PASSIVE DESIGN STRATEGIES FOR MEDIUM-FORMAT RETAIL BUILDINGS

IN TORONTO TOWARD NZE

Using Ecotect® Analysis 2011, with a case-study of a retail building in Toronto, ON

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by

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Passive Design Strategies for Medium-format Retail Buildings in Toronto toward NZE

Master of Building Science, 2016

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ABSTRACT

This paper studied passive design strategies available for medium-format retail buildings in Toronto. An existing retail building, designed by the researcher and built in 2014, was chosen as a case study. A framework of four models to show incremental improvements was created and multiple passive design strategies were applied to each model.

The framework targeted four energy goals. Each goal represented a level of higher efficiency using Energy Use Intensity (EUI). Each of the four design models was simulated using Ecotect® and all results documented and analyzed. At the end of last model's analysis, an architectural design project to exhibit design strategies was created.

There are perhaps two significant points that the study has achieved. First point was the identification of key passive strategies that can be implemented in retail buildings in Toronto. The second was the methodology by which incremental improvements with pre-set energy targets can be followed with validated results.

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1. INTRODUCTION

This research paper reports on the opportunities to reduce energy consumption in retail buildings in Toronto. This was done through adapting passive design strategies and Ecotect® Analysis 2011 simulation software, with the aim to reach Net Zero Energy levels. A final design project accompanies this research paper and is part of this paper.

1.1. Overview

Retail buildings play important part in modern life. They are part of a large stock of commercial buildings that provide services to the public. On the other hand these retail buildings are also responsible for large energy consumption, hence big damage to the environment. This is due to the fact that these buildings are still poorly operating from the energy point of view. They almost completely depend on mechanical systems for their heating and cooling and lighting demands. The current stock of retail buildings are designed in old ways that need to be changed.

There is an urgent need to utilize passive methods of design in order to minimize retail building's reliance on energy-based systems and maximize the use of passive design techniques that are available and practically free. The passive design techniques are far from being new. They had been in use for thousands of years. With our new scientific knowledge and technology advancements, especially in the building envelope such as glazing and in computer energy simulation, we are much more able to deploy these techniques to help us design and build healthier, sustainable, and highly efficient retail buildings to the point of becoming net zero energy buildings NZEB.

Retail buildings in Canada lag behind in terms of energy use efficiency. A study conducted by Statistics Canada published in 2007 (based on survey conducted in 2005 for all of Canada) found that commercial establishments consumed over 1,036 million GJ (for the entire year of survey, 2005) of energy to run their facilities (NRC, 2007). "This total energy consumption corresponds to the annual consumption of some 9 million Canadian households[1] or the equivalent of nearly twice the energy consumption of all private households in Ontario"[2]. Among all commercial establishments, retail surveyed in 2005 retail trade occupied 14 % of the total commercial buildings' consumption or around 146.8 million GJ[3] (NRC, 2007).

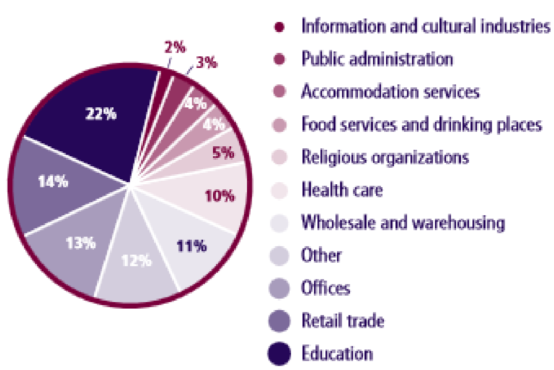


Figure 1 - Retail trade consumes 14% of total energy consumption in the commercial sector in Canada (NRC, 2007).

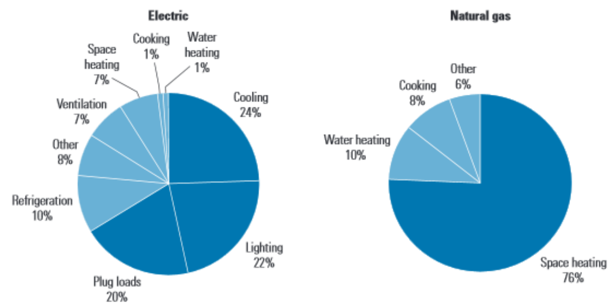


Figure 2 - Distribution of energy intensity in retail facilities (Energy Star, 2008).

Stores, Supermarkets and Malls	Typical Annual Energy Consumption Range*	Average Annual Energy Intensity*
Non-Food Retailers	0.8-1.0 GJ/m²	0.9 GJ/m²
Non-Food Big Box	0.6-1.8 GJ/m²	1.1 GJ/m²
Food Retailers	2.5-3.4 GJ/m²	2.8 GJ/m²
Enclosed Shopping Malls	1.2-1.4 GJ/m²	1.4 GJ/m²
Strip Malls	1.2-1.9 GJ/m²	1.2 GJ/m²
Total	**0.8-3.4 GJ/m²**	**1.5 GJ/m²**

*Benchmarking figures from Roche ltd based on various sources.

Table 1 - Average Annual Energy Intensity EUI for non-food retailers and Strip Malls (NRC, 2015)

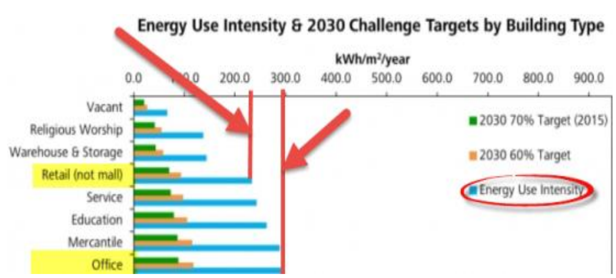


Figure 3 - shows the EUI targets adopted by 2030 Challenge by building type. The red lines and arrows point to retail and office sectors and their current use of energy (NRC, 2015).

This high level of energy consumption indicates that retail buildings are responsible for high share of CO_2 emissions and that this is projected to grow faster than any other sector with

[1] For 2005.
[2] Expressing energy use in terms of number of households involves a calculation using the energy intensity of households (GJ/household) as determined by the Office of Energy Efficiency for 2004 – the most recent year – in the Energy Use Data Handbook, published in August 2006. The number of households is taken from Statistics Canada's 2001 Canadian census (NRC, 2007).
[3] For 2005.

emissions projected to grow the fastest – 1.8% a year through 2030 (USGBC, 2013). Retail buildings use electric and natural gas to cover their load demands. Figure 2 shows that the highest electric demand is on air-conditioning, then lighting, then plug loads such as cash registers and computers, while most of the natural gas consumption goes to space heating (Energy star, 2008).

Statistics Canada survey mentioned earlier shows that retail buildings energy performance is poor. Table 1 shows two types of retail buildings; strip plazas and non-food retailers. For strip plaza prototypes, EUI is shown to be 1.2 GJ/m²yr or 333.33 kWh/m²yr. This is higher energy intensity than those of non-food retailers of around 250kWh/m²yr. This is because strip malls usually include retailers that use high-demand appliances such as grocery stores and restaurants resulting in much higher EUI than non-food/restaurant retailers. In both cases the survey results show that EUI for retail in general is much higher than the goals set by Challenge 2030 of around 70kWh/m²yr (figure 3).

The opportunity to make a real impact on reducing carbon emissions rests considerably on optimizing the energy performance of retail buildings including retail especially medium and big-box formats. This paper attempts to lay a scientific basis for this process and define its parameters within a design framework that utilizes passive design strategies that can lead and facilitate architects' attempts in this direction.

1.2.Research Objectives

The main research objective is to come up with a framework that can help architects improve retail buildings in Toronto through adapting key passive design strategies towards achieving higher standards of performance, and eventually to NZEB. In order to do that, the research aims first at identifying the factors that contribute to current medium-format retail buildings' poor performance. These factors can include, but not restricted to, building envelope thermal performance, type and properties of materials used, orientation, mass and fenestrations configurations, besides other issues such as program and site planning. Electric lighting, HVAC systems are part of the active strategies which were not included in the research, however they were factored in during the investigation but only to the extent that they become subsidiary. The iterative approach was used in this research through creating four models that can show-case the same set of key passive design strategies, incrementally improved. It is the objective of this research paper therefore, to explore different passive design strategies and select the appropriate ones that can, within Toronto's climate criteria, be implemented on each model to make improvements in each step.

1.3. Research Questions

1. What are the key passive design strategies architects can implement that can make the biggest impact on retail buildings' energy consumption in Toronto?
2. What is the design framework or blueprint that can be followed by architects aiming to improve energy performance of retail buildings in Toronto through deploying suitable passive design strategies incrementally? What are the components of this framework?
3. To what extent can NZE or close-to NZE targets be achieved in retail buildings in Toronto through passive design strategies alone?

1.4. Key Passive Strategies and their potential in Retail Buildings

Passive design strategies can apply to many building types and in a variety of climates. However, retail has some unique requirements and possibilities that are different from other uses. The following are some of the areas that can play an important role in the reduction of energy consumption of retail buildings in Toronto passively:

1.4.1. Space Volume

Retail buildings have excessive heights which cause increase in space volumes. As air conditioning system attempts to maintain comfort levels, more energy are spent to maintain temperatures and relative humidity at the set design levels. Toronto's climate has high number of Heating Degree Days (HDD). Therefore there is a potential to decrease space heights in order to minimize heating and cooling loads.

1.4.2. Orientation

Medium-format retail buildings' design usually follows a functional program and a site plan for major shopping centres' developments. Although it is not possible for planners to consider orientation for every retail building they design on the site, it is important that orientation comes back as a major consideration in locating retail buildings in order to benefit from passive solar heating and cooling possibilities which are freely available.

1.4.3. Solar Radiation Harvesting

Solar radiation can be transferred into heat when allowed into a building. This heat can reduce heating loads required in winter, especially in cold climates. For retail buildings in Toronto to become high-performing buildings, it is essential to include solar radiation passive strategy during the schematic design stage. As mentioned earlier, retail buildings are still highly driven by location and program. Solar radiation and the study of sun path can introduce high potential for energy savings in retail buildings through solar harvesting.

1.4.4. Passive Cooling Techniques

The key strategy for passive cooking is protecting the fenestration area from direct solar radiation in the summer (in northern hemisphere). Even though medium to large-format retail buildings use canopies or other forms of shading structures, this use does not always seem to be congruent with their design purpose. Many of the retail prototypes use canopy for aesthetics and to reinforce branding. Other passive cooling techniques could be the thermal mass, stack ventilation, and wind ventilation in certain moderate seasons.

1.4.5. Day-lighting

Medium to large-format retail buildings have deep floor layouts. The possible methods for introducing day-lighting into such buildings are, in addition to the glazed store-fronts, skylights, rooftop monitors, or clerestory windows. When deep spaces inside retail building get more natural daylight, the need for electric lighting can be reduced.

2. LITERATURE REVIEW

2.1.Background

The literature review included seven themes which are most relevant to passive design strategies, retail buildings energy efficiency, and importance of climate specifics in the utilization of passive design strategies, as follow; (a) passive design strategies and the role of the architect; (b) climate and site analysis; (c) the importance of the holistic approach; (d) the energy targets; (e) Medium-format retail buildings in Toronto; (f) Net Zero Energy in retail; and (g) energy modeling and the design process. The literature converges in terms of stressing the importance of energy efficient buildings in medium and big-box retail formats; the importance of sustainable design strategies to minimize energy consumption, and the impact that building energy simulation technology (BES) to aid design have made into the design process, particularly Ecotect Analysis 2011®. One major document that was found to be quite useful in combining all of the five themes, and substantiated the value of early design energy simulation and importance of site and climate analysis if any goal to achieve higher efficiency in retail is to be achieved (ASHRAE, 2011). Although many of the literature reviewed stressed the holistic approach and the importance of climate and site specific understanding by architects, none was found to be specific in tying up all the themes in a methodical way to achieve higher energy goals while utilizing energy simulation program. The literature review in general came to the conclusion that there is hardly any guided set of practices, geared towards architects with an aim to bring the main elements of sustainable design strategies together in a real-life and methodical way yet.

ASHRAE’s Advanced Energy Design Guide for Medium to Big Box Retail Building was reviewed. This document treated passive design techniques as part of a whole Integrated Design Process. ASHRAE’s guide however comprehensive in its recommendation of the best practices did not assign special significance for passive strategies in retail buildings as such. For example, in chapter 2 under Integrated Design Process, it was recommended that certain design measures to reduce energy consumption are climate dependent (ASHRAE, 2011). These recommendations were general rather than specific to passive design strategies or techniques such as passive heating or cooling, and lacked applications of how to achieve these recommendations or how information about climatic zones could be specifically analyzed or interpreted, which understandably was outside the scope of the Guide. Passive design strategies were encouraged in chapter 5, and under Design Considerations, it was suggested that “simple measures, such as passive strategies that integrate efficiency with the building envelope and structure, have low O&M costs and lower life-cycle costs, in general, than comparable, tech-heavy measures” (ASHRAE, 2011).

2.2. Passive Design Strategies and the Role of the Architect

As much as ASHRAE’s guide focused on the improvement of energy efficiency of buildings, many architects probably until today, are not clear about what passive design strategies are, how to tackle or verify if they apply to that particular situation. Architects often delegate matters of energy consumption of efficiency to energy experts or engineers usually at the design development, or even later at the construction document stage. Kwok and Grondzik points out to this problem and think that this must be corrected. They state that “architects must be active participants in shaping green building – through early, reasoned, and appropriate integration of green design strategies (Kwok and Grondzok, 2007). Anderson (2014), on the other hand, adds more tasks to the architect’s involvement and states that “Architects are uniquely positioned to affect passive strategies in their design. They need to have the means to evaluate design decisions to take advantage of this, however” (Anderson, 2014). Hootman (2013) also confirms the leadership role when he emphasizes that architects need to reclaim their leadership role in order to transform the industry and the built environment. He also makes the claim that architect should not depend completely on engineers or energy modelers but depend on their own effort and take ownership of the energy efficiency for buildings:

> *We (architects) need to take ownership of the energy design problems inherent in our projects, rather than relegating them to the engineers and energy modelers* (Hootman, 2013).

2.3.Climate and Site Analysis

Climate and site analysis are the underlying causes to any successful application of passive design strategy. The understanding of the characteristics of environment at a certain location is becoming a crucial part of architect's role as a generalist of building performance rather than his conventional role as a specialist of form (Kwok and Grondzik, 2007). Part of this knowledge of building performance is how to use building simulation to test the early concepts of design. "An in-house design simulation program offers the ability to have some early design decisions evaluated or validated within a day's time" (Anderson, 2014).

In discussing the possibility of achieving net zero projects, Hootman's Net *Zero Energy Design, A Guide for Commercial Architecture*, is a comprehensive study of all passive design techniques that can provide opportunities to reduce energy consumption of commercial buildings to the minimum. The initial decision at schematic level then can be honed and improved during the later stages of the design. The building design decisions can only be realized through thorough assessment activity which "will supply the design process with relevant design data.." (Hootman, 2013). According to Hootman energy design conditions include an understanding of the project's climate; site resources and constraints; building typology, massing, and orientation; and building program and building occupancy (Hootman, 2013). Hootman provides a structured method of understanding the impact of climate, site, building typology, and program on our ability to implement the right and appropriate passive design strategies.

Hootman also stresses the importance of climate in exploring the different design options for high-performance buildings. Climate influences external thermal loads of a project, and is also a source of free energy (Hootman, 2013). But Hootman also states that climate is not the only or the dominant factor in achieving Net Zero energy. Building typology and program have a more profound influence on meeting this objective. (Hootman, 2013).

ASHRAE's *Advanced Energy Design Guide for Medium to Big Box Retail Buildings*, also emphasizes the role of climate zone understanding

> *The efficiency opportunities and challenges by climate zone is necessary for a retailer to reach advanced levels of energy savings. Retailers will have to be prepared to apply the most effective efficiency strategies by climate zone to the base prototype designs. There are several major climatic variables that impact the energy performance of buildings, including temperature, wind, solar, and moisture. These variables continuously change and can be characterized by annual or seasonal metric.* (ASHRAE, 2011).

2.4.Holistic Approach

On the theoretical side of the design process, Maclay (2014) stresses the need of a new paradigm of thinking in design of high performance buildings if we are to grasp the passive design opportunities available within climatic, site-specific parameters, building typology and program. He states that the previous mechanistic paradigm still prevalent today cannot provide us with the proper understanding of how to achieve high-performance buildings and calls for a new paradigm he calls the New Building Paradigm (Maclay, 2014). He thinks that unlike the mechanistic paradigm, the new building paradigm is complex and involves integrated processes as we see it in nature.

Yeang (2008) also emphasizes the same concept of the need to complex and non-mechanistic approach to design. In his *Ecodesign: a manual for Ecological Design*, he discusses the multidisciplinary and holistic approach to design and stresses that “a radically different model of these human activities that can be permitted in the natural environment and of the way that we design our built environment is needed” (Yeang, 2008).

2.5.Energy Targets

Goal setting is a key element to consider in the path to achieve high-energy-performance retail buildings. In this regard, ASHRAE (2011) suggested that in order to “achieve a retail building that uses 50% less energy than the industry standard takes careful goal setting”. It also stressed that “setting a target of 50% less than a baseline fictitious building built to a standard is a recognized goal” (ASHRAE, 2011). On the other hand, the metric for energy targets must also be defined. ASHRAE described the use of Energy Use Intensity (EUI) as “a best practice". It elaborated that "the EUI targets can be used to select design teams as part of a procurement strategy to set early design goals, to track design development progress, and to verify performance during operations (ASHRAE, 2011). There are few data sources to generate EUI targets. The ones that were used in this research were mainly coming from retail buildings in the applicable, or similar, climate zone, in our case, Ontario Canada, as well as that which came from the case-study building considered in this study as the baseline for the four models. Initially, the design of the baseline building followed Ontario Building Code's supplementary standard SB10 (enacted January 2012) which requires buildings to perform 5% below ASHRAE standard 90.1, 2010.

A manual published by the Royal Architectural Institute of Canada, Sustainable Design Fundamentals for Buildings, also stressed the importance of sustainable goals to be set at the beginning of a project in order to define the environmental scope of a given project (SDBC, 2001). In regards to Canada, it stated that "typically in Canada, targets are compared to the Model National Energy Code (MNEC) and are often expressed as, for example "30% better than" the applicable standards set in the code" (SDBC, 2001). The SDBC suggest that the architect should consider defining goals with multiple objectives as it could "lead to potential synergies in green design" (SDCB, 2001). This is similar to what ASHRAE (2011) suggested in their detailed and rigorous guide.

2.6.Medium-format Retail Buildings in Toronto

Two sources about sustainable retail buildings were reviewed. Each source represents a distinct approach to sustainable design and efficiency in retail. The first is *ASHRAE's Advance Energy Design Guide for Medium to Big Box Retail Buildings, Achieving 50% Energy Savings Toward a Net Zero Energy Building*, and the second is Yudelson's *Sustainable Retail Development, New Success Strategies*. The major noted difference between the two is the metric used by each source to measure progress or improvement in efficiency. While ASHRAE's manual is based on Energy Use Intensity EUI which is an absolute metric to creating real improvement in energy consumption in building, Yudelson's metric is the LEED certification of retail buildings with other criteria such as water efficiency, recycled materials and site.

ASHRAE's energy use intensity for medium-sized retail was shown in a table for EUI targets for different climate zones (ASHRAE, 2011). For Toronto climate, which ASHRAE designated as zone 5, the EUI target was set to 50 kBtu/ft^{2}yr (or 157.7 kWh/m^{2}yr) within low plug - medium accent intensity parameters (electric lighting). This figure, as will be shown later, is higher than what the 50% above ASHRAE 90.1. 2010 target was simulated to be in model 3 - 178.6 kWh/m^{2}yr. The data source for analyzing the method to reach the 50% better than ASHRAE's 90.1- 2010, was explained when discussing model 3 in sub-section 5.3.

In order to achieve the energy target identified in ASHRAE's table, ASHRAE made several design recommendations which included passive design measures. However ASHRAE's guide did not attempt to deepen the understanding on the specific passive heating and cooling techniques but rather focused mainly on daylighting, electric lighting systems efficiency, and better equipments. Chapter 5 shows all design recommendations to achieve the 50% above ASHRAE 90.1- 2004 including daylighting and improvements to the thermal insulations for the opaque and fenestrations' parts of the building envelope (ASHRAE, 2011).

Retailers and developers in Toronto and North America at large prefer to build a prototype design model for their stores. The retail prototype maintains the brand and minimizes design and construction costs through standardization. Therefore it is quite often that retailers are hard to be bought into the idea that climate-based design and site-considered features will make their building more efficient and healthier or more appealing to customers. ASHRAE's AEDG (2011), emphasizes this point and calls for retailers to be flexible to accept the possibilities to follow the climate-specific design that is economically feasible:

> *To meet highest performance levels in all locations, retailers will need to accept more flexibility in design features to take advantage of climate-specific measures that make economic sense in some areas but not in others. For example, indirect evaporative cooling may make sense in hot, dry climates but may not in colder climates* (ASHRAE, 2011).

Yudelson's *Sustainable Retail Development, New Success Strategies*, discusses the issue of profitability when adopting sustainable design features and standards. Yudelson emphasizes that even though this seemed hard to change, it is evident that big box retailers are now realizing the financial benefits of using sustainable design strategies to minimize energy consumption and create healthier environment to customers:

> *The advent of skylights throughout the large retail store environment, pioneered by Wal-Mart, is a good example of doing well by doing good. Not only do sales increase, as shown by research, but cost recovery happens within five to ten years, depending on local prices for electricity* (Yudelson, 2009).

One of the major concepts of retail development in North America discussed in Yudelson's book is based on retail LEED certification. When discussing examples of different sustainable retail development Yudelson addresses two types of sustainable retail developments; one which is initiated by developers, and the other, is initiated by the retailers themselves. In both case studies, a business case is to be presented in order for the project to be viable and pass the corporate approvals. It is noted however that in the best case scenario, all projects mentioned have either sought LEED certification through its credit system or make serious efforts to minimize energy consumption especially through minimizing artificial lighting loads and installation of PV panels to produce free electrical energy from the large flat roof.

Going back to Maclay's & Yeangs' earlier design process paradigms, it seems hard to imagine any considerable positive shift in the sustainability of retail buildings using passive design strategies without retailers and commercial developers adopting the new building paradigm. It is our view that when it comes to retail building's efficicency and high performance building's standards, it is not the business case that should be compelling but the immediate damage that retail buildings are causing to the environment that must be highlighted and put forward. While realizing that finding such a paradigm could not be an easy task, adopting sustainable design practices and strategies that can be followed and applied is crucial to eliminate any obscurity from the design process. This can be implemented immediately without further delay.

2.7.Net Zero Energy in Retail

A project built claimed to be the first retail building was reviewed in a number of documents and online sources. This building which was planned to be the first Net Zero Energy building in the US was completely renovated by Walgreens in Evanston, Illinois, US. Bluebeam, an internet webpage, reported that the design team faced a big challenge to turn an average and older building built in 1992 which consumed around 425,000 kWh of energy per year into net zero energy (bluebeam, 2014). The source also reported that energy modeling was used throughout the design process and that passive design techniques were implemented in the store such as automatic curtain wall shade control to reduce HVAC peak loads, a curtain wall glazing above 16 feet that redirects light and eliminates glare, as well as a south oriented design of four solar-paneled roof planes to maximize daylighting. All other features inside the NZE retail dealt with active systems such as reduction of electrical loads through the use of LED lights, all-natural refrigeration system for heating, cooling, and refrigeration requirements.

Hootman's *Net Zero Energy Design, A Guide for Commercial Architecture* provides good review for the most state of the art literature on NZEB. In his book, Hootman reiterates what Yeang and Maclay call a non-mechanistic paradigm or a holistic approach to reach NZEB levels.

According to Hootman, a net zero energy goal is operational (versus theoretical). A net zero energy building can be achieved by generating renewable energy that is either equal to or offsetting the nonrenewable energy such as fossil fuel and nuclear. Practically though, a net zero energy building must be proven, through measured operation during a year's time that it has in fact achieved that balance. Another aspect of the net zero energy is related to the net zero energy definition. The net zero site energy definition applies to the energy produced on the site. That is if a boundary is drawn around a building site, and all of the energy within the site boundary is measure and added up, the result is a site energy measurement (Hootman, 2013).

2.8. Energy Modeling and the Design Process

The AIA *Architect's Guide to Integrating Energy Modeling in the Design Process* was reviewed. It stresses the importance of architects become familiar and comfortable with being able to engage in building simulation activity as part of the design process and not as a complimentary addition to it. The guideline stresses that by the concept of design synergies. It explains what a synergy means in exploring passive design techniques; each design technique is designed independently and would have to be more robust. In performance energy simulation the different systems are dealt with as a whole. This would allow reaching higher performance through synergizing the systems to optimize energy consumption (AIA, 2012).

3. METHODOLOGY

3.1. Introduction

Based on the literature review it is clear that there are many parameters to consider when considering passive design strategies. There are two strategies that must be considered simultaneously; the active strategies and the passive strategies. This study investigates the passive strategies that can best improve the building's performance. In real situations both strategies work together in synthesis in order to achieve the desired outcome.

When revisiting the research questions it is worth noting that the research methodology should be integrated with, and part of the research goal in order to help finding the answers to the questions the research raises. The study's main issue is, besides passive design strategies in retail, the possibility of coming up with a design framework or roadmap, through which retail buildings in Toronto can be incrementally and strategically improved towards a high performance standards and eventually toward net zero energy levels. The research methodology must therefore serve this purpose and be an integral part of the answer to this pivotal question.

3.2. Research Planning – The Iterative Approach

The qualitative research methodology with the iterative approach was chosen for this study. The iterative approach is based on a sequence of procedures implemented in exactly the same way every time and repeated multiple times. Part of the characteristics of this methodology is that iterative cycles that may begin as limited in size and scope then move into larger ripples with bigger outcomes. The study attempts to prove that incremental improvements to the first design model (the baseline building – model 1) within a certain paradigm or framework can be achieved to move up to higher performing models (2 through 4).

The iterations' medium was a building design framework that represented different stages or cycles of design actions. The instrument by which the tasks were executed was Ecotect® Analysis 2011. The use of Ecotect as a simulation tool was similar to the philosophy adopted by the iteration approach in that it also builds on the concept that it is best to do research tasks multiple times and save costs than applying the task in real life without the ability to know or predict its implications which can be quite costly or inefficient.

