Earth Systems Science Building - ESSB Life Cycle Assessment

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University of British Columbia

CIVL 498E

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PROVISIO

This study has been completed by undergraduate students as part of their coursework at the University of British Columbia (UBC) and is also a contribution to a larger effort – the UBC LCA Project – which aims to support the development of the field of life cycle assessment (LCA).

The information and findings contained in this report have not been through a full critical review and should be considered preliminary.

If further information is required please contact the course instructor Rob Sianchuk at rob.sianchuk@gmail.com

Life Cycle Analysis – CIVL 498E

Earth Systems Science Building - ESSB

Life Cycle Assessment

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[2012]

Executive Summary

This report presents the Life Cycle Assessment (LCA) of the new Earth Systems Science Building (ESSB) for which construction is expected to be completed in the year 2012 at University of British Columbia (UBC) in Vancouver, British Columbia.. The report shows the impact of the materials used for the structure of the complete building; specifically in raw material extraction, manufacturing of the construction materials, and construction of the envelope of the whole building. Furthermore it also takes into account the impact of the transportation of these materials. To measure the quantities of the material used in the building and to estimate the environmental impact of such materials and activities two software were used.

In addition, a sensitivity analysis was performed on five materials to determine how much it affects the environmental impact to increasing each material by a factor of 10%. The results of the analysis are presented in graphs and tables and show that concrete and glazing are responsible of the greatest environmental impacts of the building.

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Introduction

Project Description

Figure 1 ESSB, East view

The Earth Systems Science Building (ESSB) is a building currently under construction and expected to be finished during Summer 2012. With a gross square meter of 15,452 the building consists of a 5 storey Mid-Rise type with 2 underground floors[1].It includes teaching, laboratories and office spaces for the department of Earth and Ocean Science (EOS), the Department of Statistics, the Pacific Institute for Mathematical Sciences (PIMS), the Dean of Science, and the Pacific Museum of the Earth (PME).

The building is constructed at the site where both the Earth and Ocean Sciences East Building (EOS EAST) and the Engineering Annex Building were located[2]. Both buildings were demolished. The location of the new building is at 2219 Main Mall, north of Sustainability Street in Vancouver, BC. The project site boundary is defined by a 12.0m setback from the Main Mall oak trees to the East, a 30.5m setback from the Scarfe Building to the North, and in alignment with the South face of the Beaty Biodiversity Whale Pavilion to the South and the EOS Main building to the West. The construction of the building has a total cost of $75 million[3]. Its ownership is in a partnership of the Faculty of Science with UBC Properties Trust. The architects for the project are Busby and Associates Architects and Maple Argo Architects. The general contractor is Bird

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[1] Reed Construction Data, “Earth Systems Science Building (ESSB), Wesbrook Mall, UBC Main Campus, V6T 1Z4”

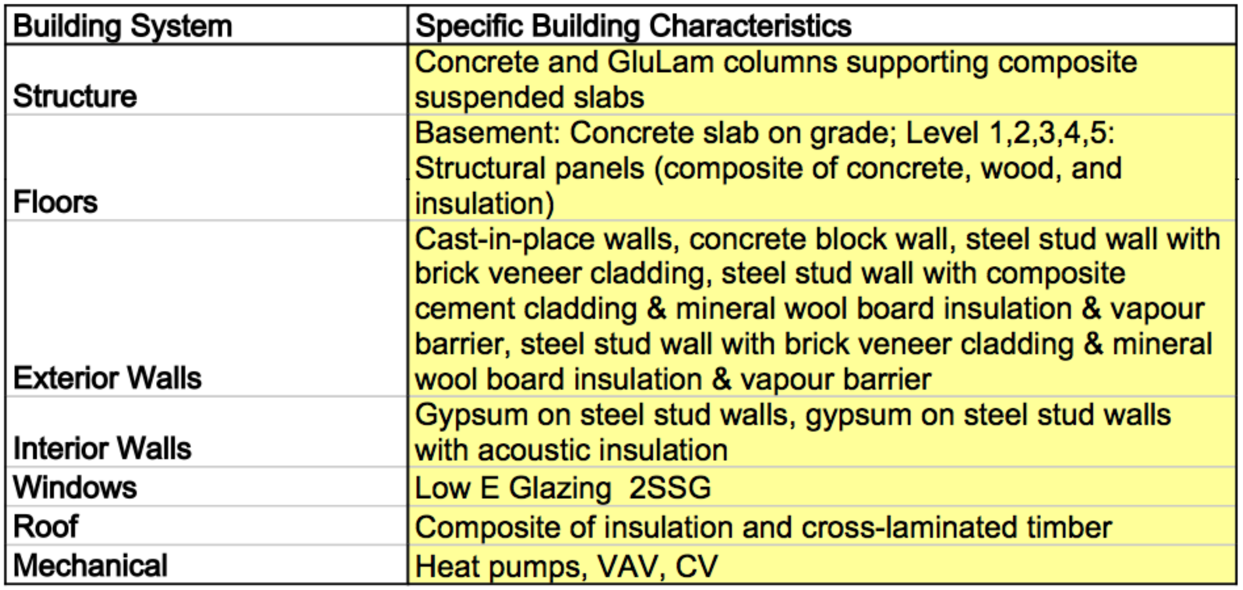
[2] Campus + Community Planning – UBC Vancouver: http://www.planning.ubc.ca/vancouver_home/consultations/current_projects/academic_lands/articles233.php

[3] University of British Columbia Request For Decision: http://bog.sites.olt.ubc.ca/files/2010/10/SUB-BG-09.06.03_5.4.pdf

Construction Company and its Environmental Construction Engineer is ACM Environmental Corporation.

Components Breakdown

The structure of the building is made of steel, concrete and timber. Concrete and rebar were mainly used for the foundations and for the support of the slabs on grade in each floor and in the basement. Timber as cross laminated timber was used in the floor of the roof. A mixture of wood and concrete columns and beams provides the structural configuration in the interior floors, which also supports the curtain wall that was designed for the building. The curtain wall provides environmental control, allowing the entrance of natural light to the interiors. It also permits the users to have views and connection with the natural landscape in the exteriors. Partitions in the interior spaces are made of steel stud framing.



Building System	Specific Building Characteristics
Structure	Concrete and GluLam columns supporting composite suspended slabs
Floors	Basement: Concrete slab on grade; Level 1,2,3,4,5: Structural panels (composite of concrete, wood, and insulation)
Exterior Walls	Cast-in-place walls, concrete block wall, steel stud wall with brick veneer cladding, steel stud wall with composite cement cladding & mineral wool board insulation & vapour barrier, steel stud wall with brick veneer cladding & mineral wool board insulation & vapour barrier
Interior Walls	Gypsum on steel stud walls, gypsum on steel stud walls with acoustic insulation
Windows	Low E Glazing 2SSG
Roof	Composite of insulation and cross-laminated timber
Mechanical	Heat pumps, VAV, CV

Figure 2 Specific Building Characteristics of the ESSB

Goal of study

This study will serve as contribution to the database of LCA studies currently being developed worldwide. The purpose of the database is to provide a framework and baseline to compare performance of buildings regarding its environmental impact.

The results of the LCA study will provide a materials inventory and environmental impact reference for the ESSB building as well as a sense of how well UBC is performing at developing less harmful buildings for the environment. The format is set so that the parameters of the study are referred to the guidelines of ISO 14040 and 14044.

Intended Application

Describes the purpose of the LCA study.

This LCA study will be used in two ways. The first one being a transparent marketing tool to communicate the impacts of removing the old EOS buildings and replacing it with the new ESSB building; and the second one, as an exemplary demonstration of the latest in environmental impact accounting methods that contributes to the further development of such activities.

When completed, this study will also contribute in creating a benchmark for new buildings in UBC, so that developers can make informed decisions about the environmental impacts associated with the construction of buildings in UBC.

Reasons for carrying out the study

Describes the motivation for carrying out the LCA study.

The motivation of this study is to demonstrate the usefulness of LCA as a tool to assess environmental impacts of buildings, aimed at identifying possible opportunities to improve the environmental performance of building’s life cycles. The study is also done to promote the development of the UBC LCA database, providing future scholars and green builders with information to carry out similar studies on LCA.

Intended audience

Describes those who the LCA study is intended to be interpreted by.

The results of this study are to be primarily communicated to those involved in building development related policy making at UBC, such as the UBC Sustainability Office, UBC Sustainability Initiative (USI), UBC SEEDS Program, and all other campus members who are involved in creating policies and frameworks for sustainable development on campus. In addition to them, other potential audiences include external organizations such as industry and government groups observing and involved in green building design, and other universities whom may want to learn more or become engaged in performing similar LCA studies within their organizations.

Intended for comparative assertions

State whether the results of this LCA study are to be compared with the results of other LCA studies.

This study is part of a group of studies being conducted on UBC buildings, which at collectively considered as the UBC LCA Database. This study has been carried out using a similar Goal & Scope document to the other studies in the UBC LCA Database. In this way, this study is being used for comparative assertions, though primarily with other studies as benchmarks being developed for future construction projects at UBC.

Scope of Study

The following are descriptions for a set of parameters associated with the actual modelling of the study.

Product system to be studied

Describes the collection of unit processes that will be included in the study.

A unit process is a measurable activity that consumes inputs and emits outputs as a result of providing a product or service. The main processes that make up the product system to be studied in this LCA study are the demolition of a building (Figure 3), the manufacturing of construction products (Figure 4) and the construction of a building (Figure 5). These three processes are the building blocks of the LCA models that have been developed to describe the impacts associated with the ESSB Building (i.e. Renovating and Building New). The unit processes and inputs and outputs considered within these three main processes are outlined below.

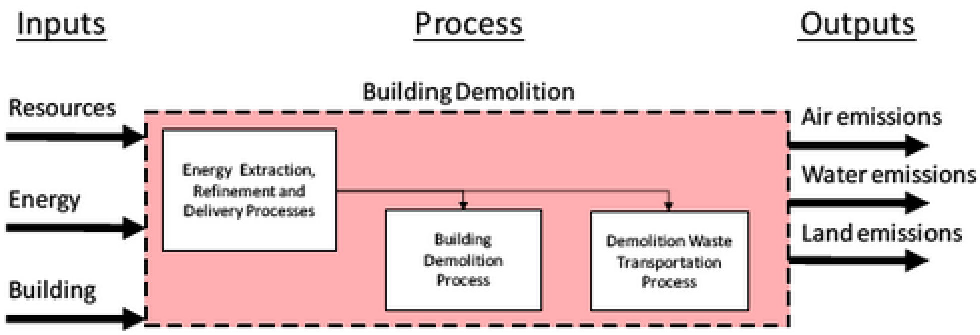


Figure 3 Generic unit processes considered within Building Demolition process by Impact Estimator software, extracted from Life Cycle Assessment of UBC Biological Sciences Complex Renew Project.

The inputs and outputs occurring at various stages in a buildings life cycle are captured. That said, the building demolition unit process captures the grave (end of life), and the construction product manufacturing and building construction processes captures the cradle to gate (ie: resource extraction, manufacturing construction products and construction of a building). The organization of these processes into the product systems to describe the impacts of renovating rather than building new requires the definition of a system boundary (detailed later in this report).

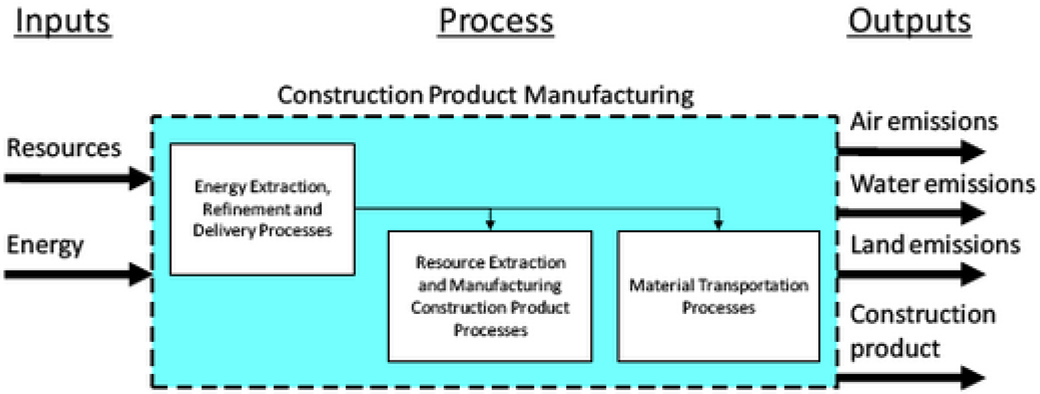


Figure 4 Generic unit processes considered within Construction Product Manufacturing process by Impact Estimator software, extracted from Life Cycle Assessment of UBC Biological Sciences Complex Renew Project

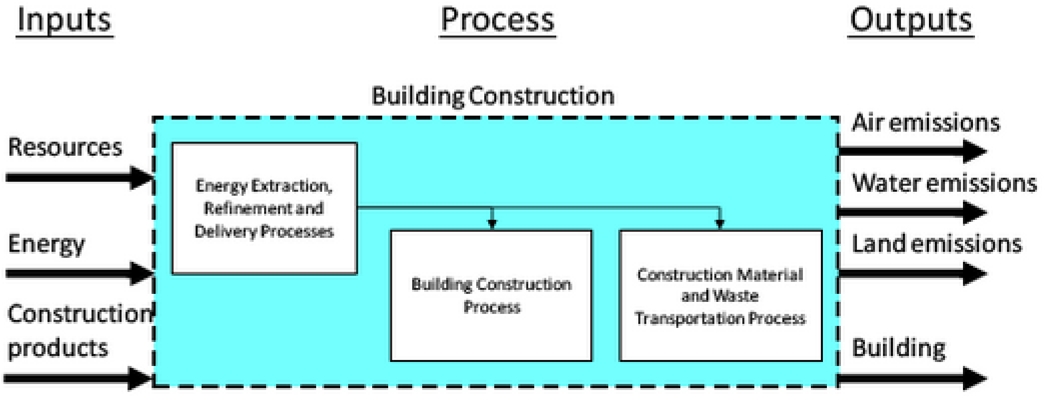


Figure 5 Generic unit processes considered within Building Construction process by Impact Estimator software, extracted from Life Cycle Assessment of UBC Biological Sciences Complex Renew Project

Functions of the product system

Describes the functions served by the product focused on in the LCA study.

