Windows	1.10	2.30	18	45.54
				0.00		1.10	1.30	6	8.58
				0.00					0.00
				34.26					**48.71**
Mullions and Framing					Mullions and Framing				
				3.81					5.41
Wall Area					Wall Area				
	22.00	26.00	1	572.00		21.30	7.00	1	149.10
	12.00	4.60	1	55.20		14.00	9.00	1	126.00
	16.50	26.00	1	429.00		7.00	14.00	1	98.00
	10.00	7.00	1	**1,056.20**					**373.10**
WWR					WWR				
				3.24%					13.05%
assamption	10%				assamption	10%			
North	m	m	Units	m2	West	m	m	Units	m2
Glazed Area					Glazed Area				
Punched Window	1.50	2.44	18	65.88	Punched Windows	1.50	2.44	10	36.60
	1.50	4.00	18	108.00		1.50	4.00	10	60.00
				156.49					**86.94**
Mullions and Framing					Mullions and Framing				
				17.39					9.66
Wall Area					Wall Area				
	29.00	23.00	1	667.00		25.00	18.00	1	450.00
				0.00					0.00
				667.00					**450.00**
WWR					WWR				
				23.46%					19.32%

Building #14

Assumed WWR = 23% (based on Google Earth images)

Building #15

Building O - Côte-St-Luc, Quebec				10%	assamption	10%			
23.00%									
South	m	m	Units	m2	East	m	m	Units	m2
Glazed Area					Glazed Area				
Punched Window	1.20	2.40	80	230.40	Punched Windows	1.20	2.40	40	115.20
	1.20	2.40	16	46.08		1.20	2.40	5	14.40
	4.30	3.00	2	25.80					0.00
				272.05					**116.64**
Mullions and Framing					Mullions and Framing				
				30.23					12.96
Wall Area					Wall Area				
	41.00	18.00	1	738.00		25.00	18.00	1	450.00
	22.00	18.00	1	396.00		3.00	18.00	1	54.00
				1,134.00					**504.00**
WWR					WWR				
				23.99%					23.14%
assamption	10%				assamption	10%			
North	m	m	Units	m2	West	m	m	Units	m2
Glazed Area					Glazed Area				
Punched Window	1.20	2.40	70	201.60	Punched Windows	1.20	2.40	40	115.20
	1.20	2.40	30	86.40		1.20	2.40	5	14.40
				259.20					**116.64**
Mullions and Framing					Mullions and Framing				
				28.80					12.96
Wall Area					Wall Area				
	41.00	18.00	1	738.00		25.00	18.00	1	450.00
	22.00	18.00	1	396.00		3.00	18.00	1	54.00
				1,134.00					**504.00**
WWR					WWR				
				22.86%					23.14%

Appendix 3

Appendix C

Thermal resistance calculations

Calculations only performed for case-study buildings #1, #2 and #3 because architectural drawings were only available for these buildings.

Typical Wall Assembly

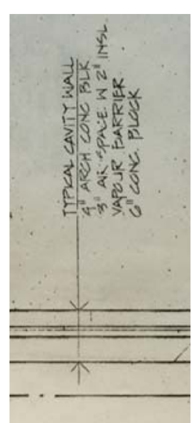
Building A - Toronto, Ontario

All thermal resistance values are based on ANSI/ASHRAE/IES Standard 90.1-2010 (CHAPTER 26), Table 4 Typical Thermal Properties of Common Building and Insulating Materials
Existing building RSI-values are compared to "Minimum thermal values requirements of building envelopes as per SB-10", Climate Zone 6, TABLE SB5.5-6, (Supersedes Table 5.5-6 in ANSI/ASHRAE/IESNA Standard 90.1)

Building Component	Materials	Material Thickness (mm)	Conductivity k W/(m•K)	Resistance R (m2•K)/W
Concrete blocks - Limestone aggregate	16.3 kg concrete, 2 cores with pedite-filled cores, 2200 kg/m3	102	0.541	0.19
Air Space	Air Space	75	0	0.00
Insulating Materials - Blanket and batt	Glass-fiber batts, 10 to 14 kg/m3	50	0.043	1.16
Concrete blocks - Normal-weight aggregate (sand and gravel)	16 kg concrete, with perlite-filled cores, 2100 kg/m3	155	0.571	0.27

Type of Existing Exterior Wall

Mass



Thickness of Building Component	**382 mm**	
Total Thermal Resistance	**1.62 (m2•K)/W**	
Min. thermal values requirements of building envelopes as per SB-10	**2.7 (m2•K)/W**	**Greater Thermal Resistance Required**

