LEED Operations versus LEED Design: The Vale Living with Lake Centre Case Study

by

Danielle Lavergne-Giroux

Undergraduate Thesis

Laurentian University, 2016

Table of Contents

List of Figures

List of Tables

Chapter 1:

Introduction and Purpose of Study

1.1 Introduction

Worldwide, more than 85% of current energy needs are met using fossil fuels (Natural Resources Canada, 2012). According to the *Survey of Commercial and Institutional Energy Use-Buildings 2009,* 54% of Canadian commercial and institutional buildings used natural gas as the primary energy source for space heating (Natural Resources Canada, 2012). Therefore, buildings can have a significant impact on a nation's energy consumption.

The conventional way of heating and cooling buildings using traditional methods such as steam turbines (fueled with coal, natural gas, or petroleum) are not renewable or sustainable. These fossil fuels result in the deterioration of air quality and they contribute to climate change and are, therefore, environmentally disruptive. Over the years, this has become a pressing issue and many different initiatives attempt to alleviate the impacts of using fossil fuels. Increasing energy efficiency, using alternatives or implementing policies on energy consumption have all assisted in mitigating the impacts of fossil fuel consumption. Energy efficiency is a measure of how effectively the energy is used to provide a specific level of service with less energy consumed. This differs from energy intensity which represents the ratio of energy used per unit of activity (Natural Resources Canada, 2014). Alternatives to using fossil fuels can include renewable energy such as solar energy, geothermal heat, wind energy etc.

1.2 Ontario Regulation 397/11 – Energy Conservation and Demand Management Plans

However, most buildings still operate using mostly non renewable resources and it is therefore, important to have clear policies and regulations in place in order to monitor a building's energy consumption. An example of such policies on energy is the *Ontario Regulation 397/11 – Energy Conservation and Demand Management Plans (O. Reg. 397/11)*. This regulation requires all Ontario public agencies to develop energy management plans. The agencies are obliged under the regulation to prepare, publish and submit to the Ministry of Energy their data on energy consumption and greenhouse gas (GHG) emission for year one of operation (starting January 2011- December 2011) and annually thereafter. Also, every public agency must establish and publish a detailed energy conservation and demand management plan (Government of Ontario, 2015). This initiative helps agencies understand how and where they use energy in order to develop conservation plans to guide them towards efficiency. This open data allows the agencies and the public to track energy consumption and monitor trends over the years.

Ontario universities, since they are publicly funded institutions, must adhere to this regulation and, therefore, are required to follow O. Reg. 397/11. Laurentian University in Sudbury Ontario is one of the provinces 20 publicly supported universities. It is one of six universities (Carleton, Ottawa, Nipissing, Laurentian, Algoma and Lakehead) in the northern portion of the province. In terms of 2015 student population, it ranks 16th (OCUL) and sports a total indoor floor area of 169,250 m^2 for the main campus including 2,643 m^2 for the Vale Living with Lakes Centre (VLWLC) and an additional 1,361 m^2 for its downtown School of Architecture campus. Table 1 shows Laurentian University's energy consumption from the latest report under O. Reg. 397/11 which was published in 2015 and shows the data for 2013.

Table 1.1 Laurentian University 2013 Energy Consumption Summary

	Electricity (kWh)	Natural Gas (GJ)	GHG Emission (Kg)	Energy Intensity (ekWh/sqft)
Laurentian University Main Campus	22,071,104	131,046	8,153,338	30.27

1.3: Research Goal

This research aims to analyze the design goals of energy usage of the VLWLC building on the Laurentian campus compared to the building's actual energy use with a focus on the energy consumption used for the building's space heating. The objective of this comparison is to identify reasons why the building is not meeting design expectations and to offer recommendations to assist other LEED designed building to have their operational results match or exceed design expectations.

Chapter two of this paper presents an overview of the history of green buildings in the United States and in Canada with a review of various energy policies that encouraged the progression of green buildings. This review is informed by articles found in peer reviewed journals and government publications. Next, chapter two will be followed by an introduction of the U.S Green Building Council and its most known rating system; LEED and lastly, it will present the VLWLC and its features that make it a green building. Since this research aims to analyze the building's energy consumption, mostly in terms of heating and cooling, chapter three describes the major heating and cooling systems that are used by the VLWLC. Chapter four establishes a method to analyze the data and assess the VLWL in terms of its operation versus it design expectations, presents the research's methodology and limitations, applies the method of investigation to the case study of the VLWLC and lastly, chapter four includes an overall critique of the LEED rating system. To finish, chapter five consists of a brief overview of the future of green buildings as well as a short summary of the analysis.

Chapter 2:
LEED Overview and the VLWLC

2.1: Introduction

The buildings in which we live, work and play protect us, provide us with security, privacy and comfort. However, these buildings can affect our health and environment in many different ways (Torcellini & Crawley, 2006). In fact, the built environment has direct, complicated, and ongoing impacts on the natural environment. Annually, the building sector (residential and commercial) contributes up to 30% of global green house gas emissions and consumes up to 40% of the primary energy and 71% of the total electricity in the United States (United Nations Environmental Program, 2009; Torcellini, Crawley, 2006). It is no surprise then that after the "energy crisis" of the early 1970s that the governments, developers and architects have been interested in reducing the energy requirements of construction and operating buildings in the residential, commercial or institutional sector.

2.2: Overview of Green Building History in the United States and Canada

Rachel Carson's most famous book, *Silent Spring*, publish in 1962, inspired the emergence of an environmental movement in the United States (Lutts, 1985). Amongst many other initiatives, this movement inspired the introduction of several environmental and energy frameworks in the United States and Canada. In 1970, the first of the modern environmental policy acts, *the National Environmental Policy Act* was created. The act set a series of goals and policies for the United States. Its most significant outcome was the requirement that agencies prepare environmental impact assessments for every major activity done or funded by the federal government (NRDC, 2011). This paved the way for many other policies such the *Energy Policy and Conservation Act of 1975* which aimed to reduce energy demands and provide energy efficiency to Americans.

In more recent years, the *President's Blueprint for a Secure Energy Future* enacted in 2011, includes a three-part strategy aiming to first, develop and secure America's energy supplies, secondly, to provide consumers with choices to reduce costs and save energy and lastly, to offer innovative ways to a clean energy future (White House, 2011). According to the International Energy Agency (IEA), if energy efficiency policies had not been introduced 30 years ago, the global energy consumption would be 50 percent higher than today's actual consumption (Natural Resources Canada, 2009).

As the impacts of traditional buildings became more demanding in terms of high energy consumption, green buildings gained momentum. A green or sustainable building is a building designed, constructed and operated to be healthier and more resource-efficient to help minimize the total environmental impacts through its entire lifecycle, from construction to renovation, operation, maintenance and demolition (Torcellini & Crawley, 2006). It was not, however, until 1993 that such buildings obtained recognition from the government in the United States (McCluskey, 2015).

2.2.1: U. S Green Building Council

Today, the U.S Green Building Council (USGBC) is at the forefront of green buildings since its creation in 1993 (USGBC, 2015 a). The USGBC is a non-profit organization committed to promote sustainability in the building and construction industry. This is done through the design and construction of cost-efficient and energy-saving green buildings.

To achieve this goal, there are many different programs such as *Leadership in Energy and Environmental Design* (LEED), which is the Council's most distinguished program. LEED is a set of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighborhoods. LEED, however, is an independent green building certification system that is recognized internationally. Today, over 150 different countries and territories around the globe have LEED certified buildings (USGBC, 2015 a). This certification can be accomplished in two different ways. First, if a country does not have its own version of a green building council, such as the USGBC, then it can apply the USGBC's LEED rating systems to a project in order achieve a LEED certification (USGCB, 2015 b). However, certain countries like Canada have their own equivalent of the USGBC.

The Canadian Green Building Council (CaGBC) has been operating since 2002, and it offers five different sets of rating systems to Canadians which are designed and adapted for Canadian climates. The rating system provides a method of standardization for new and existing buildings to be designed and built using sustainable practices (USGBC, 2015 b). As a first objective, LEED wanted to define green buildings. This objective also included raising awareness for green buildings while highlighting leaders in the sustainable building industry and, importantly, to create competition within the industry for environmental sustainable buildings. Overall, LEED wanted to educate building owners, builders and operators to respect resources and to provide examples of responsible construction practices (McCluskey, 2015). In 1998, USGBC launched the first pilot version of LEED, version 1.0, then two years later it introduced a revised version, LEED Green Building Rating System version 2.0 (Institute for Environmental Entrepreneurship, 2012). From the very beginning, an important aspect of the

LEED rating system was to evolve with the newest emerging green building technologies and to utilize them (USGBC, 2015 b).