The New ESSB Building modelled in this LCA is designed to fulfill two main functions: 1) act as safe and climate controlled buildings that separate their occupants and structures from the environment; 2) act as an academic institutional building for students and faculty at the University of British Columbia Vancouver campus.

Functional Unit

A performance characteristic of the product system being studied that will be used as a reference unit to normalize the results of the study.

The functional units used in this study to normalize the LCA results for material components of the ESSB Building are per whole post-secondary academic building constructed.

System Boundary

Details the extent of the product system to be studied in terms of product components, life cycle stages, and unit processes.

The system boundary is determined by having a Cradle-to-Grave approach to the study. In the case of this study for the Earth Science Systems Building, two existing buildings had to be demolished (EOS East Northwing and EOS East Southwing) and a new building is built in place.

This LCA models the impact of these scenarios of a new building being constructed. The Impact Estimator software produces these impacts based on the unit processes. Specifically this study includes the construction products used to create their structure and envelopes. The materials included are indicated by defining product components within the products studied. These material product components consist of the following: Footings, slabs on grade, walls, columns and beams, floors, roofs, associated doors and windows and insulation. These material components are at the same time assemblies of construction products.

The finishing materials used in the ESSB were not included in this study’s system boundary.

Allocation procedures

Describes how the input and output flows of the studied product system are distributed between them and other related product systems.

The end of the existing EOS Building and the cradle-to-grave of the new ESSB Building presented a conflict in determining the cut-off because of their shared life cycles. This required an allocation requirement for the ESSB LCA study. To ensure that only the impacts directly caused by a product within a given life cycle stage are allocated to that product, a cut-off allocation method was used.

The result of applying the cut-off application method is that the manufacturing of the previous EOS Building is allocated to the previous life cycle and is thus outside of the system boundary of the new ESSB Building. Including the demolition effects in the new ESSB results is essential to capture additional impacts caused by this process. Although construction and demolition are both wastes direct from the product systems, their potential subsequent life cycles were outside the scope of this LCA study. For that matter, the study will not include the consideration of waste treatment processes or possible subsequent life cycles.

Tools and Methodology

The study is developed by utilizing two software currently used in LCA. To take quantities from the building drawings necessary for On-Screen Takeoff 3 was utilized through documenting area, linear and count quantities. Using imported digital drawings, the program facilitates the calculation of these quantities by keeping takeoffs organized. Once the measurements were completed, Athena Impact Estimator v.4.1, the only available software capable of meeting the requirements of this study, was used to generate a whole building LCA model for the Earth Science Systems Building (ESSB). The tool achieves this by applying a set of algorithms to the inputted takeoff data in order to complete the takeoff process and generate a bill of materials (BoM). This BoM then utilizes the Athena Life Cycle Inventory (LCI) Database, in order to estimate a cradle-to-grave LCI profile for the building[4].

The IE filters the LCA results through a set of characterization measures based on the mid-point impact assessment methodology developed by the US Environmental Protection Agency (US EPA), the Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI) version 2.2. In order to generate a complete environmental impact profile for the ESSB, all of the available TRACI impact assessment categories available in the IE are included in this study, listed as;

- Global warming potential
- Acidification potential
- Eutrophication potential
- Ozone depletion potential
- Photochemical smog potential
- Human health respiratory effects potential
- Weighted raw resource use
- Primary energy consumption

The primary sources of data used in modeling the structure and envelope of the ESSB are the set of architectural and structural drawings provided by the firms to conduct the LCA study. The assemblies of the building that are modeled include the foundation, columns and

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[4] Life Cycle Assessment of the Hebb Building CIVL 498C Final Report, 3/29/2010

beams, floors, walls and roofs, as well as their associated envelope and/or openings (i.e. doors and windows). The decision to omit other building components, such as flooring, electrical aspects, HVAC system, finishing and detailing, etc., are associated with the limitations of available data and the IE software, as well as to minimize the uncertainty of the model[5]. During the analysis of the different assemblies, several assumptions had to be made to complete the modelling in the IE software, mainly due to the lack of specific information in the drawings. Furthermore, there are inherent assumptions made by the IE software in order to generate the bill of materials and limitations to what it can model. These assumptions and limitation are contained and detailed in the Input Assumptions document in Appendix B.

Building Model Development

Structure and envelope

Material Takeoff Development

For the foundation, areas of footings were found using the area conditions in OnScreen Takeoff (OST). The thickness of each footing was listed in the Footing schedule in the structural drawings of the building. For the columns and beams, count conditions were used so that we know how many columns and beams are on each floor. The floor-to-floor heights were calculated from the elevations of each floor from the structural drawings.

The floors areas were also estimated using OST. Areas were accounted for each floor depending on their thickness and material. Each take-off was taken separately for each material. In other words, several take-offs were performed depending on how many materials the floor was composed of. Only the structural materials were taken into account.

The roof take-offs were performed in the same manner as the floors. The areas were taken separately from the roof level and from level five, which included a deck around the perimeter of the floor.

For walls, a linear condition was used in the OnScreen Takeoff software (OST). The assembly of each wall was done determined through architectural plans, sections and elevations. These

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[5] Life Cycle Assessment of the Hebb Building CIVL 498C Final Report, 3/29/2010

drawings provided specific details for each type of wall, describing structural components as well as interior and exterior finish schedules. One of the main challenges faced here was trying to associate the actual materials used in the walls with the ones available in the Impact Estimator software. The criteria was asking the course instructor, using the 'Help' section in the software and web-searching for the most similar surrogate materials. For concrete walls, the information was provided by the structural drawings, containing shear walls and retaining walls. It was difficult though to find specific heights for some of the walls in the drawings, and so floor-to-floor heights were used. Finally, doors and windows were associated with each type of wall using a count condition in OST. Here again, the more similar types of doors were used when the actual ones did not exist.

Material Takeoff Assumptions

For many of our quantity takeoffs, the material used in the actual structure is not found in the Impact Estimator, so we have to assume a similar type of material in the software.

Furthermore, in the quantity takeoffs conducted for floors, for level one was considerably thicker than other levels in some sections of the floor. To account for the difference it was assumed that extra concrete was used in place. Although this assumption did not affect the Impact Estimator result, it did affect the height of columns of adjacent floors.

Roof material specifications were not clear either from the structural and architectural drawings. In some parts in the deck of level five the composition was of a roof assembly "roof deck" and of "future green roof". The difference between both composition was that one included concrete and the other one consisted of a composite of wood and insulation. The assumption made was that "future green roof" was taken as the final choice for the Impact Estimator inputs because most of the deck was made of this type of roof, and only a relatively small section was presenting this conflict.

For the case of walls modeling other considerations were taken into account as well. The length of the concrete cast-in-place walls needed adjusting to accommodate the wall thickness limitation in the Impact Estimator. It was assumed that interior steel stud walls were light gauge (25Ga) and exterior steel stud walls were heavy gauge (20Ga). According to the general notes in the structural plans, normal weight concrete for retaining walls is 25MPa and for shear walls 35Mpa. The IE allowed for 20, 30 or 60MPa, so 30MPa was used to model all concrete walls. In the other hand, fly ash content for retaining walls was modeled as 40%, which was found to be the closest value for the actual content of 35%. Interior walls also needed some adjustments. Gypsum boards were adjusted depending on their location and most similar element found in the IE, for example, Gypsum Fire Rated Type X 5/8'' was the closest surrogate for Type X Gypsum Board Gypsum. Also the thickness of these elements was fixed in the IE (25.381mm-507.614mm). Another variation was regarding the insulation where acoustic insulation was modeled as fiberglass batt, as it was the closest surrogate to this kind of material. Finally, no information about the type of painting was provided in the architectural plans, so Latex Water Based was assumed to be used where painting finish was indicated.

For more information on how numbers were obtained and what assumptions were made to complete specific parts of the quantity takeoffs, please refer to the IE Inputs Assumptions Document in Appendix B.

Use phase

Energy Use Development

Use phase energy consumption information were found in results of the LEED energy model of the ESSB building, detailed in a memo written by Stantec provided to us via Rob Sianchuk. The model is developed using construction drawings and specifications dated September 7th, 2010, information from the design team, and approved shop drawings. The model was completed for May 27th, 2011. Please note that this date is before to the completion of the ESSB building. For further details and a summary of the results in the energy model, refer to a later section entitled “Energy Use” under “Inventory Analysis”.[6]

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[6] Martina Soderlund, Stantec Consulting, “Earth System Science Building (ESSB) - LEED Energy Model Results Summary”, Memo dated May 26, 2011

Energy Use Assumptions

As the building remains incomplete to this day, the energy model is only an estimate of the proposed building's performance in terms of energy use. Some modelling inputs were assumed for the assembly of the building, based on baseline values of a reference building and modelling guides. Also, energy consumption associated with lab water heating and specific lab equipment were excluded from calculations as they are considered process energy. Moreover, the memo we received which details these results have not been subject to third party review, and is not a part of the final package for the energy model. [7]

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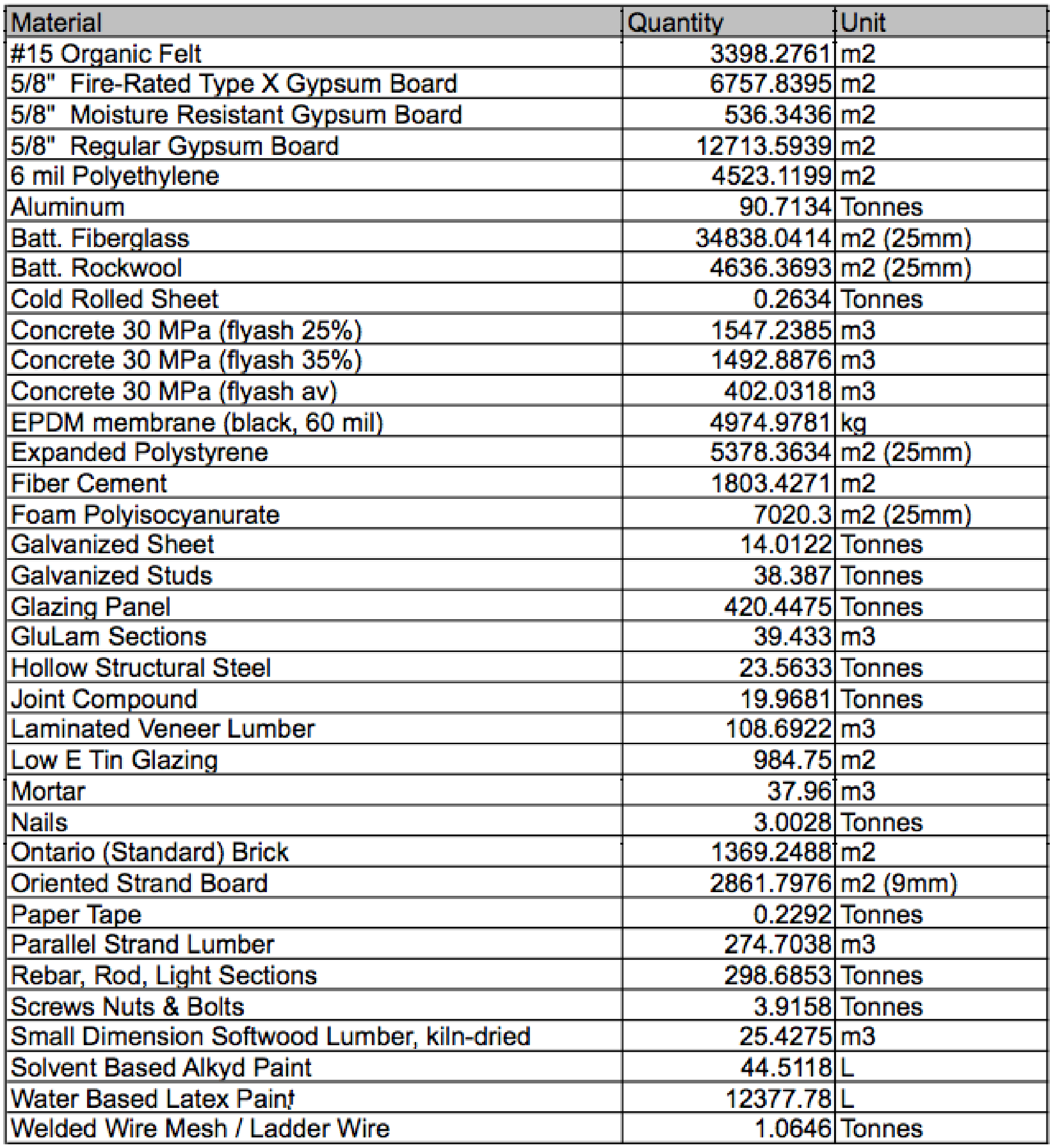
[7] Martina Soderlund, Stantec Consulting, "Earth System Science Building (ESSB) - LEED Energy Model Results Summary", Memo dated May 26, 2011