Typical Roof Assembly

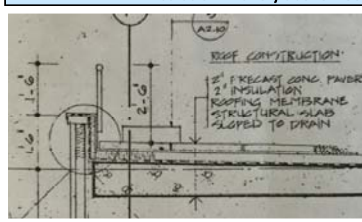
Building A - Toronto, Ontario

All thermal resistance values are based on ANSI/ASHRAE/IES Standard 90.1-2010 (CHAPTER 26), Table 4 Typical Thermal Properties of Common Building and Insulating Materials
Existing building RSI-values are compared to "Minimum thermal values requirements of building envelopes as per SB-10", Climate Zone 6, TABLE SB5.5-6, (Supersedes Table 5.5-6 in ANSI/ASHRAE/IESNA Standard 90.1)

Building Component	Materials	Material Thickness (mm)	Conductivity k W/(m•K)	Resistance R (m2•K)/W
Concretes	Low-mass aggregate or limestone concretes - Expanded shale, clay, or slate; expanded slags; cinders; pumice (with density up to 1600 kg/m3); scoria (sanded concretes have conductivities in higher end of range), 1600 kg/m3	130	0.800	0.16
Air Space	Air Space	51	0.000	0.00
Insulating Materials - Blanket and batt	Glass-fiber batts, 10 to 14 kg/m3	2	0.043	0.05
Concrete blocks - Normal-weight aggregate (sand and gravel)	16 kg concrete, with perlite-filled cores, 2100 kg/m3	150	0.571	0.26

Type of Existing Roof

Insulation Entirely above Deck



Thickness of Building Component 333 mm

Total Thermal Resistance 0.47 (m2•K)/W

Min. thermal values requirements of building envelopes as per SB-10 5.3 (m2•K)/W **Greater Thermal Resistance Required**

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Typical Windows

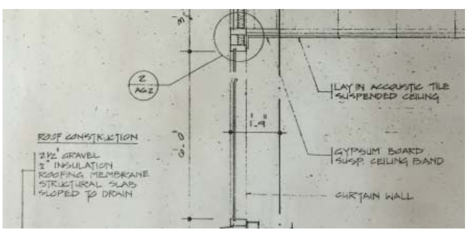
Building A - Toronto, Ontario

From the drop down list below select existing building component and materials for existing **windows** of the building. Thermal Conductivity value will appear automatically, however to calculate Thermal Resistance - material thickness should be entered.

Building Component	Materials	Material Thickness (mm)	Conductivity k W/(m•K)	Resistance R (m2•K)/W	
Windows	Insulated Glass - Double (6mm air space)	1	0.153	0.15	*assamption*

Type of Existing Windows

Metal framing: curtainwall



Thickness of Building Component	**1 mm**
Total Thermal Resistance	**0.15 (m2•K)/W**
Min. thermal values requirements of building envelopes as per SB-10	**0.50 (m2•K)/W**

Greater Thermal Resistance Required

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Overall Thermal Resistance

Building A - Toronto, Ontario

Select building envelope component "button" to enter materials information; all entered materials will be summarised below (cells are locked and can not be modified). If type of material is not provided in the drop down list, than "Other" should be selected, R-value will be entered manually.

Exterior wall

Materials	(m2•K)/W	Revised (m2•K)/W
16.3 kg concrete, 2 cores with pedite-filled cores, 2200 kg/m3	0.19	
Air Space	0.00	
Glass-fiber batts, 10 to 14 kg/m3	1.16	
16 kg concrete, with perlite-filled cores, 2100 kg/m3	0.27	
Total	**1.62**	

Greater Thermal Resistance Required

Roof

Materials	Typical Value	(m2•K)/W
Low-mass aggregate or limestone concretes - Expanded shale, cl	0.16	
Air Space	0.00	
Glass-fiber batts, 10 to 14 kg/m3	0.05	
16 kg concrete, with perlite-filled cores, 2100 kg/m3	0.26	
Total	**0.47**	

Greater Thermal Resistance Required

Windows

Materials	Typical Value	(m2•K)/W
Insulated Glass - Double (6mm air space)	0.15	
Total	**0.153**	

Greater Thermal Resistance Required

Overall Thermal Transmittance

Total Area	**10827.85**	**m2**	100%
Wall Area	**6089.85**	**m2**	56%
Windows Area	**4738.00**	**m2**	44%

Effective thermal resistance

Ro = 3RiAi/Ao= (R1A1 + R2A2 + ... + RnAn)/Ao			
Ao	10827.85	m2	
R wall	1.62	W/(m2•K)	0.153
A wall	6089.85	m2	
R window	0.15	W/(m2•K)	
A window	4738.00	m2	
	0.980	**W/(m2•K)**	

Typical Wall Assembly

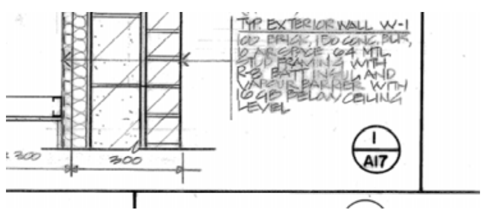
Typical Exterior Wall W-1 (1/A17)