2.2.2: Canadian LEED Rating System

For the purpose of this study, the Canadian versions of the rating systems are presented and used to frame an assessment of the VLWLC, located in Sudbury Ontario, which was recently awarded LEED platinum certification. LEED Canada, version 1.0 of 2009 has five main rating systems which are designed to reflect differences in the type of structure in question and are available, for instance, for commercial buildings, schools, homes and even entire neighborhood communities. Each rating system has a different set of requirements that suits the needs of a specific building or project to lead it towards a certification.

The LEED *Core and Shell (CS)* rating system applies to new construction as well as major renovations of institutional and commercial buildings where the developer does not control the final interior design, usually in the case of buildings that will house various tenants in a variety of custom office spaces. The rating system *Commercial Interiors* (CI) is targeted at individuals who may not have control over the entire building and so, will only be able to make green modifications to their space. It is recognized for certifying healthy, productive places within which to work at a reduced environmental footprint. The *Existing Building* (EB) rating system aims to measure operation, improvements and maintenance to help business owners and operators maximize operational efficiency while minimizing environmental impacts.

The *Neighborhood Development with Canadian Alternative Compliance Path (ACP)* is inspired by USGC's equivalent rating system. USGC's version, LEED for Neighborhood and Development guides and assesses communities towards sustainability. The Canadian version, LEED ACP, is still using standards based on the American version. The ACP offers approaches to clarify and guide Canadian projects using certain American standards but also by adapting others given geographic and climatic differences between the two countries. For Canadian projects, the ACP is then more appropriate to use then USGBC's version of the rating system. Although it is not yet entirely adapted for Canadian conditions, it offers more appropriate and realistic standards suited for Canada (CaGBC, 2009).

Lastly, the *New Construction* (NC) rating system applies to new construction as well as major renovations of both commercial and institutional buildings. It is, however, flexible enough to also apply to retail buildings, mid-and high-rise multi-unit residential buildings and other types of buildings (CaGBC, 2009). The VLWLC was evaluated according to this rating system.

2.3: LEED Credits and Certification

Each rating system is based on credits and prerequisites. In order to qualify for a CaGBC LEED certification, the prerequisites for a given rating system must be achieved. Projects earn points towards certification by meeting or exceeding each credit's requirements (CaGBC, 2009). Since the rating system used for certification of the VLWLC was the LEED Canada-NC (New Construction), v. 1.0, this section will present the specifics of this rating system. Although all six credit categories under the LEED Canada-NC v.1.0 are presented here, only the Atmosphere and Energy category is relevant to this study since it is responsible for the assessment the VLWLC's energy consumption.

Under each credit, multiple points can be earned for higher environmental performance levels and those points are what determine which of the four LEED certifications a project is awarded upon completion of its construction or renovations (USGBC, 2013). For this version of the rating system, there are 6 different categories in which a project can earn credits.

In the *Sustainable Sites* category, a project can earn up to 14 points in 8 different credits. For the category *Water Efficiency*, there are 3 different credits in which a project can earn up to 5 points. In the *Energy and Atmosphere* category, a total of 17 points can be earned in 6 credits. Next, the category *Materials and Resources* contain 8 credits for a total of 14 points, the *Indoor Environmental Quality* category has 8 credits in which a project can earn up to 15 points and last but not least, the Innovation *in Design Process* category includes 2 credits worth 5 points (USGBC, 2015 b). Whichever rating system is chosen, there are four levels of LEED certification. The lowest LEED certification is simply known as LEED Certified, in which a building earns between 26-32 points. This is, followed by LEED Silver which requires a total of 33-38 points. The third level, LEED Gold, is awarded when 39 and 51 points are earned and lastly, LEED Platinum, the highest certification requires earning 52 points or more (USGBC, 2015 b).

During construction, supporting documentation and evidence are compiled and submitted to the USGBC. Based on that information, the USGBC determines whether or not points are awarded. No points are awarded until the construction, retrofitting or renovation of the project is finished, and the certification is not received until after completion. Any changes made during construction require a resubmission of the supporting documentation (USGBC, 2013). Although there are no municipal policies that make it mandatory for buildings to get a LEED certification, many cities have frameworks working towards standardizing green buildings. This initiative could potentially improve CaGBC's existing LEED certifications and encourage more buildings to have a certification, like the VLWLC (CaGBC, 2012).

2.4: The Vale Living with Lakes Centre

Laurentian University is home to one of the most celebrated LEED certified buildings in Canada, the Vale Living with Lakes Centre (VLWLC). The VLWLC complex consists of two buildings, the Living with Lakes Centre, the main building which is 2,125 m^2 and the Watershed Centre which is 518 m^2 for a total of 2,643 m^2. The Living with Lakes building, built on the shore of Ramsey Lake was designed to contour the shape of the body of water. All vegetation planted on the property, such as white pines, white birch, blueberry plants and so on are all native to Ontario. The parking lot is also designed small to encourage methods of transportation other than driving.

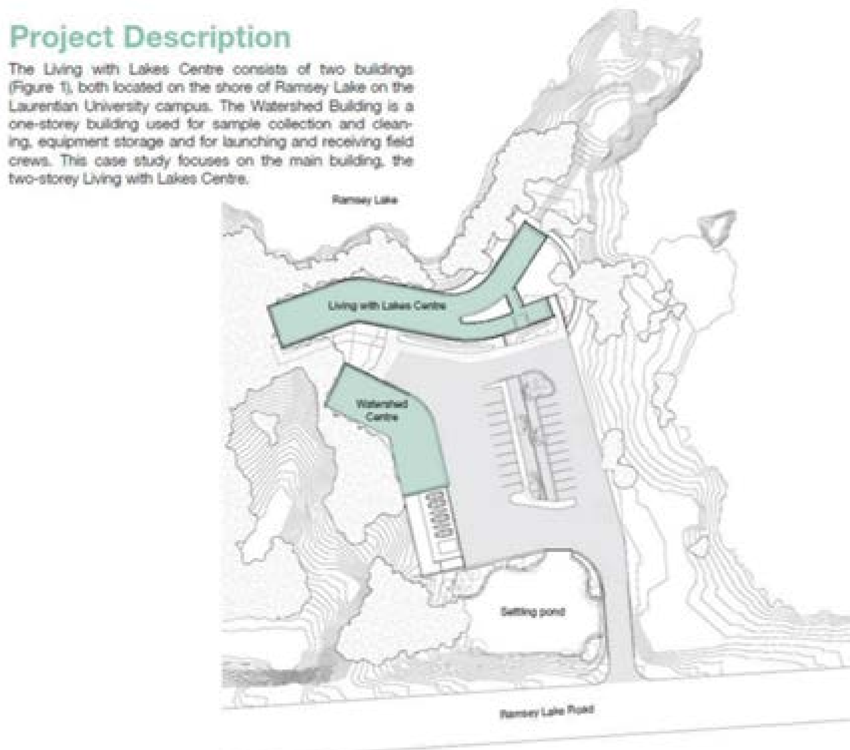


Figure 2.1: VLWLC Property
Source: Canadian Wood Council: Living with Lakes Centre, 2015.

The complex was complete 4 years ago and was designed to exceed the LEED Platinum standards. Since its completion, the VLWLC has won many different awards. To name a few, in 2015, the VLWLC won two awards from the Ontario Architects Association (OAA), Design Excellence Award and the OAA's Sustainable Design Excellence Award (Canadian Wood Council, 2012). The building's LEED Platinum certificate has positioned it to serve as a benchmark for architects, institutions and the public to learn about green building design and green systems in northern Ontario and beyond.

2.5: Green Features of the Vale Living with Lakes Centre

The VLWLC includes many green features that make it stand apart from conventional buildings. The major heating and cooling systems of the building will be further explained the next chapter.

2.5.1: On Site Water Management

During the design process of the project, on site water management was such an important aspect that goals were set independently from the LEED criteria with the ambition to surpass them. Ultimately, the goal was to manage water in a way that the quality of draining water would exceed its quality before the construction of the buildings.