Another aspect of this methodology is the processes that were repeated in each design theme (model). The following are the repetitive steps that were used in all iterations:

1. Collecting site, climate, and retail buildings' data;
2. Simulation of data using Ecotect;
3. Make deductions or conclusions;
4. Improve the design model and producing new data;
5. Re-simulating the new data using Ecotect;
6. Inductions from results;
7. Carry out further improvements;
8. Acquire results;
9. Repeat the process with new model
10. Comparison of results;
11. Deductions

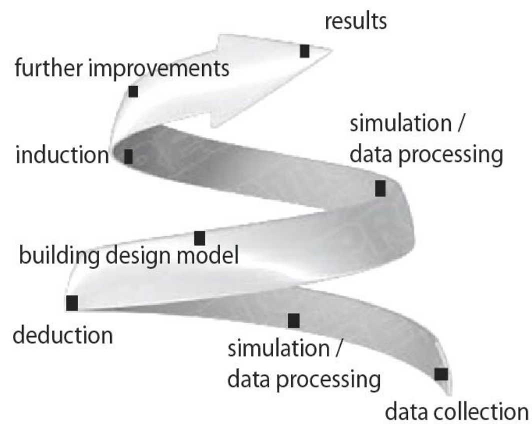


Figure 4 - Graphic representation of the Iteration approach implemented

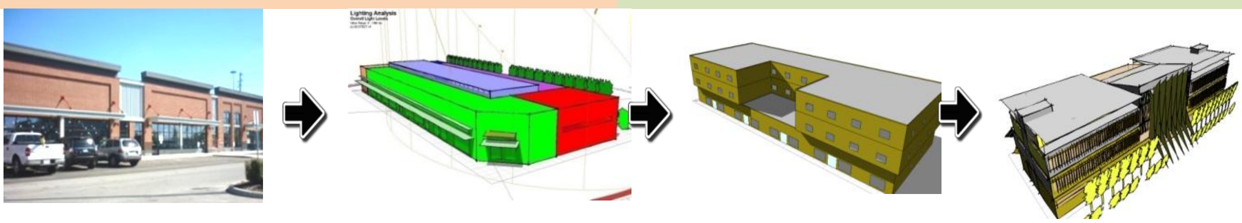
Figure 5 - The baseline building: built in 2014 in Toronto, ON, following Ontario Building Code – SB10

3.3.The Four Research Models

The iterative approach was applied on four progressing models. Each model was incrementally improved with passive design strategies over the preceding model. All of the models were tested by the same tasks. The following are the four models:

1. Model 1 is a representation of an existing medium-format retail building that was designed by the researcher in 2013 and built in Toronto in 2014.
2. Ecotect was used to simulate the model and reach at a benchmark of energy intensity that complied with 5% below ASHRAE 90.1- 2010.
3. Model 2 is an improved version of model 1 of 25% below ASHRAE 90.1. 2010.
4. Ecotect was used to analyze and acquire energy simulation results.
5. Model 3 is an expanded and improved model. New programmatic changes were introduced including increased density by adding two office floors. The cycle was

Model 1	**Model 2**	**Model 3**	**Model 4**
Baselines Building	**Improved Baseline**	**Improved Design**	**Close to NZE**



Exist. Building – single storey- 6 fashion retailers – 1 fast-food retailer – designed thermally 5% below ASHRAE 90.1-2010 as per OBC- SB10.	**Thermally improved by 25% below ASHRAE 90.1 – 2010, optimized orientation, enhanced day-lighting to retail units – all windows protected with shading devices using ECOTECT® shading design wizard**	**Thermally and architecturally improved for 50% below ASHRAE 90.1-2010 – 2 office floors added - Optimized mass configuration – optimized window configuration**	**Thermally Optimized-day lighting enhanced – multiple energy efficiency design strategies - shading devices over improved windows with PVs over pitched roof toward south - Site planning & landscaping improvement**
Medium-format single storey retail		**Mixed-Use, 3 storey Retail/Office**	

Figure 6 - the four-research models forming the design framework: incremental improvements from existing baseline building (represented by model 1) to final design (model 4)

repeated using Ecotect.

6. Model 4 is the final design model that included refined and elaborated design. The model has assumed the addition of photovoltaic panels to its roof to produce energy. The details of the active design strategy were not included or analyzed as it was outside the scope of this study.

The final design project is the graphic representation of model 4 in Revit® Architecture 2015. Two sets of architectural and construction drawings were produced.

3.4.Data Collection

Data was collected from two sources; the baseline building construction documents, and climate and site data available. In addition to these two sources, energy benchmark data for retail buildings in Canada was also collected for comparison. Although design data related to the baseline building was available, energy consumption historic data was unavailable at the time of the research as the building was not yet completely occupied.

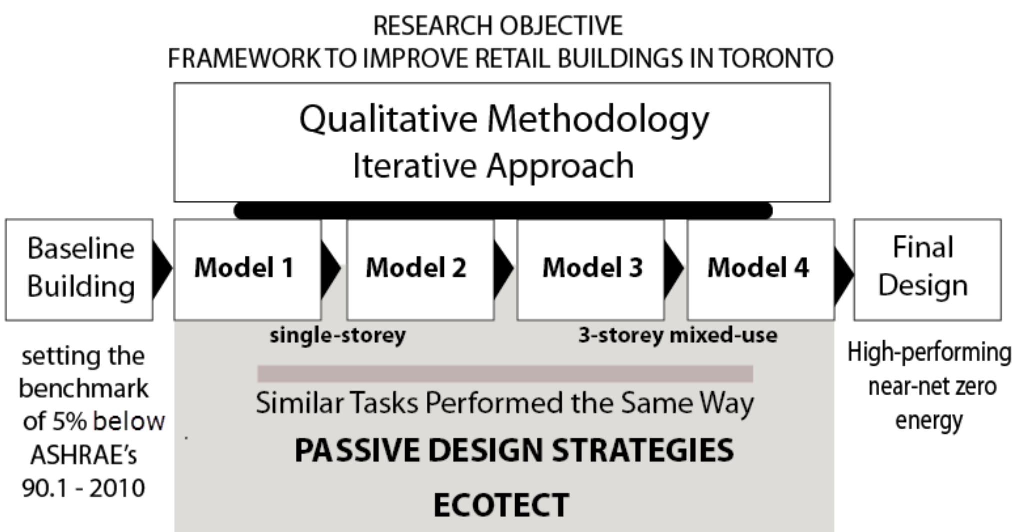


Figure 7 - Research and design methodology adapted

3.4.1. Tasks Performed

Two types of repetitive tasks were performed the same way on each model during the study:

1. Passive Design Strategies' tasks

2. Analysis of heating and cooling loads, and lighting design and levels using Ecotect

3.4.2. Passive Design Strategies Considered

The following passive design strategies were considered in the study: building envelope's thermal resistance improvement, optimization of orientation, mass configuration, fenestration configuration, passive solar heating, passive solar cooling, and Daylighting.

3.5. Energy Target method Implemented

As mentioned in the literature review section, ASHRAE issued a target for achieving 50% improvement below its 90.1, 2004 in a climate zone 5 (ASHRAE, 2011). That target was set to be 50 kBtu/ft^{2}yr (or 157.7 kWh/m^{2}yr). However, the target applied in this study, although close in value to that of ASHRAE's Guide, was referenced, but not followed. The research chose to follow a different analysis path for setting the energy targets for the four incrementally-improved models. The assumption to determine the 5% below ASHRAE 90.1 – 2010 EUI value was based on the following analysis:

EUI benchmark for retail buildings in Ontario (before ASHRAE 90.1 2010 was introduced) as discussed in the introduction section, was averaged in the survey to be around 1.7 GJ/m2/year. If we consider that ASHRAE 90.1 2010 roughly improved ASHRAE 90.1 2004 by 30%, then the value of the improved EUI was lowered to 1.2 GJ/m2/year (for practical purposes, the study considered that the stock retail buildings surveyed in Canada followed ASHRAE 90.1-2004). The Ontario Building Code's SB10 Compliance method further required the EUI to be at least 5% better than ASHRAE 90.1 2010. That requirement caused further drop to the EUI value, to approximately 1.14 GJ/m2/Year or 316.7 kWh/m^2/year. The latter EUI value (which represents the 5% below ASHRAE's 90.1, 2010 for retail buildings in Toronto) was then considered the benchmark upon which all four simulated models were compared. 316.7 kWh/m^{2}yr is slightly below the baseline building's simulated EUI value (simulated at the final design stage of the baseline building) of 333kWh/m^{2}yr (Table 6).

3.6. Strengths and Limitations of Ecotect

Ecotect is a software that was used to build and simulate all models used in this study. Dr. Marsh, Ecotect developer, considers Ecotect as unique amongst performance analysis tools in that it is aimed primarily at architects and is intended for use during the earliest, most conceptual stages of design. Ecotect's strengths are mainly: a) it is aimed mainly at architects; b) it is intended for use during earliest and most conceptual stages of design; c) it integrates relatively simple and intuitive 3D modeling interface with a range of analysis functions; and d) it has an interactive approach to performance analysis where modeler can simulate different scenarios easily and fast. However, and due to the same fact that Ecotect is an early design software, it has limitation in that it is incapable of producing detailed analysis of HVAC systems as explained by its developer:

> *…It is important to note that ECOTECT itself is concerned only with comfort (for passive buildings) and space loads (for mechanically serviced buildings) - not with the detailed analysis of supply systems installed to meet those loads* (Marsh, 2006).

4. SITE AND CLIMATE ANALYSIS

The baseline building which is the basis for model 1 is located at the intersection of North Queen St. and Index Road, to the west of Toronto. The site is part of a larger development of medium to large retail shopping centres which are connected by large parcels of parking lots. The baseline building was one of the latest to be built in the development.

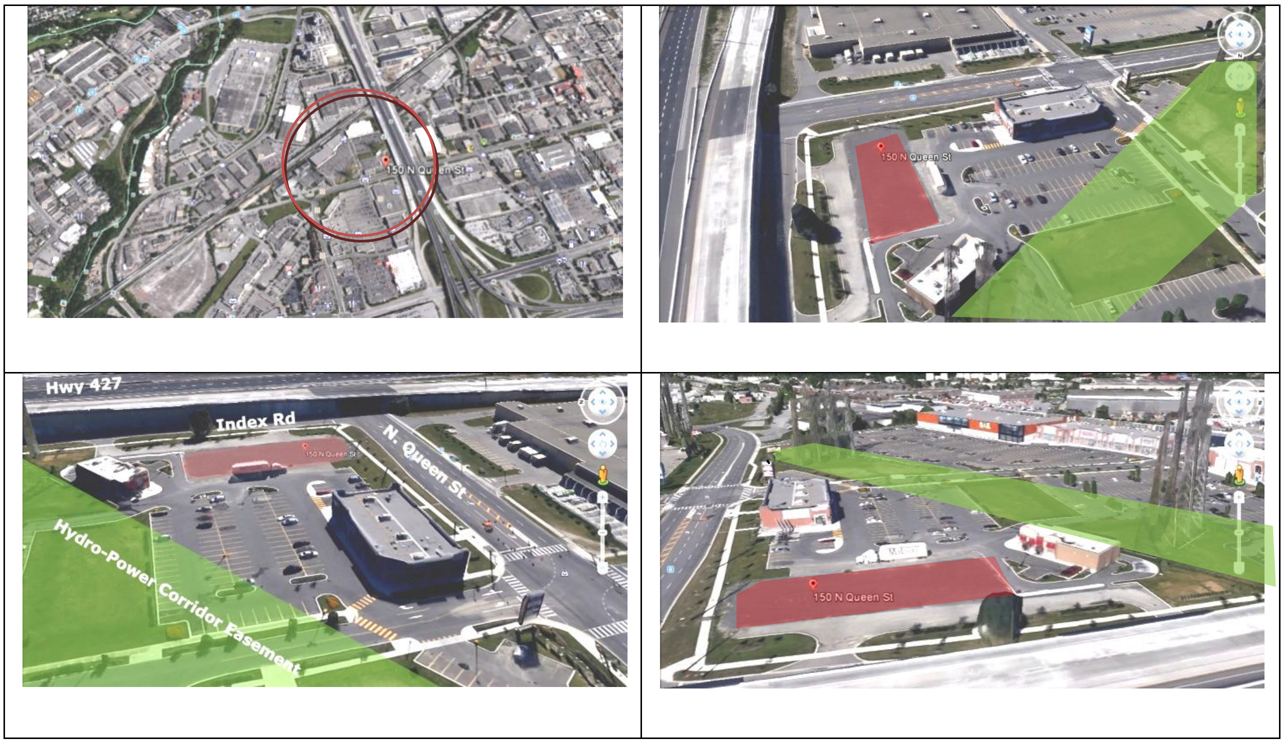


Figure 8 - Areal views of baseline building site in Toronto before start of construction

The site is flanked by Hwy 427 from the east and a hydro power-corridor easement that runs from the east- south to the north-west of building.

4.1.Climate Data Sets

4.1.1. Toronto Weather Classification

Toronto weather is cold in the winter and moderate and humid in the summer. As will be shown in the next pages, a potential for passive heating design strategies can be explored during winter and spring seasons while passive cooling design strategies are compatible with Toronto's weather during summer.

4.1.2. Toronto Heating Degree Days HDD

Toronto is located in zone 5A (MMAH, 2008). Heating Degree Days in Toronto (HDD) are much higher than Cooling Degree Days (CDD). Since Toronto weather imposes much higher heating loads on buildings, a far more important issue is know how to utilize passive strategies that could minimize heating loads in winter. This can mostly be done through passive solar heating techniques.

4.1.3. Diurnal Temperatures in summer

Wet bulb temperatures in Toronto have larger swings during summer days (15^{o} C on average). This means that night purge cooling strategy can be used to cool down the building during the night time through natural ventilation hence maintaining inside temperatures within comfort zone levels as long as possible for the next day. Although this difference drops in spring and fall, natural ventilation through the day can be effective as temperatures tend to be milder.

4.1.4. Wet Bulb Temperature

On the other hand, wet bulb temperatures' swings seem much less than that of dry bulb temperatures throughout summer. This could translate into the fact that a passive design strategy such as evaporative cooling (adding moisture to air) is much less likely to work in Toronto during summer than night-purge cooling.

4.1.5. Relative Humidity

The average relative humidity hovers around 70% while the maximum averages go up to over 90% and minimum to about 60%. More fluctuation in relative humidity can be noticed in the summer than in winter. Best passive design strategy to modify thermal comfort inside buildings in high relative humidity climates is generally to use natural ventilation (wind ventilation through the space) in order to remove excess moisture out of the air. In hotter days however, natural ventilation becomes unacceptable.

4.1.6. Wind Frequency

One of the most missed opportunities in passive design strategies is that concerning prevalent wind and wind frequencies. Understanding wind frequency and speed can help us decide, for example, which directions to avoid in terms of fenestration especially wind-gust with a high velocity during winter months.

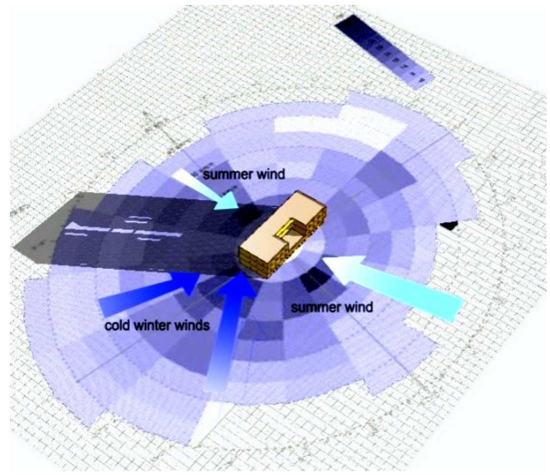


Figure 9 - Climate analysis: wind Rose applied to site showing prevalent winds in summer and winter

There are two major trends in wind frequencies and speeds. One is that of the summer season where wind blows at higher frequency from the south and south-west reaching an average speed of 65Km/hour, while frequency changes in winter to mostly west with a speed reaching 75Km/hour. The most important elements in studying wind frequency is to know where the maximum speed winds are coming from in winter in order to provide protection for the building while utilizing the wind for Natural Ventilation strategy during the summer (Figure 9).

4.1.7. Solar Radiation

Understanding direct and indirect solar radiation falling on the site is crucial. It allows the architect to understand how to make use of this radiation to increase heat gains in winter (in the northern hemisphere) and minimize it in summer to keep the building cool. Solar radiation is divided into direct solar radiation and diffused solar radiation. Understanding direct and diffused solar radiation helps in making the decision to utilize the building roof for energy production through photovoltaic panels.

Figure 10 shows a graphic comparison between two different days in Toronto (mid-summer and fall) using Ecotect weather tool. The graph displays the inter-relation between direct solar, diffused solar, relative humidity, and temperatures in specific days. Direct solar in summer for example shows more peaks and valleys than in fall which in turn makes the reliance on diffused solar more critical. The following points can be made on direct and diffused solar radiation in Toronto:

1. Direct and diffused solar radiation peak in summer between mid May to mid August.
2. Direct solar radiation is effective most of the day from 8 am to 4 pm.

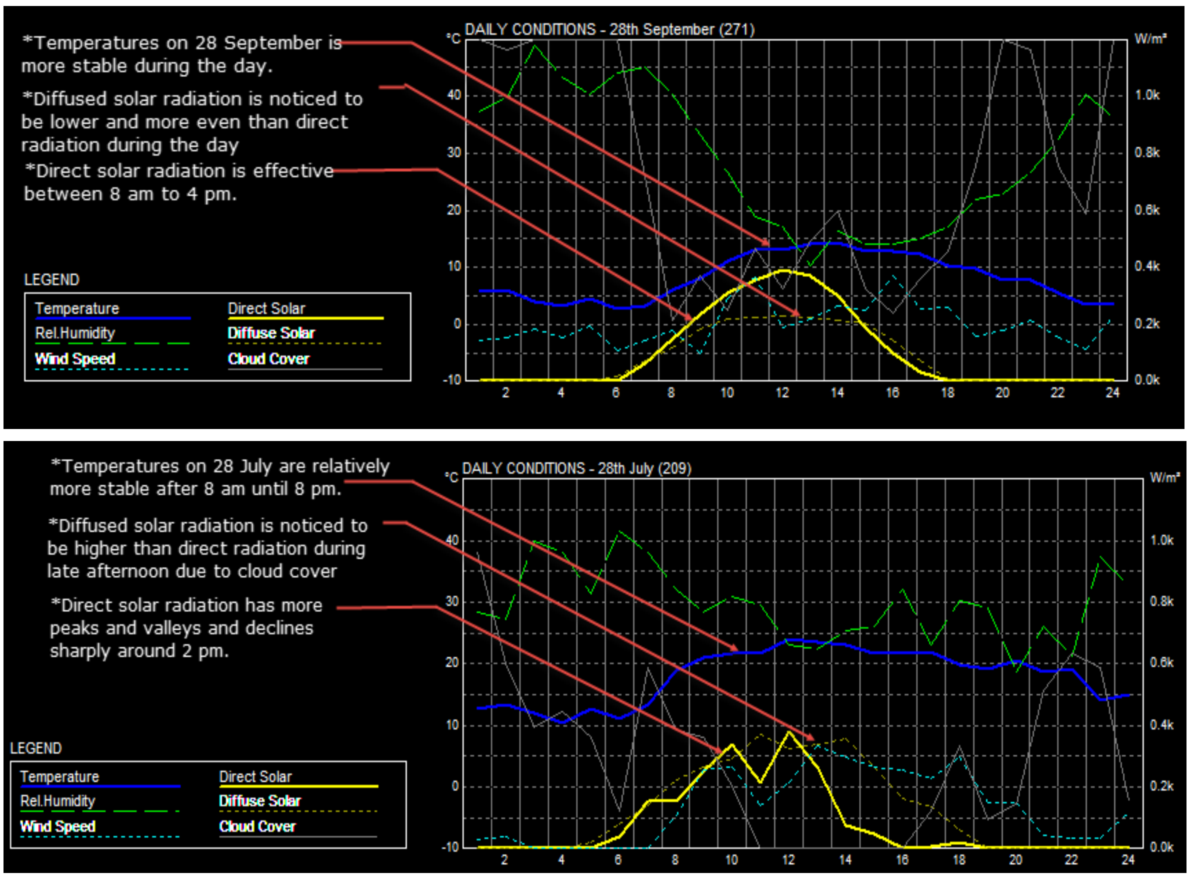


Figure 10 - Comparison between two-days' weather conditions in Toronto*

***The lower figure shows more peaks and valleys in direct solar in a summer day than in a fall day. This condition impacts design decisions about the use of both passive and active design strategies; photovoltaic panels location, direction, and installation angle.

3. While direct solar radiation has more fluctuations during the day, indirect solar radiation tend to be more stable across the day.

4.2.Passive Design Strategies Based on Climate Data Sets

4.2.1. Multiple Passive Design Techniques

Ecotect provides a good picture of the many passive design techniques that can be implemented (or avoided). Figure 11 plots all possible techniques that could be used in our baseline building.

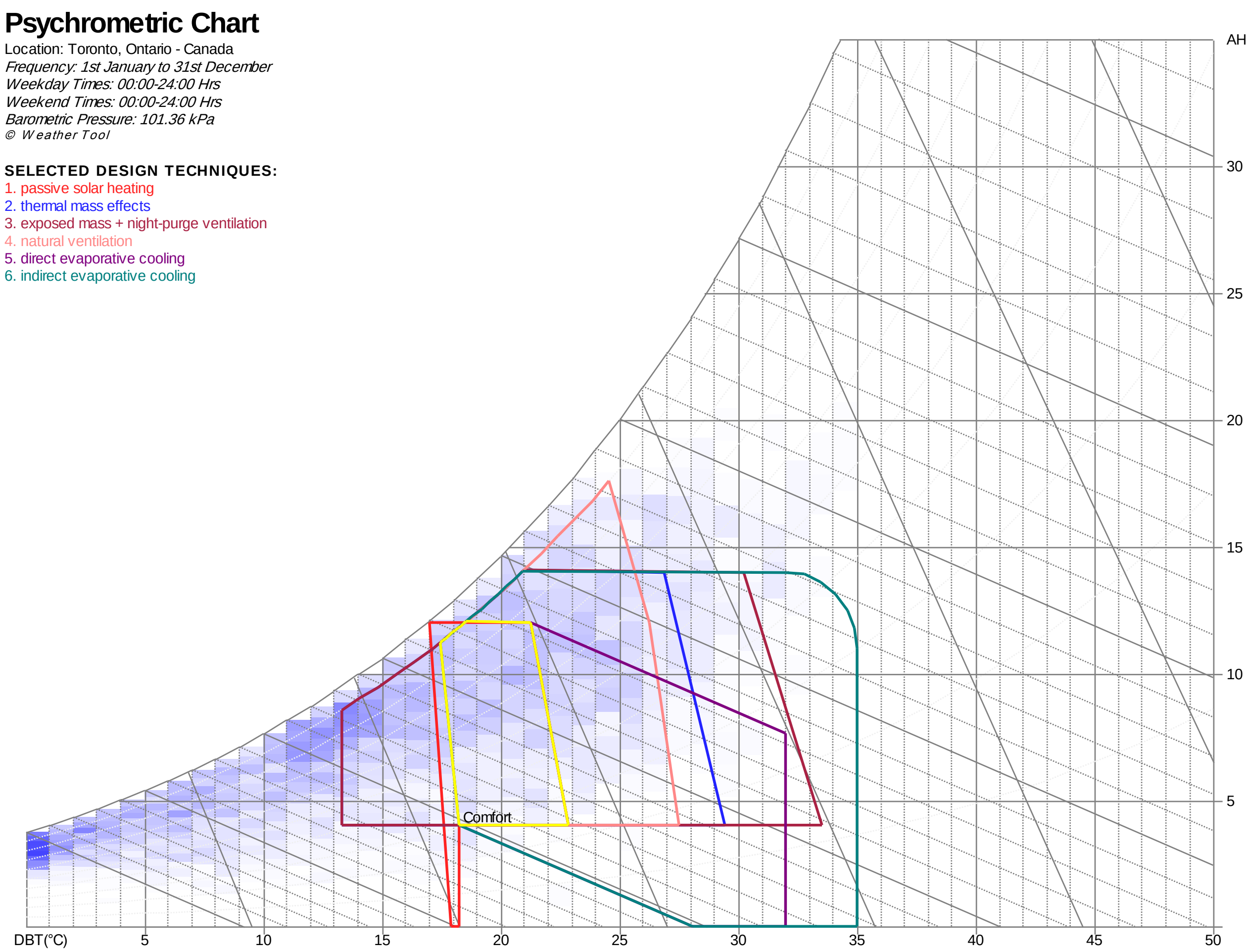


Figure 11 - Psychrometric chart showing potential passive design strategies in buildings in Toronto*

***** The blue spots show Toronto's weather characteristics as depicted by Ecotect including temperatures (dry and wet bulb) and relative humidity RH. The yellow rectangle indicates Comfort Zone. All other colored rectangles indicate potential passive strategies. Rectangles that are off the "blue-spot" zone indicate ineffectiveness which suggests that active strategies must be engaged to modify conditions.

4.2.1.1. Active Cooling

Active cooling can be enacted when passive cooling is unable to achieve comfort levels. Ecotect lists all the scenarios of active cooling in the summer. It is noted that evaporative cooling in high summer relative humidity areas such as Toronto is not quite effective due to high moisture content of air in that season. Ventilation or air-conditioning becomes necessary when air temperatures are above 26^{o}C while air-conditioning becomes a necessity when temperature exceeds the 30^{o}C mark. In Toronto, maximum temperatures can reach 30^{o}C but air temperature can still be cooler especially if it passes through vegetation or water bodies. From this phenomenon, it can be concluded that a myriad of natural ventilation techniques can be utilized in varying degrees to cool the building without the need for air-conditioning.

4.2.1.2. Indirect & Direct Evaporative Cooling

Although direct and indirect evaporative cooling techniques can be utilized in Toronto, these techniques are less effective than natural ventilation as explained above due to high relative humidity during summer months.

4.2.1.3. Natural Ventilation

As discussed earlier, natural ventilation can be effective when dry bulb temperature does not exceed 26^{o}C and relative humidity is between 20-90%. Considering the summer temperatures in Toronto, this design potential can be very effective to cool down the spaces during summer. Many design strategies can be implemented to utilize the natural ventilation passive cooling such as cross-ventilation where there are two opposite windows across the space, stack effect, or clerestory where operable windows can vent out the warm air and flush the space with fresh air normally received from lower levels.

4.3. *Passive Strategies Suitable for Retail in Toronto*

From the above-mentioned analysis, the following can be concluded:

- Conditioned volume of building needs to be minimized.
- The long facade of the building should be along the south-north axis with high solar heat gain coefficient values for southern windows and low values for northern windows.