Building B - Mississauga, Ontario

All thermal resistance values are based on ANSI/ASHRAE/IES Standard 90.1-2010 (CHAPTER 26), Table 4 Typical Thermal Properties of Common Building and Insulating Materials
Existing building RSI-values are compared to "Minimum thermal values requirements of building envelopes as per SB-10", Climate Zone 6, TABLE SB5.5-6, (Supersedes Table 5.5-6 in ANSI/ASHRAE/IESNA Standard 90.1)

Building Component	Materials	Material Thickness (mm)	Conductivity k W/(m•K)	Resistance R (m2•K)/W
Masonry Materials - Masonty units	Brick, fired clay, 1760 kg/m3	100	0.85	0.12
Concrete blocks - Normal-weight aggregate (sand and gravel)	16 kg concrete, with perlite-filled cores, 2100 kg/m3	150	0.571	0.26
Air Space	Air Space	10	0	0.00
Insulating Materials - Blanket and batt	Glass-fiber batts, 10 to 14 kg/m3	75	0.043	1.74

Type of Existing Exterior Wall
Mass



Thickness of Building Component 335 mm

Total Thermal Resistance 2.12 (m2•K)/W

Min. thermal values requirements of building envelopes as per SB-10 2.7 (m2•K)/W **Greater Thermal Resistance Required**

Typical Roof Assembly

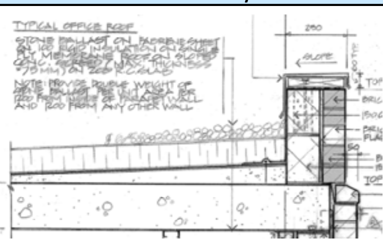
Building B - Mississauga, Ontario

All thermal resistance values are based on ANSI/ASHRAE/IES Standard 90.1-2010 (CHAPTER 26), Table 4 Typical Thermal Properties of Common Building and Insulating Materials
Existing building RSI-values are compared to "Minimum thermal values requirements of building envelopes as per SB-10", Climate Zone 6, TABLE SB5.5-6, (Supersedes Table 5.5-6 in ANSI/ASHRAE/IESNA Standard 90.1)

Building Component	Materials	Material Thickness (mm)	Conductivity k W/(m•K)	Resistance R (m2•K)/W
Roofing	Ballast	130	0.000	0.00
Air Space	Air Space	10	0.000	0.00
Building Membrane	Vapor-permeable felt	2	0.000	0.00
Concrete blocks - Normal-weight aggregate (sand and gravel)	16 kg concrete, with perlite-filled cores, 2100 kg/m3	75	0.571	0.13

Type of Existing Roof

Insulation Entirely above Deck



Thickness of Building Component	**217 mm**	
Total Thermal Resistance	**0.13 (m2•K)/W**	
Min. thermal values requirements of building envelopes as per SB-10	**5.3 (m2•K)/W**	**Greater Thermal Resistance Required**

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Typical Windows

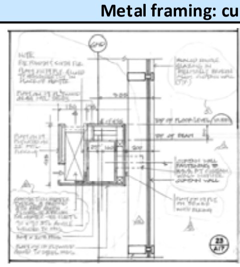
Building B - Mississauga, Ontario

From the drop down list below select existing building component and materials for existing **windows** of the building. Thermal Conductivity value will appear automatically, however to calculate Thermal Resistance - material thickness should be entered.

Building Component	Materials	Material Thickness (mm)	Conductivity k W/(m•K)	Resistance R (m2•K)/W	
Windows	Insulated Glass - Double (6mm air space)	5	0.153	0.15	*assamption*

Type of Existing Windows

Metal framing: curtainwall



Thickness of Building Component	**5 mm**
Total Thermal Resistance	**0.15 (m2•K)/W**
Min. thermal values requirements of building envelopes as per SB-10	**0.50 (m2•K)/W** — **Greater Thermal Resistance Required**

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Overall Thermal Resistance

Building B - Mississauga, Ontario

Select building envelope component "button" to enter materials information; all entered materials will be summarised below (cells are locked and can not be modified). If type of material is not provided in the drop down list, than "Other" should be selected, R-value will be entered manually.