All runoff water is designed to make its way to the settling pond located at the entrance of the property in the parking lot (Figure 1). For example, the parking lot of the VLWLC is designed with nature to ensure infiltration and slow dispersal of water. There are gaps between the lock-stone paving make it permeable which allows rainwater to slowly drain off the parking lot and make its way to the pond. In addition, the water draining from the green roof of the Living with Lakes building will be directed to the pond. The cat-tails in the pond help to naturally clean the water before it is filtered trough two large, green tanks of sand located in the Watershed Building then passed through a UV treatment unit. This water collection system was designed to increase water efficiency by using rainwater for toilet flushing and other non-potable purposes such as irrigation, washing of boats to clean off any potential evasive species, and so on. Due to technical reasons, the usage of this water collection system for toilet flushing is not in operation. There is no on site sewage treatment and therefore, flushed water from washroom is sent to the municipal sewage treatment plant.

Hot water used in the Living with Lakes building is provided from a high efficiency natural gas boiler. The use of this boiler will be kept at a minimal due to the use of an evacuated tube system. This concept consists of using the natural heat from the sun to warm glycol which is contained in evacuated tubes. The intensely heated glycol then pre-heats the water in a hot water tank, see figure 2 below, (Morrison, Budihardjo, Behnia, 2004).

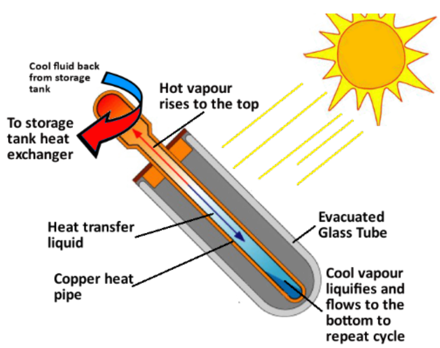


Figure 2.2: Evacuated Tube Diagram.
Source: The Renewable Energy Hub, 2014.

2.5.2: Energy, Heat Recovery and Passive Conservation

The VLWLC also includes many heating and cooling systems that contribute to making it a green building. The major heating and cooling systems of the building will be further explained the next chapter.

One of these distinct characteristic is its energy production with geothermal heat pumps drilled 122 meters down into the bedrock beneath the parking lot of the building which provides basic space heating and cooling in both buildings. The buildings also have modern in-floor heating systems with concrete floor slabs which act as a heat reservoir to slowly release heat and warm the air above. The Living with Lakes building also has a heat recovery system which can be used during the winter. Heat is recovered from the building air in two energy recovery ventilators, one on each floor, before it makes its way out of the building. The energy recovered from this system is then used to warm the fresh air brought into the building.

The VLWLC is also equipped with passive conservation methods. The atrium in the Living with Lakes Building was designed to let escape the warm summer air that rises to the top of the atrium and once that air reaches 24 °C, louvers will automatically open, allowing the warm air to exit the building and thus passively cool the building without the need of air conditioning systems. Due to technical reasons, the passive cooling provided by the atrium is not operational. However, The Living with Lakes Building has other operational passive conservation methods. Vertical sun blades installed on the windows. The blades are strategically positioned according to the direction of which the window faces to minimise the entrance of intense heating by the sun during the summer and to allow the opposite affect during the summer. The building also includes a green roof which acts as an insulator, reducing heat gains in the summer and heat losses in the winter.

2.5.3: Building Materials Used During the Construction of the Vale Living with Lakes Centre

Many construction materials used were natural, renewable, local and had a low ecological footprint. Under the *Materials and Resources* category of the LEED Canada-NC v. 1.0, 65% of all construction materials used must be regionally manufactured or extracted within 800 km of the site (CaGBC LEED Canada, 2014).

Fossiliferous Ordovician limestone from Manitoulin Island is used for the exterior stone cladding. Counter tops, patio pavers and the entrance bridge are also all made of this limestone. The structure itself, the framing and exterior of the buildings are all made of wood since it is renewable, it stores carbon and it is available locally. Jack pine from forests in Northern Ontario and Québec were used for the structural posts and beams while red pine from Thessalon in northern Ontario was used for the decking of the upper floor and roof. The siding of the buildings, see Figure 3 below, is untreated eastern white cedar from Manitoulin Island. Although cedar is very resistant to decay and will last about 50 years before needing to be replaced, since it is untreated, this wood will naturally turn grey with age.

Figure 2.3: Wood siding and stone cladding shown on the Living with Lakes building. Obtained from Laurentian University Office of Sustainability.

2.6: Conclusion

However, despite the accolades the VLWLC's design earned, its operation seems to have fallen short of expectations in general and the use of energy for lighting, heating and cooling in particular. Given the gap between designed and actual operational efficiencies of the VLWLC, the move toward incorporating LEED standards in new buildings elsewhere in the province and country and, most importantly, the fact that a critical aspect of the LEED philosophy is to have its credits and requirements evolve to benefit from emerging green building technologies, it is important to assess the performance of this LEED Platinum building. The VLWLC provides an excellent case study to identify some operational shortcomings and to relate these to potential weaknesses or problems inherent in LEED credits, requirements and/or centralized assessments of a project's design and, perhaps, to link these to limited local contractor knowledge of green construction demands and techniques. The performance of the VLWLC is framed in the following chapter against design expectations and local climate records. The actual assessment is presented in Chapter 4.

Chapter 3:

The Vale Living with Lakes Centre Major LEED Systems and Performance 2013, 2014 and 2015.

3.1: Introduction

As indicated in the previous chapter, the energy requirements and the associated green house gas emissions resulting of and from construction and operating buildings of all types have major environmental repercussions. Therefore, green building technologies and standards like LEED certification have been developed recently in order to greatly reduce the environmental impact associated with building construction and operation of buildings. However, building design efficiencies are not always reflected in building operations, especially in the first years of operations.

Due to the high economic cost of energy for day to day operations and the existence of reliable data regarding the consumption of energy for the VLWLC, this case study compares the building's current energy consumption to its expected and LEED designed performance. The following chapter identifies the relevant energy saving features of the VLWLC, the associated LEED awarded points under the LEED *Energy and Atmosphere Category* and the expected performance of the lighting, heating and cooling systems (in terms of kilowatt hours or the equivalent). It also outlines the actual energy consumption of the building and determines, where possible, which aspects of energy use differ from expectations. The results of this comparison form the basis of an assessment in Chapter 4 that identifies possible reasons for the performance discrepancies.

The VLWLC was designed to meet LEED Platinum certification and perform approximately 65% more efficiently than buildings of similar size built according to the requirements of the 1997 Model National Energy Code for Buildings (Stantec, 2012). This performance was calculated to result in energy cost savings of around a million dollars over the course of 25 years (Stantec, 2012). In order to achieve such performance, however, the design went through a number of iterations before the design team decided which elements to include. The decision to include a specific design or not was based on construction costs and the potential economic return on investment. For instance, two of the early considerations for inclusion were wind power and photovoltaic panels. These were examined and were determined not to be suitable for the project due to the lack of wind required for wind turbines and the relative inefficiency and high cost associated with photovoltaic panels. The Center however, has not ruled out the option of future usage of wind power and photovoltaic panels. Tests to determine the suitability of geothermal energy indicated less than ideal results, but the conclusion was that the amount of energy available was sufficient and geothermal energy was selected for space heating and cooling. The following sections in this chapter identify and describe the major energy using systems that were incorporated into the building.

3.2: Major Heating and Cooling Systems

3.2.1: The Geothermal System

As briefly mentioned above, a geothermal system was designed into the VLWLC given its expected superior performance to wind and solar systems. The city of Greater Sudbury, Ontario is located on the Canadian Shield at a latitude of approximately 46.5° North. The city has a humid continental climate (Köppen climate classification: *Dfb*) (Hudson, 2000). As such it has warm and often hot summers with long, cold and snowy winters. Since it is situated north of the Great Lakes it is susceptible to receiving cold air masses in the winter months (Hudson, 2000). The average increase in temperature with depth (geothermal gradient) for the Sudbury area is 12-18 °C/km, meaning that for every kilometer further down into the earth's crust, the temperature will increase of 12-18 °C (VLWLC, 2012). The geo-exchange wells of the VLWLC are 122 meters into the ground and at this depth, the rock temperature remains between 8-9 °C. This not only makes the VLWLC's geothermal system one of the first rock geothermal system of this scale in northern Ontario (VLWLC, 2012), it also has the capacity to provide energy for basic space heating during the winter and cooling during the summer due to the temperature differential between the bedrock and surface air temperatures most of the year.