- Mass configuration can maximize solar heat gains in winter while minimizing heat loss through building envelope and fenestrations.
- Thermal mass to store heat from sun and release it slowly during night. Thermal mass can be used effectively for both passive heating and cooling.
- Distribution of stored solar energy back to the interior spaces, when required, through natural convection and radiation.
- Isolated gain, sunspace, or passive heating collects the sunlight in an area that can be closed off from the rest of the building. The doors or windows between the sunspace and the building are opened during the day to circulate collected heat, and then closed at night, allowing the temperature in the sunspace to drop. Small circulating fans may also be used to move heat into adjacent rooms (WBDG, 2015).
- Nighttime purge cooling is a passive technique in climate zones where the summer temperatures during the day are too hot to bring in. Toronto has high temperature summers and a wide diurnal swings between day and night that could very well benefit from what night-time purge can offer, which is flushing out the hot air during evenings.
- Stack ventilation through atrium or vent shaft is an effective strategy as hot air goes up according to Bernoulli's principle.
- Cross ventilation through space using operable windows can be an effective passive cooling strategy but only in spring and fall.

5. ANALYSIS AND RESULTS

5.1. Model One: Baseline Building

5.1.1. Description

The Baseline building was designed following Ontario Building Code with its supplementary standard SB10, as a single storey with gross floor area (GFA) of approximately 1070 m² (total built-up). The retail space was divided up to seven commercial retail units (CRUs). Six of the units were similar in area and type (non-food retailers). The seventh was to be occupied by fast-food restaurant with a commercial kitchen.

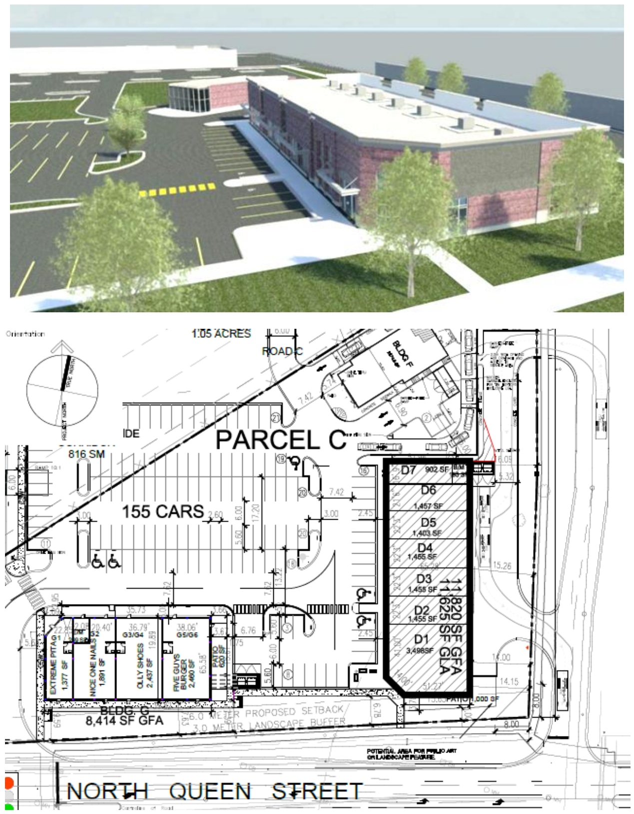


Figure 12 - Model 1: baseline building's site plan and orientation.

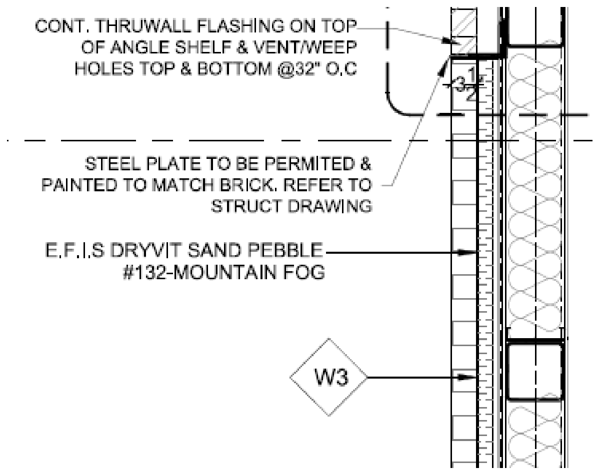
5.1.1.1. Program and Site Plan

The building form was a rectilinear box with long direction along north-south axis within a larger parcel that contained two other retail buildings with one as a smaller outparcel occupied by a drive-through coffee shop store. Vehicular access to the building was provided from Index road for shipping trucks and from the plaza side for customers' parking. The building was permitted after an energy simulation was required as part of the permitting requirements. The energy simulation showed a better performance than required by supplementary standard SB10.

5.1.1.2. Building Envelope

The baseline building's envelope is composed of 3.5 inches brick veneer and 1 inch rigid insulation with thermal blanket insulation filling the cavity between the 6-inch metal studs.

Some parts of the exterior wall were designed as Exterior Insulation Finish System (E.I.F.S) with slightly higher thermal value than the brick veneer parts.



Building Envelope	Code Requirements	Achieved
Wall RSI Value	2.28+1.76 c.i. (R13+R10 c.i.)*	3.34+1.4 c.i. (R-19 + R8 c.i.)
Roof RSI Value	5.28 (R30 c.i.)	3.5 (R20 c.i.)
Window total shading coefficient	0.40	South: 0.40 North 0.28
Window/Wall Ratio	40%	18%
Air-tightness	0.5	1 AC/h
Room resultant temperature set points	18-24 C°	18-24 C°
EUI** (kWh/m²Yr)	≈316.7	318.7

* c.i. means continous insulation
** Energy Use Intensity

Figure 13 - Model 1: baseline building envelope actual properties (achieved) compared to OBC (Ontario Building Code) requirements with a detailed typical wall section

5.1.1.3. Shading Devices

Shading devices in baseline building were designed as protruding metal tubes with no horizontal opaque elements to block the sun rays. This design rendered the canopies practically non-functional, as they could not protect the west-north façade from the afternoon sun especially during summer. This eventually caused higher cooling loads and visual discomfort to both business owners and customers.

Figure 14 - Baseline building: shading devices on west main facade

5.1.1.4. Space Volume

Medium-format and big-box retail building prototypes are designed with excessively space heights which causes increase in space volumes. The baseline building was no exception to that design criterion. The interior clear height is 5.48 m (18 feet) including Open Web Steel Joists' depth. Therefore, there is a potential of saving considerable heating and cooling energy through optimizing retail space height (figure A-1 upper image).

5.1.1.5. Orientation

The building was orientated according to existing lot that extends along north-south axis. This orientation causes the main façade to directly face the sun during afternoon summer hours especially late afternoon. This resulted in visual discomfort as well as unwanted heat gains during the hottest times of summer days (figure A-2 lower image).

5.1.1.6. Mass and Fenestration Configuration

The building mass was a rectangular box of around 55 m (181 feet) by 19.14 m (62.8 feet) by 6.7 m (22 feet) height (top of parapet). Seven glazed storefronts were designed on the west facade. Few windows faced south and north short facades, while rear east façade was kept opaque except for 8 service metal doors and spandrel panels aimed to simulate windows. Overall Window to Wall Ratio (WWR) reached 18% excluding spandrel and service doors at the rear façade.

5.1.1.7. Daylighting

The depth of retail space was 19.1 m (62.8 feet) with store-front fenestration located only on one side. This design caused the uneven distribution of daylighting; very bright at the store front while very dark at the middle and rear. When simulated in Ecotect, the retail space showed daylighting levels of around 60 Lux (the required level for retail display is 500 Lux). That means the retail space depended almost entirely (except for areas close to the store fronts) on electric lights during day times. This solution is not sustainable as electric lighting consumes considerable portions of electric power. More daylighting will lead to reduction in electric lighting dependency.

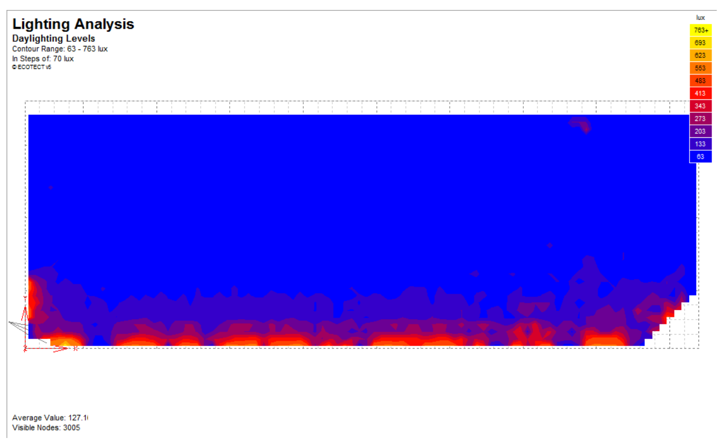


Figure 15 - Model 1: baseline building's dimmed lighting levels

5.1.2. Simulation Criteria

Model 1 which represented the baseline building was divided up into different zones with different thermal loads. Different materials were assigned to the building envelope. Properties of model 1 were similar to baseline building's properties so that a benchmark for the four-model framework can be established in order measure all other improved models against. It was indicated earlier that the largest energy intensity by energy source were consecutively: space heating, electric lighting, space cooling, and plug loads. Those energy consuming indicators were considered while simulating the baseline building (table 2).

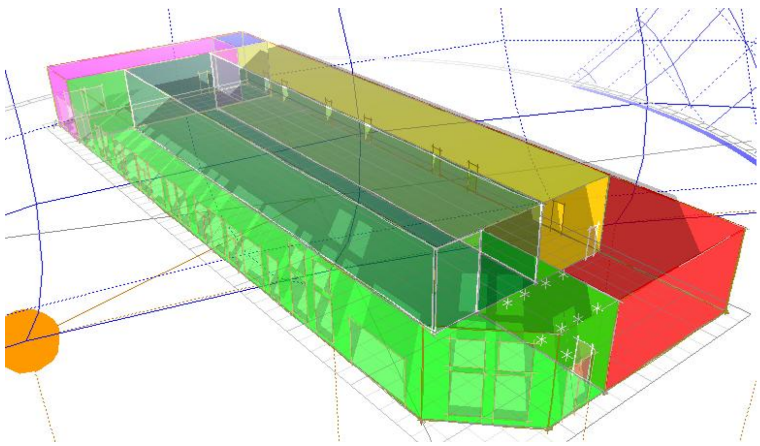


Figure 16 - Model 1: building zones as simulated in Ecotect

Energy Intensity by Source	Source	Percentage	Passive Design Strategy
Space Heating	Natural Gas	76%	passive solar heating
Water heating, cooking and other		24%	
Space cooling	Electric	24%	passive Cooling
Electric lighting		22%	daylighting
Plug Loads		20%	none
Refrigeration		10%	
Other		24%	

Table 2 - Major drivers in energy consumption in retail buildings in Toronto and their corresponding passive-design strategies (extracted from figure 2)

As part of the simulation criteria, plug loads' efficiency was factored in but not measured as Ecotect does not have the capacity to measure mechanical loads. More efficient appliances and equipments can participate in reducing energy consumption but also can reduce different zones' heat gains. Automation of appliances and lighting is another major source for minimizing electric lighting and plug loads.

5.1.3. Simulation Procedure

Ecotect simulation procedure was designed to achieve a particular goal; to come up with the passive design strategies that can improve building energy performance. In order to do that, areas of potential improvements had to be defined. The modeling analysis therefore focused on the following areas:

A. Weather & site analysis including orientation optimization;
B. Heating and cooling loads analysis;
C. Electric light and plug loads' analysis;
D. Shading devices design and;
E. Daylight analysis.

Within each of the above, information about different aspects of the model had to be considered. Two major sets of information were required for the simulation to be valid:

- Properties of each thermal zone;
- Building Envelope materials.

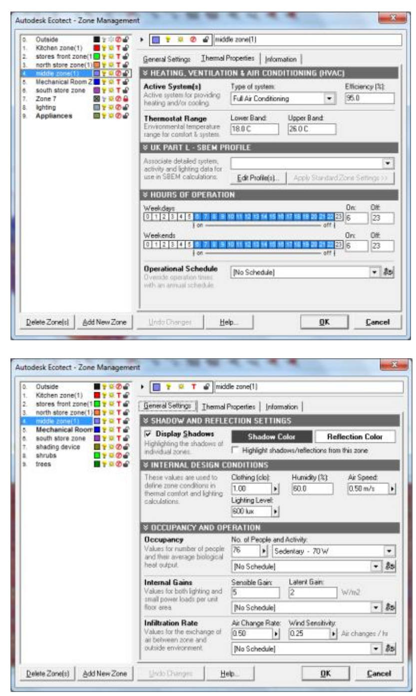


Figure 17 - Model 1: upper, schedule of operation, lower, zones properties

5.1.4. Zones' Properties

As noted before, zones were not simulated according to their functional uses but according to each zone's thermal characteristics (including proximity to exterior environment). The only exception to this was the kitchen zone which included several heat sources (appliances; fridges, stoves, ovens, and microwaves). Zones properties were then set up to simulate the real conditions of baseline building. This included

(a) Operational criteria; (b) Thermal range; (c) Active mechanical system; (d) Occupancy; (e) Infiltration rates; (f) Internal gains; (g) Lighting levels; (h) Humidity and; and (i) Activity type.

Ecotect - Zone Management Data													
Internal Design Conditions				Occupancy		Internal Gains		Infiltration Rate		HVAC Active System			Hours of Operation
Clothing	Humidity	Air speed	Lighting Levels	No. of people	Activity	Sensilbe	Latent	Air Change Rate	Wind Sensitivity	Full Air-Conditioning	Efficiency	Thermost at Range	Weekdays & Weekends
light businessn suit	60%	0.5 M/s	600 Lux	veriable	sedentary	5 w/m2	2 w/m2	1-2 AC/h	0.5		95%	18-26	6 am - 11 pm

Table 3 - Model 1: Typical zone management data used to simulate model 1

5.1.4.1. Building Envelope Properties

Building envelope's materials and thermal resistances have direct impact on thermal loads. Ecotect allows changing the materials of the building envelope in order to reach the best solution considering the direction of each wall or fenestration.

The exterior wall of model 1 was simulated and its thermal resistance values (R-values) were entered to be similar to those of the baseline building's R-values.

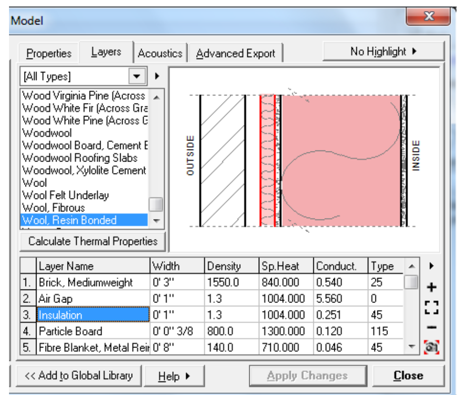
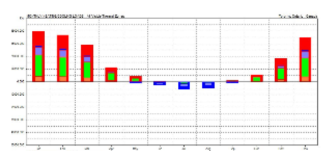


Figure 18 - Model 1: baseline typical wall assembly shows two layers of insulation materials.

MONTHLY HEATING/COOLING LOADS

All Visible Thermal Zones
Comfort: Adaptive - Average (± 1.75)

Max Heating: 186.744 kW at 12:00 on 1st January
Max Cooling: 60.774 kW at 12:00 on 20th July



MONTH	HEATING (kWh)	COOLING (kWh)	TOTAL (kWh)
Jan	47724.312	0.000	47724.312
Feb	44150.027	0.000	44150.027
Mar	34784.773	0.000	34784.773
Apr	13366.302	0.000	13366.302
May	5234.542	1828.258	7062.799
Jun	204.493	3577.641	3782.134
Jul	13.028	7216.172	7229.200
Aug	8.290	6003.077	6011.367
Sep	1275.778	1588.665	2864.443
Oct	6581.897	0.000	6581.897
Nov	21864.863	0.000	21864.863
Dec	41882.898	0.000	41882.898
TOTAL	**217091.203**	**20213.812**	**237305.016**
PER M²	**202.729**	**18.877**	**221.606**
Floor Area:		**1070.843 m2**	

end of report

Table 4 - Model 1: Monthly heating and cooling loads (kWh)

5.1.5. Simulation Results

5.1.5.1. Heating and Cooling Loads

From the heating and cooling loads' table of model 1, the following can be deduced:

1. Heating loads are much higher than cooling loads. This is due to longer heating degree days in Toronto (HDD). Percentage of energy consumed on cooling compared to total cooling and heating loads was 8%.
2. Store fronts zone on North West orientation has the highest heating and cooling loads due to its high exposure to exterior environment through window to wall ratio.
3. In the month of May the building required both heating and cooling although heating was still more than cooling.
4. In September heating and cooling loads are shown to be equal.
5. Therefore, passive cooling like night-time purging, wind, or stack ventilations can be quite effective in spring and fall due to the fact that outside temperature, in those seasons, tend to drop during the night hence provide opportunity to flush out heat from interior spaces.

5.1.5.2. Lighting Levels

As discussed earlier, the middle and rear parts of the retail space were almost completely dimmed (figure 15). Electric light levels required for retail general display areas are 500 Lux, for washrooms, 150 Lux, and for mechanical room, 150 Lux. The lamp types used in the design included 150 T8 pendent fixtures each with 2 bulbs of 42 Watts for the general merchandise retail space and 18 fixtures for the kitchen. When this number of fixtures was simulated in Ecotect the result showed sufficient electric lighting levels as shown in figure 19. Lighting schematic design with lamp types and loads is shown in table 5.

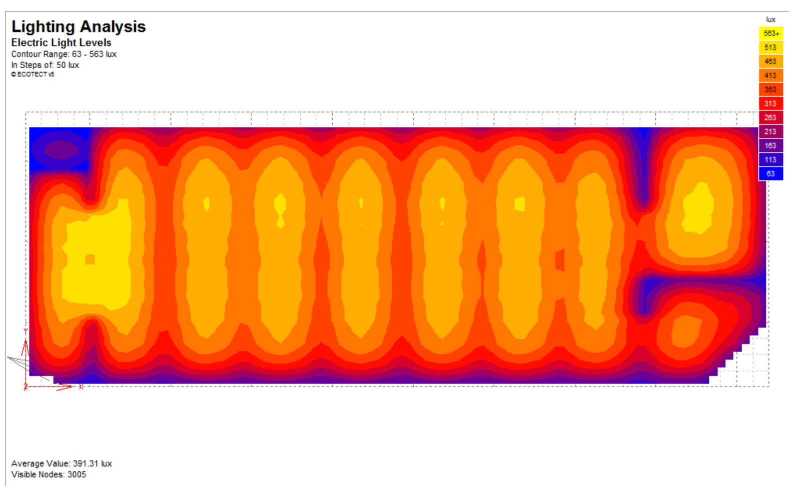


Figure 19 - Model 1: electric lighting design as simulated in Ecotect to reach acceptable levels for general retail display

5.1.5.3. Electric Lighting Design

With the building lacking any special design for daylighting, dependence on electric lighting is expected. There were two main parameters in lighting layout to consider; (a) the type of lamps used, and (b) the number of lamps required to achieve specified lighting levels. In model 1 the type of lamps considered was T-8 pendent compact fluorescent lamps (CFL). The number of lamps in each fixture was 2 and the total number of fixtures was 150 (retail space only). That caused a total yearly consumption of 53,495.5 kWh/yr (table 5).

5.1.5.4. Plug Loads

Ecotect are not designed to perform plug load calculations. However because plug load and electric lighting calculations have major impact on the annual energy consumption, an assumption for all equipment and appliances use and light fixtures were estimated as indicated in table 6. As shown, appliances were divided up according to space use with total annual energy consumption of 50,893 kWh.

Model 1 Baseline building Lighting Fixtures											
Space	**Fixture Type**	**Fixture power Ratio**	**Qty**	**Lamps / Fix**	**Lumens/ Watt**	**Lamp Power (w)**	**Total (kW)**	**Daily Ave.(h)**	**No. of days**	**Year (kWh)**	**Intensity (Kwh/m²yr)**
Retail	Pendent - CFL*	1	150	2	85	35	11				
Kitchen	T-8 Fluor.	1	18	2		35	1				
Mechanical Room	T-8 Fluor.	0.9	2	2		42	0.1512				
Washroom	T-8 Fluor.	0.9	4	2		42	0.3024				
Total							**12**	**12**	**365**	**53495.568**	**50.0**
* CFL - Compact fluorescent lamp											

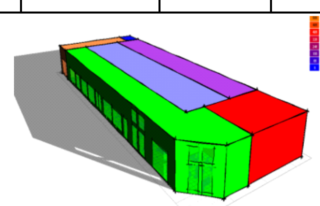
Table 5 - Model 1: electric lighting breakdown

Model 1 - Appliances / plug loads						
Use	**Appliance**	**Qty**	**Ave. daily use (hour)**	**power (kW)**	**year (kWh)**	**Intensity (kWh/m²yr)**
Restaurant	Commercial Range	2	4	5.1	14688	
	Fridge	3	2	1.4	3024	
	fans	3	6	0.7	4536	
	mixers / microwaves	2	2	1.7	2448	
	cash registers	3	3	0.2	1254	
	computers & monitors	1	4	0.24	345.6	
	TV	2	6	0.3	1296	
Retail	cash registers	9	8	0.2	5184	
	fans	2	5	0.4	1440	
	computers & monitors	3	8	0.24	2073.6	
	mixers / microwaves	3	0.5	1.5	810	
	TV	6	8	0.3	5184	
Washrooms	hand-dryer	2	1	2.3	1656	
Mech/Elec.	pumps	1	2	1	720	
Domestic Hotwater	water heaters	2	2	5.2	7488	
Total					**50893.2**	**47.6**

Table 6 - Model 1: Plug loads breakdown

5.1.5.5. Total Energy Use Intensity (EUI) for Model 1

The Ecotect analysis of monthly heating and cooling loads indicated the energy use intensity of 221 kWh/m²yr. That figure excludes electrical lighting and plug loads values. Once measured and added up to the EUI of the Ecotect analysis, the total EUI came up to 319.34kWh/m²yr. This number is close to the SB10 (5% below ASHRAE 90.1, 2010) figure of 316.7 kWh/m²yr as shown in table 6.

Model 1 - Baseline Building: Matrix								
Elements	5% over ASHRAE 90.1 - 2010 (OBC-SB10)	simulated	Passive Design Strategies					
Wall RSI value	2.28+1.76 c.i. (R-13+R-10 c.i.)	3.34+1.4 c.i. (R-19 + R-8 c.i.)	Volumen	Orientation	Mass and Fenestrations Configuration	Passive Heating	Passive Cooling	Daylighting
Roof RSI value	5.28 c.i. (R-30 c.i.)	3.5 c.i. (R-20 c.i.)	5.45m (18'-0")	Not Considered	Not considered	Not considered	Not considered	Not Considered
Window total shading coefficient	0.4	South: 0.40 North 0.28						
Window/Wall Ratio	≤40%	18%						
Air-tightness	0.5	0.5 AC/h						
Room resultant	18-24°C	18-24°C						
EUI (kWh/m²Yr)	≈ 316.7 *	319.34**						

* The assumption to determine this value was based on the following analysis: EUI benchmark of retail buildings in Ontario (before ASHRAE 90.1 2010 was introduced) as discussed in the introduction section, was averaged 1.7 GJ/m2/year. ASHRAE 90.1 2010 improved ASHRAE 90.1 2004 by 30%. This improvement made EUI lower at 1.2 GJ/m2/year. Ontario Building Code 2012 however required buildings to perform at least 5% better than ASHRAE 90.1 2010 which made this value to approximately 1.14 GJ/m2/Year or 316.7 kWh/m2/year. That target is slightly lower than the baseline building's simulated EUI (at the design stage) of 333kWh/m²yr.

** This value was the result of Ecotect simulation and plug and lighting loads.

Table 6 - Model 1: baseline building Matrix

Model 1- Energy Consumption Accoding to Source					
Electric Power	Area Cooling (kWh)	Electric Light (kWh)	Plug Loads (kWh)		Total (kWh)
	20213.812	53495.568	50893.2		124603
Natural Gas	Area Heating (kWh)				Total
	217091.203				217091
EUI* (heating and cooling loads only)					221.7804
EUI total**					319.34

* As shown in Ecotect analysis (only for cooling and heating)
** including electric light and plug loads

Table 7 - Model 1: energy consumption according to source

All the other values shown in table 6 are requirements of the Ontario Building Code with the corresponding values that were extracted from Ecotect analysis of model 1. Those values replicated the baseline building in order to make all next simulations based on the properties set up by model 1. All Improvements that will be made on models 2 through 4 will be measured against model's 1 values.

5.1.6. Lessons Learned

The Ecotect analysis showed a potential to improve energy efficiency of baseline building in the following areas:

1. Volume can be optimized through building height reduction from 5.45m to 3.96m (18 to 13 feet). This can save around 27% of heating and cooling loads;
2. Orientation can be optimized to achieve maximum building exposure to south and north directions and minimize it on east and west facades;
3. Building envelope:
   A. Thermal resistance values can be improved to minimize heating loads for opaque and fenestration parts;
   B. Spandrel system to be eliminated to improve average wall assembly's R value through minimizing thermal bridging;
   C. Reduce thermal bridging in other areas by providing thermal breaks and continuous insulation;
4. Solar radiation strategy including:
   A. Maximizing solar penetration to the interiors (blocking it in summer).
   B. Use of thermal mass in interiors:
      - possible use of 4 inches exposed concrete slab in all sun-exposed retail areas (south orientation)
      - possible use of 88.9 to 100 mm (3.5-4 inch) brick veneer on interior walls (or similar thermal mass) to increase heat retention from direct solar radiation;
   C. Use of shading devices to minimize or block of solar radiation during summer and maximize it in winter;

D. Utilize Daylighting to minimize dependence on electrical lighting especially in deeper retail spaces;

E. Improvement of architectural program by allowing more exposure of the retail to consumers on the rear side of the building;

F. Possible introduction of store fronts on the opposite side of retail to increase visibility of merchandise and increasing sales.

5.1.7. Proposed Strategy to Decrease Electric Lighting Loads

A strategy can be suggested to reduce electric lighting load crucial in retail. This strategy is based on two steps:

1. To allow more daylighting into retail space especially in deeper zones; and
2. To improve the electric lighting system's efficacy by using more efficient light fixtures and systems.

Even though the study considered the two steps as part of the improvement strategy, it mainly focused on increasing daylight levels first (passive strategy), then considered improving the electric lighting system but without any attempt to come up with specific conclusions in this regard.