Exterior wall

Materials	(m2•K)/W	Revised (m2•K)/W
Brick, fired clay, 1760 kg/m3	0.12	
16 kg concrete, with perlite-filled cores, 2100 kg/m3	0.26	
Air Space	0.00	
Glass-fiber batts, 10 to 14 kg/m3	1.74	
Total		**2.12**

Greater Thermal Resistance Required

Roof

Materials	Typical Value	(m2•K)/W
Ballast	0.00	
Air Space	0.00	
Vapor-permeable felt	0.00	
16 kg concrete, with perlite-filled cores, 2100 kg/m3	0.13	
Total		**0.13**

Greater Thermal Resistance Required

Windows

Materials	Typical Value	(m2•K)/W
Insulated Glass - Double (6mm air space)	0.15	
Total		**0.153**

Greater Thermal Resistance Required

Overall Thermal Transmittance

Total Area	**4597**	**m2**	100%
Wall Area	**3350.05**	**m2**	73%
Windows Area	**1246.95**	**m2**	27%

Effective thermal resistance

Ro = 3RiAi/Ao= (R1A1 + R2A2 + ... + RnAn)/Ao

Ao	**4597**	**m2**	
R wall	**2.12**	**W/(m2•K)**	**0.153**
A wall	**3350.05**	**m2**	
R window	**0.15**	**W/(m2•K)**	
A window	**1246.95**	**m2**	
	1.590	**W/(m2•K)**	

Typical Wall Assembly

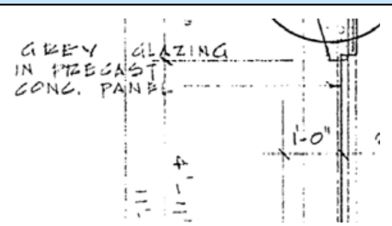
Building C - Toronto, Ontario

All thermal resistance values are based on ANSI/ASHRAE/IES Standard 90.1-2010 (CHAPTER 26), Table 4 Typical Thermal Properties of Common Building and Insulating Materials
Existing building RSI-values are compared to "Minimum thermal values requirements of building envelopes as per SB-10", Climate Zone 6, TABLE SB5.5-6, (Supersedes Table 5.5-6 in ANSI/ASHRAE/IESNA Standard 90.1)

Building Component	Materials	Material Thickness (mm)	Conductivity k W/(m•K)	Resistance R (m2•K)/W
Concrete blocks - Medium-weight aggregate (combinations of normal and lightweight aggregate)	13 kg concrete, 2 or 3 cores, 1550 to 1800 kg/m3	250	0.741	0.34

Type of Existing Exterior Wall

Mass



Thickness of Building Component **250 mm**

Total Thermal Resistance **0.34 (m2•K)/W**

Min. thermal values requirements of building envelopes as per SB-10 **2.7 (m2•K)/W** **Greater Thermal Resistance Required**

Typical Roof Assembly

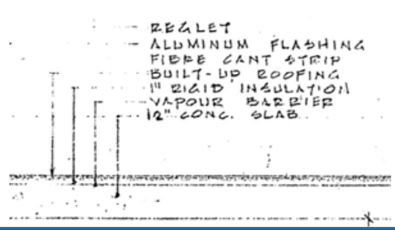
Building C - Toronto, Ontario

All thermal resistance values are based on ANSI/ASHRAE/IES Standard 90.1-2010 (CHAPTER 26), Table 4 Typical Thermal Properties of Common Building and Insulating Materials
Existing building RSI-values are compared to "Minimum thermal values requirements of building envelopes as per SB-10", Climate Zone 6, TABLE SB5.5-6, (Supersedes Table 5.5-6 in ANSI/ASHRAE/IESNA Standard 90.1)

Building Component	Materials	Material Thickness (mm)	Conductivity k W/(m•K)	Resistance R (m2•K)/W
Building Membrane	Regley	2	0.000	0.00
Building Siding	Aluminum, steel, or vinyl). 4 over sheathing - hollow-backed	25	0.085	0.29
Fibre Strip				
Roofing	Built-up roofing, 920 kg/m3	50	0.169	0.30
Insulating Materials - Board and slabs	Expanded polystyrene, molded beads, 15 to 25 kg/m3	25	0.035	0.71
Building Membrane	Vapour Barrier	2	0.000	0.00
Concrete blocks - Normal-weight aggregate (sand and gravel)	16 kg concrete, 2 or 3 cores, 2100 kg/m3	300	1.053	0.28

Type of Existing Roof

Insulation Entirely above Deck



Thickness of Building Component	**404 mm**
Total Thermal Resistance	**1.59 (m2•K)/W**
Min. thermal values requirements of building envelopes as per SB-10	**5.3 (m2•K)/W**

Greater Thermal Resistance Required

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Typical Windows

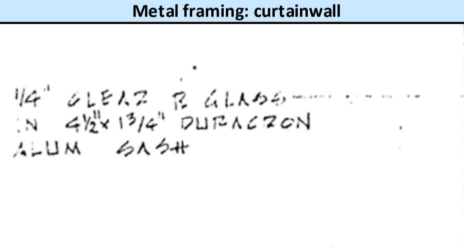
Building C - Toronto, Ontario

From the drop down list below select existing building component and materials for existing **windows** of the building. Thermal Conductivity value will appear automatically, however to calculate Thermal Resistance - material thickness should be entered.