The geothermal system used by the VLWLC consists of 40 vertical geo-exchange wells which are drilled 122 m into the bedrock underneath the Center's parking lot (VLWLC, 2012). Pipes of 15 cm in diameters are grouted into each well. The pipes are filled with a mix of glycol (antifreeze) and water which circulates down each of the 40 geo-exchange wells Figure 3.1 gives a general understanding of the concept.

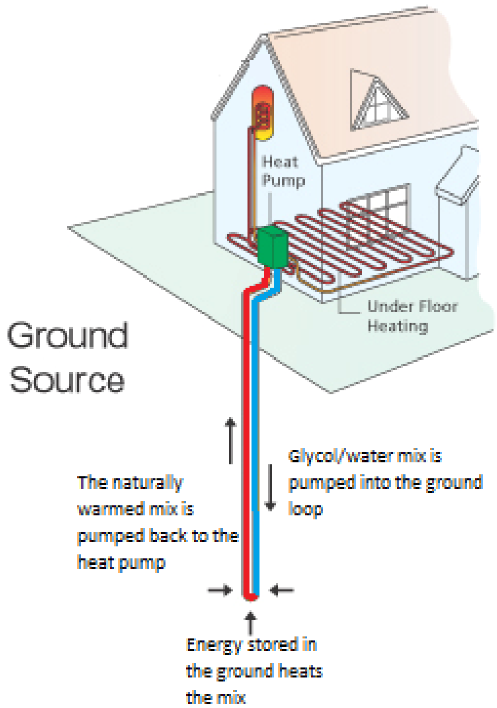


Figure 3.1: Demonstrates vertical geo-exchange wells with one boreholes (the VLWLC geo-exchange system contains 40 wells). The blue represents the glycol/water mix which circulates down the well. Once the mix circulates down the well, it is heated to about 9 °C, represented by the red. It is important to note that unlike shown in this figure, the heat exchange system (heat pump) for the VLWLC is not located in a separate building. Source: Politecnico di Torino, 2016.

Once the glycol/water mix is pumped down the loops, it then makes its way to the heat exchange system which is located in the Watershed Building. When the liquid mix passes through the heat exchange system, it is compressed which raises its temperature to about 50 °C. This system is similar to the operation of a common refrigerator (the coil holding compressed coolant at the back of a refrigerator is hot and radiates away energy captured from the inside of the fridge), (VLWLC, 2012). Once the heated glycol/water has passed through the heat exchange system, it transfers the accumulated heat to an in-floor “hydronic” water heater that circulates through highly durable tubing, from the heat exchanger (in the Watershed Building), then through concrete floor slabs in both buildings (See Figure 3.2). The in-floor ‘hydronic’ water heating then radiates heat which is absorbed and released by the concrete flooring without large temperature fluctuations to warm the air above to allow space heating during the winter time.

Figure 3.2: Second floor or the Living with Lakes Building. The in-floor radiant heating tubing is installed and ready for the concrete to be poured over. Source: VLWLC 2012

In the Living with Lakes Building, the tubing in the floor slabs is installed in twelve separate zones which allow for the temperature of each zone to be controlled individually. Temperature changes are done remotely by operating valves in order to adjust the amount of warmed liquid water entering and exiting the various areas of the floor slabs through the in-floor heating. However, the changes in temperature cannot be modified rapidly with this system alone since the concrete of the floor slabs absorb the heat which will slowly be released to steadily warm the air.

The Living with Lakes Building is broken down into 31 zones (about three offices make up a zone) where rapid air temperature changes can be achieved. This is done by a large box like air-vent with holes cut out which is suspended across the ceiling permitting quick temperature adjustments on both floors (See Figure 3.3). Inside the box vent, air is passed over a coiled tube in which hot or cold water has been pumped from the mechanical room in the Watershed Building. This cools or warms the air before it is expelled out of the box through the cut out holes and allows quick temperature adjustments (VLWLC, 2012).

Figure 3.3: Class room located on the main floor of the Living with Lakes Building. Showcases the “box vent” in the top left corner. Source: Obtained from Laurentian University Office of Sustainability

3.2.2: Energy Recovery Ventilation Systems

The VLWLC has three energy recovery ventilation systems, one on each floor of the Living with Lakes Building and one on the roof of the Watershed Building. These aim to reduce the waste of energy put into the air of the Living with Lakes Building by the in-floor heating system or the heating coils in the box vent.

Energy recovery ventilators consist of two separate air-handling systems. The first collects and exhausts stale indoor air and the second is used to draw fresh outside air and distribute it throughout the building. The system transfers latent energy (humidity) from the most humid air current to the driest, while transferring heat. So in winter, the outside air will absorb exhaust air's humidity and in summer the reverse, see Figure 3.4, (Natural Resources Canada (a), 2015).

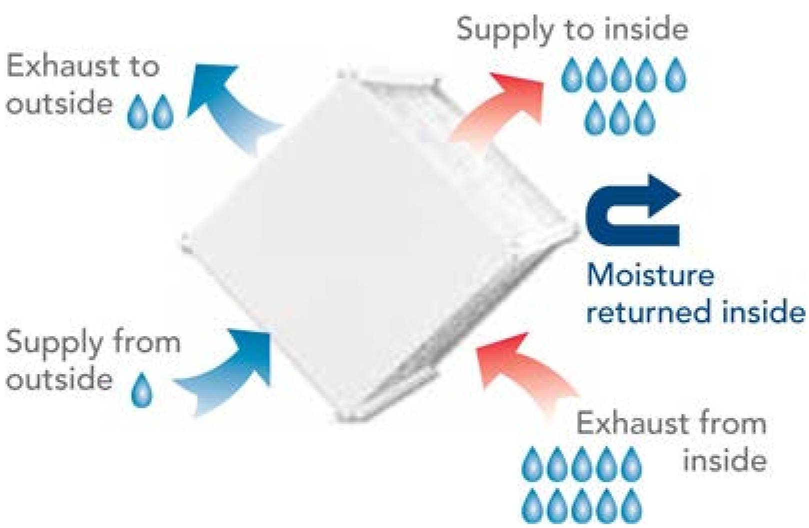


Figure 3.4: Energy Recovery Ventilation Systems.
Source: Venmar: Clean Air Living, 2016.

The energy recovered from this system is used in two different ways, during the winter it warms the fresh air brought into the building and secondly, it is used in the process of actively warm the bedrock in the summer time.

3.2.3: Efficiency of the Bedrock Based Geothermal System

After using the heat in the bedrock over the winter and the general cooling of the rock during the winter, it needs to be actively warmed up each summer to ensure its capability to produce a sufficient amount of energy the following winter. To assist in this process, warm glycol is circulated down the boreholes of each of the 40 wells. This process is necessary considering rock is a very poor heat conductor and since the bedrock cools down during winter time and cannot warm up enough on its own to be efficient for the geothermal system (VLWLC, 2012).

Despite this process, the summer recharge of energy is not guaranteed to be equivalent or surpass the needs of energy during the winter. In these situations, space heating will be provided by back up natural gas fired condensing boiler (Stantec, 2012).

3.3: Data

Table 3.1 highlights a few key characteristics of the VLWLC. The construction of the building was finalized in 2011 and two years later, the VLWLC underwent its first review to determine which certification the building would receive. In January of 2014, the final review took place and the building achieved a total of 53 points which earned it the LEED Canada New Construction v.1.0 Platinum certification.