5.2. Model Two: Improved Baseline Model

5.2.1. Characteristics

Model 2 was an improvement to model 1 (the baseline building). The general design features of model 2 therefore remained the same as in model 1 including footprint, architectural design, and program. The added improvements focused mainly on introducing passive design strategies that were based on the analysis of site, weather conditions, and typology of building. Ecotect has the capacity to optimize the orientation once the weather file

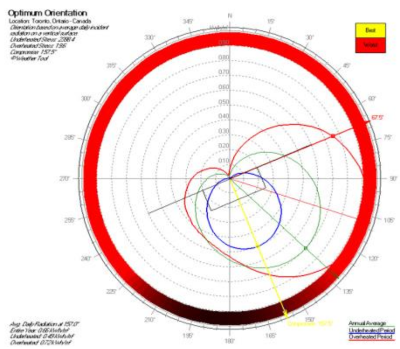


Figure 20 - Model 2: optimized orientation in Ecotect

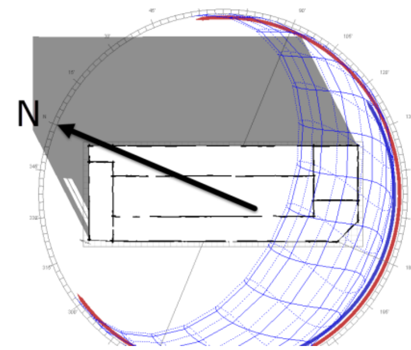


Figure 21 - Baseline building's original orientation

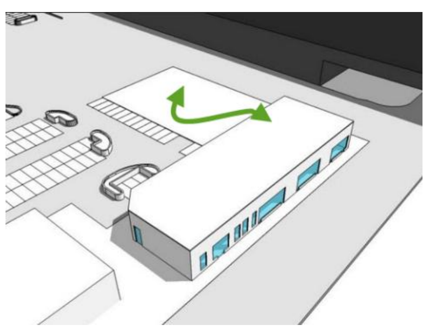


Figure 22 - Model 2: tilting the building 90º

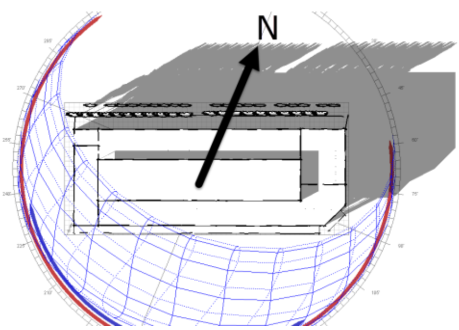


Figure 23 - Model 2: optimized orientation in Model 2

(Toronto in our study) has been uploaded. By utilizing this tool, Ecotect suggested a new optimized orientation to model 1. The optimized orientation was based on locating the building such that the longer axis followed east-west orientation. When measuring the exact degree of the optimized location, it matched that of North Queen Street (east-west). This allowed the optimized orientation to have the long axis of model 1 located at almost 90º to the original axis (figures 20-23).

5.2.2. Technical Details of Improvements

Below are the main details of improvements that were implemented in model 2:

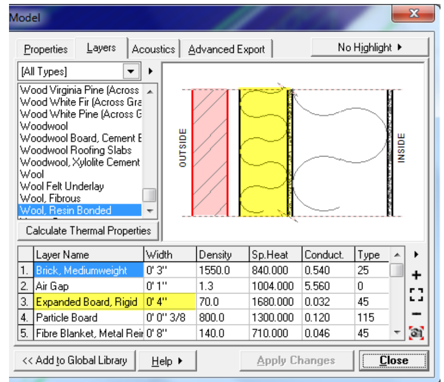


Figure 24 - Model 2: building envelope improved

Models	Model 1	Model 2
Elements	**Properties**	**Changes**
Wall RSI value	3.34+1.4 ci (R-19.0+R-8.0 ci)	3.34+2.8 ci. (R-19.0+R-16.0 ci)
Roof RSI value	3.5 ci. (R-20.0 ci)	8.8 ci (R-50.0 ci)
Window total shading coefficient	South: 0.40 North 0.28	South: 0.40 North 0.28
Ave. WWR*	18%	40%
Air-tightness	1 AC/h	0.5 AC/h
Room resultant temperature set points	18-24°C	18-24°C
EUI (kWh/m²yr)	319.34	238.5

* window to wall ratio

Table 8 - Model 2: Improvements to model 1

1. Window to Wall Ratio (WWR) on west façade was reduced from 49.5% (model 1) to 9% (model 2). This was done through optimizing building orientation;
2. General average WWR (window to wall ratio) increased from 18% to 40%;
3. Exterior walls were improved from RSI-4.7 (R-27.0) of model 1 to RSI-6.1 (R-35.0), a 30% increase, with continuous insulation around the exterior side of wall assembly to minimize thermal bridging. Roof`s insulation was also increased from RSI-3.52 (R-20.0) to RSI-8.8 (R-50.0), a 150% increase.
4. Although window percentage was increased through creating another row of store-fronts on the north façade, windows properties were improved by reducing their U values from 0.35 to 0.30 W/m2/C°. All spandrel panels were eliminated.
5. Air tightness improved from 1 AC/h to 0.5 AC/h.
6. Windows total shading coefficient SC remained as before, with 0.28 for windows facing north and 0.40 for windows facing south. However, WWR for south and north facades have increased, and for west and east facades minimized.
7. Due to introduction of daylighting as roof-top monitors, clerestory windows, and rear façade storefront windows, an additional improvement to the electric lighting system was performed. This was done through replacing all T-8 fixtures with T-5 and reducing the number of fixtures from 150 to 108 to reduce energy consumption resulting in electric

lighting load of 36,553 kWh/yr. This is a 31% drop in total lighting energy consumption from model 1 (table 9).

Model 2 Electric Lighting Loads											
Space	Fixture Type	Fixture power Ratio	Qty	Lamps / Fix	Lumens/Watt	Lamp Power (w)	Total (kW)	Daily Ave.(h)	No. of days	Year (kWh)	Intensity (Kwh/m²yr)
Retail	Pendent - CFL *	1	108	2	90	32	7				
Kitchen	T-5 Fluor.	1	17	2		32	1				
Mechanical Room	T-5 Fluor.	0.9	2	2		32	0.1152				
Washroom	T-5 Fluor.	0.9	4	2		32	0.2304				
Total							**8**	12	365	**36553.728**	**34.2**

* CFL - compact fluoresecent lamp

Table 9 - Model 2: electric lighting breakdown

5.2.3. Passive Heating Strategies Introduced to Model 2

5.2.3.1. Passive heating

A. Increase direct solar radiation to the interiors closest to southern windows in winter;

B. Create thermal mass in retail interiors; this can be done by using exposed concrete floor (100 mm (4 inches) of concrete with no covers);

C. Potential using the front zones of the retail space (heated in winter by direct summer radiation) as sun space;

D. Use of passive convective heating to heat deeper spaces (figure A-2);

E. Use of vestibules at entrances.

5.2.3.2. Passive cooling

A. Prevent direct sun radiation using shading devices (figure A-2);

B. Plant trees and shrubs to block hot summer sun while allowing winter sun (figure A-2);

C. Use of vestibules at entrances.

5.2.3.3. Daylighting

A. Use roof-top monitors, clerestory windows above retail storefronts, interior light shelves, and adding more windows to the north façade as shown in figures 25 & 26.

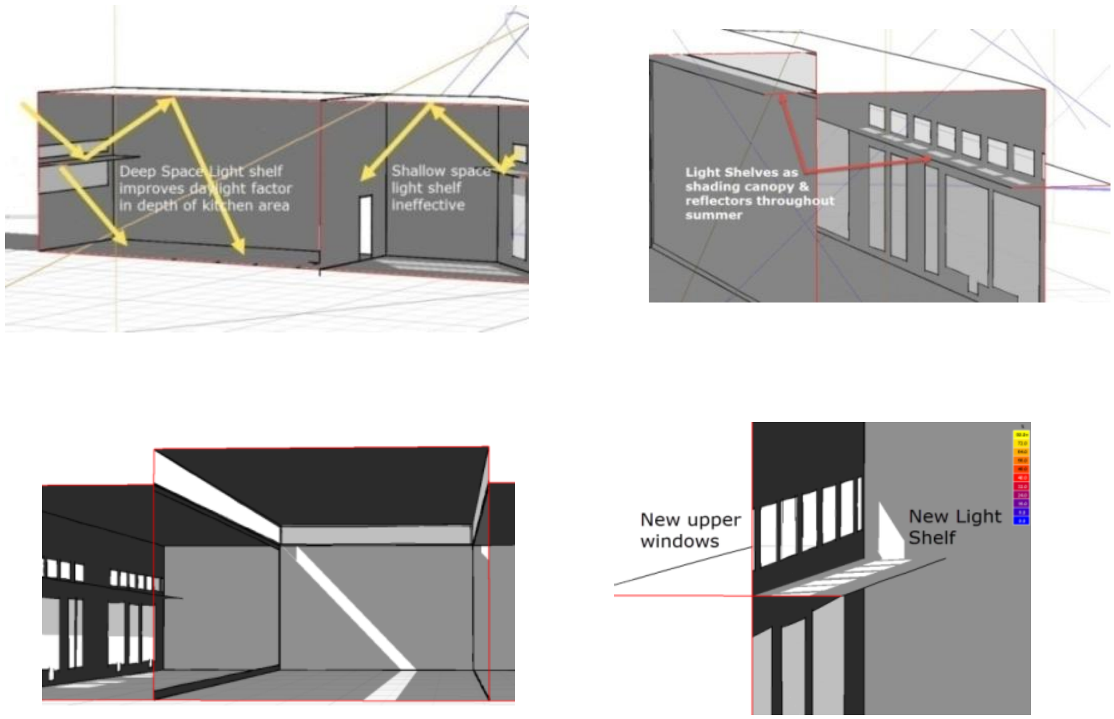


Figure 25 - Model 1: Rooftop monitors, clerestory windows, light shelves and shading devices were added to model 2 to improve building energy performance

B. Reduce the number of electric lights and their operation schedule. The middle zone was the targeted zone where most of the daylighting was needed. Roof-top monitor type fenestrations were created above the middle zone to allow light in. Clerestory windows were also added above the store front windows to increase light in deeper areas with the support of light shelves. Store fronts were introduced at the rear façade as shown in figure A-2 (lower image).

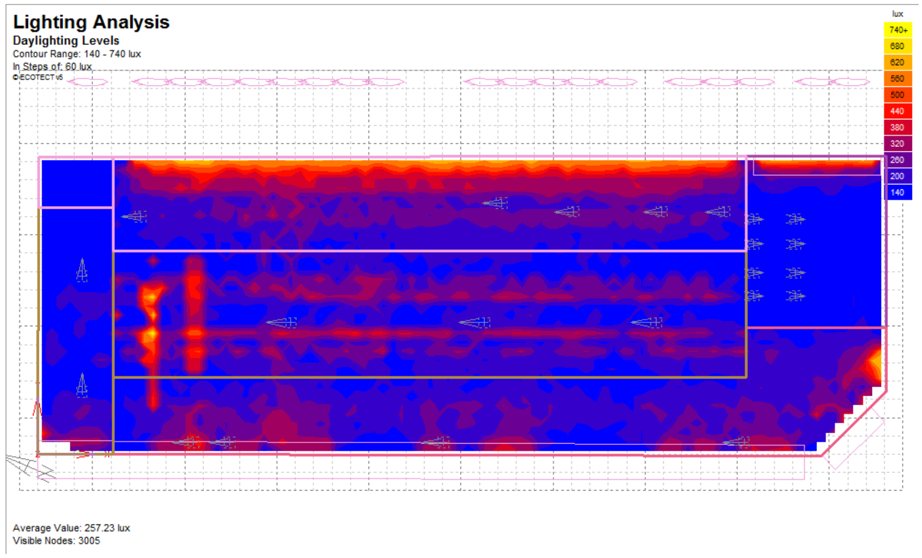


Figure 26 - Model 2: daylight level was increased by using (a) rooftop monitors over mid-zone, (b) clerestory windows above north-west store-fronts, (c) new store-front windows at south-east façade

5.2.3.4. Interior Surface Colors and Finish Reflectance

Reflectance values for room surfaces significantly impact daylight performance. Highly reflective surface reflects more daylight, however, it may also cause glare or visual discomfort. It is desirable to keep the reflectance of ceiling, wall and floors at 80%, 50% and 20% respectively. Of the various room surfaces, floor reflectance has the least impact on daylighting penetration.

5.2.4. Plug Loads

An assumption was made to improve plug loads of model 2 by 20% in order to achieve at a total energy consumption for model 2. A 20% output improvement in the plug loads was not related to the use of passive design strategies. It was made to lower heat gains associated with equipment used in different zones as mentioned before. When the plug loads are improved their impact will eventually be less on the overall heat gains in both winter and summer. The 20% improvement to plug loads resulted in a reduction in annual energy consumption of the building from 50,893.2 kW to 41,717.7 kW (table 10).

Model 2 - Appliances / plug loads							
Use	**Appliance**	**Qty**	**Ave. daily use (hour)**	**power (kW)**	**year (kWh)**	**20% Improvement**	**Intensity ($kWh/m^2{}_{yr}$)**
Restaurant	Commercial Range	2	4	5.1	14688	11750.4	
	Fridge	3	2	1.4	3024	2419.2	
	fans	3	6	0.7	4536	3628.8	
	mixers / microwaves	2	2	1.7	2448	1958.4	
	cash registers	3	3	0.2	1254	1003.2	
	computers & monitors	1	4	0.24	345.6	276.48	
	TV	2	6	0.3	1296	1036.8	
Retail	cash registers	9	8	0.2	5184	4147.2	
	fans	2	5	0.4	1440	1152	
	mputers & monitors	3	8	0.24	2073.6	1658.88	
	mixers / microwaves	3	0.5	1.5	810	648	
	TV	6	8	0.3	5184	4147.2	
Washrooms	hand-dryer	2	1	2.3	1656	1324.8	
Mech/Elec.	pumps	1	2	1	720	576	
Domestic Hotwater	water heaters	2	2	5.2	7488	5990.4	
Total					**50893.2**	**41717.8**	**39.0**

Table 10 - Model 2: Plug loads showing 20% improvement

Model 2- Energy Consumption Accoding to Source				
Electric Power	**Area Cooling (kWh)**	**Electric Light (kWh)**	**Plug Loads (kWh)**	**Total (kWh)**
	36601	**36553.728**	**41717.76**	**114872.5**
Natural Gas	**Area Heating (kWh)**			**Total**
	140362.6			**140362.6**
EUI* (heating and cooling loads only)				**165.4**
EUI total**				**238.5**

* As shown in Ecotect analysis (only for cooling and heating)
** including electric light and plug loads

Table 11 - Model 2: Total energy consumption according to source and total EUI value

5.2.5. Simulation Results

5.2.5.1. Heating and Cooling Loads

Model 2 was analyzed for monthly loads. The following observations can be drawn from table 11:

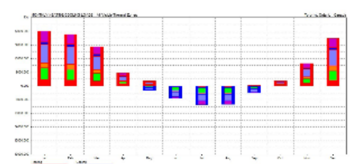
A. Total heating and cooling loads dropped from 221 kWh (model 1) to 165 kWh (a 25% improvement in energy consumption). This is due to the increase in R-values of building envelope in addition to the increase in direct solar radiation in winter caused by the optimized orientation. Design of shading devices caused a decrease in direct solar gains during summer which caused a drop of cooling loads;

B. Percentage of cooling to the overall energy consumed in heating and cooling rose from 9% (model 1) to 26%. This was probably due to the increase of WWR when more fenestrations were designed on the long north-east façade to allow retail accessibility and visibility toward North Queen Street. As noted before, glazing shading coefficient SC

MONTHLY HEATING/COOLING LOADS

All Visible Thermal Zones
Comfort: Adaptive - Average (± 1.75)

Max Heating: 139.636 kW at 12:00 on 1st January
Max Cooling: 52.352 kW at 12:00 on 20th July



MONTH	HEATING (kWh)	COOLING (kWh)	TOTAL (kWh)
Jan	32115.354	0.000	32115.354
Feb	30119.439	0.000	30119.439
Mar	23041.545	0.000	23041.545
Apr	7575.945	0.000	7575.945
May	2997.782	2809.172	5806.954
Jun	78.856	7450.248	7529.104
Jul	8.658	11041.939	11050.597
Aug	3.839	10951.392	10955.231
Sep	392.254	4310.338	4702.593
Oct	2983.045	38.078	3021.124
Nov	13169.816	0.000	13169.816
Dec	27876.084	0.000	27876.084
TOTAL	**140362.625**	**36601.168**	**176963.797**
PER M²	**130.934**	**34.142**	**165.076**
Floor Area:		**1072.013 m2**	

end of report

Table 12 - Model 2: monthly heating and cooling loads

was not changed from model 1 considering 0.40 for south-east orientation windows and 0.28 for the north-west;

C. Even though the total loads decreased from model 1 to model 2, it is noted that the actual cooling loads rose from 20,213 kWh in model 1 to 36,601 kWh in model 2. This can be explained by the possible increase in heat gains through the new store fronts which were introduced along the north-west façade (it was completely opaque in model 1) and also the new transom windows above the store-fronts on the south-east facades, in addition to the new rooftop windows (figure 25 – top right);
D. On the other hand the heating loads decreased from around 217,091 kWh in model 1 to 140,362 kWh in model 2. This could be that more sun radiation was admitted to the spaces through the south-east elevation protected by horizontal canopies that allow low-angled winter sun into the spaces causing lower heating loads through direct gains. Another factor that greatly impact the increase in solar direct gains is the optimization of orientation of model 2 compared to model 1 (figures 20-23);
E. May and September showed equal minimal cooling and heating loads at the same time which indicate potential for passive heating and cooling;
F. Due to introduction of vestibules to all retail entrances, air change rate was improved from 1 AC/h (in model 1) to an average of 0.5 AC/h. This improvement could have caused about 30% improvement in energy consumption;
G. Although there was a big increase in Window to Wall Ratio (WWR), the result showed that the cost of improving building envelope properties can still provide potential to allow for more fenestrations and still can better the efficiency of the building. As model 2 got better orientation than model 1, the shorter facades are now facing east and west.

5.2.6. Daylighting

5.2.6.1. Daylighting's Impact on Electric Lighting

It was found that the introduction of rooftop monitor / clerestory windows and storefronts at the north façade to allow natural lighting impacted lighting levels (only during the day) in display areas and retail isles where 500 Lux and 300 Lux respectively are required. Figure 27 shows the Ecotect simulation of model 2 electric lighting levels. It is noted that there is a possibility of reducing the electric lighting levels during the day and increase it in the evenings to reach the required 500 Lux in general. An approximate saving in the number of electric light fixtures during the daytime operation was calculated as follows:

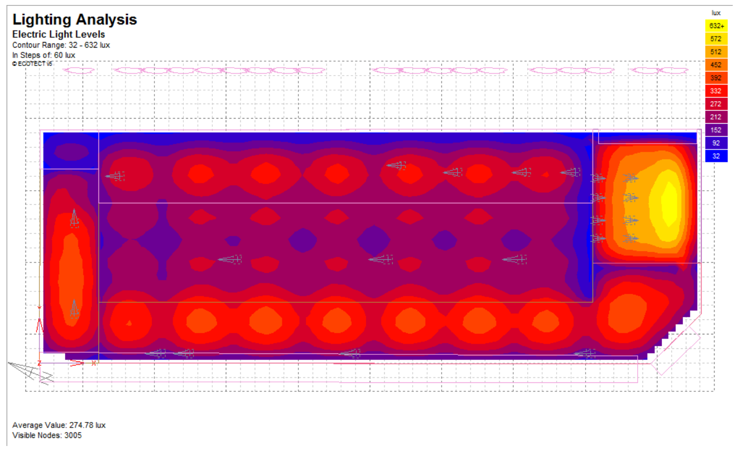


Figure 27 - Model 2: reduced over-all electric lighting due to introduction of rooftop monitors / clerestory windows

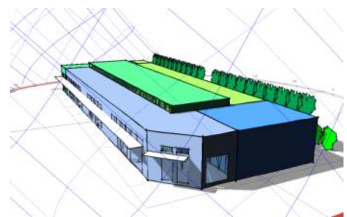
Model 1: number of T-8 lamps required to reach the 500 Lux level in main retail area = 300

Model 2: number of lamps required to reach the 500 Lux level after introducing daylighting = 300 – 84 = 216 (this is due to the fact that Lumens per Watt (LPW) of T-5 lamps is higher than that of T-8, hence more efficient).

Overall lighting levels of model 1 = 518 Lux

Overall lighting levels of model 2 = 522 Lux.

In addition to reducing number of lamps to reach the target lighting levels, lamps were improved by 20% through switching from T8 to T5 (table 9).

Model 2 - Matrix								
Elements	Assumed 25% over ASHRAE 90.1 -2010	Simulated	Passive Design Strategies					
Wall RSI value	3.34+1.76ci (R-19.0+R-10.0 ci)	3.34+2.8 ci. (R-19.0+R-16.0 ci)	Volume Height	Orientation	Mass and Fenestrations Configuration	Passive Heating	Passive Cooling	Daylighting
Roof RSI value	5.28ci (R-30.0 ci)	8.8ci (R-50.0 ci)	5.45m (18'-0")	Optimized	south and north fenestrations	direct & indirect solar radiation	canopies, trees	rooftop monitors, clerestory windows, transom windows, light shelves
Window total shading coefficient	0.4	South: 0.40 North 0.28						
Window/Wall Ratio	≤40%	40%						
Air-tightness	0.5	0.5 AC/h						
Room resultant temperature set points	18-24°C	18-24°C						
EUI (kWh/m²Yr)	≈ 253 *	238.5						

* The previous OBC-SB10 (5% over ASHRAE 90.1 - 2010) figure was considered in determining the 25% above ASHRAE 90.1- 2010 target.

Table 13 - Model 2: matrix showing results of Model 2 simulation. The EUI result from Ecotect shows better value than the target EUI assumed to be that of 25% better than ASHRAE 90.1. – 2010

5.2.6.2. Total Energy Use Intensity (EUI) for Model 2

Ecotect analysis of heating and cooling loads in model 2 indicated that the EUI resulted was 165 kWh/m²yr (table 12). After measuring the improved electric lighting and plug loads, the total EUI went up to 238.5 kWh/m²yr. This value was 5% improvement to the assumed (25% below ASHRAE 90.1. 2010) value of 253kWh/m²yr, as indicated in table 13.

5.2.7. Lessons Learned

The analysis has shown a potential to improve the building's energy efficiency in the following areas:

1. Improving building energy performance is an interactive process that involves many aspects. However orientation is the key step to start the optimization process and implement other key passive design strategies.
2. Air tightness of both building envelope and retail space (through vestibule that are correctly designed) has major impact on energy consumption.

3. Windows can be added in the south and north facades to achieve better view or higher solar radiation or both. However the increase in the area of windows can be counteracted by improving the windows' resistance value.
4. Solar radiation is great source of heat for the building in the summer. A careful design should maximize solar radiation along with installing thermal mass materials and finishes on the interior parts that are exposed to direct sun light.
5. Passive cooling should always start by preventing direct sun radiation from entering the space during summer time. It is the best practice to start any design by designing shading devices that can cover the whole window during summer and allow maximum solar radiation in the winter
6. Daylighting can be carefully considered in retail to illuminate the middle parts and avoid relying solely on electric lighting to provide all the lumens necessary to perform the selling process. Different methods can be available and should be tried in a model before deciding which one is more efficient or suitable.

5.3. Model Three: Increased Density and Building Prototype Change

5.3.1. Characteristics

At model 3, and later model 4, the building prototype was decided to be changed as a mixed-use with higher occupancy density instead of the typical single-storey retail building. That change in building prototype required changes in the architectural program as well. The following changes were carried out in model 3:

5.3.1.1. The Architectural Program

Two floors were added to the top of the original retail building with the same footprint and area as the retail. In model 3 the focus of the analysis will be mainly on the impact of mass and fenestrations configuration on the energy efficiency of the building. Therefore an architectural program will not be discussed until this issue was decided (Table A-1).

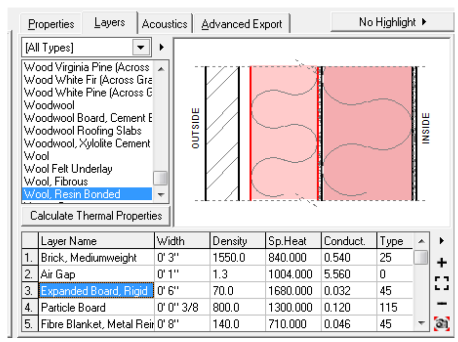


Figure 28 - Model 3: building envelope improved

Models	Model 2	Model 3
Elements	**Properties**	**Changes**
Wall RSI value	**3.34+2.8 ci. (R-19 + R16 ci)**	**3.34+4.2 ci. (R-19 + R24 ci)**
Roof RSI value	**8.8 ci. (R50 ci.)**	**8.8 ci. (R50 ci.)**
Window total shading coefficient	**South: 0.40 North 0.28**	**South: 0.47 North 0.24 double glazing**
Ave. WWR*	**40%**	**34%**
Air-tightness	**0.5 AC/h**	**0.5 AC/h**
Room resultant temperature set points	**18-24°C**	**18-24°C**
EUI (kWh/m²yr)	**238.5**	**203.7**

*** window to wall ratio**

Table 14 - Model 3: Improvements to model 2

5.3.1.2. Technical Details of Improvements

The following changes were introduced in model 3:

1. Thermal improvement to all building exterior walls we added. The R value for exterior walls was raised from RSI 6.16 (R-35) in model 2 to RSI 7.56 (R-43) in model 3 with continuous insulation around the exterior side of the wall assembly to eliminate thermal bridging. Figure 28 shows the rigid insulation layer outside of the exterior sheathing was increased to 125.4 mm (6 inches) with RSI 4.2 (R-24) (RSI 0.70/inch). Roof`s insulation was not raised in model 3 and was kept at RSI 8.8 (R-50) continuous insulation;

2. Window to Wall Ratio (WWR) was improved from 40% to 34% upon reaching the final fenestration configuration (table 14).
3. Solar total shading coefficient SC was increased for windows facing south orientation while maintained low for other facades' windows. Windows were used as low E double glazed windows with thermal breaks.
4. Air tightness remained at 0.5 AC/h, through maintaining vestibules at all entrances.