Results and Interpretation

Inventory Analysis

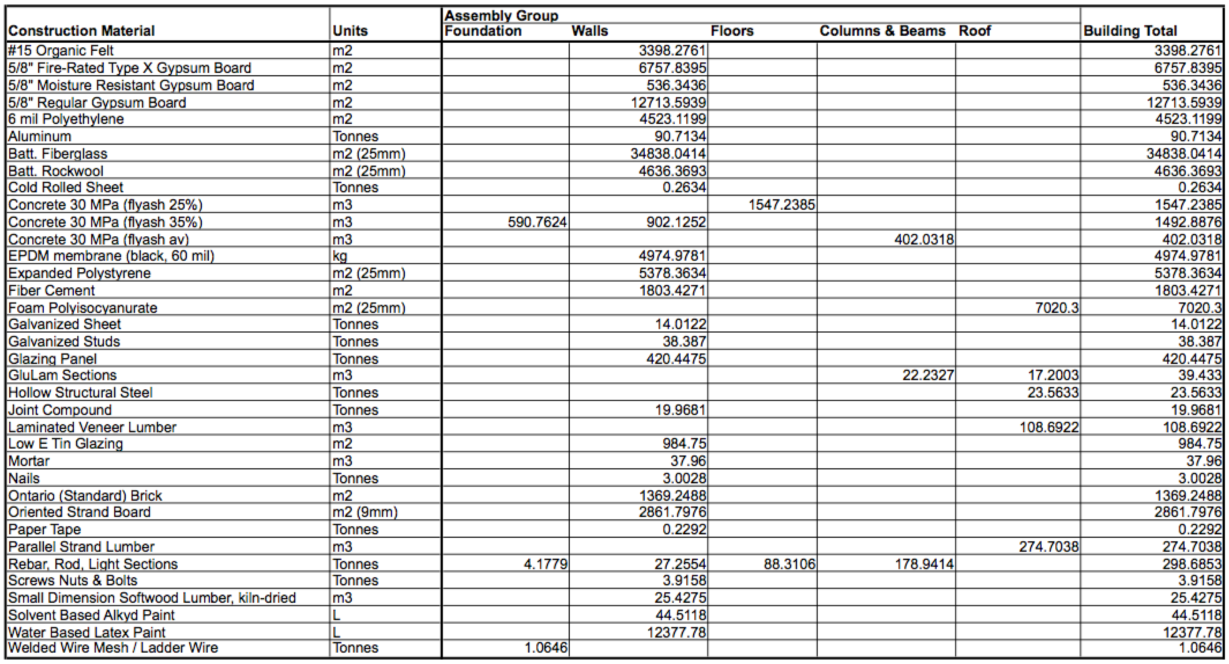
Bill of Materials

The materials used to construct the ESSB building are listed below in the Bill of Materials. Refer to Table 1 for Bill of Materials of the Building Total, and refer to Table 2 for the Bill of Materials broken down into different assemblies of the building.



Material	Quantity	Unit
#15 Organic Felt	3398.2761	m2
5/8" Fire-Rated Type X Gypsum Board	6757.8395	m2
5/8" Moisture Resistant Gypsum Board	536.3436	m2
5/8" Regular Gypsum Board	12713.5939	m2
6 mil Polyethylene	4523.1199	m2
Aluminum	90.7134	Tonnes
Batt. Fiberglass	34838.0414	m2 (25mm)
Batt. Rockwool	4636.3693	m2 (25mm)
Cold Rolled Sheet	0.2634	Tonnes
Concrete 30 MPa (flyash 25%)	1547.2385	m3
Concrete 30 MPa (flyash 35%)	1492.8876	m3
Concrete 30 MPa (flyash av)	402.0318	m3
EPDM membrane (black, 60 mil)	4974.9781	kg
Expanded Polystyrene	5378.3634	m2 (25mm)
Fiber Cement	1803.4271	m2
Foam Polyisocyanurate	7020.3	m2 (25mm)
Galvanized Sheet	14.0122	Tonnes
Galvanized Studs	38.387	Tonnes
Glazing Panel	420.4475	Tonnes
GluLam Sections	39.433	m3
Hollow Structural Steel	23.5633	Tonnes
Joint Compound	19.9681	Tonnes
Laminated Veneer Lumber	108.6922	m3
Low E Tin Glazing	984.75	m2
Mortar	37.96	m3
Nails	3.0028	Tonnes
Ontario (Standard) Brick	1369.2488	m2
Oriented Strand Board	2861.7976	m2 (9mm)
Paper Tape	0.2292	Tonnes
Parallel Strand Lumber	274.7038	m3
Rebar, Rod, Light Sections	298.6853	Tonnes
Screws Nuts & Bolts	3.9158	Tonnes
Small Dimension Softwood Lumber, kiln-dried	25.4275	m3
Solvent Based Alkyd Paint	44.5118	L
Water Based Latex Paint	12377.78	L
Welded Wire Mesh / Ladder Wire	1.0646	Tonnes

Table 1 Bill of Materials (Building Total)



Construction Material	Units	Assembly Group Foundation	Walls	Floors	Columns & Beams	Roof	Building Total
#15 Organic Felt	m2		3398.2761				3398.2761
5/8" Fire-Rated Type X Gypsum Board	m2		6757.8395				6757.8395
5/8" Moisture Resistant Gypsum Board	m2		536.3436				536.3436
5/8" Regular Gypsum Board	m2		12713.5939				12713.5939
6 mil Polyethylene	m2		4523.1199				4523.1199
Aluminum	Tonnes		90.7134				90.7134
Batt. Fiberglass	m2 (25mm)		34838.0414				34838.0414
Batt. Rockwool	m2 (25mm)		4636.3693				4636.3693
Cold Rolled Sheet	Tonnes		0.2634				0.2634
Concrete 30 MPa (flyash 25%)	m3			1547.2385			1547.2385
Concrete 30 MPa (flyash 35%)	m3	590.7624	902.1252				1492.8876
Concrete 30 MPa (flyash av)	m3				402.0318		402.0318
EPDM membrane (black, 60 mil)	kg		4974.9781				4974.9781
Expanded Polystyrene	m2 (25mm)		5378.3634				5378.3634
Fiber Cement	m2		1803.4271				1803.4271
Foam Polyisocyanurate	m2 (25mm)					7020.3	7020.3
Galvanized Sheet	Tonnes		14.0122				14.0122
Galvanized Studs	Tonnes		38.387				38.387
Glazing Panel	Tonnes		420.4475				420.4475
GluLam Sections	m3				22.2327	17.2003	39.433
Hollow Structural Steel	Tonnes					23.5633	23.5633
Joint Compound	Tonnes		19.9681				19.9681
Laminated Veneer Lumber	m3					108.6922	108.6922
Low E Tin Glazing	m2		984.75				984.75
Mortar	m3		37.96				37.96
Nails	Tonnes		3.0028				3.0028
Ontario (Standard) Brick	m2		1369.2488				1369.2488
Oriented Strand Board	m2 (9mm)		2861.7976				2861.7976
Paper Tape	Tonnes		0.2292				0.2292
Parallel Strand Lumber	m3					274.7038	274.7038
Rebar, Rod, Light Sections	Tonnes	4.1779	27.2554	88.3106	178.9414		298.6853
Screws Nuts & Bolts	Tonnes		3.9158				3.9158
Small Dimension Softwood Lumber, kiln-dried	m3		25.4275				25.4275
Solvent Based Alkyd Paint	L		44.5118				44.5118
Water Based Latex Paint	L		12377.78				12377.78
Welded Wire Mesh / Ladder Wire	Tonnes	1.0646					1.0646

Table 2 Bill of Materials (by Assembly Group)

Foundations

For the foundation, because it is made up of only concrete and rebar, makes up a significant portion of the total concrete and steel for the building. Because of their lengths and thicknesses, the strip footings (ie: Footing_SF1 and Footing_SF4) have a greater impact as they use more concrete and rebar than the pad footings. Because of the software limitations, what was measured and what we were able to input were different, such as the 40% actual flyash used in all the concrete for foundations, versus the 35% selected flyash, which is the closest number to the actual value for the Athena Impact Estimator. This causes the Bill of Materials to list a material that might not actually be in the building.

Columns & Beams

For columns and beams, the major materials are concrete and rebar, as most of the larger structural columns in this building are concrete columns. There are also wood columns, but they are smaller in comparison. The basement has the greatest number of concrete columns (Column_Concrete_Beam_N/A_Basement), so this is the input that makes up the greatest portion of concrete for columns and beams. For all columns, the amount of rebar was not calculated through measurements or numbers in the structural drawings, but was calculated automatically by the Impact Estimator when we imported our inputs. This could cause an under or over estimation of rebar and affect the amount of steel in our building.

Floors

Materials components of the floor assembly were very consisted and it did not deviated between each floor. The structure of the floor was characterized by insulated suspended slab consisting of a composition of concrete, which is the greater contributor to the thickness of the floor; a thin layer of insulation; and, a layer of wood accounted as laminated strand lumber.

The material with the largest amount is concrete. Concrete is presented in the study with two different thickness, especifically as Floor_Concrete_Suspendedslab_193mm and as Floor_Concrete_SuspendedSlab_100mm. Both descriptions of the material account for an area of 4468.7 m2 throughout the building.

The next material with the largest quantity measured is insulation which was assumed to be Foam Polyisocyanurate. Insulation is present as a sublayer of the floor in between the two main components, concrete and wood; and it is referenced in the study as Floor_Insulation_SuspendedSlab_25mm. Insulation takes an area of 3056 m2 and although it is a thin layer, it is used throughout the building and it adds up to a larger number.

Lastly, wood is utilized in the bottom part of the floor structure. It has been assumed that the wood utilized is laminated strand lumber with a reference in the study as Floor_Wood_SuspendedSlab_89mm. The area accounted for wood is similar to the insulation with 3056 m2.

Roof

The roof assembly consists of two different levels with the same structure. The first level is referred as a deck of the fifth floor and the roof of the building itself is on top of the fifth floor. It has been assumed that both roof consist of the same composition, although in the architectural drawings it was not clear whether the composition was a future green roof or a typical R1 roof. We assumed it to be a future green roof in every section where this conflict was present.

Roof composition consisted of two main components: Wood as Cross Laminated Timber and insulation as Foam Polyisocyanurate. Insulation in the roof is referenced in the study as Roof_insulation and the area accounted for insulation of the roof is 718m2.

Cross laminated timber is the main structural component of the roof. It supports the roof in an efficient way and its thickness is of 0.152 meters. The reference for the cross laminated timber in the roof is Roof_CrossLaminatedTimber and the area accounted for the cross laminated timber in the roof and the deck of the fifth floor is of 708 m2.

Walls

The wall assemblies for the ESSB consist of concrete cast-in-place interior and exterior walls in the basement and sub-basement levels. The building was designed with three different structural cores also made of reinforced concrete. These walls accounted for the greatest use of concrete among walls due to their thickness (from 350-430mm) and run through the total height of the building. Concrete strength was set to 35 MPa and 35% percent content of concrete fly ash for these type of walls. For all the other concrete walls (basement level) concrete strength was set to 25 MPa and 35% content of concrete fly ash was used to model the building, as indicated in the general notes in the structural plans. Many of these walls required length adjustments to accommodate the wall thickness limitation of either 200mm or 300mm in the Impact Estimator.