Table 3.1: Characteristics of the Vale Living with Lakes Centre

Gross Floor Area (m^2)	Year of Completion	First Review Date for Certification	Final Review Date for Certification	LEED Energy and Atmosphere points earned	LEED Total Points Earned
2,643 m^2	2011	June 2013	January 2014	12 (out of a possible 17 points)	53

Under the LEED Energy and Atmosphere category, the VLWLC achieved a total of 12 points out of a possible 17. The most significant credit under this category is credit number one which has 10 points available and aims to optimize energy performance shown below in Table 3.2

Table 3.2: Summary of Energy and Atmosphere Category

	Credit Name	Description	Points Achieved
Credit 1	Optimize Energy Performance	The applicant has submitted the signed LEED letter template declaring that the building achieves an energy cost reduction of 65% compared to the MNECB 1997 Energy Code reference building. The applicant has also submitted the modeling report, along with an energy modelling review report by an approved third party.	10 points
Credit 2.1	Renewable Energy, 5%	Credit Not Attempted	0 Points
Credit 2.2	Renewable Energy, 10%	Credit Not Attempted	0 Points
Credit 2.3	Renewable Energy, 15%	Credit Not Attempted	0 Points
Credit 3	Best Practice Commissioning	Credit Not Attempted	0 Points

Credit 4	Ozone Protection	REVIEW The applicant has submitted the signed LEED letter template declaring that the HVAC&R systems as-built are free of HCFC's.	1 Point
Credit 5	Measurement & Verification	Credit Not Attempted	0 Points
Credit 6	Green Power	The applicant has submitted the signed LEED letter template declaring that the project has purchased 50% of the project's annual regulated electricity load in renewable power certificates for a period of two years. The applicant has also submitted a copy of the contract between the Owner and Renewable Choice for 425,668 kWh of renewable energy certificates.	1 Point

A baseline modeled building was chosen as reference standard for the proposed design (VLWLC) to help determine the energy consumption, the Model National Energy Code for Buildings, (MNECB) was chosen to help make the evaluation. A comparison between the reference building (located in North Bay, Ontario), and the VLWLC design is presented in Table 3.3

Table 3.2 shows the energy utilization in kWh/m^2/year for the reference building (MNECB), the proposed building and the average of the VLWLC's consumption for 2013, 2014 and 2015. The individual energy utilization data (plug loads, lighting, cooling etc.) for the reference and the proposed building was taken from the *Living with Lakes Centre Energy Modeling Report*, prepared by Stantec. The actual energy consumption data for the previous three years of operation of the VLWLC cannot be individually broken down into separate categories since they are not monitored by circuit. However, Table 3.3 allows for a comparison of total energy consumption between the three scenarios and illustrates the theoretical percentage use of each category of electrical use.

Table 3.3: Energy Utilization in kWh/m^2/year

	Reference Building (MNECB)	Proposed/Design VLWLC	Actual VLWLC (Average of 2013, 2014, 2015)
Plug Loads	14	14	8.7%
Domestic Hot Water - Electric	0	0	0
Domestic Hot Water - Gas	20	17	10.5%
Fans	46	33	20.1%
Pumps	62	4	2.5%
Cooling	18	3	1.9%
Heating-Gas	0	42	26.1%
Heating-Electricity	287	25	15.5%
Lighting	48	23	14.3%
Total	495	161	396

3.4: Conclusion

The VLWLC has many energy saving features such as the geothermal system which aim to optimize energy performance. Under the *Energy and Atmosphere Category* of LEED Canada-NC v. 1.0, the Centre earned 12 out of a possible 17 points which contributed to its LEED Platinum certification. However, for various reasons, building design efficiencies are not always reflected in building operations. In certain situations, like the projected 2050 winter climate, the efficiency of design features like the geothermal system might actually improve. Comparing the projected energy performance of the VLWLC to its actual energy consumption permits to highlight discrepancies within the system. Although the lack of existing data for the yearly actual energy consumption of each individual use, (plug loads, cooling, lighting and so on) limits this comparison, the theoretical data provides a good reference point to further the analysis. Chapter 4 discusses this comparison and investigates possible reasons why the VLWLC is not meeting design expectations.

Chapter 4:

Analysis of Actual Energy Consumption for the Vale Living with Lakes Centre and Possible Explanations

4.1: Introduction

As mentioned above, even though green buildings and standards such as the LEED certification are designed to lower energy consumption and, as a result, also reduced relate emissions of green house gases, the actual rates of consumption and emissions do not always reflect the projections of the proposed design. In reality, certain factors affect actual the energy consumption thereby resulting in different rates of energy than anticipated. This Chapter discusses some of the possible reasons why the VLWLC's energy consumption during its first three full years of operation vary from the predicted usage.

4.2: Overview of Analysis

Even though the VLWLC opened in 2011, only the last three years are important to this study because it was not until 2013 that the Centre became completely operational and fully occupied. Therefore, the building's energy consumption of 2013, 2014 and 2015 are used to assess the building's design for energy efficiency. Having more than one year of energy data allows for the comparison of differences and similarities between the systems' energy consumption patterns and the design efficiencies. In addition, it allows for a better evaluation of potential weather and occupancy fluctuations between years.

The number of people who are assigned permanent space in the building has varied over the study period. Therefore, in addition to calculating the overall energy use for the VLWLC complex, the Centre's occupancy data for 2013 and 2014 are available and allow to calculate the per capita energy use. This per capita energy use lends further understanding to the variation in energy use between years. Local climatic records for 2013, 2014 and 2015 were also studied to provide a better understanding of the geothermal system therefore possibly explain certain fluctuations in the energy consumption and to further the analysis of the work orders.

In addition, data exists outlining the number of work orders initiated and completed with respect to the operation of the heating and cooling systems. This data is categorized by season for each year during the study period and trends are identified. These trends are also used as a means to assess the effectiveness of the geothermal system and the general comfort of the building's occupants. However, before undertaking this analysis, the Centre's energy consumption for the study period is presented.

4.3: Actual Energy Consumption Data

As mentioned in the previous chapter, during the design of the geothermal system it was expected that there would be need for back up heating at particular times of the year and if, and when, ambient temperatures for extended periods of time overtaxed the geothermal system. Natural gas is used for heating water for use in the Centre and for back up space heating. Therefore, all other energy needs are met by using electricity: lighting, plug loads, operating the HVAC system, and so on.

4.4: Methodology and Data Limitation

All assumptions made are based from available data and findings in similar case studies. For the purpose of this study, only the energy consumption of the VLWLC will be examined. All of the data used for the analysis was provided by the Laurentian University Office of Sustainability including actual annual energy consumption, summary of annual maintenance Work Orders, *Living with Lakes Centre Report* prepared in 2012 by Stantec. Within the Work Orders, temperature complaints were documented and analyzed for the three years relevant to the study period. Although they demonstrate some inefficiencies in the HVAC system, certain temperature complaints lack precise information, i.e. the temperature during the complaint or an explanation for the complaint. Not having access to all the information limits the analysis, however, a general understanding of the problem is possible. Also, the available data for the building's occupancy was obtained from information found on the VLWLC's website. Although the data for 2013 and 2014 are available, the number of occupants for 2015 was not yet available during the time of the analysis. However, having the data for 2013 and 2014 allows for a comparison of the Centre's energy consumption per occupant for those two years. The local climatic records for the three years in the study period were obtained from Environment Canada. Table 4.1 below shows the VLWLC's actual energy consumption for the three study years.

Table 4.1. Review of Energy Consumption for the Vale Living with Lakes Centre

	2013	**2014**	**2015**	**Average Consumption**
Natural Gas (m^3)	38,568	34,577	16,073	29,739
Natural Gas Conversion	398,407	357,180	166,034	307,207

(ekWh from m^3)				
Electricity (kWh)	616,511	652,528	717,000	662,000
Energy Use Intensity (ekWh/m^2)	384,00	382,03	334.10	367,000

Conversions from Natural Gas to ekWh (equivalent kilowatt hours) were made to facilitate the comparison of the two different types of energy used by the VLWLC. The information and conversion tables for the ekWh and the Energy Use Intensity were obtained from Natural Resources Canada and can be found online, https://www.nrcan.gc.ca/energy/publications/efficiency/buildings/5985

Depending on the purpose of a building, its energy consumption will always be higher or lower than another building of different purpose, for example, an elementary school uses relatively little energy compared to a hospital. This makes it challenging to compare the energy uses between buildings of different uses. Measuring only the amount of energy used for a chosen time period does not take into consideration the size of the building or its type of use. Therefore, an Energy Use Intensity (EUI) indicator helps to compare in a more even way the energy use between various types of buildings and evaluate ways of reducing overall energy consumption. Essentially, the EUI is used to represent a building's "footprint" in terms of energy use (Archtoolbox 2014).