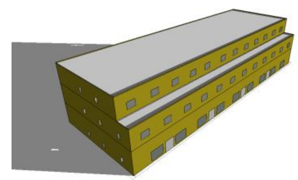
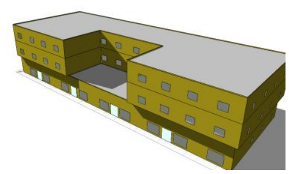
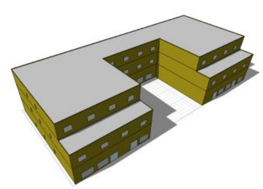
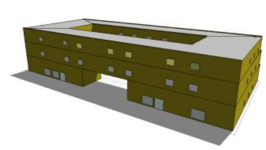
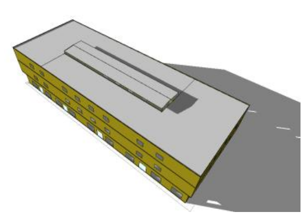
5.3.2. Mass and Fenestrations Configurations

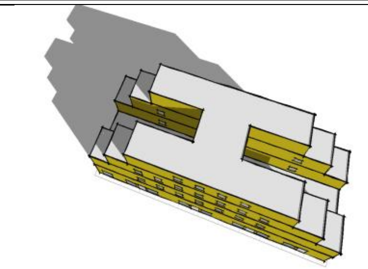
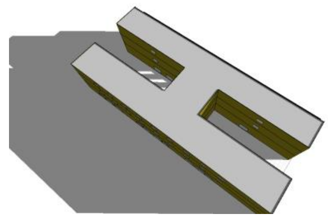
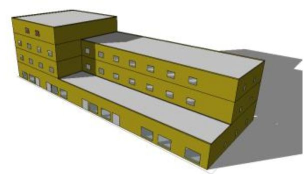
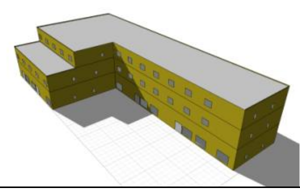
While the information of getting an energy consumption benchmark in model 1 was the basis for model 2, establishing the most efficient form and fenestration configuration will become the basis for the final design of model 4. The process of analyzing the mass configuration was based on the following criteria:

1. Within the general architectural program of model 3, experiments were performed on different mass configurations of the multi-story building of model 3. The aim is to increase the density without excessive surface exposure. The building footprint (or area coverage), was kept constant as in models 1 and 2.
2. Nine mass configurations were chosen to simulate. Those forms were random forms that attempted to capture the widest range of configurations possible within model 2 footprint.
3. Option 3 benefited from the technical improvements and passive design strategies implemented on model 2.
4. The roof-top monitors and clerestory windows created in model 2 for natural lighting was neglected in model 3 since the building model requires two additional floors on top of the retail main floor.
5. The retail's total space height was optimized from 5.48 m (18 feet) (models 1 and 2) to 3.96 m (13 feet) with clear height of 3-3.35 m (10-11 feet).

5.2.1.1. Mass Configuration

The following alternatives were designed and later simulated in Ecotect to understand the performance of each option's energy performance within exact identical conditions; orientation, floor area, building envelope's thermal resistance values, windows properties, materials, and WWR (window to wall ratio). In other words, mass configuration was the only variable in the mass configuration simulation. Inside Ecotect, all zones properties were made identical for all options which were in turn similar to the data entered for model 2. After analyzing the nine mass configurations, the best option was found to be mass 2 as it bears the least EUI among all mass configurations, as shown in figure 29.

Model 3 – **Mass 1**: design features Office floors are staggered towards the south orientation creating a long balcony for the upper floor to enjoy the view and harvest warm solar radiation in winter. The retail floor remains unchanged.		**Simulated EUI** kWh/m²yr **274**
Model 3 – **Mass 2**: design features The concept is to include a roof garden or an atrium at the office floors levels open towards the south. The retail floor remains unchanged from models 1 and 2 including its footprint.		**Simulated EUI** kWh/m²yr **258.7**
Model 3 – **Mass 3**: design features The concept is to create a U shaped building on all floors including the retail around a courtyard facing south. Retail floor is changed.		**Simulated EUI** kWh/m²yr **278.76**
Model 3 – **Mass 4**: design features The concept is to create a building wrapped entirely around a courtyard including the retail floor. This concept requires complete change of the retail format.		**Simulated EUI** kWh/m²yr **301.5**
Model 3 – **Mass 5**: design features Compact form of building with interior atrium that brings light and air circulation into the core all the way to retail floor. The retail floor remains unchanged.		**Simulated EUI** kWh/m²yr **284.32**

Model 3 – **Mass 6**: design features 3 floors to offices was suggested in the mass in order to maximize exposure to sun and minimize width of floor plate and provide maximum natural daylight. The retail floor is kept unchanged.		**Simulated EUI** kWh/m²yr **268.35**
Model 3 – **Mass 7**: design features A typical H shaped building with long corridors for offices and 2 rows of retail shallow floor plates for better daylighting. The retail format here is completely different from that common in shopping centres around Toronto.		**Simulated EUI** kWh/m²yr **286.04**
Model 3 – **Mass 8**: design features The office mass is divided into two here; one is long and facing the south and the other is clustered in a box. There is a potential of utilizing the open space above retail as a “deep balcony” towards south. The retail remains unchanged.		**Simulated EUI** kWh/m²yr **293.29**
Model 3 – **Mass 9**: design features Retail and office floors share same mass configuration where there is a potential of creating a green space as a focal point facing south.		**Simulated EUI** kWh/m²yr **332.28**

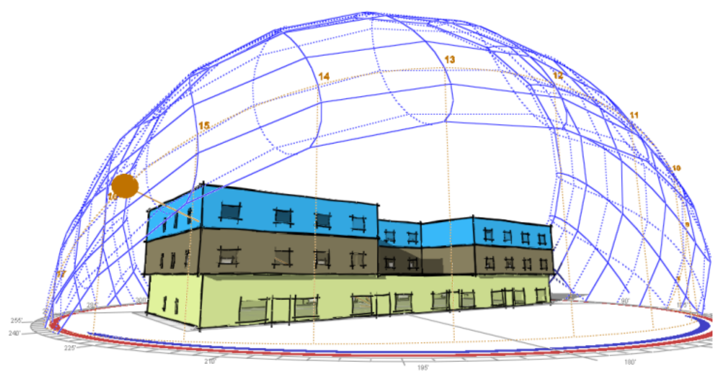
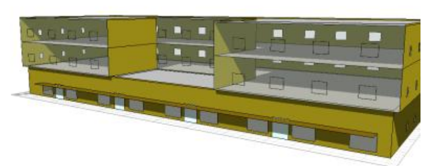
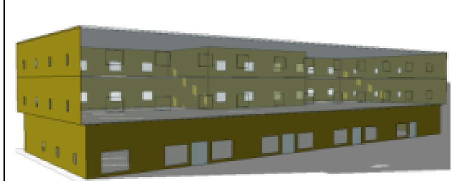


Figure 29 - Model 3: mass configuration’s analysis using Ecotect and the optimized option (mass 2) EUI of 258.7 kWh/m²yr

5.3.2.1. Fenestration Configuration

Once the optimum mass configuration option was concluded using Ecotect, the model was further analyzed to discover the best fenestration configuration's scenario within mass 2. With fenestrations configuration the following consideration were taken into account:

1. Orientation of fenestrations;
2. Area of fenestrations;
3. Programmatic impact;
4. Daylighting;
5. Impact on adjacent urban spaces through overshadowing and solar access.

The experiment to find the most energy-efficient fenestration configuration assumed the retail facades to be similar to those of model 2. The upper floors were already simulated as simple individual windows in all facades. Only office mass was exposed to different fenestration configuration using Ecotect to study the impact of glazing each of the building's facade has had on the total energy performance of the whole building (retail fenestration configuration was considered a constant). Façade 1: South east façade completely glazed. High heating loads resulted.		**Simulated EUI** kWh/m²yr 266.4
Façade 2: North west façade completely glaze. Highest heating loads resulted.		**Simulated EUI** kWh/m²yr 267.5

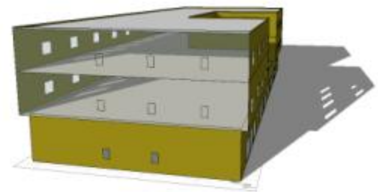
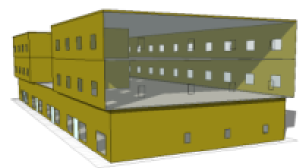
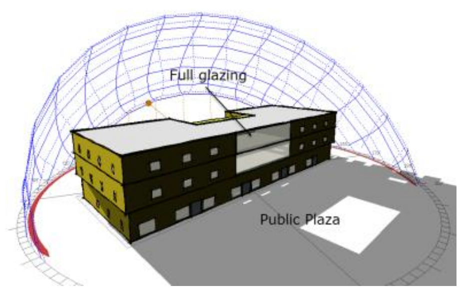
Façade 3: South west façade completely glazed. Lowest heating loads resulted.		**Simulated EUI** kWh/m^2yr 264.2
Façade 4: North east façade completely glazed. Low heating loads resulted.		**Simulated EUI** kWh/m^2yr 266.4
Final design based on simulation analysis done in Ecotect. It showed relatively the lowest heating loads and an average value of cooling loads. The design concept was also based on addressing the issue of urban space and possibility of the building making an overshadowing effect. The use of glazing on both sides of the building envelope (North and South) can have a better visual impact for users as well as allowing the sun in certain parts of the day (in winter) to illuminate parts of the public plaza on the north west side of the building.	 	**Simulated EUI** kWh/m^2yr 263.5

Figure 30 - Model 3: fenestration configuration of four variations using Ecotect

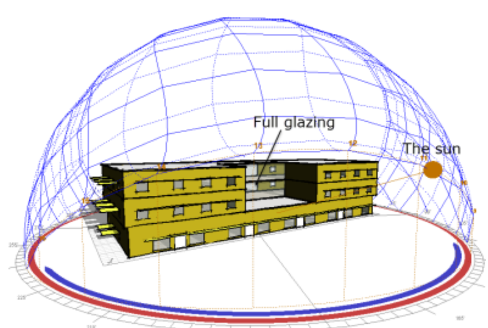


Figure 31 - Model 3: optimum solution for mass and fenestration configuration with EUI 263.5 kWh/m^2yr

5.3.3. Simulation Results

5.3.3.1. Heating and Cooling Loads

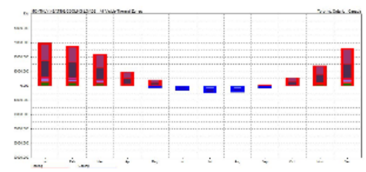
Upon reaching the best mass and fenestration configurations, a monthly heating and cooling loads analysis was conducted on model 3 and the following conclusions were drawn from the analysis (table 15):

1. Due to the increase in area of model 3 after including two office floors to the retail floor, the total energy consumption of the whole building increased from 176,963 kWh (models 1 and 2) to 628,684 kWh (model 3).
2. Although the building size was increased by adding two new office floors, the total energy use intensity for model 3 was lowered from 319.34.5kWh/m²yr (model 2) to 238.5kWh/m²y (table 19). That is a 25% reduction in total EUI.
3. In model 3 there was a decline in cooling loads and rise in heating loads compared to model 2. This is due to the increase in surface area of building envelope (more heat loss). For example, cooling loads' percentage in model 3 was only 10% of the total energy spent on cooling and heating, while in model 2 it formed 20%. That difference went to heating.
4. As noted in model 2, spring and fall months have a slight need for both heating and cooling as the weather in those seasons become transitional and fluctuation of temperatures becomes wider. Passive heating and cooling strategies became more relevant and applicable. This includes thermal mass use in heating and wind ventilation in cooling. This in turn can reduce heating and cooling mechanical loads.

MONTHLY HEATING/COOLING LOADS

All Visible Thermal Zones
Comfort: Thermal Neutrality (± 1.75)

Max Heating: 489.351 kW at 12:00 on 1st January
Max Cooling: 153.249 kW at 12:00 on 20th July



MONTH	HEATING (kWh)	COOLING (kWh)	TOTAL (kWh)
Jan	119277.508	0.000	119277.508
Feb	111290.211	0.000	111290.211
Mar	88637.805	0.000	88637.805
Apr	38691.793	77.491	38769.285
May	16942.342	6066.051	23008.395
Jun	99.601	12765.751	12865.352
Jul	0.000	20717.344	20717.344
Aug	0.000	18210.469	18210.469
Sep	4237.321	7127.262	11364.582
Oct	22490.092	506.875	22996.969
Nov	56407.844	0.000	56407.844
Dec	105138.750	0.000	105138.750
TOTAL	**563213.188**	**65471.242**	**628684.438**
PER M²	**140.856**	**16.374**	**157.230**
Floor Area:		**3998.508 m2**	

end of report

Table 15 - Model 3: heating and cooling loads

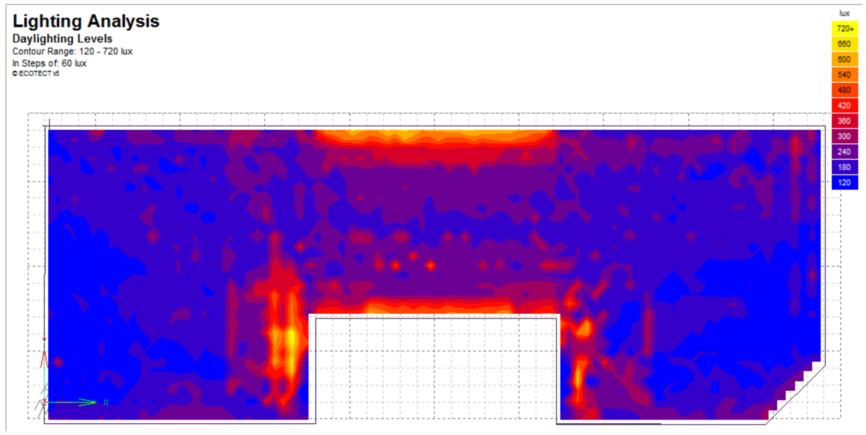
5.3.3.2. Electric Lighting Design

In model 3, the lighting design was further improved to minimize energy consumption. The T-5 fixtures were replaced with LED lighting pendants in retail and office spaces. Although number of light fixtures was raised in ground-floor retail (due to lack of natural lighting especially in middle zones), the energy consumption of the new LED system was less than that of previous T-5 fixtures. This resulted in total annual energy consumption of 48,933 kWh or a 25% increase in electrical light consumption compared to that of model 2 of 36,553kWh (table 16). Although building area was increased, annual light energy intensity was reduced by 50%, from 34 kW/m²yr in model 2 to 17 kW/m²yr in model 3, due to use of higher efficiency lighting fixtures.

5.3.3.3. Daylighting in Retail and Office Space

Daylighting as a passive design strategy in model 3 was not considered. This is due to the fact that more focus was directed towards discovering, through Ecotect, the optimum mass and fenestration configuration. Daylighting in retail floor was in effect not changed from that of model 1. This is because the roof-top monitors that were added in model 2 could no longer be applicable and had to be eliminated to allow for office floors. In figure 32 lighting analysis of a typical office floor was simulated, and an assumption was made to the lighting levels necessary to perform office tasks.

Model 3 - Daylighting levels in office floors as simulated in Ecotect are higher near curtain wall windows on south-east façade and north-west façade.



Model 3 – Overall lighting levels in office floors as simulated after optimizing electrical lighting in office floors.

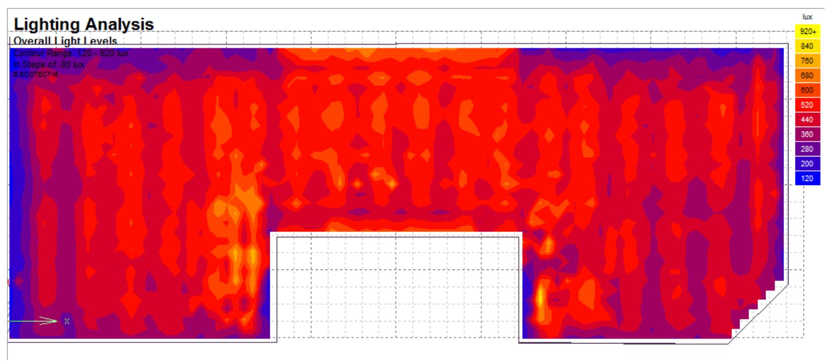


Figure 32 - Model 3: daylighting and overall lighting levels of a typical office floor

Model 3 Lighting Fixtures											
Space	**Fixture Type**	**Fixture power Ratio**	**Qty**	**Lamps / Fix**	**Lumens/Watt**	**Lamp Power (w)**	**Total (W)**	**Daily Ave.(h)**	**No. of days**	**Year (kWh)**	**Intensity (Kwh/m²yr)**
Retail	Pendent - LED *	1	165	2		15	5				
Office floor 1	Pendent - LED	1	80	2		15	2				
Office floor 2	Pendent - LED	1	80	2	99	15	2				
Kitchen	LED	1	15	2		15	0.4500				
Mechanical Room	LED	0.9	12	2		15	0.3240				
Washrooms	LED	0.9	24	2		15	0.6480				
Total							**11.17**	12	365	**48933.36**	**17.4**

* LED - Light Emitting Diode: a two-lead semiconductor light source.

Table 16 - Model 3: lighting fixtures design for retail and offices

Model 3 - Appliances / plug loads							
Use	Appliance	Qty	Ave. daily use (hour)	power (kW)	year (kWh)	20% Improvement	Intensity (kWh/m²yr)
Restaurant	Commercial Range	2	4	5.1	14688	11750.4	
	Fridge	3	2	1.4	3024	2419.2	
	fans	3	6	0.7	4536	3628.8	
	mixers / microwaves	2	2	1.7	2448	1958.4	
	cash registers	3	3	0.2	1254	1003.2	
	computers & monitors	1	4	0.24	345.6	276.48	
	TV	2	6	0.3	1296	1036.8	
Retail	cash registers	9	8	0.2	5184	4147.2	
	fans	2	5	0.4	1440	1152	
	mputers & monitors	3	2	0.24	518.4	414.72	
	mixers / microwaves	3	0.5	1.5	810	648	
	TV	6	3	0.3	1944	1555.2	
Washrooms	hand-dryer	6	1	2.3	4968	3974.4	
Office	mputers & monitors	88	5	0.24	38016	30412.8	
	fans	5	3	0.4	2160	1728	
	electric heaters	5	1	1.5	2700	2160	
	Fridge	3	2	1.4	3024	2419.2	
	mixers / microwaves	4	2	1.7	4896	3916.8	
Mech/Elec.	pumps	1	2	1	720	576	
Domestic Hotwater	water heaters	2	2	5.2	7488	5990.4	
Total					**100206**	**81168**	**28.9**

Table 17 - Model 3: plug loads

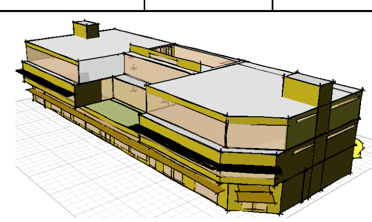
5.3.3.4. Plug Loads

The plug loads for model 3 was increased and diversified to reflect the multiple uses in model 3. The retail use however remained in model 3 and included similar number of plug loads while more plug loads were required to cover the office use in two floors. Table 17 shows that in addition to retail new plug loads were added including computers and monitors, fans, electric heaters, fridges, mixers and microwaves, in addition to increasing domestic hot water heaters. The total loads resulted reaches 100,206 kWh/yr which was then optimized with the assumption that the equipments and appliances would be 20% more efficient than those utilized in model 2. The final plug loads reached therefore was 81,168 kWh/yr. With electrical lighting load, plug load was added to heating and cooling loads to reach final energy use intensity as shown in tables 18 and 19.

Model 3- Energy Consumption Accoding to Source				
Electric Power	Area Cooling (kWh)	Electric Light (kWh)	Plug Loads (kWh)	Total (kWh)
	65471	48933.36	81168	195572.36
Natural Gas	Area Heating (kWh)			Total
	563213			563213
EUI* (heating and cooling loads only)				157.3
EUI total**				203.7

* As shown in Ecotect analysis (only for cooling and heating)
** including electric light and plug loads

Table 18 - Model 3: Energy consumption according to source and total EUI value

Model 3 - Matrix								
Elements	Assumed 50% below ASHRAE 90.1 -2010	Simulated	Passive Design Strategies					
Wall R-value	R-43	R-19 + R24 c.i.	Volume height	Orientation	Mass and Fenestrations Configuration	Passive Heating	Passive Cooling	Daylighting
Roof R-value	R-50	R-50	Optimized Retail 13'-0" Offices 13'-0"	Optimized	south and north fenestrations	direct & indirect solar radiation	canopies, trees, operable windows for offices	clerestory windows, upper windows, light shelves
Window total shading coefficient	0.40 w/(m²k)	South: 0.47 North 0.24						
Window/Wall Ratio	≤40%	34%						
Air-tightness	0.5	0.5 AC/h						
Room resultant temperature set points	18-24°C	18-24°C						
EUI (kWh/m²yr)	≈ 189.7*	203.7						

* The previous 25% over ASHRAE 90.1 - 2010 figure was considered in determining the 50% above ASHRAE 90.1- 2010 target.

Table 19 - Model 3: matrix shows heating and cooling loads and passive strategies implemented

5.3.4. Total Energy Use Intensity (EUI) for Model 3

Ecotect analysis of heating and cooling loads of model 3 indicated that the EUI resulted was 157.3 kWh/m²yr (table 15). After measuring the required (and improved) electric lighting and plug loads, the total EUI reached 203.7 kWh/m²yr. This value is slightly higher than the assumed 50% below ASHRAE 90.1. 2010 of 189.7 kWh/m²yr (table19) by 6%.   A summary of all technical improvements in model 3 (compared to model 2) is shown in table 14.

5.4. Model Four: Optimized Building – Close to NZE

5.4.1. Characteristics

Model 4 was an elaborated and expanded design of model 3. In model 4 the design concept was elaborated and finalized following Passive House standards. Passive design strategies for both heating and cooling were pronounced. The following are the main technical details of improvements in model 4.

5.4.2. Technical Details of Improvements

1. Exterior walls' thermal resistance were improved from RSI 7.5 (R-43) of model 3 to RSI 10.38 (R-59) a 37% increase, with continuous insulation around the wall assembly. Roof`s insulation was also increased from RSI 8.8 (R-50) to RSI 12.6 (R-72), a 44% increase.

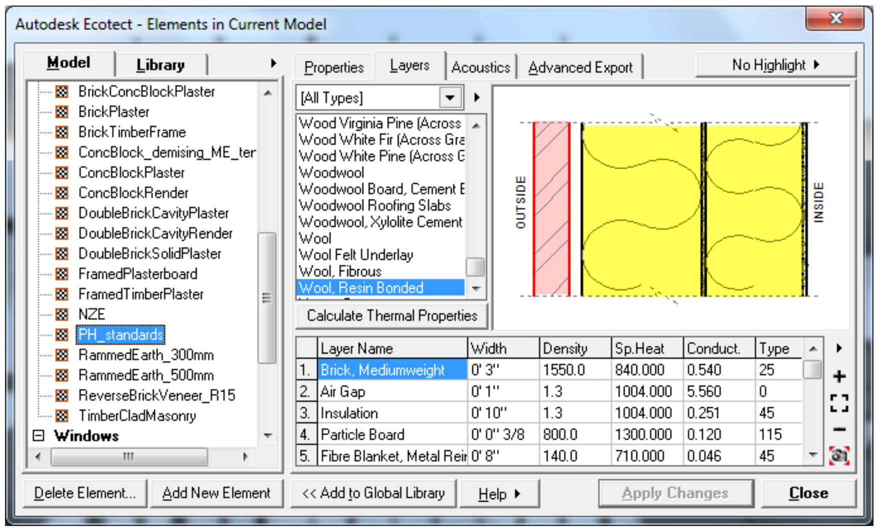


Figure 33 - Model 4: Ecotect wall assembly layers showing a 10" rigid insulation over the exterior sheathing to achieve R70

2. Window to Wall Ratio (WWR) increased from overall 34% to 55% due to increase in number of windows and curtain wall glazing's area in Atrium and North West façade. WWR was designed approximately as 35% in north facade and 65% on south facade.
3. The solar coefficient of all windows was raised to 0.80 w/(m²K). Windows properties followed Passive House standards of triple glazing, thermally separated, and installed inside the insulation layer.
4. Air tightness remained at 0.5 AC/h.
5. The mechanical system was changed from full HVAC system to ventilation only with heat recovery.

5.4.3. Implemented Passive Design Strategies

Passive design strategies were utilized in model 4 within the following parameters:

5.4.3.1. Passive Heating Strategies

The following strategies were utilized in model 4 (table 24):

1. Isolated solar gain: this strategy used sun space (Atrium) was designed to occupy the niche created in model 3 as part of mass configuration process. The Atrium is a glass room that retains solar heat and slowly emitting it in the evening towards the internal spaces through convection (figure 34). This method of passive heating requires materials that have thermal mass such as concrete, brick, terra cotta, tiles that can store energy and release it slowly.

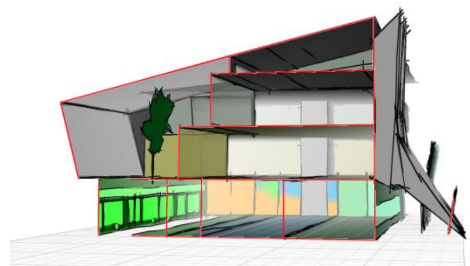


Figure 34 - Model 4: sun space (Atrium) oriented toward the south

Figure 35 - Model 4: solar direct gain through southern windows on January 1st. at 12:45 pm.

2. Direct gain: windows exposed to south orientation allow maximum solar heat gain inside. This strategy was combined with thermal mass using 100 mm (4 inches) of exposed concrete floor and brick finishes in areas exposed to direct winter sun radiation (figure 35).
3. Preventing sun radiation from entering retail and office spaces during cooling season is the first passive cooling design strategy that were considered in model 4. A complete shading devices' design was simulated using Ecotect on the south-east and north-west facades. On the south

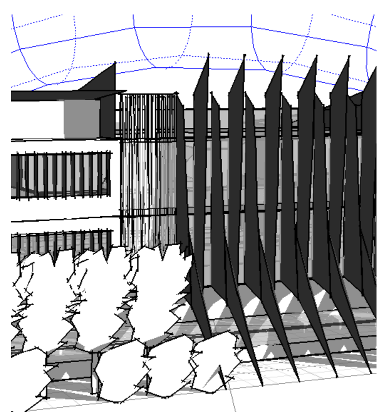


Figure 36 - Model 4: passive cooling strategy, vertical louvers at north-west facade

façade, the retail windows benefited from a cantilever of the 2nd floor to provide shading. The second floor's windows used metal grilles as shading devices. The 3rd. floor benefited from the projection of the photovoltaic grid located on the roof. On the north-west façade only vertical shading devices could perform to block the afternoon sun. The shading devices were designed to completely prevent solar radiation from entering the spaces in all seasons while maintaining vision towards the shopping centre located to the north-west side (figure 36).