Building Component	Materials	Material Thickness (mm)	Conductivity k W/(m•K)	Resistance R (m2•K)/W	
Windows	Insulated Glass - Double (6mm air space)	5	0.153	0.15	*assamption*

Type of Existing Windows

Metal framing: curtainwall



Thickness of Building Component	**5 mm**	
Total Thermal Resistance	**0.15 (m2•K)/W**	
Min. thermal values requirements of building envelopes as per SB-10	**0.50 (m2•K)/W**	**Greater Thermal Resistance Required**

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Overall Thermal Resistance

Building C - Toronto, Ontario

Select building envelope component "button" to enter materials information; all entered materials will be summarised below (cells are locked and can not be modified). If type of material is not provided in the drop down list, than "Other" should be selected, R-value will be entered manually.

Exterior wall

Materials	(m2•K)/W	Revised (m2•K)/W
13 kg concrete, 2 or 3 cores, 1550 to 1800 kg/m3	0.34	
Total	**0.34**	

Greater Thermal Resistance Required

Overall Thermal Transmittance

Total Area	**4558.18**	**m2**	100%
Wall Area	**2783.29**	**m2**	61%
Windows Area	**1774.89**	**m2**	39%

Roof

Materials	Typical Value	(m2•K)/W
Regley	0.00	
Aluminum, steel, or vinyl). 4 over sheathing - hollow-backed	0.29	
Built-up roofing, 920 kg/m3	0.30	
Expanded polystyrene, molded beads, 15 to 25 kg/m3	0.71	
Vapour Barrier	0.00	
16 kg concrete, 2 or 3 cores, 2100 kg/m3	0.28	
Total	**1.59**	

Greater Thermal Resistance Required

Effective thermal resistance

Ro = 3RiAi/Ao= (R1A1 + R2A2 + ... + RnAn)/Ao

Ao	**4558.18**	**m2**	
R wall	**0.34**	**W/(m2•K)**	**0.153**
A wall	**2783.29**	**m2**	
R window	**0.15**	**W/(m2•K)**	
A window	**1774.89**	**m2**	
	0.266	**W/(m2•K)**	

Windows

Materials	Typical Value	(m2•K)/W
Insulated Glass - Double (6mm air space)	0.15	
Total	**0.153**	