Out of all three years studied, the building's first year in full operation, 2013 had the highest consumption of natural gas per m^3 and the lowest usage of electricity per kWh. Since the electricity consumption provides energy for a large number of uses, for example plug loads, lighting, the geothermal system and so on, and the natural gas is only used for water heating and back up space heating, it is possible that start up complications with the geothermal system resulted in higher than intended use of the back up space heating system provided by natural gas. This is a possible explanation as to why the natural gas consumption is the highest and why the electricity usages are the lowest out of all three years. In addition, the per capita energy consumption for 2013 is 16.6 % for 23 occupants.

In 2014, the consumption of natural gas is slightly lower than the consumption in 2013 with an increase in electricity usage. The local climatic records reveal that 2014 was the coldest year out of the three years used for the study period with a yearly average of 2.6 ˚C and a Winter (January, February and December) average temperature of -12.2 ˚C. The yearly average for 2013 was 3.3 ˚C and -12.5 ˚C during the Winter while the yearly temperature average in 2015 was 3.9 ˚C and -12.3 during the Winter. Therefore, this increases the need for space heating and could explain the slight increase in the electricity consumption from 2013 to 2014 while maintaining a natural gas relatively at the same consumption of 2013. The per capita energy consumption for 2014 was 11.6 % for 33 occupants which represents a reduction of 5% despite the 10 additional occupants from one year to the other.

In 2015, the natural gas consumption represents almost half of the consumption for the previous two years. This however, does not necessarily translate into a reduction in energy consumption since the electricity consumption for this year was the highest out of all three years. Data for VLWLC's occupancy is available for 2013 and 2014 which revealed a yearly increase in the number of occupants from 23 in 2013 to 33 in 2014. With the development of the Centre, the amount of occupants in 2015 surely increased. Because the majority of energy needs are met through the use of electricity, this increase could be a result of a small alteration in the VLWLC's occupancy patterns, number or type of equipment used. In addition, the local climatic records reveal that 2015 had the warmest overall temperature with an average of 3. 9 ˚C, requiring less space heating than previous years which could explain why the natural gas consumption is almost half of the natural gas consumption for the two previous years.

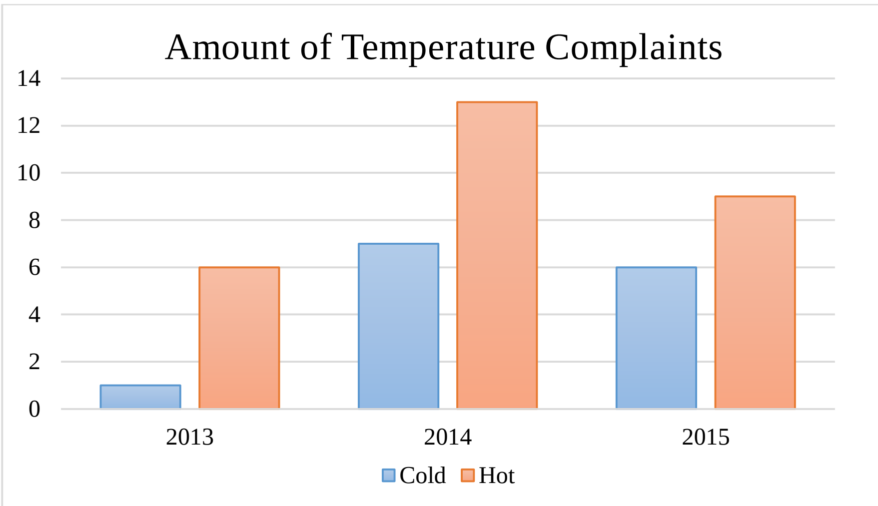
Over the course of the three years analyzed, the natural gas consumption steadily decreases while the electricity consumption increases. This occurrence could support the assumption above, backing up the idea that the geothermal system's efficiency reflects the type and amount of energy used. This means that the reduction of natural gas consumption could possibly represent that the system is becoming more efficient over time thus requiring less back up space heating produced by natural gas and since the geothermal system runs on electricity, increasing its usage.

Also, the energy use intensity calculated decreases from one year to the other. Despite that the reduction is not substantial, it nonetheless represents a reduction in the VLWLC's overall energy consumption. This could support the idea that the system's efficiency required more than one year in operation to function as projected.

4.5: Work orders

The air handling units, the in-floor heating as well as the air supply and return are all controlled by temperature set points on the *Building Automation System.* Since some components of the HVAC are automated, temperature complaints found in the work orders suggest a malfunctions in the system. Work orders for 2013, 2014 and 2015 were analyzed to determine the issues with the HVAC system. This allows the categorization of the complaints for each season of per year to help determine exactly when the system is faulty and whether or not it is due to the system overworking itself on its own (cold complains in the summer) or due to human error (warm complaints during the winter due to opened window). All work orders reported have been resolved. Figure 4.2 illustrates the overall number of temperature complaints for the three periods relevant to this case study.

Figure 4.1 Overall Number of Temperature Complaints for the Vale Living with Lakes Centre



Out of all three years, 2013 represents the year with the least number of complaints for both hot and cold temperatures. There are two possible explanations for this. The first explanation being that the geothermal system was very efficient for that year and the second explanation, the more likely one, that the occupants of the building were not familiar with how the building would operate. Overall, warm temperature complaints are more frequent then cold temperature complaints with many comments mentioning the in floor hydronic heating system as the reason for the warm temperature. The complaints for both, cold and warm temperatures significantly increase from 2013 to 2014, the year with greatest number of complains and therefore, the most problems with the HVAC system. However, the temperature complaints slightly decrease from 2014 to 2015.

Table 4.2 below indicates the number of temperature complaints for each season per year. This illustrates that there are more temperature complaints during the shoulder seasons, Spring and Fall then in Summer and Winter. As discussed in Chapter 3, this supports the notion that the geothermal system does not quickly respond to the variability in temperatures of the Spring and Fall.

Table 4.2 Temperature Complaints per Season

	2013	2014	2015	Total
Spring	2	9	3	14
Summer	0	3	2	5
Fall	5	4	6	15
Winter	0	4	4	8

The temperature complaints found in the work orders required the occupant who filed the complaint to document the date the complaint was made, the area or room it affected, the temperature at the time of the complaint and to add a comment explaining their complaint. This information helps to understand, using the local climatic records, whether the complaint was made due to extreme weather events of because of inefficiencies in the VWLWC's systems.

Table 4.2 shows that there are more temperature complaints during the shoulder seasons, Spring and Fall than in Summer and Winter. This means that the system has a hard time transitioning the building's temperature for those seasons. Over the Winter the temperature of the bedrock decreases and thus limits initial energy available for the following Spring. This is why the process of actively warming up the bedrock is very important despite the fact that the amount of energy available is not guaranteed (VLWLC 2012).

In 2013, there was a total of seven temperature complaints that were documented. Two of those complaints were made in the Spring, both were warm temperature complaints, specifying that the temperature was approximately 27 ˚C at the time of the complaint. Also, there were four warm temperature complaints filed during the Fall again, indicating very warm temperatures. The only cold temperature complaint was filed during the Fall, indicating that the temperature was at 14 ˚C, just days after a warm temperature complaint was previously documented.

The year 2014 represents the year with the most temperature complaints with a total of 20 complaints made during all four seasons. The majority of the temperature complaints were made in Spring. For the warm temperature complaints, two of them were made in the Winter, five in the Spring, three during the Summer and another three during the Fall. Some of these complaints indicated that the temperature in certain areas were as high as 28 ˚C in the Winter and Spring time. There was a total of seven cold temperature complaints where many of them the temperature was as low as 15 ˚C during the Fall and Winter. Four of the complaints were in the Spring time, one in the Fall and the other two were made during the Winter. Many of the warm complaints made in 2014 added a comment regarding the in floor heating system and questioned whether it was activated when it should not have been or simply stated that the indoor temperature was too warm for the time of the year. This further supports the notion that the system does not transition well from one season to another and suggests that there are malfunctions in the HVAC system since the in floor hydronic heating system is automated by controlled set points and some of these complaints mention about the in floor heating system being activated during the Summer.

During 2015, there were a total of 15 temperature complaints made, with a total of 9 warm temperature complaints, three in the Winter, three during the Spring, one in the Summer and two during the Fall. The other six complaints were cold temperature complaints, one in

Winter, another during the Summer and the other four during the Fall. For the warm temperature complaints, a few comments mention the in floor hydronic heating system. Many comments for the cold temperature complaints made in 2015 mentioned that there was continuous cold air blowing out of the box shaped air vent in the Living with Lakes Building. This makes it evident that the system is over working itself and, again, supports the idea of there being inefficiencies in the HVAC system, in this case, the rapid air temperature change system.