4. Wind ventilation in spring and fall seasons was utilized through the use of operable windows in offices.

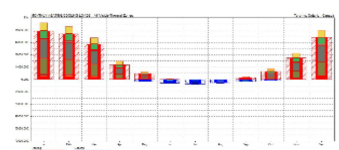
5.4.4. Simulation Results

5.4.4.1. Heating and Cooling Loads

MONTHLY HEATING/COOLING LOADS

All Visible Thermal Zones
Comfort: Zonal Bands

Max Heating: 249.484 kW at 12:00 on 1st January
Max Cooling: 95.081 kW at 12:00 on 20th July



MONTH	HEATING (kWh)	COOLING (kWh)	TOTAL (kWh)
Jan	55307.117	0.000	55307.117
Feb	51705.887	0.000	51705.887
Mar	40301.621	0.000	40301.621
Apr	16797.648	130.639	16928.285
May	6940.395	2707.786	9648.180
Jun	332.681	4468.354	4801.035
Jul	11.611	5608.535	5620.146
Aug	11.790	4253.499	4265.289
Sep	2149.638	2394.233	4543.872
Oct	9352.474	1256.832	10609.306
Nov	24662.604	31.404	24694.008
Dec	47850.855	0.000	47850.855
TOTAL	**255424.359**	**20851.279**	**276275.656**
PER M²	**81.173**	**6.626**	**87.799**
Floor Area:		**3146.677 m2**	

end of report

Table 20 - Model 4: heating and cooling loads

Model 4- Energy Consumption Accoding to Source				
Electric Power	**Area Cooling (kWh)**	**Electric Light (kWh)**	**Plug Loads (kWh)**	**Total (kWh)**
	20851.279	**35951.04**	**81168**	**137970.3**
Natural Gas	**Area Heating (kWh)**			**Total**
	255424.359			**255424.4**
EUI* (heating and cooling loads only)				**87.8**
EUI total**				**125.0**

* As shown in Ecotect analysis (only for cooling and heating)
** including electric light and plug loads

Table 21 - Model 4: energy consumption according to source and total EUI value

Model 4 Lighting Fixtures										
Space	**Fixture Type**	**Fixture power Ratio**	**Qty**	**Lamps / Fix**	**Lumens/Watt**	**Lamp Power (w)**	**Total (W)**	**Daily Ave.(h)**	**Year (kWh)**	**Intensity (kWh/m²yr)**
Retail	Pendent - LED	1	110	2	99	15	3,300			
Office floor 1	Pendent - LED	1	60	2		15	1,800			
Office floor 2	Pendent - LED	1	60	2		15	1,800			
Kitchen	LED	1	15	2		15	450			
Mechanical Room	LED	0.9	12	2		15	324			
Washrooms	LED	0.9	24	2		15	648			
Total							**8,322**	12	**35951**	**11.4**

Table 22 - Model 4: lighting fixtures improvement

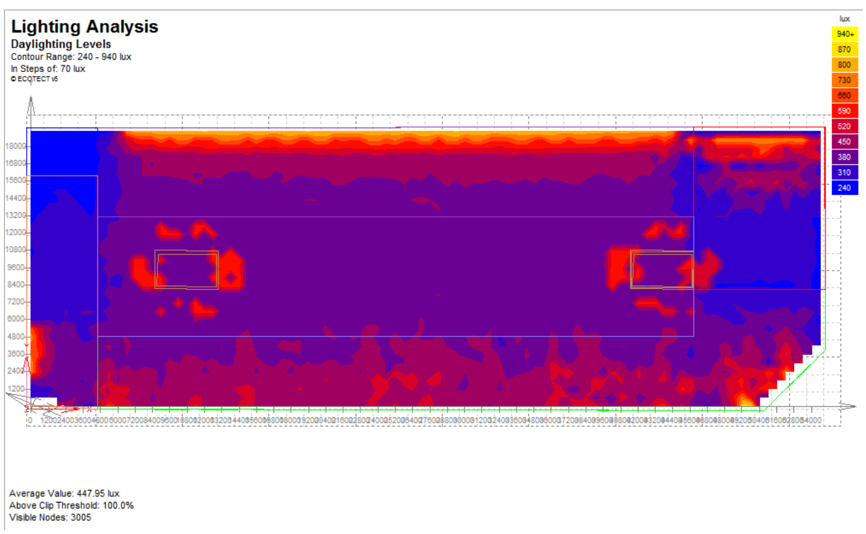


Figure 37 - Model 4: daylight levels at retail floor after introducing light wells

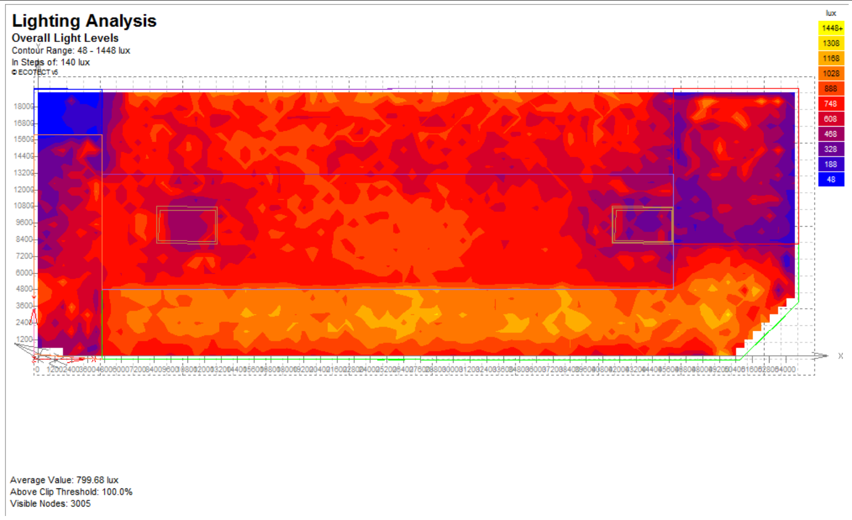


Figure 38 - Model 4: overall lighting levels at retail

Model 4 - Appliances / plug loads							
Use	**Appliance**	**Qty**	**Ave. daily use (hour)**	**power (kW)**	**year (kWh)**	**20% Improvement**	**Intensity (kWh/m²yr)**
Restaurant	Commercial Range	2	4	5.1	14688	11750.4	
	Fridge	3	2	1.4	3024	2419.2	
	fans	3	6	0.7	4536	3628.8	
	mixers / microwaves	2	2	1.7	2448	1958.4	
	cash registers	3	3	0.2	1254	1003.2	
	computers & monitors	1	4	0.24	345.6	276.48	
	TV	2	6	0.3	1296	1036.8	
Retail	cash registers	9	8	0.2	5184	4147.2	
	fans	2	5	0.4	1440	1152	
	computers & monitors	3	2	0.24	518.4	414.72	
	mixers / microwaves	3	0.5	1.5	810	648	
	TV	6	3	0.3	1944	1555.2	
Washrooms	hand-dryer	6	1	2.3	4968	3974.4	
Office	computers & monitors	88	5	0.24	38016	30412.8	
	fans	5	3	0.4	2160	1728	
	electric heaters	5	1	1.5	2700	2160	
	Fridge	3	2	1.4	3024	2419.2	
	mixers / microwaves	4	2	1.7	4896	3916.8	
Mech/Elec.	pumps	1	2	1	720	576	
Domestic Hotwater	water heaters	2	2	5.2	7488	5990.4	
Total					**100206**	**81168**	**25.8**

Table 23 - Model 4: plug load breakdown

5.4.5. Additional Measures in Building Envelope

Other measures were taken in model 4 to minimize thermal bridging of metal studs (since this is the most common construction method in retail it was decided to follow the same construction trend). A foam cover to wrap around metal studs to fuse the conduction between the interior and exterior were used.

An issue regarding possible condensation in the inner layers of the wall assembly required looking into pressure differential between saturated and partial vapor pressures. Once the latter are equalized a problem of condensation can occur in a non-water-resistive material. This can cause a concern to the batt insulation inside the cavity between metal studs, the sheathing, or the gypsum wall boards, at the interior side of the building envelope.

This has been avoided through:

1) Increasing the exterior rigid insulation layer much more than the interior insulation so as to move the Dew point away from the interior of the building envelope thus condensation occurs only in the water-resistive materials such as the cavity or the rigid insulation;

2) Avoid using highly impermeable vapor retarders on the interior face of the wall assembly to allow for drying to the inside.

5.4.6. Optimized Building Façade based on Solar Insolation

At this level it was decided that model 4's south-east façade was to be re-designed including increasing window sizes for better daylighting in retail and offices. Understanding Insolation helped validate previous design decisions to install photovoltaic cells on the roof, and explore different options including the one to increase south façade's window sizes to allow more daylight and view (figure 41). Simulating the Insolation on the surface of the building helped elaborate the design of the exterior recess space on the 2nd floor, which will be turned, in the final design into a sun space Atrium (figures 41 through 44).

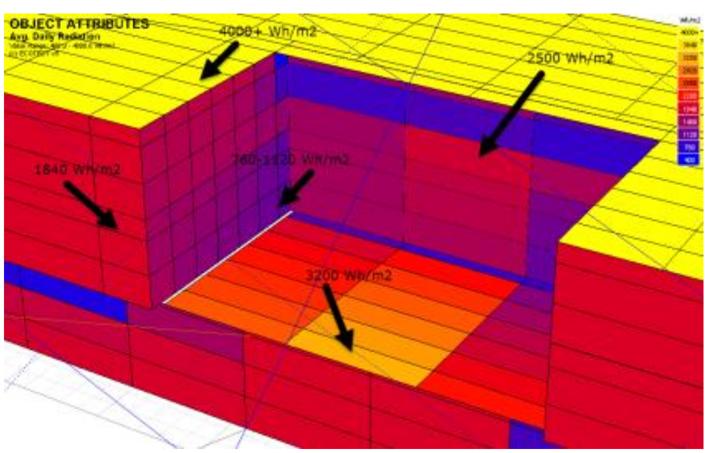
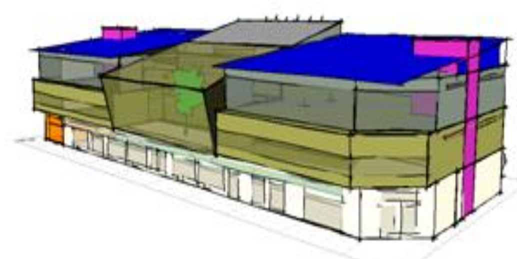


Figure 39 - Model 4: Insolation analysis in Ecotect shows solar radiation per meter square on different parts of the building envelope. This analysis contributed to the design of the atrium and PVs

Model 4 - Matrix

Elements	Passive House Standard	Simulated	Passive Design Strategies					
Wall RSI value	8.8 (R-50)	3.34+ 7c.i. (R-19 + R40 c.i)	Volume	Orientatio	Mass and Fenestrations Configuration	Passive Heating	Passive Cooling	Daylighting
Roof RSI value	12.3 (R-70)	12.67 (R-72)	Space height: Retail and offices 3.96m (13'-0")	Optimized	south and north fenestrations	Direct solar gain: south oriented window, thermal mass, atrium as sunspace with operable windows to transfer heat to interior spaces by convection	Shading devices; vertical louvers and horizontal canopies, trees, shrubs, water surfaces, stack ventilation inside atrium, wind ventilation	Roof-top monitors, clerestory windows, upper windows, light shelves & vertical light wells
Window total shading coefficient	0.8 w/(m²k)	South: 0.80 North 0.80 Thermally separated - Triple glazing Installed inside insulation layer						
Window/Wall Ratio	N/A	55% Total 35% North, 65% South						
Air-tightness	0.5	0.5 AC/h						
Room resultant temperature set points	18-24°C	18-24°C						
EUI (kWh/m²yr)	≈ 15*	125**						

* this EUI value represents heating only

** this value represents total EUI- heating-only EUI as simulated in Ecotect shows 81 kWh/m²yr.

Table 24 - Model 4: final Matrix

Models	Model 3	Model 4
Elements	**Properties**	**Changes**
Wall RSI value	3.34+4.2 c.i (R-19 + R24 c.i)	3.34+7 c.i (R-19 + R40 c.i)
Roof RSI value	8.8 (R-50)	12.67 (R-72)
Window total shading coefficient	South: 0.47 North 0.24	South: 0.80 North 0.80 triple glazing
Ave. WWR*	34%	34%
Air-tightness	0.5 AC/h	0.5 AC/h
Room resultant temperature set points	18-24°C	18-24°C
EUI (kWh/m²yr)	203.7	125

* window to wall ratio

Table 25 - Model 4: a comparison between model 3 and 4 improvements

5.4.7. Total Energy Use Intensity (EUI) for Model 4

Ecotect analysis of heating and cooling loads of model 4 calculated the EUI to be 87.8 kWh/m²yr (table 20). After measuring the required (and improved) electric lighting and plug loads, the total EUI reached 125 kWh/m²yr (tables 24 and 25). The simulated heating-only EUI for model 4 was 81 kWh/m2yr which is much higher than the Passive House EUI set-target of 15kWh/m²yr (table 24).

5.5. The Final Design Project

The Final design project was based on model 4 with the same improved architectural program. It was further detailed and enhanced through adding more passive design strategies and techniques. The architectural program of both model 4 and the final design project is shown in Table A-2.

5.5.1. Passive Design Strategies Implemented in the Final Design

1. Optimization of retail volume
2. Optimization of orientation
3. Passive Heating Strategies
    a. Direct Heating Gain
    b. Isolated Solar Gain: Sun Space
    c. Thermal Mass
    d. Mass and Orientation
4. Passive Cooling Strategies
    a. Shading Devices
    b. Wind ventilation / Evaporative Cooling
    c. Stack Ventilation and Bernulli's Principle
    d. Night-Purge Ventilation
    e. Mass and Orientation for Cooling

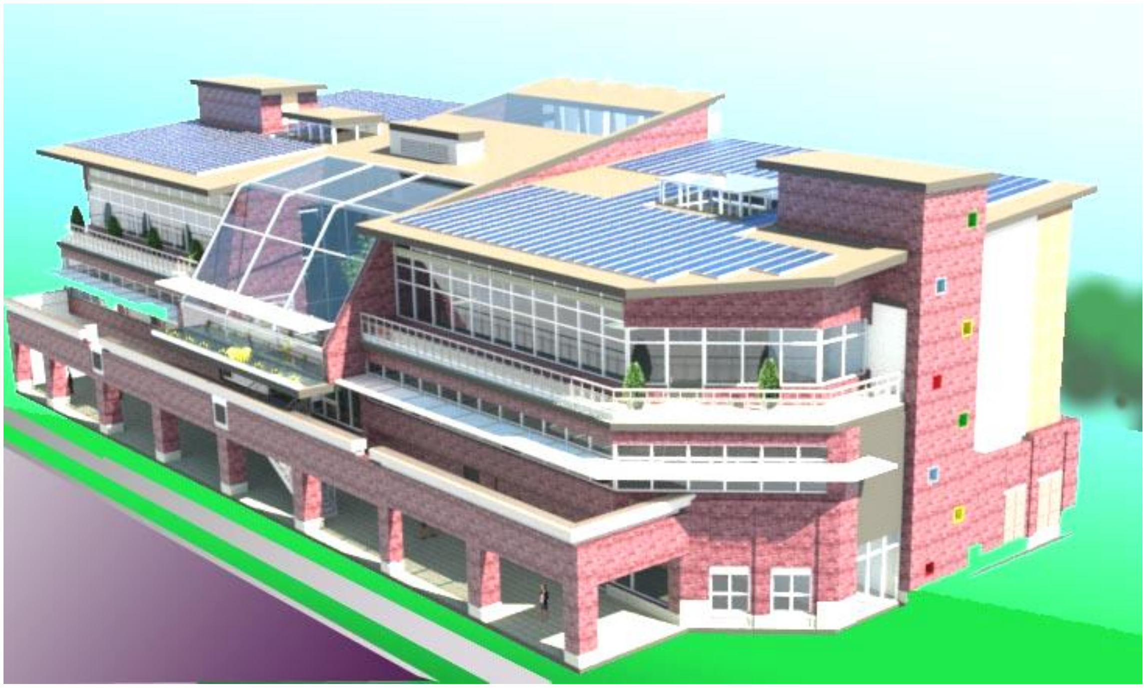


Figure 40 - Perspective view of final design: all applicable passive design strategies analyzed during the study were implemented in the final design

Figure 41 - General section through atrium

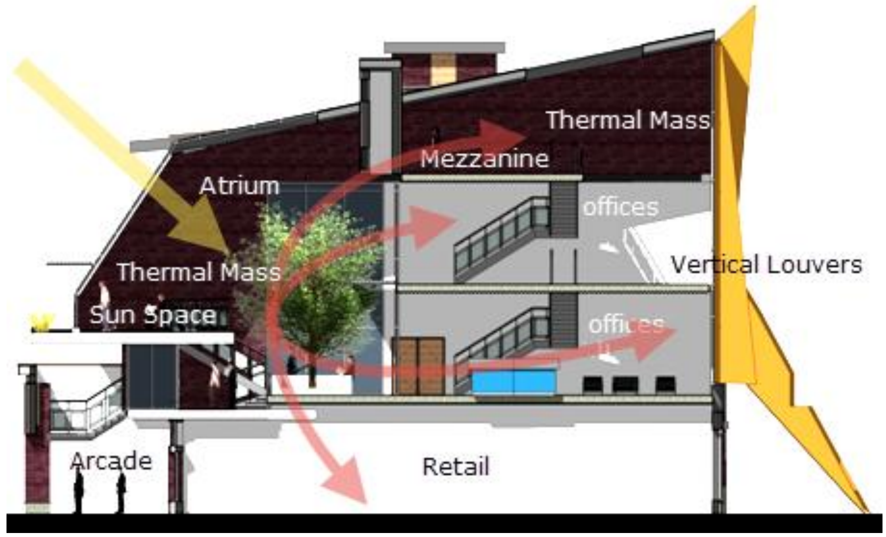


Figure 42 - Passive Heating Strategies: Section through central atrium: a) Direct Heating Gain, b) Isolated Solar Gain, c) Thermal Mass, and d) Convective Heating from atrium to interior spaces.

Figure 43 - Final design: metal grille shading devices on south facade with light shelves extending inside the space

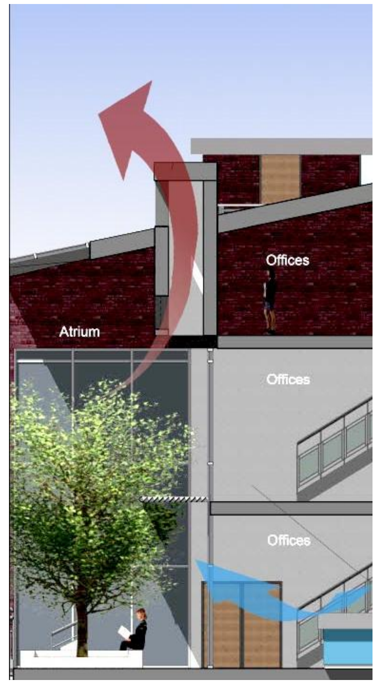


Figure 44 - Final design: stack chimney as part of passive cooling ventilation strategy in central Atrium

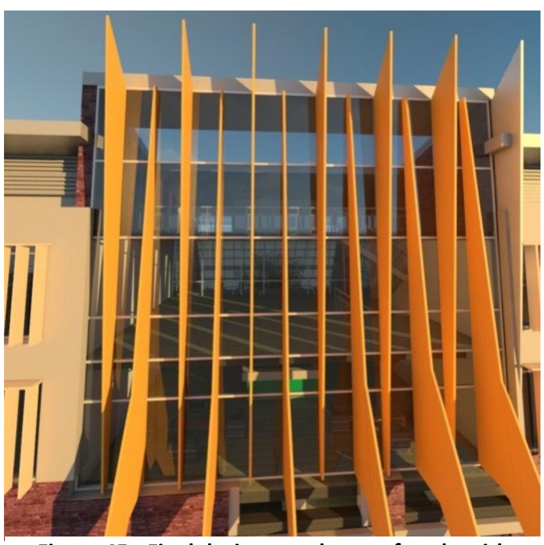


Figure 45 - Final design: north-west façade with vertical louver to block afternoon sun

Figure 46 - Final design: light well as a source of daylighting to retail and office floors

6. CONCLUSIONS

6.1. Introduction

The study was set out to explore the concept of utilizing passive design strategies in retail buildings in Toronto towards reaching a net zero energy levels. It has identified mainly the available passive design strategies in Toronto climate for retail buildings. In addition, the study has also identified the energy-efficient drivers for utilizing the passive strategies, the possibilities and the extent required for the implementation of these strategies, and finally the role and impact of climate and site-specific data on the implementation of these strategies. The study has also sought to know whether there is a potential to create a framework or roadmap that can lead building designers to design more efficient retail buildings in general and Toronto in particular that can result in high energy saving, particularly in medium format retail building. The general theoretical literature on this subject and specifically in the context of Toronto is inconclusive on several vital questions within the sustainable and passive design strategies discourse specifically in retail. The study sought to answer the following questions:

a. What are the key passive design strategies architects can implement that can make the biggest impact on retail buildings' energy consumption in Toronto?
b. Can there be a design framework or blueprint to be followed by architects aiming to improve energy performance of retail buildings in Toronto through deploying suitable passive design strategies incrementally? What are the components of this framework?
c. To what extent can NZE or close to NZE targets be achieved in retail buildings in Toronto through passive design strategies alone?

6.2. Empirical Findings

The main findings of this study are chapter-specific and were summarized within the respective chapter "Analysis and Results". This section will synthesize the empirical findings to answer the study's three research questions.

1. *What are the key passive design strategies architects and buildings designer can utilize that can make the biggest impact on retail buildings' energy consumption in Toronto?*

a. Optimum Volume: Optimizing space volume in retail buildings can often provide a valuable first-step to minimize energy consumption. This can be achieved by reducing space height in order to minimize HVAC heating and cooling loads. 5.48 m (18 feet) height could go down to 3.96-4.27 m (13-14 feet) without affecting functionality of retail space. In a stand-alone retail building, space height can be considered at an early design stage and discussed with the owner. In urban scenarios where retail is part of a multi-use building height cannot be controlled at early stage but effectively reduced through the use of suspended ceiling to minimize the air-conditioned volume.

b. Optimum Orientation: In Toronto, locating retail buildings on site is normally governed by site planning and program. When building orientation however, is a variable, orientation should always be considered a priority. The best orientation in Toronto to benefit from solar radiation is to layout the building's long axis along the east-west. This layout would allow the building longest facades to benefit from direct solar radiation in winter while protected in summer and, at the same time, avoid direct west and east low-angled sun radiation. Proper orientation of retail building is essential as it can immediately provide opportunity to minimize HVAC loads, provide possibility of locating PV system, and create many possibilities to create passive design opportunity to save energy through daylighting.

c. Passive Heating: Sun radiation is a free source for heating. Toronto has a high Heating Degree Days (HDD). That requires careful attention to the potential of utilizing sun radiation to lower HVAC loads during the winter. Certain passive design strategies could be implemented in retail to achieve that goal:

- Use of sun spaces: Sun spaces can be used in winter as heat sinks. Those rooms then can transfer the stored (and trapped) heat to other parts of the retail building through convection. This strategy seems achievable if orientation was considered at an early stage. Thermal mass forms part of the solar direct gain strategy.

- Maximize fenestrations toward the south: this can allow the sun to warm the perimeter along the south façade. With the prospect of handling the heat gained in the thermal mass (such as exposed concrete floors or other thermal mass materials), heat can then be slowly transferred to other parts of the building to make them warmer, hence lowering HVAC over-all loads.

d. Shading devices: this strategy aims at preventing sun radiation from entering the retail space through its windows during summer. It is the first technique in the passive cooling strategy that should be considered. Shading devices come in many shapes and materials. South oriented windows should be provided with horizontal shading devices to protect the window during summer months while east or west oriented facades, vertical louver must be implemented while maintaining visual connection to the outside in case there was a need to open in these directions.

e. Night-time purging: even though the study did not specifically modeled the impact of this passive cooling technique, it is worth stressing here that Toronto has high diurnal and seasonal temperature fluctuations that could form proper conditions to effectively utilize night-time purging to cool the interior spaces of retail. This technique works by allowing fresh cool air from outside to flush out the hot air through upper vents or chimney specifically in spring and fall where outside temperatures drop at night while remain higher than comfort levels in the day.

f. Wind ventilation: can be used as part of the passive cooling strategy but only in spring and fall where outside temperatures are cooler than the inside. Operating windows in retail buildings however can be impractical for reasons such as security, or availability of personnel to operate the opening and closing of windows on a daily basis.

2. What is the design framework or blueprint that can be followed by architects aiming to improve energy performance of retail buildings in Toronto through deploying suitable passive design strategies incrementally? What are the components of this framework?

a. A framework based on incremental improvements to retail buildings in Toronto was developed by setting up simulation models based on the minimum energy requirements as set by ASHRAE's 90.1 – 2010, and enforced by the Ontario Building Code with its supplement SB10 early 2012. This framework takes an empirical approach to develop an existing building through utilizing Ecotect Analysis 2011 as simulation software to prove that incremental improvements based on specific pre-set energy intensity targets for all the models progressively.
b. This framework is based on four major elements or milestones: (a) defining energy targets early; (b) consider incremental improvement for each milestone; (c) utilizing energy simulation software to check progress; and (d) testing results through more detailed modeling and comparing them to benchmarks.
c. This framework would use a similar methodology followed in architectural design process in that it requires cyclical revisions of decisions based on evolving form with more complicated outcomes including new data which becomes available through employing early-design simulation computer software.
d. The simulation software utilized is still schematic. It was discussed that early design analysis is important. However, it is as important to verify or test the results and make sure that there was improvement in energy performance. The tool itself can give general directions of how potent a certain passive design strategy is in achieving the predicted incremental reduction in energy use towards the set energy targets.