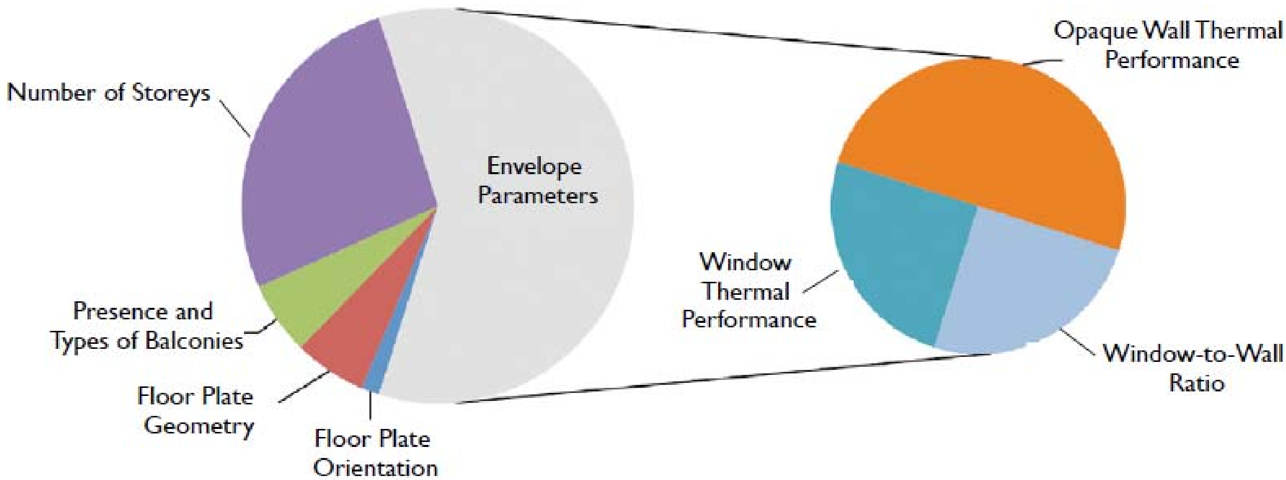
Greater Thermal Resistance Required

Appendix 4

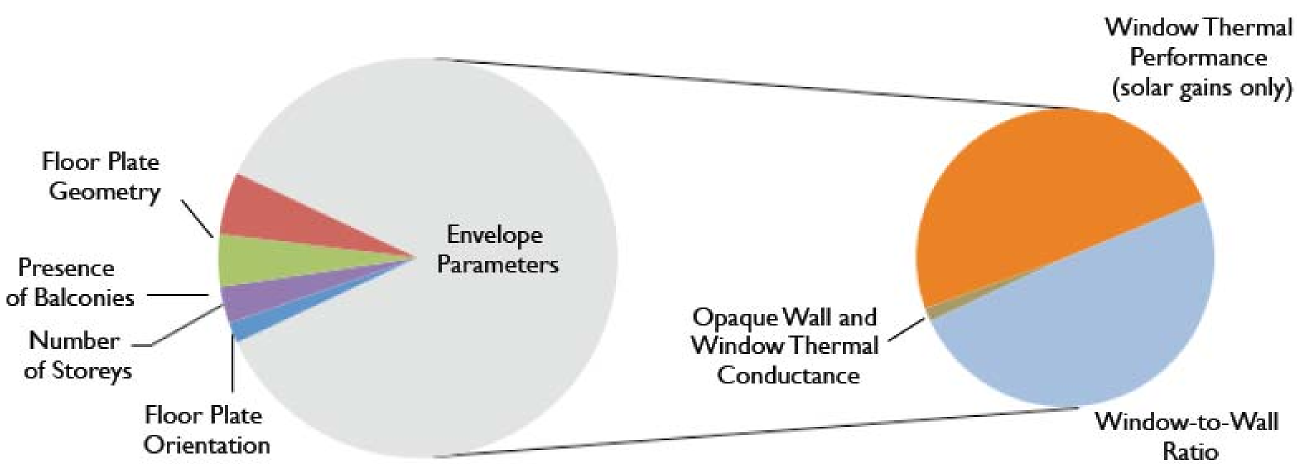
Appendix D

Energy Balance percentages calculations examples:

Relative Impact of Architectural Features on Heating Loads (Canada Mortgage and Housing Corporation (CMHC), 2014):



Relative Impact of Architectural Features on Cooling Loads (Canada Mortgage and Housing Corporation (CMHC), 2014):



Figures above were retrieved from Canada Mortgage and Housing Corporation report completed in November 2014. This report summarizes a research of impact of architectural form on the potential energy performance of multi-unit residential buildings. Research explains that thermal characteristics of wall and window areas of the building envelope, as well as proportion of window area to wall area can have a significant impact on the annual heating and cooling loads of building. Percentages in the figure above were calculated by using computerized hourly building energy consumption modelling to assess the impact of these parameters on heating and cooling loads. Simulations were conducted in Toronto, Ontario, and investigated five different building shapes (floor plate geometries), three wall thermal resistance values, six window performance levels, three window to wall ratios, three balcony configurations, three different number of stories (low-rise 3 storey, mid-rise 5 storey, and high-rise 10 storey), and in four orientations. Facilities comparison was also made on number of suites and occupants. Research results showed that floor plate geometry and building orientation were typically found to have a minor impact on heating loads, however slightly bigger on cooling loads. On the other hand, wall insulation, WWR and window U-value had much greater impacts on heating and cooling loads than other factors.

Appendix 5

Appendix E

Energy loads (electricity and gas) distributions for cooling, heating and lighting.

Cooling Loads Distribution (Electricity) in GJ Based on Architectural Features Indicators

	Heating Loads Percentage Distribution		5%	5%	35%	35%	5%	15%
			GJ					
	Address	**Cooling Loads Electricity Balance**	**Number of Stories**	**Building Orientation**	**Window to Wall ratio**	**Window Thermal Performance**	**Opaque Wall Thermal Performance**	**Other**
1	Building A - Toronto, Ontario	8%	37,495.4	37,495.4	262,467.8	262,467.8	37,495.4	112,486.2
2	Building B - Mississauga, Ontario	8%	14,852.9	14,852.9	103,970.3	103,970.3	14,852.9	44,558.7
3	Building C - Toronto, Ontario	8%	13,386.9	13,386.9	93,708.1	93,708.1	13,386.9	40,160.6
4	Building D - Mississauga, Ontario	8%	23,953.6	23,953.6	167,675.4	167,675.4	23,953.6	71,860.9
5	Building E - Mississauga, Ontario	8%	3,178.5	3,178.5	22,249.4	22,249.4	3,178.5	9,535.4
6	Building F - Scarborough, Ontario	8%	1,662.7	1,662.7	11,638.6	11,638.6	1,662.7	4,988.0
7	Building G - Ottawa, Ontario	8%	16,509.1	16,509.1	115,563.5	115,563.5	16,509.1	49,527.2
8	Building H - Ottawa, Ontario	8%	12,808.9	12,808.9	89,662.4	89,662.4	12,808.9	38,426.8
9	Building I - Ottawa, Ontario, Tower C	8%	9,506.3	9,506.3	66,544.3	66,544.3	9,506.3	28,519.0
10	Building J - Ottawa, Ontario, Tower B	8%	42,851.5	42,851.5	299,960.4	299,960.4	42,851.5	128,554.5
11	Building K - Ottawa, Ontario, Tower A	8%	12,795.0	12,795.0	89,565.1	89,565.1	12,795.0	38,385.0
12	Building L - Montreal, Quebec	8%	5,176.7	5,176.7	36,237.0	36,237.0	5,176.7	15,530.1
13	Building M - Vaudreuil-Dorion, Quebec	8%	11,845.4	11,845.4	82,917.8	82,917.8	11,845.4	35,536.2
14	Building N - Côte-St-Luc, Quebec	8%	21,426.0	21,426.0	149,981.8	149,981.8	21,426.0	64,277.9
15	Building O - Gatineau, Quebec	8%	13,351.9	13,351.9	93,463.4	93,463.4	13,351.9	40,055.8