Figure 4.2: Amount of Money Spent Yearly Fixing the HVAC System for the Vale Living with Lakes Centre

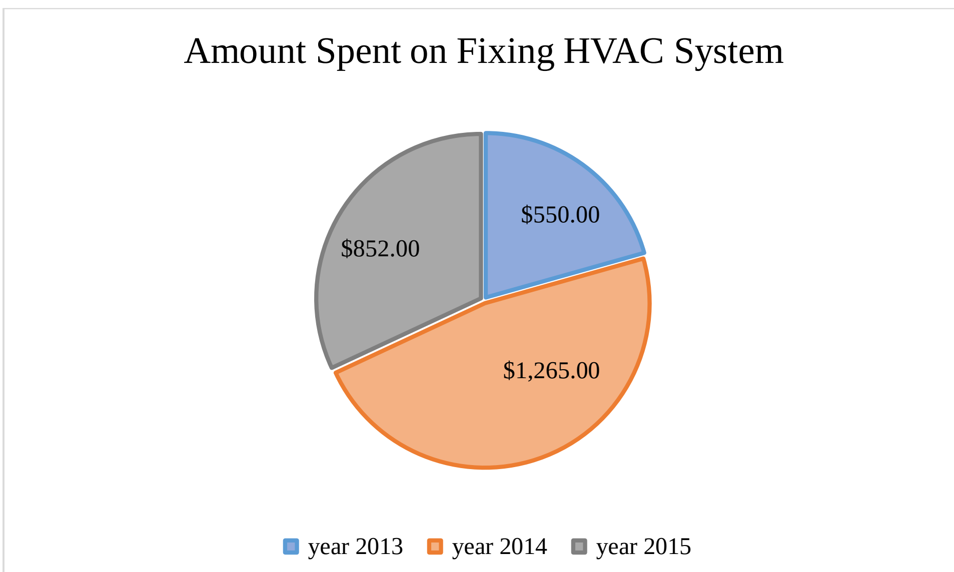


Figure 4.2 presents the annual costs of repairs to the HVAC system. The year where the largest amount was spent is 2014, which corresponds with the findings in Figure 4.1. Breakdowns in the system demonstrate that it is not as efficient as designed. However, the improvement in the system from 2014 to 2015 leads to two conclusions. The first being that those working in the building must have collaborated to work with the system to ensure its optimal performance, i.e. respect the *Building Automation System's* set temperature points,

refrain from opening windows, report all malfunctions in the system and so on. The second conclusion suggest that it might require the system a few years of operation to be able to regulate itself to its proposed design efficiency goals. Based on the information gathered for this case study, it is believed that for the VLWLC, a combination of both conclusions took place which improved the building's overall energy consumption. Green buildings and buildings with a LEED certification operate differently than traditional buildings, therefore, how they operate is not commonly known or yet understood. This assumption is supported by an American case study done by the University of California in 2006 which investigated the energy consumption of 21 buildings with various LEED certifications. Amongst the many conclusions made by the study, the authors emphasis that the occupants of the building must work with the building, and not against it, to ensure maximum efficiency (Diamond, 2006).

4.6: LEED Critiques and recommendations

Standards such as LEED and other similar standards and rating systems to evaluate green buildings are essential to further the advancement of green buildings and help the transition towards more sustainable buildings and homes. However, as it currently stands, there are a lot of areas in which LEED standards and criteria could be modified to improve the overall efficiency of LEED designed buildings.

First of all, to determine which level of certification a building receives, an evaluation is made according to the rating system that was chosen for the project. Although there are three various stages of the evaluation process, (first, second and final review), there are no post occupancy evaluation, meaning that all evaluations are done either during the final stages of the renovation, construction or the retrofitting of the building or shortly afterwards. This will not show a true representation of the building's consumption's such as energy or water usage since the building is not fully occupied.

Also, LEED's evaluation to determine the level of certification a building received does not take into consideration possible breakdowns or inefficiencies the building's green features might experience after the evaluation is done. Some of these green features possibly played a crucial role in the its certification. For example, in the *Water Efficiency* category, all five credits in this category, (each worth one point) focus on water use reduction and on site water management. Therefore, if the systems and techniques used to reduce water usage and manage water on site are properly functioning during the building's final review, the building will earn the associated points which will contribute to its certification. However, if the building experiences issues with these systems or techniques at any point after they received their certification, they may choose to stop using them without losing their certification. This is highly beneficial for a building since it increases its chances to potentially earn and maintain a higher level of certification than it might deserve. To adjust this, including a post-occupancy evaluation of the building, perhaps a year or two after it becomes fully functional and fully operational would better reflect its sustainability and give a better understanding of the building, including which areas to improve and so on.

The overall goal of LEED is to certify buildings which aims to reflect in lower environmental impacts. However, the system is a 'point hunting' approach meaning that it is not designed to have the largest positive impacts but rather to award the most points to a building to encourage certification. For example, in addition to having no post occupancy evaluation which supports this assumption, breakdown of points associated with each credit are not equally assigned between various options. For example, in the *Energy and Atmosphere* category, a total of 17 points can be awarded where 10 of those 17 points can be earned in one credit if a building achieves an energy cost reduction of 65% compared to the MNECB 1997 Energy Code reference building while a credit requiring a building to have 20% of renewable energy will only give one point. Since the building manager can decide which credit to accomplish, it is possible to only attempt the credits with the largest amount of points associated which will reflect in a high certification level without necessarily reflecting in the most positive improvements. Also, to achieve the second lowest level of certification, LEED Canada Silver, it is possible to get the minimum score (33-38 points) required to attain this certification level without even improving the energy performance of the building.

However, LEED is continuously reviewing its standards and changing its rating systems to include the latest techniques and be as environmentally forward thinking as possible. Although in many cases, green buildings do not perform as efficiently as predicted, especially during the first few year of operation, they do demonstrate the potential of being highly beneficial from an environmental, social, economic and health perspective. It is important to view these case studies not as failures but as valuable learning opportunities that provide essential information which will help improve the future green buildings and their standards.

4.7: Conclusion

By comparing the VLWLC's three latest years of operation as well as analysing the work orders for those same years, it is clear that there are discrepancies in the efficiency of the building's systems that provide heating, especially during the shoulder seasons. The local climatic records as well as the number of occupants in the building demonstrated how there are many factors that can modify a building's energy consumption from year to year. Many other similar case studies demonstrate that these new technologies which are often used in buildings with a LEED certification require more than one year to perform to the predicted standards. The VLWLC case study is no exception since the geothermal system as well as the in floor hydronic system seem to have worked through some initial issues and the building's EIU is slowly decreasing. Also, the geothermal system used to provide the majority of the space heating for the VLWLC is designed to be adaptable to the changing climates which will therefore increase its efficiency overtime.

Chapter 5:

Conclusions and Implications

Green buildings are still relatively new to the construction sector and only earned recognition from governments about 25 years ago (McCluskey, 2015). They are therefore still at the beginning of their development phase and are slowly being introduced to communities.

Many of the techniques and technologies used for the construction or retrofit of these green buildings are still being developed and / or perfected which makes their applications challenging. Also, there are not many workers that are specifically trained to work with green technologies or systems which make it difficult for such technologies or systems to be properly installed to reduce potential future issues, to maintain and take care of these systems or to repair them in the event of a breakdown (GhaffarianHoseini, Dahlan, Berardi, GhaffarianHoseini, Makaremi, & GhaffarianHoseini). For example, in the case of the VLWLC, the system was designed to use rainwater for toilet flushing and other non potable uses is currently not in operation and so, the Centre uses the conventional municipal system. Likewise, our understanding of how green buildings' daily, seasonally, and yearly operation is currently limited since they are still new and being developed. However, with every new green building, we are able to document the efficiency of the green systems, techniques or technologies that were used, analyse them and determine ways to optimize these systems to apply them to future green buildings or incorporate them into the operation of existing green building to increase their efficiency (Diamond, 2006). As years progress, these systems and green features will be perfected and standardized which will not only make green buildings more efficient, predictable and reliable but will also make them more appealing to the general public and thus, will make green building more common.