3. To what extent can NZE or close to NZE targets be achieved in retail buildings in Toronto through passive design strategies alone?

a. NZE targets cannot be achieved by passive design strategies alone. Without the intervention of active design systems, production of energy cannot be possible. Active design systems can produce electric power to run building systems at a minimal level. In NZEB, photovoltaic system is required to produce energy to cover the remaining minimal demand.

b. However, by using passive design strategies a considerable reduction in energy consumption can be achieved that would allow for the remainder of the retail building required energy to be produced through active systems such as photovoltaic cells and solar hot water systems. Therefore passive design strategies are crucial in achieve the target of NZE only through dropping the demand to a limit that can be affordably replace with mechanical or active systems.

c. In the study's attempt to reach close-to-Net Zero, that same methodology was followed on Toronto's retail buildings; reduce energy consumption to the level, after which, an energy production system can take over to provide for the remaining demand. In model 4, the Passive House (PH) energy intensity target of 15 kWh/m^2yr, was targeted. However, it could only achieve, based on the Ecotect simulation of model 4, a 81 kWh/m^2yr (based on heating loads only). The reason for that might lie in the limitation of Ecotect software itself as an early design software that lacks the ability to run detailed analysis. In addition to that, Passive House construction detailing requires careful attention to all construction and environmental detailing, including hefty thermal bridging measures at interfaces in addition to other requirements such as air-tightness, high quality triple glazed windows and doors, and continuous insulation applications.

6.3. Theoretical Implications

The investigation's attempt was to layout the passive design strategies in medium-format retail buildings in Toronto through a case-study, and within a process of incremental and predetermined improvements, in applicable framework. This is a theoretical paradigm that have been discussed but not implemented in research yet. The role of the architect in the process has been investigated in various studies. It was stressed upon by Anderson (2014) and Hootman (2013). Also, technical guidelines on how to improve buildings in stages or milestones have also been investigated by reputable research organizations (ASHRAE, 2011). However, the study attempted to exemplify these parameters in a way that moves within the iteration approach of the qualitative research methodology, by providing an integrated linkage between the theoretical basis of passive design strategies and both; design stages and energy targeting. Another theoretical addition this study has attempted to achieve was to tie-in all the aspects within which the passive design strategies in retail buildings in Toronto can be implemented with the energy simulation software Ecotect. In the study, Ecotect has not been dealt with as a result-producing simulation software as much as integral part of a whole theoretical integrated paradigm that Maclay (2014) and Yeang (2008) stressed upon; a part of a design process that is cyclical and integrative rather than mechanistic.

6.4.Policy Implications

A particular policy program with extended theoretical underpinning is the continuous emphasis on the necessity for the integrated design process IDP as a design paradigm and the importance of the concept of net zero energy in retail buildings, and the use of incremental improvements approach as part of a whole framework to develop retail toward NZE in Toronto. It is often found, that architects in their practice lack the knowledge or studies that exemplify the integrated design process in a meaningful way, not only as a team-playing process, but as integration of multiple factors including passive design strategies, within a strategic framework. The following can be suggested to encourage political implication based on what the recommendations of the study:

1. A retail design criteria can be developed to improve medium-format retail buildings particularly in Toronto. That could include such aspects as the revision of space heights, signage, store-front criteria, loading docks, use of spandrel systems as pseudo-windows, exterior lighting, large roofs design, parking surfaces, landscaping, the use of passive design strategies, and so on.
2. More rigorous regulations should be in place to increase the use of passive design strategies in retail buildings in Toronto.
3. Analyzing and understanding of local climates are suggested to be part of the permitting process for all municipalities. This analysis is not merely to understand the

number of HDD or CDD but to be able to perform complete analysis of the weather in order to come up with ideas to reduce energy consumption in retail in different uses.

4. Medium-format as well as big box retail buildings' site planning should be re-evaluated. The site planning of single-story medium to large retail buildings within huge parking lots has become outdated and new sustainable approaches to site planning shopping centres should be encouraged.
5. More efforts are be made by municipalities to utilize historic and conventional retail typologies through the use of medium-density developments, within smaller communities that can minimize the harmful reliance on private vehicles.
6. More policies could be inscribed by the bodies representing architects in Ontario and other provinces in Canada to support architects reclaiming their leadership role in the design of high-performing energy efficient buildings especially the stress that architects become fluent in building science and energy simulation methods especially at the schematic design stage.

6.5.Recommendations for Future Research

The scale of this study is multifaceted even at the specific level of retail buildings in Toronto. To generate achievable policy strategies and development targets with regards to improving energy efficiency of buildings through passive design strategies, there is need for more case studies at the level of retail buildings in Toronto to allow further assessment of local dimensions of the subject. Exploring the following as future research strategies can facilitate the attainment of this goal:

- Potential for the use of passive design strategies in retail buildings located in urban areas of Toronto: urban area retail developments bear different design criteria than those located in the sub-urban area; lack of land, lower spaces, limited solar access and problems with over-shadowing from neighboring buildings are but part of urban retail buildings' characteristics. Passive design strategies can therefore have many limitations but also potential in those locations.

- Densification of retail in Toronto sub-urban areas: the use of mixed-use developments to achieve lower Energy Use Intensities EUI in retail and create better communities;
- Passive Heating Strategies' potential in retail buildings in Toronto: A more comprehensive and detailed study aimed particularly at ways through which retail buildings in Toronto can use to harvest sun radiation and turn it into heat to minimize heating loads in Toronto's cold and long winter.
- Daylighting in medium-format, stand-alone, retail building in Toronto: This can be suggested as a survey-based studies or case-studies to show the impact of daylighting on the energy savings in retail buildings in Toronto.
- Passive design strategies in big-box retail buildings in Toronto: This can also be significant as the big-box retail has major impact on energy consumption especially heating loads.

6.6.Limitation of the Study

The study has offered an evaluative perspective on passive design strategies as conducted in retail buildings in Toronto through the formation of four design models and the use of Ecotect to analyze and measure results. It used an iteration approach of qualitative methodology to tackle this issue. As a direct consequence of this methodology, the study encountered a number of limitations, which need to be considered:

1. Passive design strategies cannot always be verified through energy simulation software's results. One of the major limitations the study (and the design) faced is its ability to evaluate passive design strategies on the decreasing of heating and cooling loads. For example, thermal mass strategy can only be estimated based on certain climatic criteria but not verified through Ecotect in order to draw conclusions or to quantify its impact.
2. Ecotect is an early design energy simulation program. It has its own limitations in dealing with rigorous energy simulations such as that of other programs. This is especially true of the final results acquired from Ecotect analysis reports regarding energy use intensity EUI and respectively heating and cooling total loads. It is highly

recommended that readers take this into account when using Ecotect and understand that it can give general directions of major schematic design decisions which are imperative. Final energy results can be acquired by transferring the models created in Ecotect to other comprehensive energy modeling programs.

3. Building design is a complex process that requires hundreds of decisions be made interactively. One of the limitations that this study had, was the fact that there is hardly any constraint in the design process and almost every element is just another variable. The research however, had to work with few variables and consider many elements which are outside its scope of this paper, constant. As an example to this challenge is the limitation of tackling the impact of active design strategies that interact with the passive ones which, in real-life scenario, can hardly be a constant.
4. Net Zero Energy buildings are not a hypothesis but a real case based on actual annual cycle of use. Only through auditioning and meters' reading a building could be claimed to be NZEB. One main limitation that the study faced was the challenge to reach the anticipated level of energy intensity EUI, less than the figure reached of 125kWh/m^{2}yr (or 81kWh/m^{2}yr based on heating only), which is still high compared to the Passive House target of only 15kWh/m^2/year.

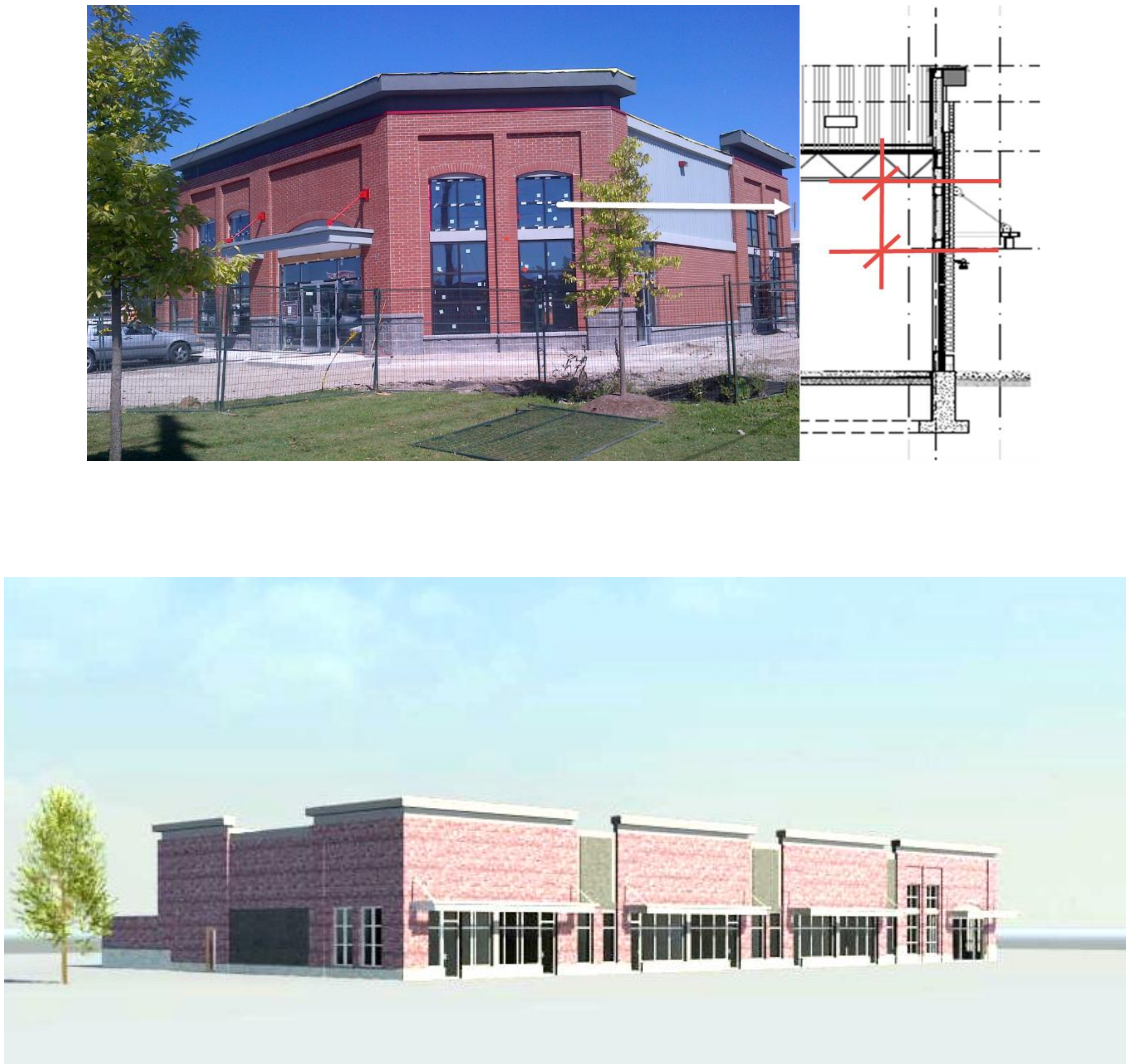
However, regardless of the above-mentioned limitations, the design project, the analysis, the methodology, and the framework to utilize passive design strategies incrementally through models, have all benefited from these limitations. It is necessary to consider these limitations not as obstacles but rather motivations for future studies in the field to overcome them and resolve these limitations and challenges.

6.7.Conclusion

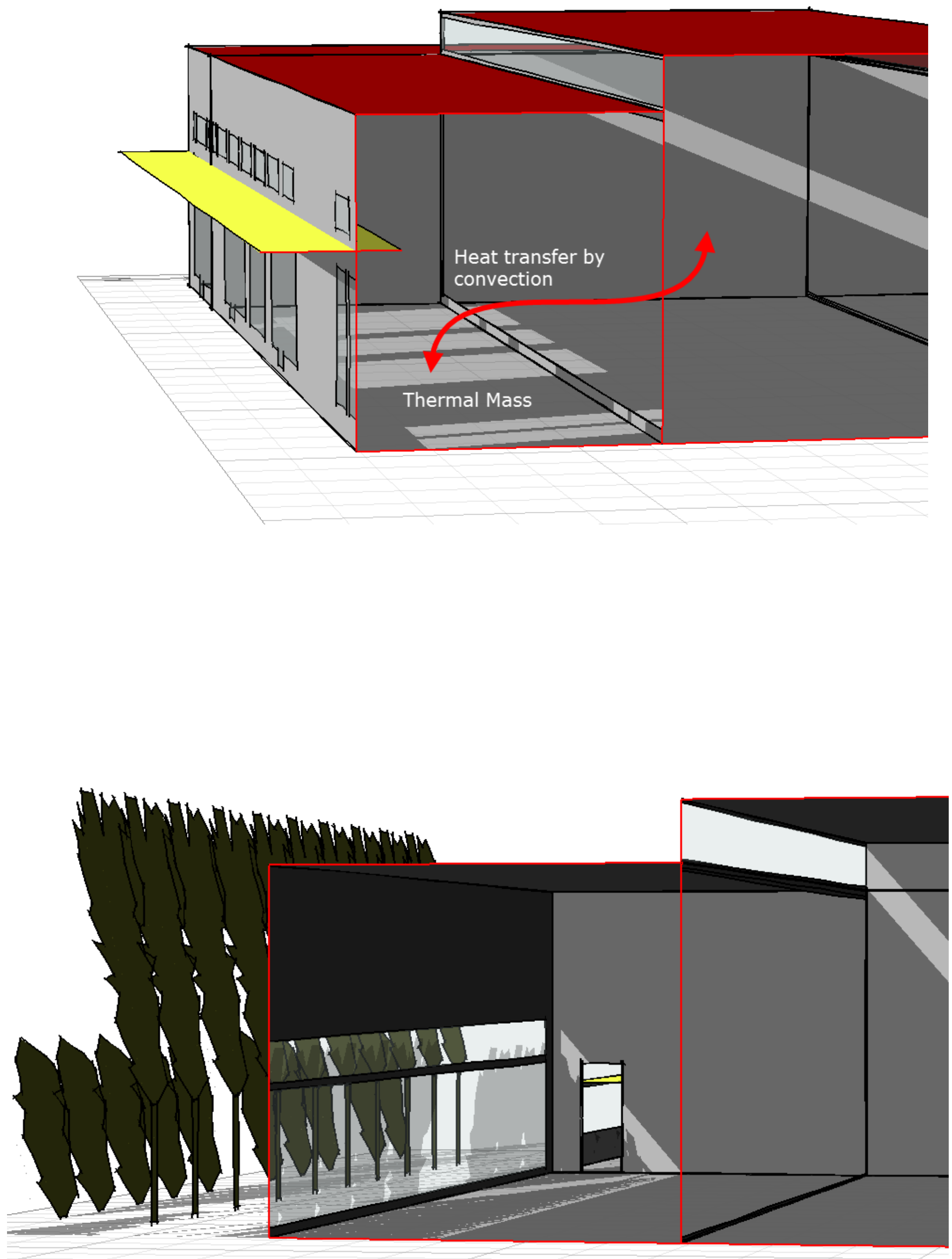
This research paper investigated the possibilities to reduce energy consumption in retail buildings in Toronto through adapting passive design strategies in retail building and the use of Ecotect® Analysis 2011 for energy simulation. This was done through adopting a strategy based on iterations of experiments on design models which culminated in a design project that solidified the findings of the empirical study.

The realm of sustainability and energy efficiency studies in buildings is vast. In addition to that, many studies tackled the subject of passive design strategies in buildings and how they can be utilized successfully. Energy targeting was also analyzed in several studies as an important consideration in the design of high energy performing buildings. The study however provided a contribution to turning the general knowledge about passive design strategies more specific by exemplifying how all the design strategies can first be analyzed within a certain geographic and environmental location, then implemented, and analyzed multiple times with the same tools and procedures. This study can provide empirical perspective for architects, designers, and building scientists, to further improve the subject of passive design strategies and the urgent need to increase their implementation on current and future buildings, in Toronto and elsewhere.

Appendix A – Images and Ecotect® Simulations



A - 1: Baseline building: upper image shows height of space, lower shows main facade facing west orientation



A - 2: Ecotect Images, upper image shows passive heating strategy based on convective heating through direct gain, below image shows passive cooling strategy based on protection of fenestrations using trees and shrubs

Model 3 - Architectural Program and Areas			
Ground Floor - Retail			
USE	**AREA SQ.FT.**	**AREA SQ.M.**	**COMMENTS**
RETAIL 1	381	35.39	Reduction in retail area compared to model 2 = 75 m² (added area for office floors lobbies and staircases)
RETAIL 2	1299	120.67	
RETAIL 3	1289	119.74	
RETAIL 4	1347	125.13	
RETAIL 5	1360	126.34	
RETAIL 6	1332	123.73	
RESTAURANT	2727	253.32	
STAIRS AREA	431	40.04	
ELECTRICAL ROOMS	176	16.35	
OFFICES LOBBIES	384	35.67	
Net total		**996.38**	
2nd Floor - Offices			
USE	**AREA SQ.FT.**	**AREA SQ.M.**	
			* roof garden created through the mass configuration simulation process ** N/A in model 3
OFFICES SPACES	7313	679.33	
RECEPTION	1671	155.23	
ROOF*	0	0.00	
WASHROOMS	285	26.47	
AUHs	408	37.90	
LIGHTWELLS **	0	0.00	
STAIRS	431	40.04	
Net Total		**938.97**	
3rd. Floor			
USE	**AREA SQ.FT.**	**AREA SQ.M.**	
OFFICES SPACES	8247	766.09	
WASHROOMS	285	26.47	
AHUs	408	37.90	
LIGHTWELLS **	0	0.00	
STAIRS	431	40.04	
Net Total		**870.51**	
Total Net Area		**2,805.85**	
Total Gross Area (incl. structure)		**3,647.61**	30% added as structure

Table A - 1: The architectural program and areas of model 3

Model 4/Final Design Project

Architectural Program and Areas

USE	AREA SQ.FT.	AREA SQ.M.
RETAIL 1	381	35.39
RETAIL 2	1299	120.67
RETAIL 3	1289	119.74
RETAIL 4	1347	125.13
RETAIL 5	1360	126.34
RETAIL 6	1332	123.73
RESTAURANT	2727	253.32
STAIRS AREA	431	40.04
ELECTRICAL ROOMS	176	16.35
OFFICES LOBBIES	384	35.67
Net total		996.38
2nd Floor - Offices		
USE	**AREA SQ.FT.**	**AREA SQ.M.**
OFFICES SPACES	7313	679.33
RECEPTION	1671	155.23
ATRIUM	1325	123.08
WASHROOMS	285	26.47
AHUs	408	37.90
LIGHTWELLS	307	28.52
STAIRS	431	40.04
Net Total		1,090.57
3rd. Floor		
USE	**AREA SQ.FT.**	**AREA SQ.M.**
OFFICES SPACES	8247	766.09
WASHROOMS	285	26.47
AHUs	408	37.90
LIGHTWELLS	307	28.52
STAIRS	431	40.04
Net Total		899.02

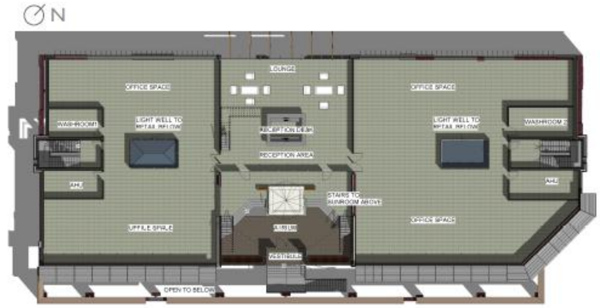
Top Floor		
USE	**AREA SQ.FT.**	**AREA SQ.M.**
OFFICES MEZZ.	1022	94.94
MECHNICAL ROOMS	2860	265.68
VESTs.	133	12.35
LIGHTWELLS	307	28.52
STAIRS	431	40.04
Net Total		441.52
Total Net Area		3,427.50
Total Gross Area (with structure)		4,284.37

Table A - 2: The architectural program and areas of model 4 and final design

Appendix B – Final Design Project – Design Drawings

PASSIVE DESIGN OPPORTUNITIES FOR MEDIUM-FORMAT RETAIL BUILDINGS IN TORONTO TOWARDS NZEB

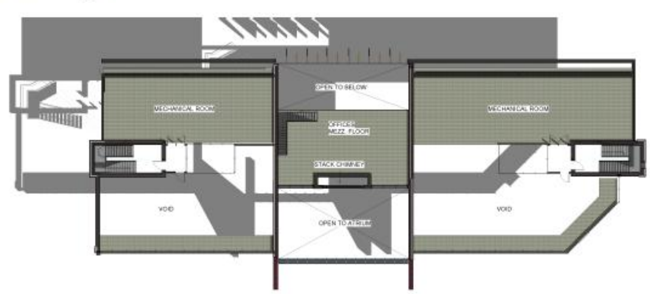
FIRST FLOOR /RETAIL
SCALE 1/8" = 1'0" N



SECOND FLOOR /OFFICES
SCALE 1/8" = 1'0" N

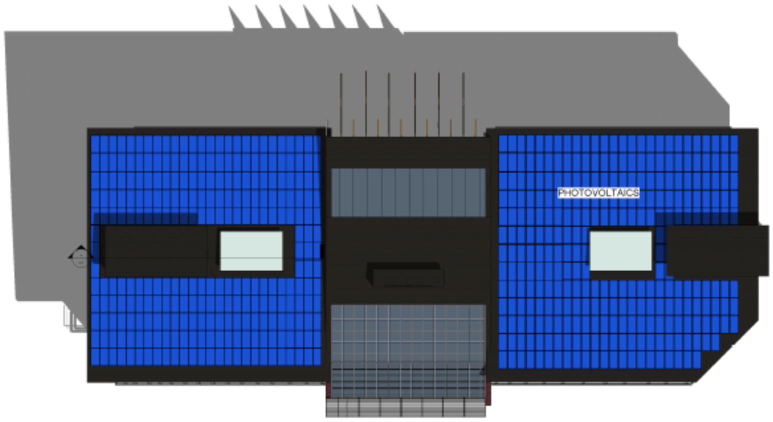
PASSIVE DESIGN OPPORTUNITIES FOR MEDIUM-FORMAT RETAIL BUILDINGS IN TORONTO TOWARDS NZEB

THIRD FLOOR /OFFICES
SCALE 1/8" = 1'0" N



FOURTH FLOOR /MECHANICAL
SCALE 1/8" = 1'0" N

PASSIVE DESIGN OPPORTUNITIES FOR MEDIUM-FORMAT RETAIL BUILDINGS IN TORONTO TOWARDS NZEB



ROOF PLAN
SCALE 1/8" = 1'0" N

PASSIVE DESIGN OPPORTUNITIES FOR MEDIUM-FORMAT RETAIL BUILDINGS IN TORONTO TOWARDS NZEB

North-East Elevation N

Ecotech Thermal Model

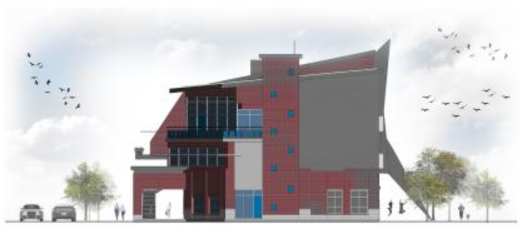
South-East Elevation N

Ryerson University
Department of Architectural Science

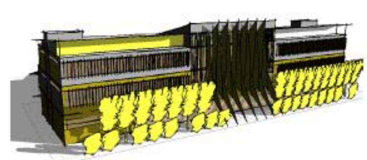
ELEVATIONS

ISSAM A SHUKOR

PASSIVE DESIGN OPPORTUNITIES FOR MEDIUM-FORMAT RETAIL BUILDINGS IN TORONTO TOWARDS NZEB



South-West Elevation N



Ecotech Thermal Model

North West Elevation N

Ryerson University
Department of Architectural Science

ELEVATIONS

ISSAM A SHUKOR

PASSIVE DESIGN OPPORTUNITIES FOR MEDIUM-FORMAT RETAIL BUILDINGS IN TORONTO TOWARDS NZEB

Transversal Section

Ecotech Thermal Model

Longitudinal Section

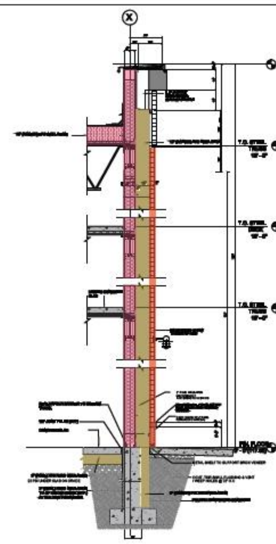
Ryerson University
Department of Architectural Science

SECTIONS

ISSAM A SHUKOR

PASSIVE DESIGN OPPORTUNITIES FOR MEDIUM-FORMAT RETAIL BUILDINGS IN TORONTO TOWARDS NZEB

Sectional Perspective



Typical Wall Section- NTS

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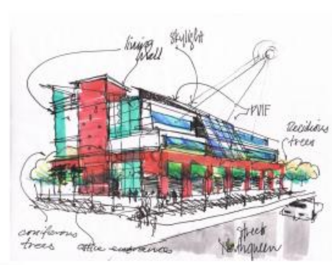
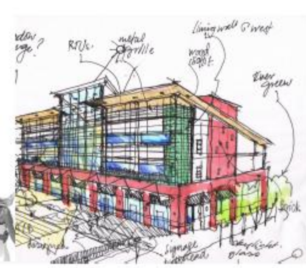
Department of Architectural Science

SECTIVES

ISSAM A SHUKOR

PASSIVE DESIGN OPPORTUNITIES FOR MEDIUM-FORMAT RETAIL BUILDINGS IN TORONTO TOWARDS NZEB





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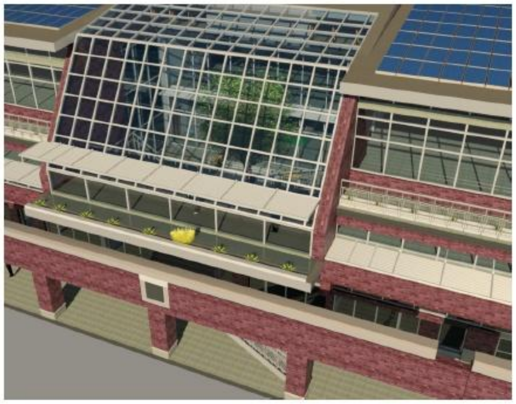
PERSPECTIVES