Cooling Loads Distribution (Electricity) in GJ/m^2/year Based on Architectural Features Indicators

	Heating Loads Percentage Distribution		5%	5%	35%	35%	5%	15%
			GJ/m2/year					
	Address	**Cooling Loads Electricity Balance**	**Number of Stories**	**Building Orientation**	**Window to Wall ratio**	**Window Thermal Performance**	**Opaque Wall Thermal Performance**	**Other**
1	Building A - Toronto, Ontario	8%	0.003	0.003	0.021	0.021	0.003	0.009
2	Building B - Mississauga, Ontario	8%	0.004	0.004	0.026	0.026	0.004	0.011
3	Building C - Toronto, Ontario	8%	0.003	0.003	0.021	0.021	0.003	0.009
4	Building D - Mississauga, Ontario	8%	0.003	0.003	0.022	0.022	0.003	0.009
5	Building E - Mississauga, Ontario	8%	0.001	0.001	0.007	0.007	0.001	0.003
6	Building F - Scarborough, Ontario	8%	0.002	0.002	0.011	0.011	0.002	0.005
7	Building G - Ottawa, Ontario	8%	0.004	0.004	0.029	0.029	0.004	0.012
8	Building H - Ottawa, Ontario	8%	0.005	0.005	0.037	0.037	0.005	0.016
9	Building I - Ottawa, Ontario, Tower C	8%	0.004	0.004	0.028	0.028	0.004	0.012
10	Building J - Ottawa, Ontario, Tower B	8%	0.011	0.011	0.075	0.075	0.011	0.032
11	Building K - Ottawa, Ontario, Tower A	8%	0.004	0.004	0.030	0.030	0.004	0.013
12	Building L - Montreal, Quebec	8%	0.003	0.003	0.021	0.021	0.003	0.009
13	Building M - Vaudreuil-Dorion, Quebec	8%	0.003	0.003	0.021	0.021	0.003	0.009
14	Building N - Côte-St-Luc, Quebec	8%	0.006	0.006	0.039	0.039	0.006	0.017
15	Building O- Gatineau, Quebec	8%	0.005	0.005	0.035	0.035	0.005	0.015

Gas consumption for heating loads calculations are shown in the tables below.

Heating Loads (Gas) Distribution in GJ Based on Architectural Features Indicators

	Loads Percentage Distribution		25%	10%	15%	15%	30%	5%
					GJ			
	Address	**Heating Loads GAS Balance**	**Number of Stories**	**Building Orientation**	**Window to Wall ratio**	**Window Thermal Performance**	**Opaque Wall Thermal Performance**	**Other**
1	Building A - Toronto, Ontario	100%	64,142.6	25,657.0	38,485.5	38,485.5	76,971.1	12,828.5
2	Building B - Mississauga, Ontario	100%	20,704.3	8,281.7	12,422.6	12,422.6	24,845.2	4,140.9
3	Building C - Toronto, Ontario	100%	39,590.7	15,836.3	23,754.4	23,754.4	47,508.8	7,918.1
4	Building D - Mississauga, Ontario	100%	14,639.0	5,855.6	8,783.4	8,783.4	17,566.8	2,927.8
5	Building E - Mississauga, Ontario	100%	4,498.8	1,799.5	2,699.3	2,699.3	5,398.5	899.8
6	Building F - Scarborough, Ontario	100%	6,630.6	2,652.2	3,978.3	3,978.3	7,956.7	1,326.1
7	Building G - Ottawa, Ontario	100%	7,990.4	3,196.2	4,794.2	4,794.2	9,588.5	1,598.1
8	Building H - Ottawa, Ontario	100%	20,441.2	8,176.5	12,264.7	12,264.7	24,529.4	4,088.2
9	Building I - Ottawa, Ontario, Tower C	100%	1,155.5	462.2	693.3	693.3	1,386.6	231.1
10	Building J - Ottawa, Ontario, Tower B	100%						
11	Building K - Ottawa, Ontario, Tower A	100%						
12	Building L - Montreal, Quebec	100%	3,665.8	1,466.3	2,199.5	2,199.5	4,398.9	733.2
13	Building M - Vaudreuil-Dorion, Quebec	100%	2,047.3	818.9	1,228.4	1,228.4	2,456.7	409.5
14	Building N - Côte-St-Luc, Quebec	100%						
15	Building O - Gatineau, Quebec	100%	16,034.7	6,413.9	9,620.8	9,620.8	19,241.6	3,206.9