Other assumptions for walls had to be made, for example, all the walls were described to have acoustic insulation which was modeled as fiberglass bat, or the gypsum board that had to be used was the standard one in the IE software. One of the most important impacts of the building refer to the glazing. The building exterior facades are composed by a curtain wall made of Low-E glazing and opaque glass spandrel with insulation. More than 70% of the buildings facades are made of glass, accounting for almost 1000m2 in the Bill of Materials. According to our sensitivity analysis, this condition produces one of the greatest overall impacts of the building.

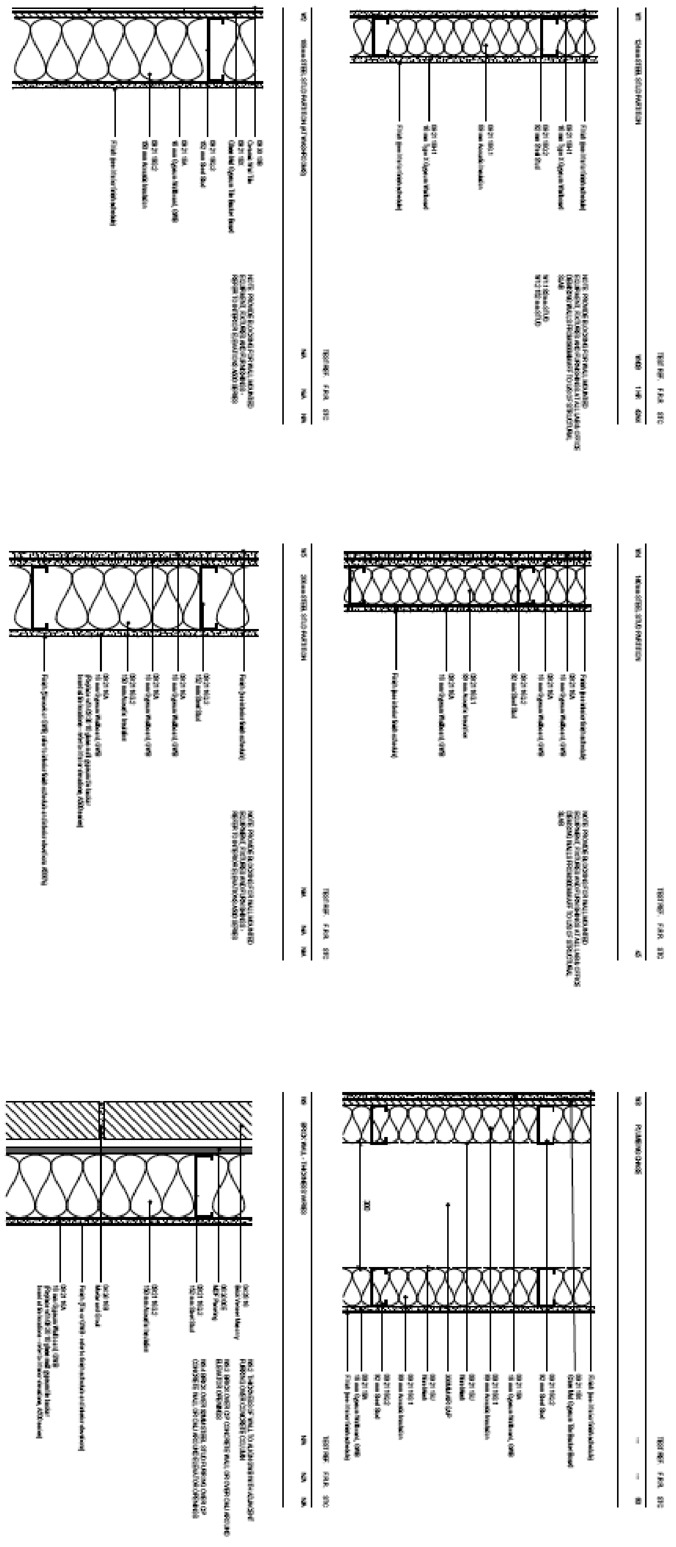
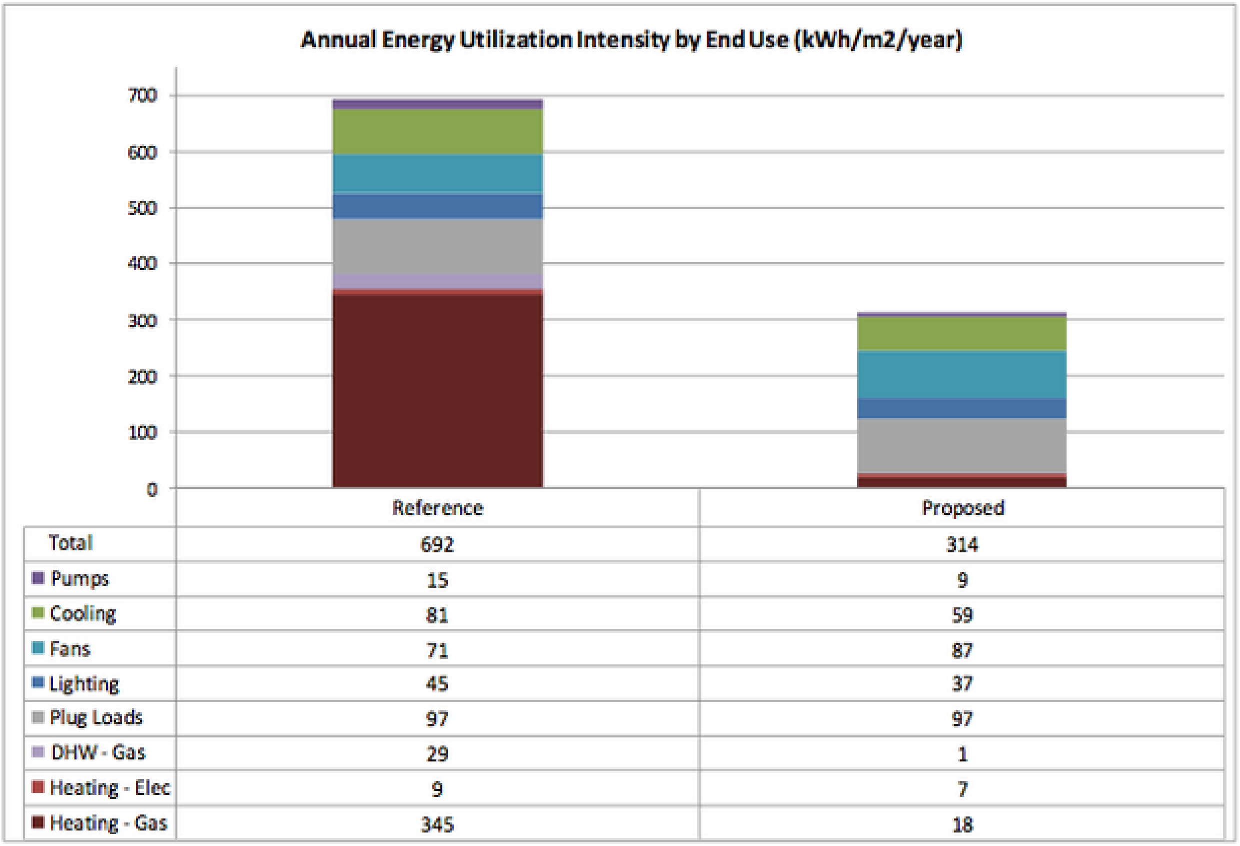


Figure 6 Examples of Interior Wall Assemblies, Extracted from Architectural Drawings

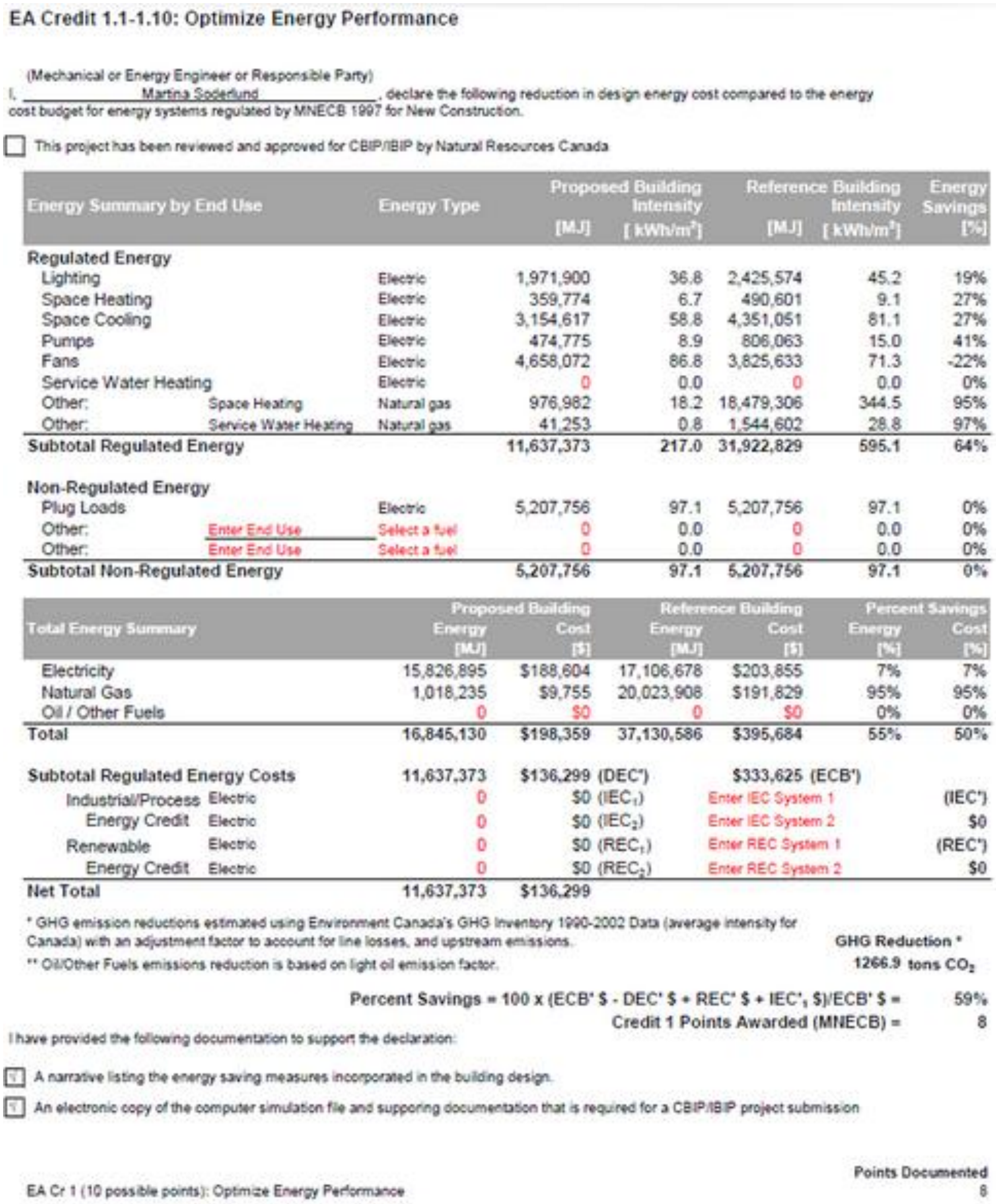
Energy use

The energy use profile is taken from the energy model detailed by Stantec, as stated previously. For this LCA study, a design life of 60 years is used for all our analyses. However, the Stantec memo on the proposed energy model does not specify the design life, it has defined that analyses are to end use of the building for the model scope. As stated in the memo, the proposed energy model will achieve 55% energy savings (including non-regulated energy) and 59% energy cost savings (excluding non-regulated energy). The reference used in this comparison is a 1997 Model National Energy Code for Buildings (MNECB) reference building. For the utilities and types of energy involved in the ESSB building, please refer to Table 3 and Figure 4.



	Reference	Proposed
Total	692	314
■ Pumps	15	9
■ Cooling	81	59
■ Fans	71	87
■ Lighting	45	37
■ Plug Loads	97	97
■ DHW - Gas	29	1
■ Heating - Elec	9	7
■ Heating - Gas	345	18

Table 3 Annual Energy Utilization Intensity by End Use for Reference building and Proposed ESSB building[8]



EA Credit 1.1-1.10: Optimize Energy Performance

(Mechanical or Energy Engineer or Responsible Party)
I, Martina Soderlund, declare the following reduction in design energy cost compared to the energy cost budget for energy systems regulated by MNECB 1997 for New Construction.