ISSAM A SHUKOR

PASSIVE DESIGN OPPORTUNITIES FOR MEDIUM-FORMAT RETAIL BUILDINGS IN TORONTO TOWARDS NZEB



View at Atrium - SE Elevation

View at Vertical Louvres - NW Elevation

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Department of Architectural Science

PERSPECTIVES | SEC-

ISSAM A SHUKOR

PASSIVE DESIGN OPPORTUNITIES FOR MEDIUM-FORMAT RETAIL BUILDINGS IN TORONTO TOWARDS NZEB

Sectional Perspectives Through The Atrium

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SECTIONAL PERSPECTIVES

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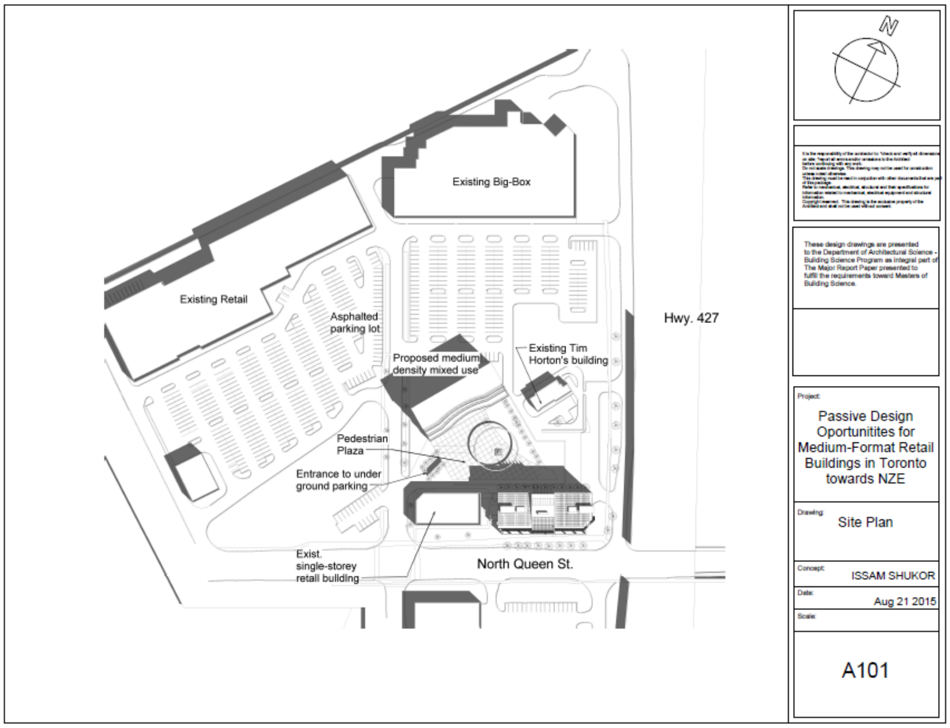
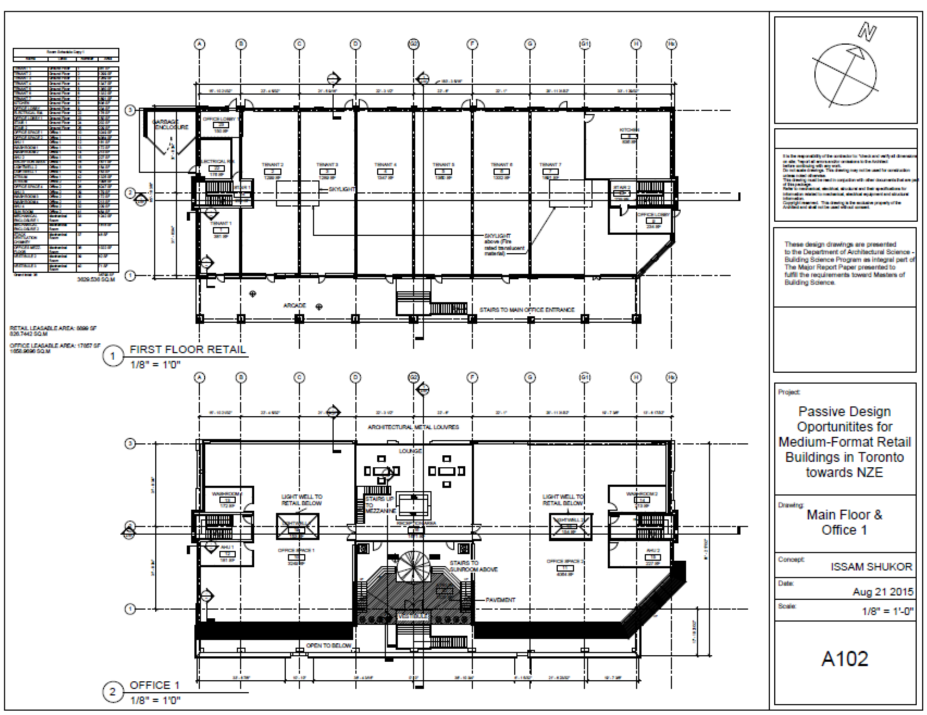
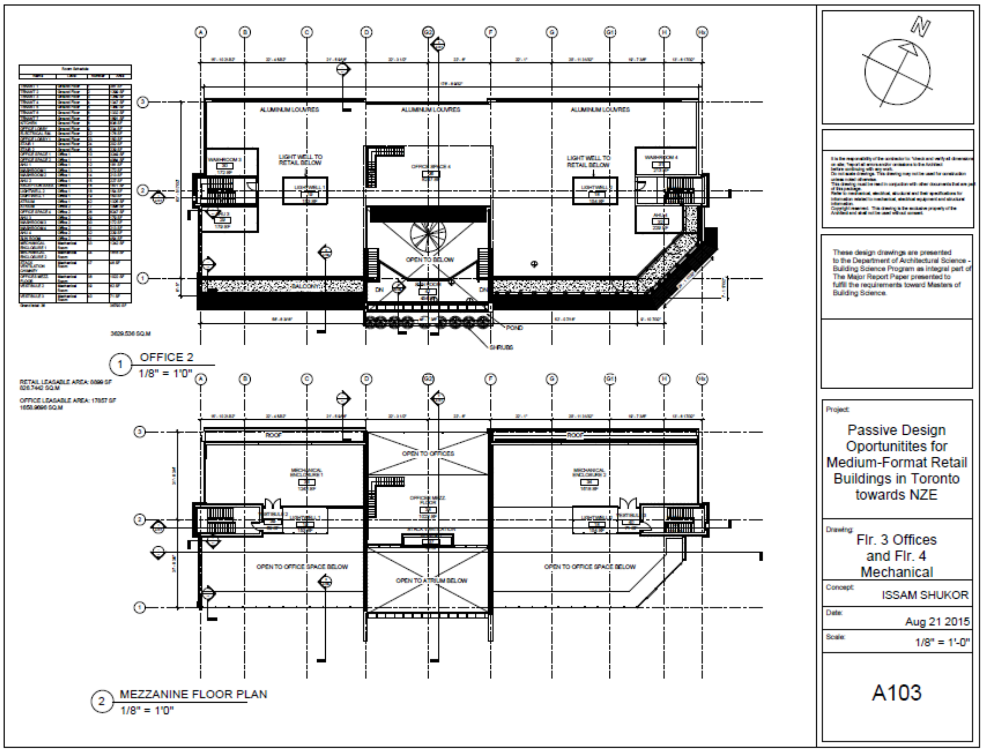
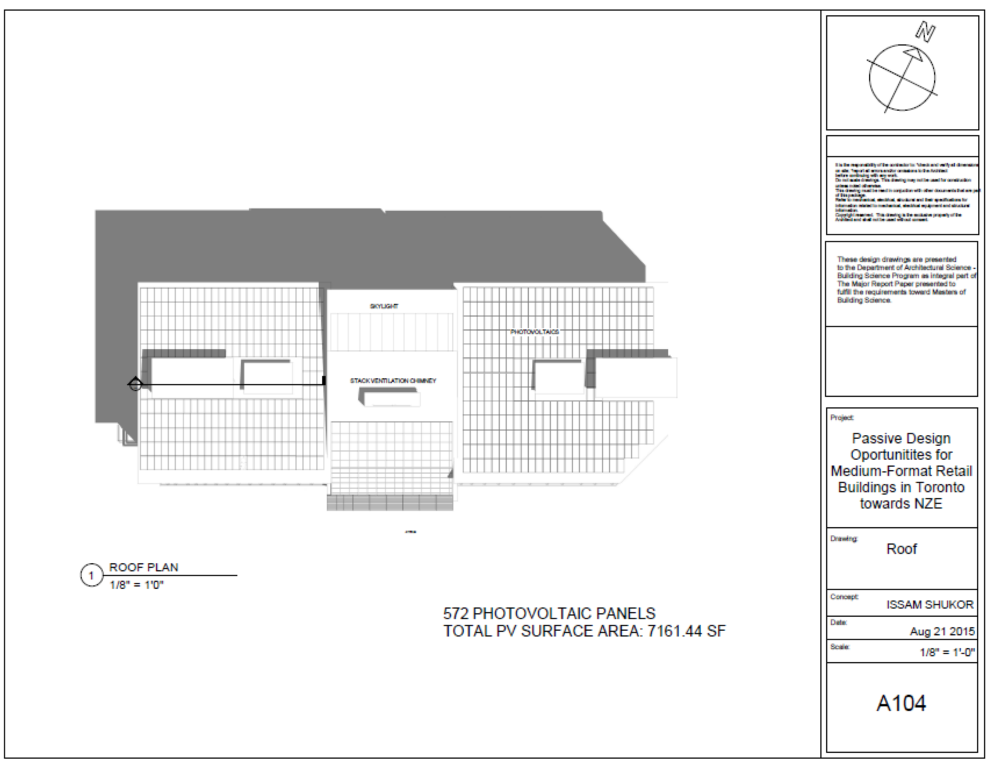
Figure B - 1 - Final Design Project: architectural drawings

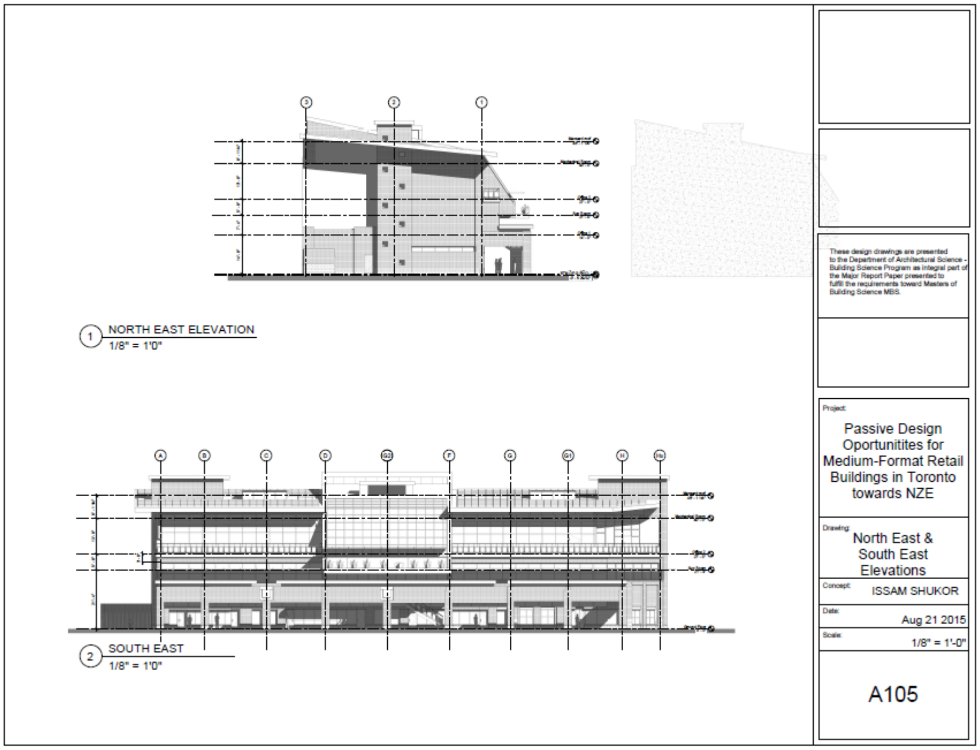
Appendix C – Final Design Project – Construction Drawings

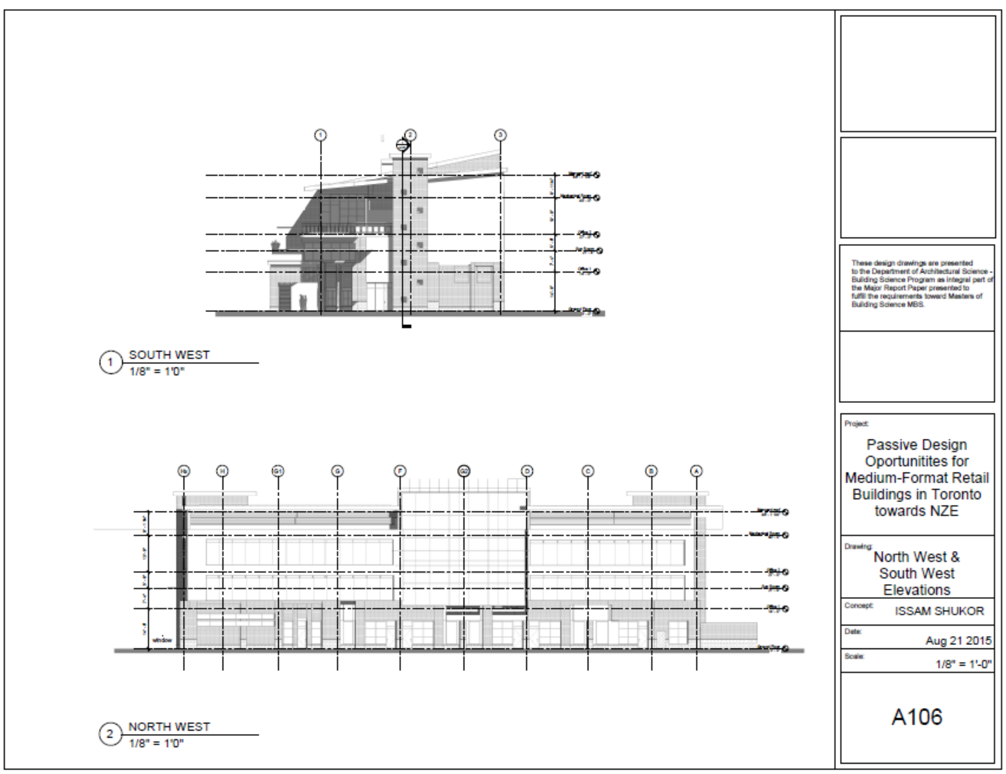


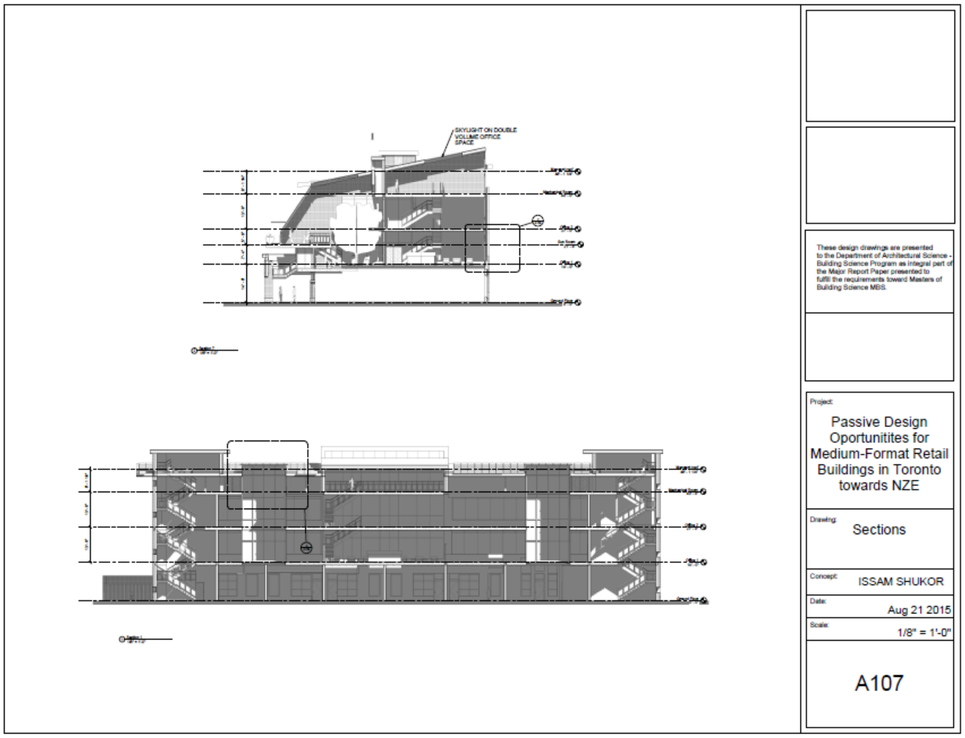


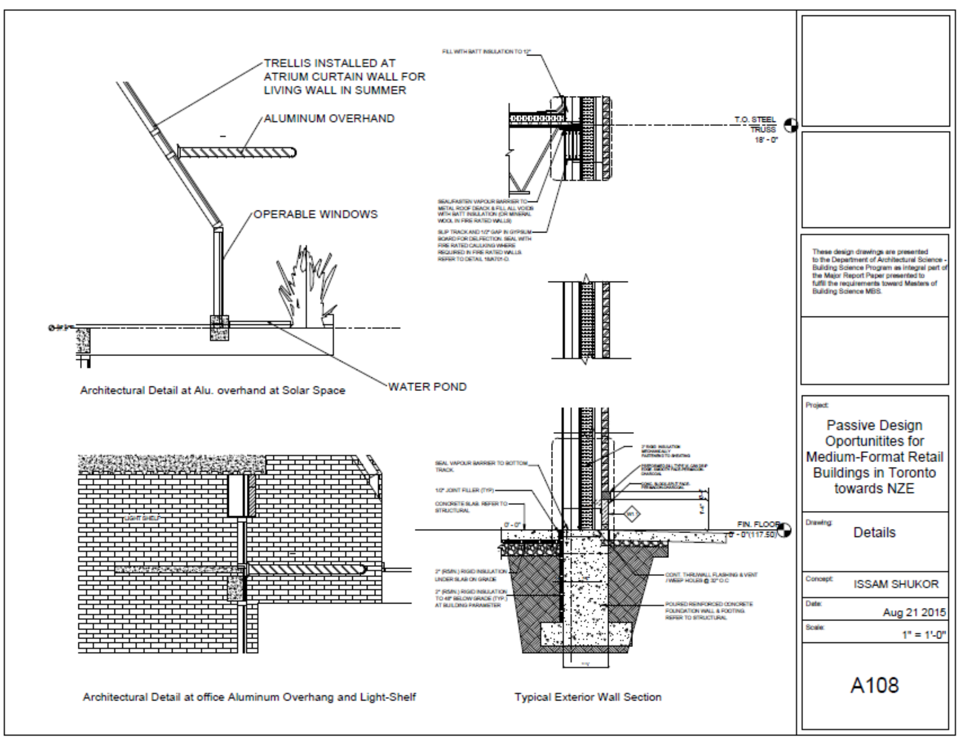

OFFICE 2
1/8" = 1'0"
MEZZANINE FLOOR PLAN
1/8" = 1'0"
Passive Design Oportunitites for Medium-Format Retail Buildings in Toronto towards NZE
Flr. 3 Offices and Flr. 4 Mechanical
ISSAM SHUKOR
Aug 21 2015
1/8" = 1'-0"
A103


ROOF PLAN
1/8" = 1'0"
572 PHOTOVOLTAIC PANELS
TOTAL PV SURFACE AREA: 7161.44 SF
Passive Design Oportunitites for Medium-Format Retail Buildings in Toronto towards NZE
Roof
ISSAM SHUKOR
Aug 21 2015
1/8" = 1'-0"
A104


NORTH EAST ELEVATION
1/8" = 1'0"
SOUTH EAST
1/8" = 1'0"
These design drawings are presented to the Department of Architectural Science - Building Science Program as integral part of the Major Report Paper presented to fulfil the requirements toward Masters of Building Science MBS.
Project
Passive Design Oportunitites for Medium-Format Retail Buildings in Toronto towards NZE
Drawing
North East & South East Elevations
Concept
ISSAM SHUKOR
Date
Aug 21 2015
Scale
1/8" = 1'-0"
A105


SOUTH WEST
1/8" = 1'0"
NORTH WEST
1/8" = 1'0"
These design drawings are presented to the Department of Architectural Science - Building Science Program as integral part of the Major Report Paper presented to fulfil the requirements toward Masters of Building Science MBS.
Project
Passive Design Oportunitites for Medium-Format Retail Buildings in Toronto towards NZE
Drawing
North West & South West Elevations
Concept
ISSAM SHUKOR
Date
Aug 21 2015
Scale
1/8" = 1'-0"
A106


SKYLIGHT ON DOUBLE VOLUME OFFICE SPACE
These design drawings are presented to the Department of Architectural Science - Building Science Program as integral part of the Major Report Paper presented to fulfil the requirements toward Masters of Building Science MBS.
Project
Passive Design Oportunitites for Medium-Format Retail Buildings in Toronto towards NZE
Drawing
Sections
Concept
ISSAM SHUKOR
Date
Aug 21 2015
Scale
1/8" = 1'-0"
A107


TRELLIS INSTALLED AT ATRIUM CURTAIN WALL FOR LIVING WALL IN SUMMER
ALUMINUM OVERHAND
OPERABLE WINDOWS
WATER POND
Architectural Detail at Alu. overhand at Solar Space
T.O. STEEL TRUSS 18' - 0"
FIN. FLOOR
Architectural Detail at office Aluminum Overhang and Light-Shelf
Typical Exterior Wall Section
These design drawings are presented to the Department of Architectural Science - Building Science Program as integral part of the Major Report Paper presented to fulfil the requirements toward Masters of Building Science MBS.
Project
Passive Design Oportunitites for Medium-Format Retail Buildings in Toronto towards NZE
Drawing
Details
Concept
ISSAM SHUKOR
Date
Aug 21 2015
Scale
1" = 1'-0"
A108

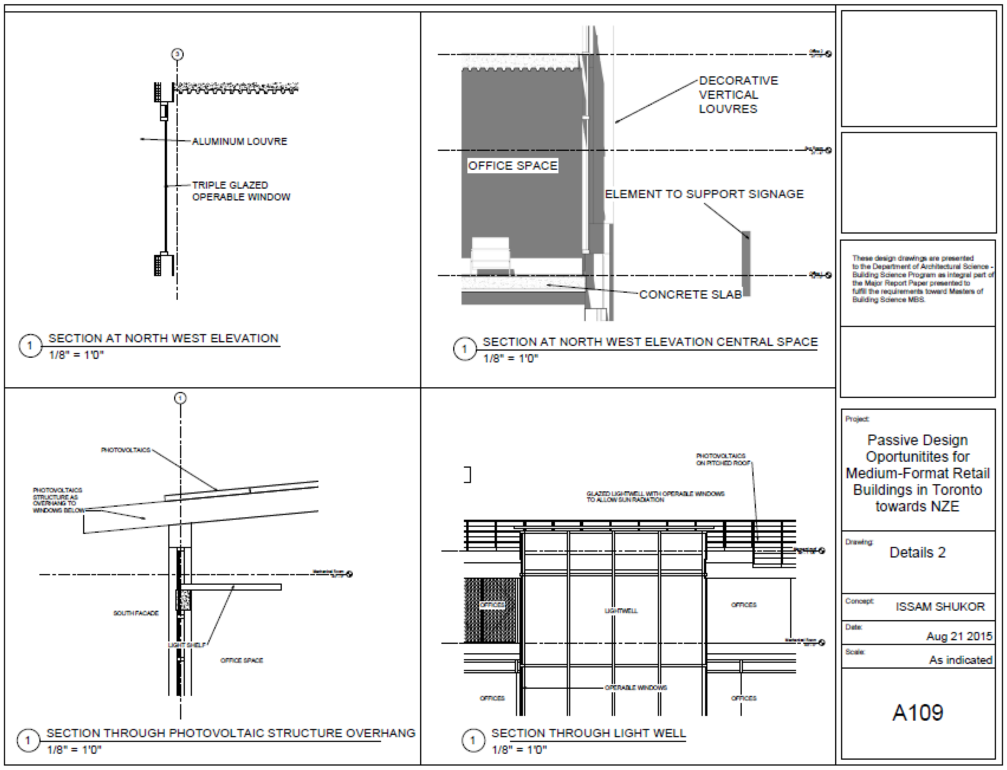


Figure C - 1 - Final Design Project: construction drawings

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8. GLOSSARY

Big-Box Retail: A large retail store whose physical layout resembles a large square or box when seen from above. A big-box store is characterized by a large amount of floor space (generally more than 50,000 square feet), a wide array of items available for sale, and its location in suburban areas (Business, 2015).

Building envelope: the exterior plus the semi-exterior portions of a building (ASHRAE, 2012)

Ecotect: Ecotect® Analysis 2011, is a computer simulation software for schematic design. It can analyze data and produce results in graphical and tabulated formats, aimed at architects and building designers.

Energy Use Intensity (EUI), expresses a building's energy use as a function of its size or other characteristics (Energy Star, 2015).

Fenestration: all areas (including the frames) in the building envelope that let in light, including windows, plastic panels, clerestories, skylights, doors that are more than one-half glass, and glass block walls (ASHRAE, 2012).

Heating degree-days: Heating degree-days for a given day are the number of degrees Celsius that the mean temperature is below 18°C. If the temperature is equal to or greater than 18°C, then the number will be zero. For example, a day with a mean temperature of 15.5°C has 2.5 heating degree-days; a day with a mean temperature of 20.5°C has zero heating degree-days. Heating degree-days are used primarily to estimate the heating requirements of buildings (Canada, 2015).

Insolation: The amount of solar radiation reaching a given area (W/m^2).

Medium-format retail: is a retail building of 10,000 to 39,999 square feet Gross Leasable Area (GLA). This type of retail is usually divided into several retail commercial units (RCU) for a variety of tenants. The configuration of this type of retail is linear in most cases or can have a "L" or "U" shape, with an attached row of stores or service outlets owned and managed as a coherent retail unit and with on-site parking usually in front of the stores but it does not include any interior walkway (ICSC, 2010).

Night-time Purging: A passive design strategy that keeps windows and other passive ventilation openings closed during the day, but open at night to flush warm air out of the building and cool thermal mass for the next day (Autodesk, 2015).

Passive Design Strategies: Design methods that help reduce the building's energy demands by using energy available from natural sources such as sun radiation, wind and cool air.

Roof-top monitors: vertical fenestration integral to the roof (ASHRAE, 2012)