Heating Loads (Gas) Distribution in GJ/m^2/year Based on Architectural Features Indicators

	Loads Percentage Distribution		25%	10%	15%	15%	30%	5%
					GJ/m2/year			
	Address	**Heating Loads Gas Balance**	**Number of Stories**	**Building Orientation**	**Window to Wall ratio**	**Window Thermal Performance**	**Opaque Wall Thermal Performance**	**Other**
1	Building A - Toronto, Ontario	100%	0.018	0.007	0.011	0.011	0.022	0.004
2	Building B - Mississauga, Ontario	100%	0.018	0.007	0.011	0.011	0.022	0.004
3	Building C - Toronto, Ontario	100%	0.031	0.012	0.019	0.019	0.037	0.006
4	Building D - Mississauga, Ontario	100%	0.007	0.003	0.004	0.004	0.008	0.001
5	Building E - Mississauga, Ontario	100%	0.005	0.002	0.003	0.003	0.006	0.001
6	Building F - Scarborough, Ontario	100%	0.022	0.009	0.013	0.013	0.027	0.004
7	Building G - Ottawa, Ontario	100%	0.007	0.003	0.004	0.004	0.008	0.001
8	Building H - Ottawa, Ontario	100%	0.029	0.012	0.018	0.018	0.035	0.006
9	Building I - Ottawa, Ontario, Tower C	100%	0.002	0.001	0.001	0.001	0.002	0.000
10	Building J - Ottawa, Ontario, Tower B	100%						
11	Building K - Ottawa, Ontario, Tower A	100%						
12	Building L - Montreal, Quebec	100%	0.008	0.003	0.005	0.005	0.009	0.002
13	Building M - Vaudreuil-Dorion, Quebec	100%	0.002	0.001	0.001	0.001	0.002	0.000
14	Building N - Côte-St-Luc, Quebec	100%						
15	Building O - Gatineau, Quebec	100%	0.021	0.008	0.013	0.013	0.025	0.004

Lighting Loads Distribution (Electricity) in GJ/m^2/year Based on Architectural Features Indicators

	Lighting Loads Percentage Distribution		40%		40%
			GJ		**GJ/m2/year**
	Address	**Lighting Loads Electricity Balance**	**Window to Wall ratio**	**Lighting Loads Electricity Balance**	**Window to Wall ratio**
1	Building A - Toronto, Ontario	33%	707,056.2	33%	0.100
2	Building B - Mississauga, Ontario	33%	280,083.3	33%	0.123
3	Building C - Toronto, Ontario	33%	252,438.1	33%	0.098
4	Building D - Mississauga, Ontario	33%	451,697.0	33%	0.103
5	Building E - Mississauga, Ontario	33%	59,937.1	33%	0.034
6	Building F - Scarborough, Ontario	33%	31,352.9	33%	0.053
7	Building G - Ottawa, Ontario	33%	311,313.8	33%	0.137
8	Building H - Ottawa, Ontario	33%	241,539.6	33%	0.173
9	Building I - Ottawa, Ontario, Tower C	33%	179,262.1	33%	0.133
10	Building J - Ottawa, Ontario, Tower B	33%	808,056.6	33%	0.352
11	Building K - Ottawa, Ontario, Tower A	33%	241,277.4	33%	0.141
12	Building L - Montreal, Quebec	33%	97,618.0	33%	0.100
13	Building M - Vaudreuil-Dorion, Quebec	33%	223,370.5	33%	0.100
14	Building N - Côte-St-Luc, Quebec	33%	404,032.6	33%	0.183
15	Building O - Gatineau, Quebec	33%	251,779.1	33%	0.164

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Glossary

Low-emissivity (low-e) A coatings applied to window glass to reduce heat loss from the inside without reducing solar gain from outside. 11

Solar Heat Gain Coefficient (SHGC) Solar heat gain through the total window system relative to the incident solar radiation. 10, 13

Visible Transmittance (VT) The fraction of visible light that having entered a layer of absorbing material reaches into the space. 10

Window-to-Wall Ratio (WWR) The ratio of the wall fenestration area to the gross exterior wall area. v, vi, xi, 1, 3, 8–15, 34, 36, 37, 43–45, 48–51, 54–57