☐ This project has been reviewed and approved for CBIP/IBIP by Natural Resources Canada

Energy Summary by End Use		Energy Type	Proposed Building Intensity [MJ]	Proposed Building Intensity [kWh/m²]	Reference Building Intensity [MJ]	Reference Building Intensity [kWh/m²]	Energy Savings [%]
Regulated Energy							
Lighting		Electric	1,971,900	36.8	2,425,574	45.2	19%
Space Heating		Electric	359,774	6.7	490,601	9.1	27%
Space Cooling		Electric	3,154,617	58.8	4,351,051	81.1	27%
Pumps		Electric	474,775	8.9	806,063	15.0	41%
Fans		Electric	4,658,072	86.8	3,825,633	71.3	-22%
Service Water Heating		Electric	0	0.0	0	0.0	0%
Other:	Space Heating	Natural gas	976,982	18.2	18,479,306	344.5	95%
Other:	Service Water Heating	Natural gas	41,253	0.8	1,544,602	28.8	97%
Subtotal Regulated Energy			**11,637,373**	**217.0**	**31,922,829**	**595.1**	**64%**
Non-Regulated Energy							
Plug Loads		Electric	5,207,756	97.1	5,207,756	97.1	0%
Other:	Enter End Use	Select a fuel	0	0.0	0	0.0	0%
Other:	Enter End Use	Select a fuel	0	0.0	0	0.0	0%
Subtotal Non-Regulated Energy			**5,207,756**	**97.1**	**5,207,756**	**97.1**	**0%**

Total Energy Summary	Proposed Building Energy [MJ]	Proposed Building Cost [$]	Reference Building Energy [MJ]	Reference Building Cost [$]	Percent Savings Energy [%]	Percent Savings Cost [%]
Electricity	15,826,895	$188,604	17,106,678	$203,855	7%	7%
Natural Gas	1,018,235	$9,755	20,023,908	$191,829	95%	95%
Oil / Other Fuels	0	$0	0	$0	0%	0%
Total	**16,845,130**	**$198,359**	**37,130,586**	**$395,684**	**55%**	**50%**

Subtotal Regulated Energy Costs		**11,637,373**	**$136,299 (DEC')**	**$333,625 (ECB')**	
Industrial/Process	Electric	0	$0 ($IEC_1$)	Enter IEC System 1	(IEC')
Energy Credit	Electric	0	$0 ($IEC_2$)	Enter IEC System 2	$0
Renewable	Electric	0	$0 ($REC_1$)	Enter REC System 1	(REC')
Energy Credit	Electric	0	$0 ($REC_2$)	Enter REC System 2	$0
Net Total		**11,637,373**	**$136,299**		

* GHG emission reductions estimated using Environment Canada's GHG Inventory 1990-2002 Data (average intensity for Canada) with an adjustment factor to account for line losses, and upstream emissions.

** Oil/Other Fuels emissions reduction is based on light oil emission factor.

GHG Reduction *
1266.9 tons CO_2

Percent Savings = 100 x (ECB' \$ - DEC' \$ + REC' \$ + IEC', \$)/ECB' \$ = 59%
Credit 1 Points Awarded (MNECB) = 8

I have provided the following documentation to support the declaration:

☑ A narrative listing the energy saving measures incorporated in the building design.

☑ An electronic copy of the computer simulation file and supporing documentation that is required for a CBIP/IBIP project submission

EA Cr 1 (10 possible points): Optimize Energy Performance	**Points Documented** 8

Table 4 Summary of the energy consumption by end use for the MNECB and the Proposed[8]

As shown, the highest energy consumers for the building comes from plug loads, fans, and cooling.[8]

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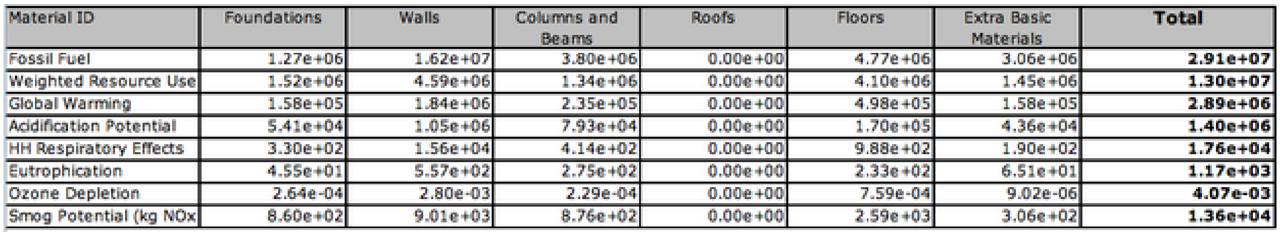
[8] Martina Soderlund, Stantec Consulting, "Earth System Science Building (ESSB) - LEED Energy Model Results Summary", Memo dated May 26, 2011

Impact Assessment

After putting our inputs into the Athena Impact Estimator, we have impact assessment results for each assembly group. These results are generated using the built-in impact assessment method (TRACI). A summary of our results for the impacts of this building are presented below in Table 5, with more details provided later in this section. Site Preparation impacts are not allocated across assembly goups, as they represent the full demolition of the previous structure, hence this data is omitted and only a final value is reported for that row.

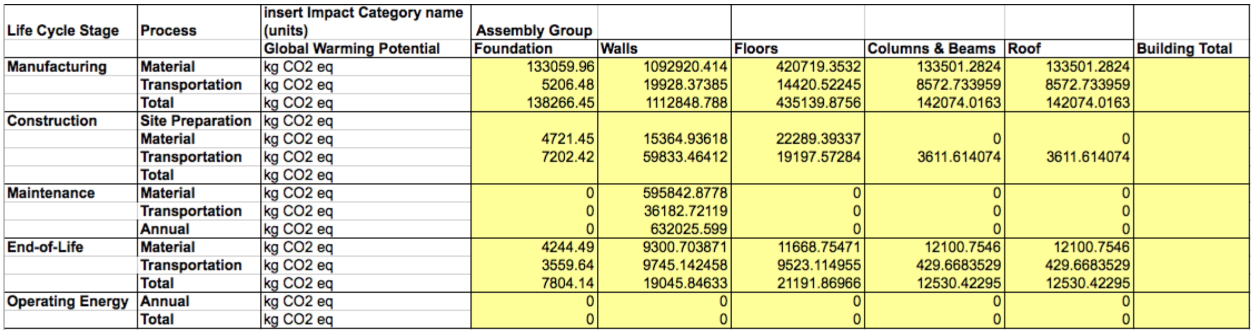


Material ID	Foundations	Walls	Columns and Beams	Roofs	Floors	Extra Basic Materials	**Total**
Fossil Fuel	1.27e+06	1.62e+07	3.80e+06	0.00e+00	4.77e+06	3.06e+06	**2.91e+07**
Weighted Resource Use	1.52e+06	4.59e+06	1.34e+06	0.00e+00	4.10e+06	1.45e+06	**1.30e+07**
Global Warming	1.58e+05	1.84e+06	2.35e+05	0.00e+00	4.98e+05	1.58e+05	**2.89e+06**
Acidification Potential	5.41e+04	1.05e+06	7.93e+04	0.00e+00	1.70e+05	4.36e+04	**1.40e+06**
HH Respiratory Effects	3.30e+02	1.56e+04	4.14e+02	0.00e+00	9.88e+02	1.90e+02	**1.76e+04**
Eutrophication	4.55e+01	5.57e+02	2.75e+02	0.00e+00	2.33e+02	6.51e+01	**1.17e+03**
Ozone Depletion	2.64e-04	2.80e-03	2.29e-04	0.00e+00	7.59e-04	9.02e-06	**4.07e-03**
Smog Potential (kg NOx	8.60e+02	9.01e+03	8.76e+02	0.00e+00	2.59e+03	3.06e+02	**1.36e+04**

Table 5 Summary measures table by Assembly Group

Global Warming Potential

Global warming potential (GWP) is measured in CO2 equivalent units and estimates the potential impact cause by released greenhouse gases. Using these units, it is much easier to compare between two assemblies that may be releasing different types of gases, as it will instead report the amount of CO2 that would be created in place of that gas which will contribute the same amount to global warming.

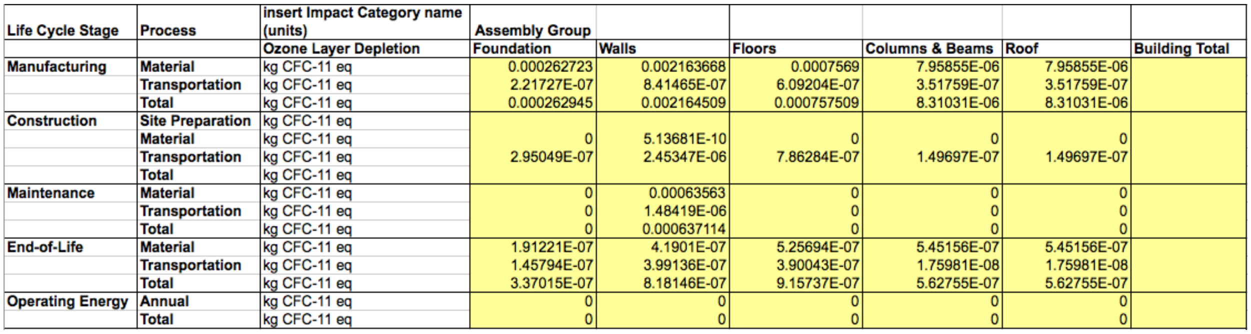


Life Cycle Stage	**Process**	**insert Impact Category name (units)**	**Assembly Group**					
		Global Warming Potential	**Foundation**	**Walls**	**Floors**	**Columns & Beams**	**Roof**	**Building Total**
Manufacturing	**Material**	kg CO2 eq	133059.96	1092920.414	420719.3532	133501.2824	133501.2824	
	Transportation	kg CO2 eq	5206.48	19928.37385	14420.52245	8572.733959	8572.733959	
	Total	kg CO2 eq	138266.45	1112848.788	435139.8756	142074.0163	142074.0163	
Construction	**Site Preparation**	kg CO2 eq						
	Material	kg CO2 eq	4721.45	15364.93618	22289.39337	0	0	
	Transportation	kg CO2 eq	7202.42	59833.46412	19197.57284	3611.614074	3611.614074	
	Total	kg CO2 eq						
Maintenance	**Material**	kg CO2 eq	0	595842.8778	0	0	0	
	Transportation	kg CO2 eq	0	36182.72119	0	0	0	
	Annual	kg CO2 eq	0	632025.599	0	0	0	
End-of-Life	**Material**	kg CO2 eq	4244.49	9300.703871	11668.75471	12100.7546	12100.7546	
	Transportation	kg CO2 eq	3559.64	9745.142458	9523.114955	429.6683529	429.6683529	
	Total	kg CO2 eq	7804.14	19045.84633	21191.86966	12530.42295	12530.42295	
Operating Energy	**Annual**	kg CO2 eq	0	0	0	0	0	
	Total	kg CO2 eq	0	0	0	0	0	

Table 6 Results broken down by assembly for Global Warming Potential

Ozone Layer Depletion

Ozone layer depletion, measured in CFC-11 equivalent units, is the reduction of the ozone layer caused by emissions such as chlorofluorocarbons (CFCs). The ozone layer is a protective layer within the atmosphere, hence its depletion could cause damaging effects to our environment, as well as negative health effects to living things.

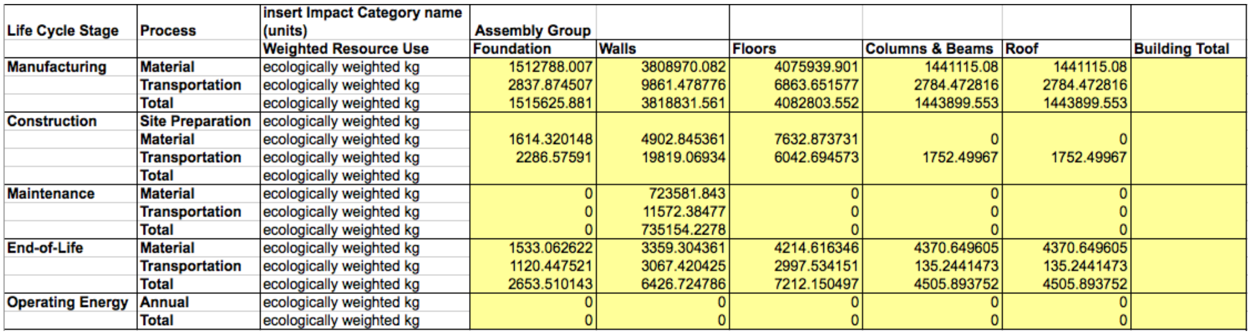


Life Cycle Stage	Process	insert Impact Category name (units)	Assembly Group					
		Ozone Layer Depletion	Foundation	Walls	Floors	Columns & Beams	Roof	Building Total
Manufacturing	Material	kg CFC-11 eq	0.000262723	0.002163668	0.0007569	7.95855E-06	7.95855E-06	
	Transportation	kg CFC-11 eq	2.21727E-07	8.41465E-07	6.09204E-07	3.51759E-07	3.51759E-07	
	Total	kg CFC-11 eq	0.000262945	0.002164509	0.000757509	8.31031E-06	8.31031E-06	
Construction	Site Preparation	kg CFC-11 eq						
	Material	kg CFC-11 eq	0	5.13681E-10	0	0	0	
	Transportation	kg CFC-11 eq	2.95049E-07	2.45347E-06	7.86284E-07	1.49697E-07	1.49697E-07	
	Total	kg CFC-11 eq						
Maintenance	Material	kg CFC-11 eq	0	0.00063563	0	0	0	
	Transportation	kg CFC-11 eq	0	1.48419E-06	0	0	0	
	Total	kg CFC-11 eq	0	0.000637114	0	0	0	
End-of-Life	Material	kg CFC-11 eq	1.91221E-07	4.1901E-07	5.25694E-07	5.45156E-07	5.45156E-07	
	Transportation	kg CFC-11 eq	1.45794E-07	3.99136E-07	3.90043E-07	1.75981E-08	1.75981E-08	
	Total	kg CFC-11 eq	3.37015E-07	8.18146E-07	9.15737E-07	5.62755E-07	5.62755E-07	
Operating Energy	Annual	kg CFC-11 eq	0	0	0	0	0	
	Total	kg CFC-11 eq	0	0	0	0	0	

Table 7 Results broken down by assembly for Ozone Layer Depletion

Weighted Resource Use

Weighted Resource Use involves the weighted measure for resource extraction effects, such as the size of the extraction site and length of time the site is disturbed. The unit, ecologically weighted kilograms, means the relative environmental effect that the extraction process creates.