Even though the VLWLC provided an excellent case study to compare and analyse the efficiency of a building with a LEED Canada certification and its many green features, it also allowed the exploration of many passive green methods. These passive methods such as the spacing between the lock stone in the parking lot, the vertical sun blades that provide shade/ increase the sunlight intake and so on proved to be very advantageous. They are effective, at a lower cost, easy to install, they do not require complex technologies, need little maintenance and can be easily incorporated to an existing building or home, a retrofit or integrated into the design and construction of a green or traditional building. Therefore, when planning green buildings, as well as investing in the development of green technologies, it is also important to maintain and develop new passive green methods. However, the current, application of green buildings and buildings with a LEED certification often do not meet their design expectations.

According to the projected energy consumption found in the Stantec report, the VLWLC's yearly energy consumption should be about 161 ekWh/m^2 which represents an equivalent number of the building's natural gas and electricity consumption. As illustrated in Table 4.1, the consumption in ekWh/m^2 for the three years combined, the VLWLC had an average of 367 ekWh/m^2 while it consumed 384 ekWh/m^2 in 2013, 382 ekWh/m^2 in 2014 and 344 ekWh/m^2 in 2015. Even though we can observe a decrease in the building's consumption, the data also shows that the VLWLC does not perform as efficiently as predicted. While not ideal, this performance demonstrates that a green building with a LEED certification does have a better performance in terms energy consumption than a building constructed with traditional methods since the consumption for the reference building is 495 ekWh/m^2.

Therefore, although green buildings with a LEED certification do not operate to their full potential they are more efficient than a traditionally built buildings and will, therefore have less overall ecological impacts. However, the certification process should go beyond simply obtaining the initial level of certification shortly after the construction or retrofit of the building. Regular post occupancy evaluations should be mandatory for the two or three first years in operation to ensure that the buildings maintain the same efficiency they demonstrated during the initial evaluation which earned them their level of certification. This would require building owners to maintain the green systems and technologies and would confirm that the buildings are operating as efficiently as promised. Certain states such as Washington have laws requiring that all new buildings and renovation projects that receive state funding be built to one of three predetermined green building standards, one of them being LEED (State of Washington Department of Ecology, 2006). In addition, due to the many effects of climate change, the advancement in green technologies and the general public awareness of standards such as LEED, will surely lead to a shift in the construction sector towards green buildings and possibly even making it mandatory by governments to have a green building certification.

References

Archtoolbox: Architect's Technical Reference. (2014). Energy Use Intensity (EUI). Retrieved March 30, 2016, from http://www.archtoolbox.com/sustainability/energy-use-intensity.html

CaGBC. (2009). LEED Canada Rating Systems. Retrieved November 30, 2015, from http://www.cagbc.org/CAGBC/LEED/CommercGreenBuild/RatingSystemsCAGBC/Programs/LEED/CommercialInstitutional/RatingsSystems/LEED_Canada_Rating_S.aspx?hkey=5490b62b-b10f-45b7-9c41-2b5a299655b8

CaGBC. (2012). About CaGBC. Retrieved November 30, 2015, from http://www.cagbc.org/cagbc/about/cagbc/aboutcagbc/about_cagbc.aspx?hkey=259347d-6d16-4417-ba6c-a442711f95a1

CaGBC LEED Canada. (2014). LEED Canada-NC v.1.0 Certification Review Report.

Canadian Wood Council. (2012). Vale Living with Lakes Centre. Retrieved November 14, 2015, from http://cwc.ca/wp-content/uploads/publications-casestudy-Living_With_Lakes.pdf

Diamond, R. (2006). Evaluating the energy performance of the first generation of LEED-certified commercial buildings. *Lawrence Berkeley National Laboratory*. Retrieved from http://escholarship.org/uc/item/498009ks

GhaffarianHoseini, A., Dahlan, N. D., Berardi, U., GhaffarianHoseini, A., Makaremi, N., & GhaffarianHoseini, M. (2013). Sustainable energy performances of green buildings: A review of current theories, implementations and challenges. *Renewable and Sustainable Energy Reviews*, *25*, 1–17. http://doi.org/10.1016/j.rser.2013.01.010

Government of Ontario. 2015. Ontario Regulation 397/11 Energy Conservation and Demand

Management Plans. Retrieved October 15, 2015, from https://www.las.on.ca/PDFs/Services/Energy-Planning-Tool/Resources/Update-on-O-Reg-39711-2015-10-04-v04.aspx

Hudson, John C. (2000.) Goode's World Atlas, Rand McNally: New York

Institute for Environmental Entrepreneurship. (2012). Green Building: A Retrospective on the History of LEED Certification. Retrieved from http://enviroinstitute.org/wp-content/uploads/2012/09/GREEN-BUILDING-A-Retrospective-History-of-LEED-Certification-November-2012.pdf

Lutts, R. H. (1985). Chemical Fallout: Rachel Carson's Silent Spring, Radioactive Fallout, and the Environmental Movement. *Environmental Review: ER*, *9*(3), 211–225. http://doi.org/10.2307/3984231

McCluskey, L. (2015). LEEDing Up to Today- A Short History of LEED. Retrieved November 26, 2015, from https://www.linkedin.com/pulse/leeding-up-today-short-history-leed-linda-mccluskey

Morrison, G. L., Budihardjo, I., & Behnia, M. (2004). Water-in-glass evacuated tube solar water heaters. *Solar Energy*, *76*(1–3), 135–140. http://doi.org/10.1016/j.solener.2003.07.024

Natural Resources Canada. 2009. Improving Energy Efficiency in Canada. Retrieved April 2, 2016, from http://oee.nrcan.gc.ca/publications/statistics/parliament07-08/pdf/parliament07-08.pdf

Natural Resources Canada. 2012. Survey of Commercial and Institutional Energy Use. Retrieved March 2nd, 2016, from http://oee.nrcan.gc.ca/publications/statistics/scieu09/scieu_e.pdf

Natural Resources Canada (a). (2015). Heat/energy recovery ventilators. Retrieved March 21, 2016, from http://www.nrcan.gc.ca/energy/products/categories/cooling-ventilating/ventilating/hrv/16197

Natural Resources Canada (b). (2015). Energy Efficiency in Buildings. Retrieved March 22, 2016, from https://www.nrcan.gc.ca/energy/publications/efficiency/buildings/5985

Natural Resources Defense Council (NRDC). (2011). Environmental Laws and Treaties. Retrieved November 27, 2015, from http://www.nrdc.org/reference/laws.asp

Politecnico di Torino. (2016). Groundwater Engineering. Retrieved March 3, 2016, from http://areeweb.polito.it/ricerca/groundwater/ricerca/geothermics.html

Stantec. (2012). Living with Lakes Centre Energy Modeling Report.

The Renewable Energy Hub. (2014). How do solar thermal panels work? Retrieved April 15, 2016, from https://www.renewableenergyhub.co.uk/how-do-solar-thermal-panels-work.html

Torcellini, P., & Crawley, D. (2006). Understanding Zero-Energy Buildings. *ASHRAE Journal*, *48*(9), 62–69.

United Nations Environment Programme. (2009). Buildings and Climate Change: Summary for Decision-Makers. Retrieved from http://www.unep.org/sbci/pdfs/SBCI-BCCSummary.pdf

USGBC. (2013). LEED User Guide. Retrieved from http://www.cabrillo.edu/~msoik/3/LEED%20v4%20guide.pdf

USGBC (a). (2015). Our History. Retrieved November 28, 2015, from http://www.usgbc.org/about/history

USGBC (b). (2015). LEED Overview. Retrieved November 28, 2015, from http://www.usgbc.org/leed

Vale Living with Lakes Centre. (2012). Being Green and Living up to it.

Vale Living with Lakes Centre. (2014). Our Staff. Retrieved April 18, 2016, from http://www3.laurentian.ca/livingwithlakes/about/staff/

Venmar: Clean Air Living. (2016). HRV and ERV - Why choose a ERV (Energy Recovery Ventilator). Retrieved April 17, 2016, from http://www.venmar.ca/22-detail-advice-hrv-and-erv-why-choose-a-erv-energy-recovery-ventilator-.html

Washington State Department of Ecology. (2006). Green Building. Retrieved April 20th, 2016, from http://www.ecy.wa.gov/programs/swfa/greenbuilding/law.html

White House. (2011). Blueprint for a Secure Energy Future. Retrieved from https://www.whitehouse.gov/sites/default/files/blueprint_secure_energy_future.