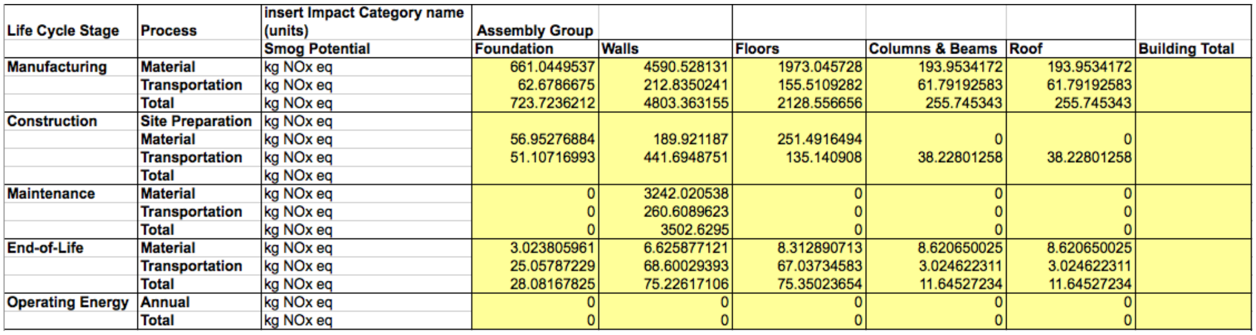


Life Cycle Stage	Process	insert Impact Category name (units)	Assembly Group					
		Weighted Resource Use	Foundation	Walls	Floors	Columns & Beams	Roof	Building Total
Manufacturing	Material	ecologically weighted kg	1512788.007	3808970.082	4075939.901	1441115.08	1441115.08	
	Transportation	ecologically weighted kg	2837.874507	9861.478776	6863.651577	2784.472816	2784.472816	
	Total	ecologically weighted kg	1515625.881	3818831.561	4082803.552	1443899.553	1443899.553	
Construction	Site Preparation	ecologically weighted kg						
	Material	ecologically weighted kg	1614.320148	4902.845361	7632.873731	0	0	
	Transportation	ecologically weighted kg	2286.57591	19819.06934	6042.694573	1752.49967	1752.49967	
	Total	ecologically weighted kg						
Maintenance	Material	ecologically weighted kg	0	723581.843	0	0	0	
	Transportation	ecologically weighted kg	0	11572.38477	0	0	0	
	Total	ecologically weighted kg	0	735154.2278	0	0	0	
End-of-Life	Material	ecologically weighted kg	1533.062622	3359.304361	4214.616346	4370.649605	4370.649605	
	Transportation	ecologically weighted kg	1120.447521	3067.420425	2997.534151	135.2441473	135.2441473	
	Total	ecologically weighted kg	2653.510143	6426.724786	7212.150497	4505.893752	4505.893752	
Operating Energy	Annual	ecologically weighted kg	0	0	0	0	0	
	Total	ecologically weighted kg	0	0	0	0	0	

Table 8 Results broken down by assembly for Weighted Resource Use.

Smog Potential

Smog potential is measured in NOx equivalents per kilogram of emissions and describes the potential of emissions to contribute to the formation of photochemical ozone, which often comes from burning fossil fuels in industry and transportation.

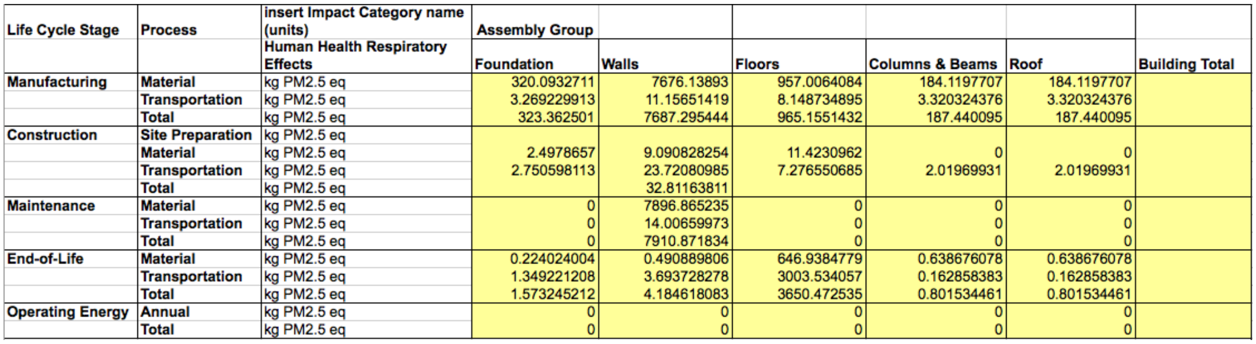


Life Cycle Stage	Process	insert Impact Category name (units)	Assembly Group					
		Smog Potential	Foundation	Walls	Floors	Columns & Beams	Roof	Building Total
Manufacturing	Material	kg NOx eq	661.0449537	4590.528131	1973.045728	193.9534172	193.9534172	
	Transportation	kg NOx eq	62.6786675	212.8350241	155.5109282	61.79192583	61.79192583	
	Total	kg NOx eq	723.7236212	4803.363155	2128.556656	255.745343	255.745343	
Construction	Site Preparation	kg NOx eq						
	Material	kg NOx eq	56.95276884	189.921187	251.4916494	0	0	
	Transportation	kg NOx eq	51.10716993	441.6948751	135.140908	38.22801258	38.22801258	
	Total	kg NOx eq						
Maintenance	Material	kg NOx eq	0	3242.020538	0	0	0	
	Transportation	kg NOx eq	0	260.6089623	0	0	0	
	Total	kg NOx eq	0	3502.6295	0	0	0	
End-of-Life	Material	kg NOx eq	3.023805961	6.625877121	8.312890713	8.620650025	8.620650025	
	Transportation	kg NOx eq	25.05787229	68.60029393	67.03734583	3.024622311	3.024622311	
	Total	kg NOx eq	28.08167825	75.22617106	75.35023654	11.64527234	11.64527234	
Operating Energy	Annual	kg NOx eq	0	0	0	0	0	
	Total	kg NOx eq	0	0	0	0	0	

Table 9 Results broken down by assembly for Smog Potential

Human Health Respiratory Effects

Human Health Respiratory Effects are the contributions of particulates in the air caused by process activity. Particulates are known to cause respiratory problems for humans.

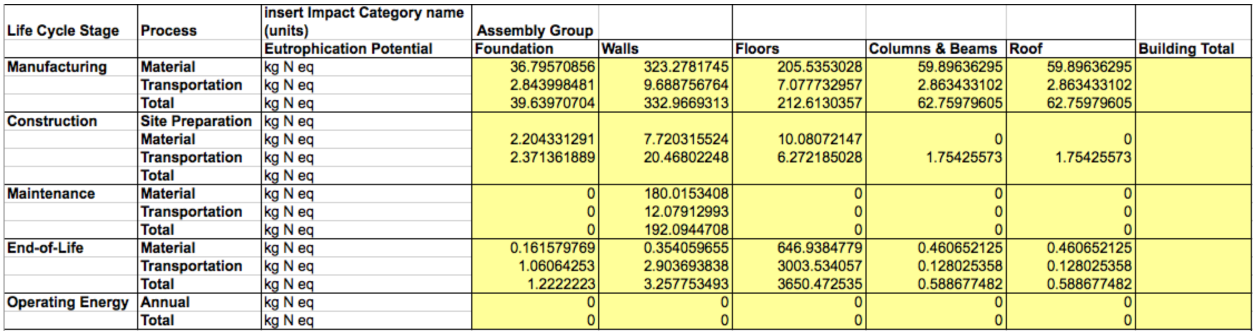


Life Cycle Stage	Process	insert Impact Category name (units)	Assembly Group					
		Human Health Respiratory Effects	Foundation	Walls	Floors	Columns & Beams	Roof	Building Total
Manufacturing	Material	kg PM2.5 eq	320.0932711	7676.13893	957.0064084	184.1197707	184.1197707	
	Transportation	kg PM2.5 eq	3.269229913	11.15651419	8.148734895	3.320324376	3.320324376	
	Total	kg PM2.5 eq	323.362501	7687.295444	965.1551432	187.440095	187.440095	
Construction	Site Preparation	kg PM2.5 eq						
	Material	kg PM2.5 eq	2.4978657	9.090828254	11.4230962	0	0	
	Transportation	kg PM2.5 eq	2.750598113	23.72080985	7.276550685	2.01969931	2.01969931	
	Total	kg PM2.5 eq		32.81163811				
Maintenance	Material	kg PM2.5 eq	0	7896.865235	0	0	0	
	Transportation	kg PM2.5 eq	0	14.00659973	0	0	0	
	Total	kg PM2.5 eq	0	7910.871834	0	0	0	
End-of-Life	Material	kg PM2.5 eq	0.224024004	0.490889806	646.9384779	0.638676078	0.638676078	
	Transportation	kg PM2.5 eq	1.349221208	3.693728278	3003.534057	0.162858383	0.162858383	
	Total	kg PM2.5 eq	1.573245212	4.184618083	3650.472535	0.801534461	0.801534461	
Operating Energy	Annual	kg PM2.5 eq	0	0	0	0	0	
	Total	kg PM2.5 eq	0	0	0	0	0	

Table 10 Results broken down by assembly for HH Respiratory Effects

Eutrophication Potential

The Eutropication Potential is the building assembly's ability to fill surface waters with nutrients (ie: Phosphurus and Nitrogen), leading to the over-consumption of other necessary chemicals such as oxygen in the water. Far too much nutrients in a body of water can be toxic to aquatic life. This can have a great impact on aquatic inhabitants and can even result in massive numbers for fish kills. The units of this impact category are units of Nitrogen equivalents.

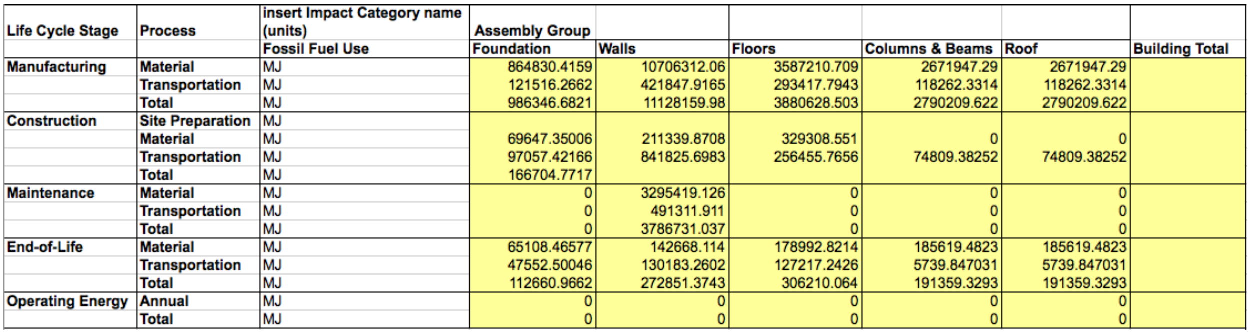


Life Cycle Stage	Process	insert Impact Category name (units)	Assembly Group					
		Eutrophication Potential	Foundation	Walls	Floors	Columns & Beams	Roof	Building Total
Manufacturing	Material	kg N eq	36.79570856	323.2781745	205.5353028	59.89636295	59.89636295	
	Transportation	kg N eq	2.843998481	9.688756764	7.077732957	2.863433102	2.863433102	
	Total	kg N eq	39.63970704	332.9669313	212.6130357	62.75979605	62.75979605	
Construction	Site Preparation	kg N eq						
	Material	kg N eq	2.204331291	7.720315524	10.08072147	0	0	
	Transportation	kg N eq	2.371361889	20.46802248	6.272185028	1.75425573	1.75425573	
	Total	kg N eq						
Maintenance	Material	kg N eq	0	180.0153408	0	0	0	
	Transportation	kg N eq	0	12.07912993	0	0	0	
	Total	kg N eq	0	192.0944708	0	0	0	
End-of-Life	Material	kg N eq	0.161579769	0.354059655	646.9384779	0.460652125	0.460652125	
	Transportation	kg N eq	1.06064253	2.903693838	3003.534057	0.128025358	0.128025358	
	Total	kg N eq	1.2222223	3.257753493	3650.472535	0.588677482	0.588677482	
Operating Energy	Annual	kg N eq	0	0	0	0	0	
	Total	kg N eq	0	0	0	0	0	

Table 11 Results broken down by assembly for Eutrophication Potential

Fossil Fuel Consumption

Primary Energy Consumption is essential the use of fossil fuel. It includes all energy used to transport and transform raw materials into products. It also includes any energy involved in extraction, processing, manufacturing, construction, and indirect energies from processing or transforming this energy. Its units of Mega joules, which is a unit for energy.

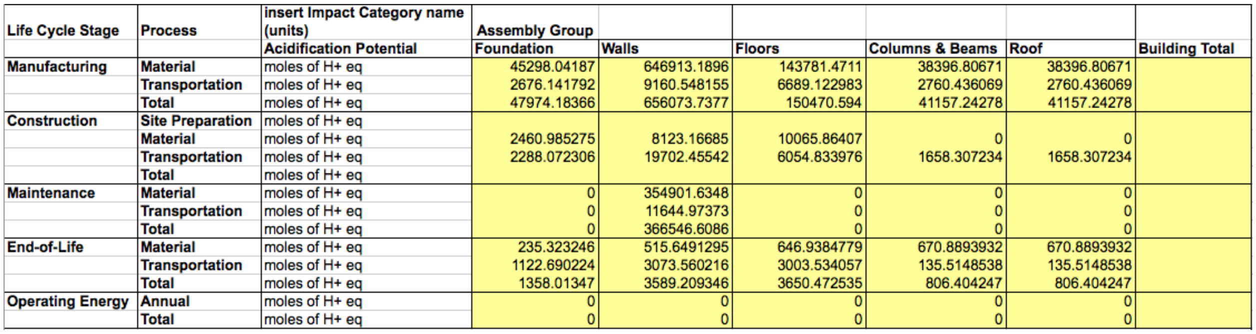


Life Cycle Stage	Process	insert Impact Category name (units)	Assembly Group					
		Fossil Fuel Use	Foundation	Walls	Floors	Columns & Beams	Roof	Building Total
Manufacturing	Material	MJ	864830.4159	10706312.06	3587210.709	2671947.29	2671947.29	
	Transportation	MJ	121516.2662	421847.9165	293417.7943	118262.3314	118262.3314	
	Total	MJ	986346.6821	11128159.98	3880628.503	2790209.622	2790209.622	
Construction	Site Preparation	MJ						
	Material	MJ	69647.35006	211339.8708	329308.551	0	0	
	Transportation	MJ	97057.42166	841825.6983	256455.7656	74809.38252	74809.38252	
	Total	MJ	166704.7717					
Maintenance	Material	MJ	0	3295419.126	0	0	0	
	Transportation	MJ	0	491311.911	0	0	0	
	Total	MJ	0	3786731.037	0	0	0	
End-of-Life	Material	MJ	65108.46577	142668.114	178992.8214	185619.4823	185619.4823	
	Transportation	MJ	47552.50046	130183.2602	127217.2426	5739.847031	5739.847031	
	Total	MJ	112660.9662	272851.3743	306210.064	191359.3293	191359.3293	
Operating Energy	Annual	MJ	0	0	0	0	0	
	Total	MJ	0	0	0	0	0	

Table 12 Results broken down by assembly for Primary Energy Consumption (Fossil Fuel Use).

Acidification Potential

Acidification Potential estimates the potential increase the amount acidity in water, soil and air cause by air emissions. This impact category is measured in terms of hydrogen ion equivalents (moles H+e), a common component of all acids. The category indicator is H+ mole equivalent per kilogram of air emissions.



Life Cycle Stage	Process	insert Impact Category name (units)	Assembly Group					
		Acidification Potential	Foundation	Walls	Floors	Columns & Beams	Roof	Building Total
Manufacturing	Material	moles of H+ eq	45298.04187	646913.1896	143781.4711	38396.80671	38396.80671	
	Transportation	moles of H+ eq	2676.141792	9160.548155	6689.122983	2760.436069	2760.436069	
	Total	moles of H+ eq	47974.18366	656073.7377	150470.594	41157.24278	41157.24278	
Construction	Site Preparation	moles of H+ eq						
	Material	moles of H+ eq	2460.985275	8123.16685	10065.86407	0	0	
	Transportation	moles of H+ eq	2288.072306	19702.45542	6054.833976	1658.307234	1658.307234	
	Total	moles of H+ eq						
Maintenance	Material	moles of H+ eq	0	354901.6348	0	0	0	
	Transportation	moles of H+ eq	0	11644.97373	0	0	0	
	Total	moles of H+ eq	0	366546.6086	0	0	0	
End-of-Life	Material	moles of H+ eq	235.323246	515.6491295	646.9384779	670.8893932	670.8893932	
	Transportation	moles of H+ eq	1122.690224	3073.560216	3003.534057	135.5148538	135.5148538	
	Total	moles of H+ eq	1358.01347	3589.209346	3650.472535	806.404247	806.404247	
Operating Energy	Annual	moles of H+ eq	0	0	0	0	0	
	Total	moles of H+ eq	0	0	0	0	0	

Table 13 Results broken down by assembly for Acidification Potential

Uncertainty

Assumptions in floor's take offs had to be taken to define the average thickness of the floor throughout the building. Different cross sections were presented specifically in the thickness of parts of the floor to counter this problem so that a concise measurement could be taken for columns calculation as well as volume of some of the components of the floors. Another assumption made was to determine that a overlap of the floor structure in the first floor was small enough to be taken into account. Furthermore, stairs were standardized and the thickness of each step was assumed to be the same for the whole building.

The cross section of the floor also presented a composite shear connector which was of the same composition of the rest of the floor (ie. concrete-insulation-wood). For that matter, it was not included in the material take off of the floor since it was very unsure the physical limit of the "shear connector" therefore, hard to quantify; and, it was determined that it will not significantly influence the overall results of the impacts.

The inputs for the Impact Estimator were modified to fit the constraints of the software. For example, area of the floors was taken from multipliers of its length and width.

In addition, extra thickness was added to the first floor due to its larger thickness of the floor, which somehow, had to be compensated with one of the composition materials.

In the roof the assumption made was that the area defined as "future green roof" is the same composition as the rest of the roof but the cover of "vegetation matter" was not taken into account because there was not such material in the Impact Estimator. Furthermore, concrete was not accounted as a material for the composition of the roof because the architectural and structural drawings mention the existence of it, it was not clearly determined if concrete was ultimately used, therefore, it was considered as incomplete information.

Sensitivity Analysis

Using the results output from the Athena Impact Estimator for Buildings, a sensitivity analysis was performed for five materials. The method for this analysis involves looking through the bill of materials, selecting the five materials we wish to analyse; then, adding 10% more of the material in the IE model and generate new results. From this output, and the selected impact categories, we can deduce which material the building is most sensitive to. This will also help us verify how much uncertainty can affect our LCA study, as many assumptions had to be made. The five materials chosen for this study are the ⅝" Gypsum board, 30MPa Concrete with 25% flyash, Galvanized studs, the Glazing panels, and GluLam sections.

Primary Energy Consumption is highly sensitive to the amount of glazing panels and somewhat sensitive to the amount of concrete in the building. This is likely because glazing panels require a large amount of energy to gather raw materials, manufacture, refine, and transport. A similar assumption can be made for concrete.

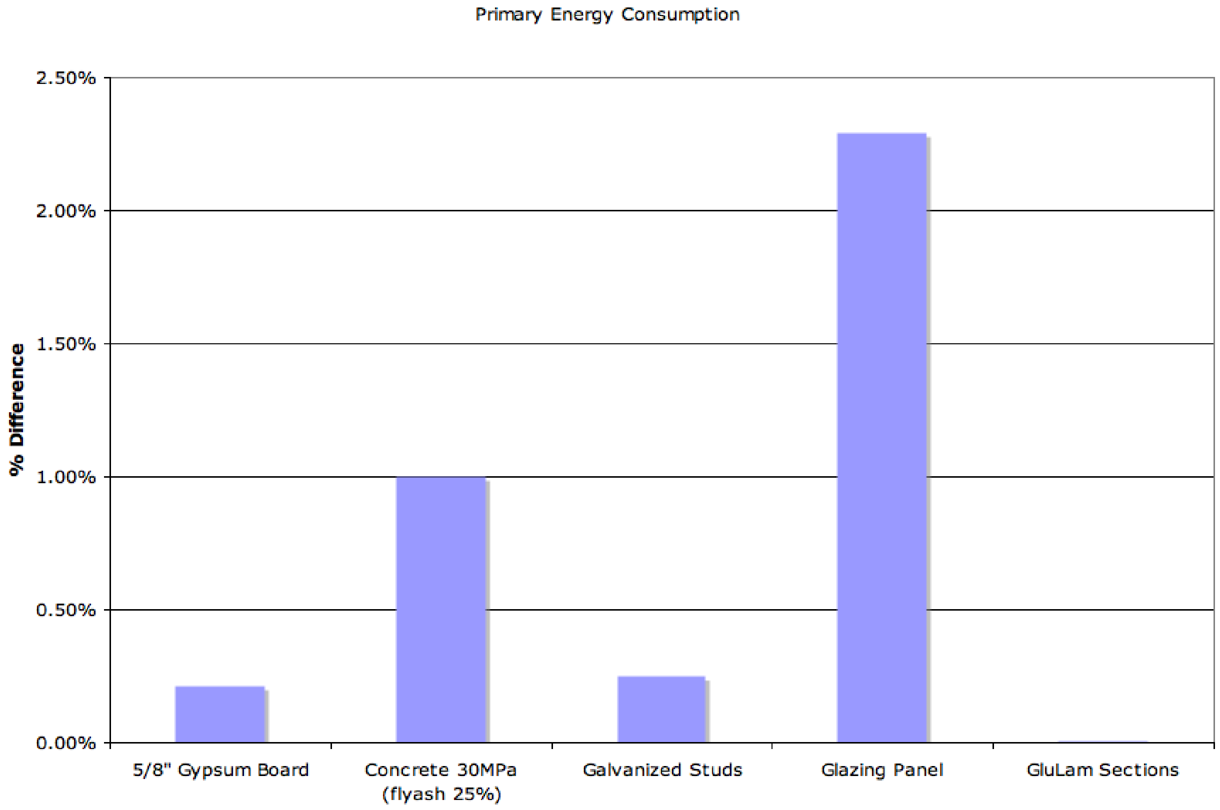


Figure 7 Sensitivity analysis results for Primary Energy Consumption

Weighted Resource Use is most affected by the amount of concrete in the building, followed by the amount of glazing panels. The other materials make very little difference in our case. The result is expected, as manufacturing concrete involves a great amount of raw materials, that is, it takes a lot of resources to produce. The same reasoning goes for why weighted resource use is also sensitive to glazing panels.

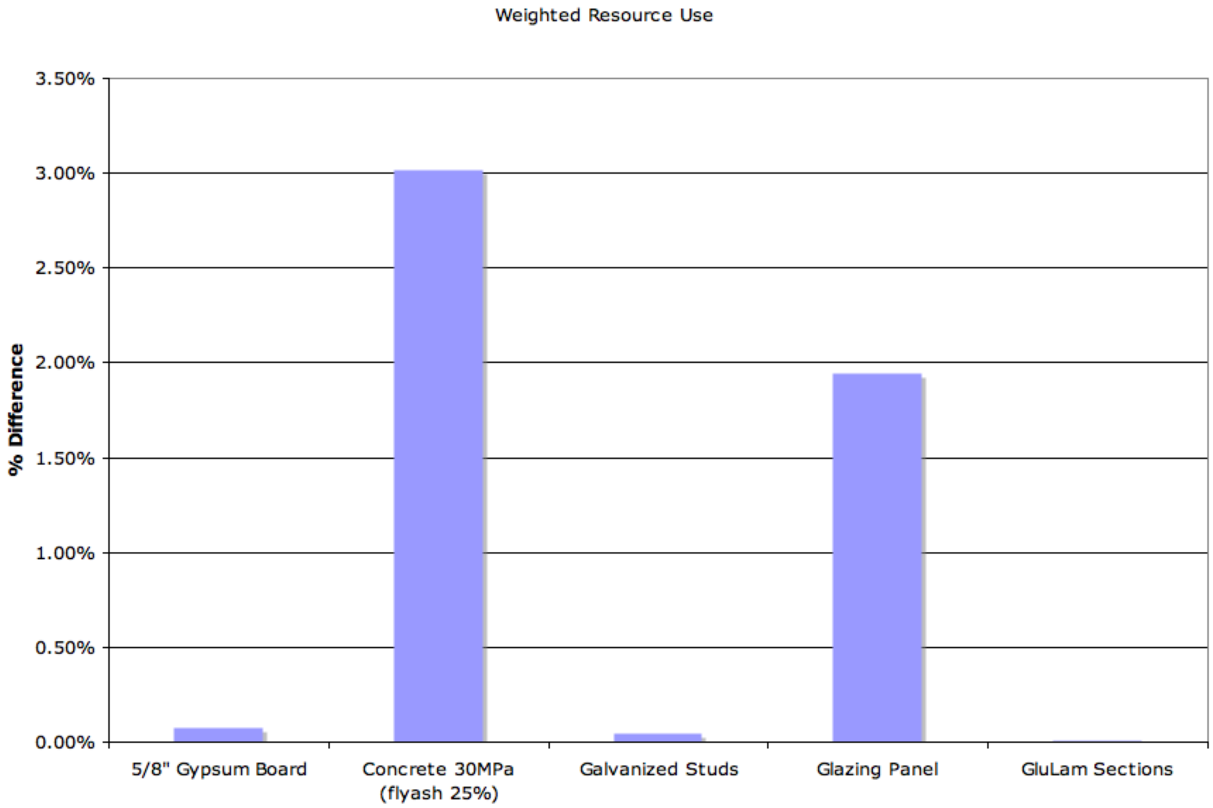


Figure 8 Sensitivity analysis results for Weighted Resource Use

Ozone depletion potential is affected on similar levels by glazing panels and concrete. Recall that the ozone layer is reduced by these types of emissions. The two materials produce the most emissions of the five during their manufacturing processes as they require more raw materials to manufacture.

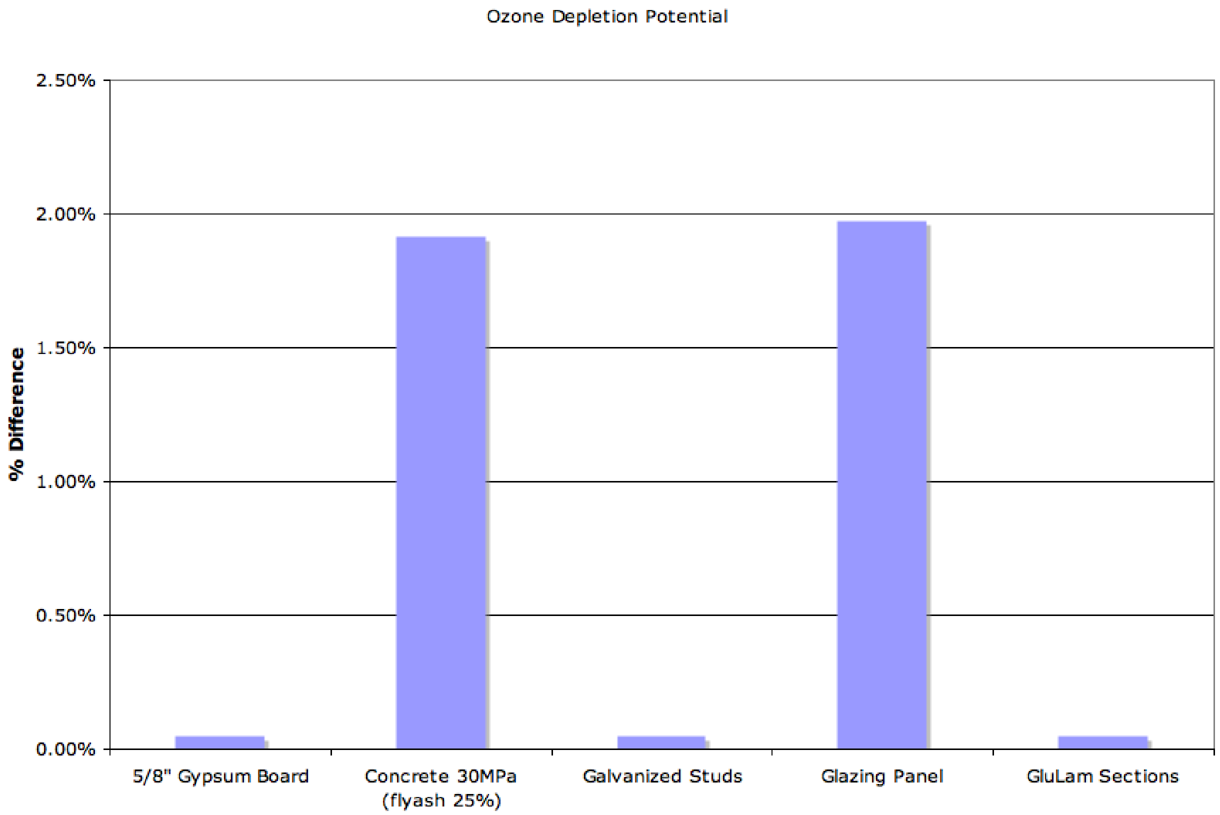


Figure 9 Sensitivity analysis results for Ozone Depletion Potential

Human Health Respiratory Effects Potential is of particular concern when it comes to impact assessments due to the potential to cause harm to human beings through air. Glazing panels are once again the material that will have the greatest impact. The other materials in the study cause little or no effect. As previously mentioned, glass panels involve chemical processes which result in chemical emissions into the environment, such as the air we breathe. The chemical particles may also be harmful to human health. Moreover, maintence of glazing panels during the lifetime of the building will also cause particulate matter to be released into the air, for example, from the cleaning process.

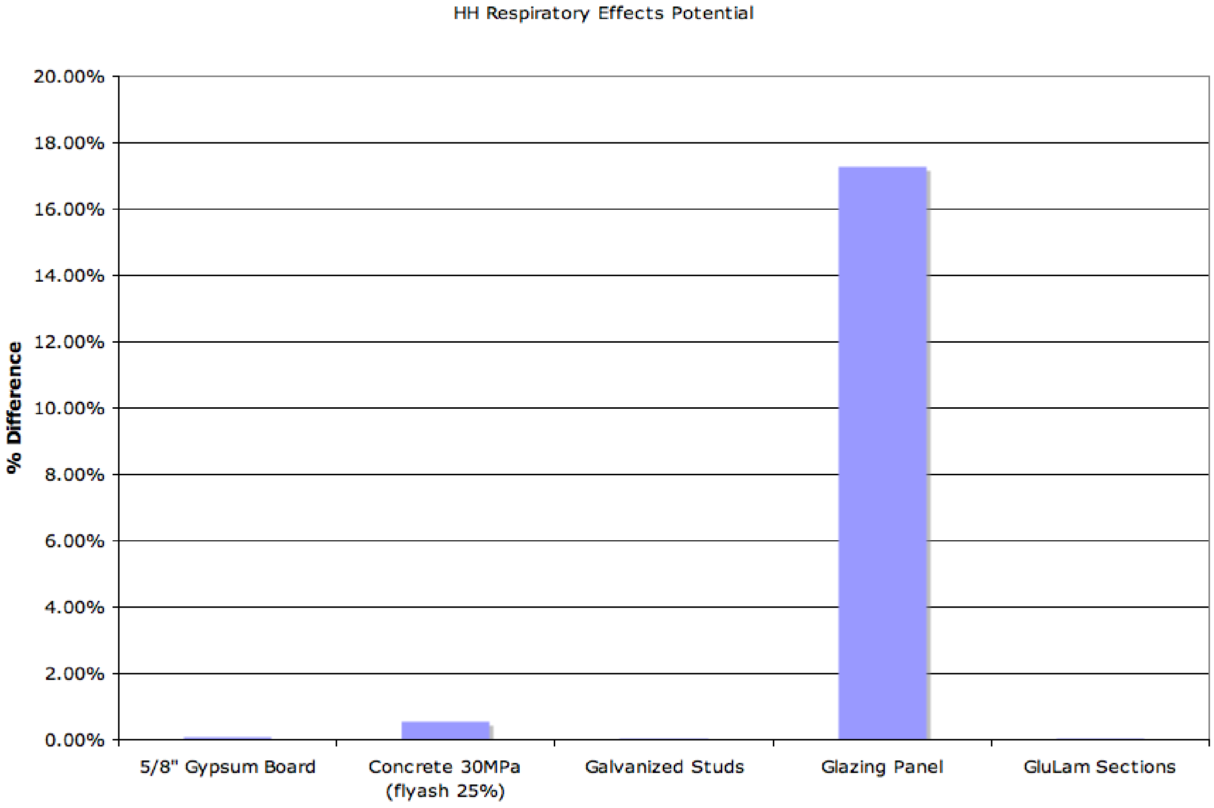


Figure 10 Sensitivity analysis results for HH Respiratory Effects Potential.

For the ESSB building, Eutrophication Potential is most affected by glazing panels, followed by concrete. Chemicals from the manufacturing and maintenance of glazing panels can easily contribute to the eutrophication potential as they could run off into bodies of water and cause harm to the aquatic environment and its inhabitants.

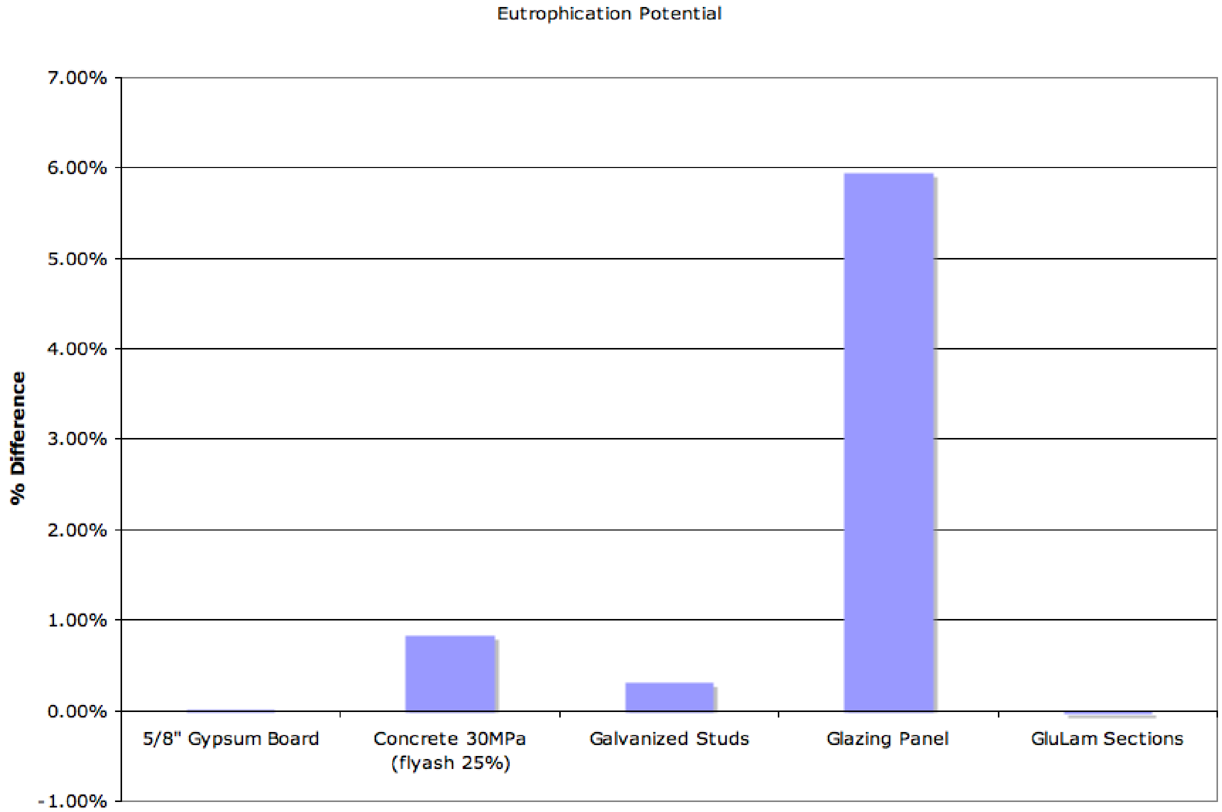


Figure 11 Sensitivity analysis results for Eutrophication Potential.

Acidification Potential, or the potential of air or water to have an increase in acidity, is most sensitive to an increase in the amount of glazing panels. Glass production involves a lot of chemicals which causes a large amount of unwanted chemicals releasing into the environment. Although concrete has some affects to acidification potential as well, this impact category is far more sensitive to glazing panels. The gypsum board, galvanized studs, and glulam sections show almost no effect, due to the small percentage they make up for the entire building.

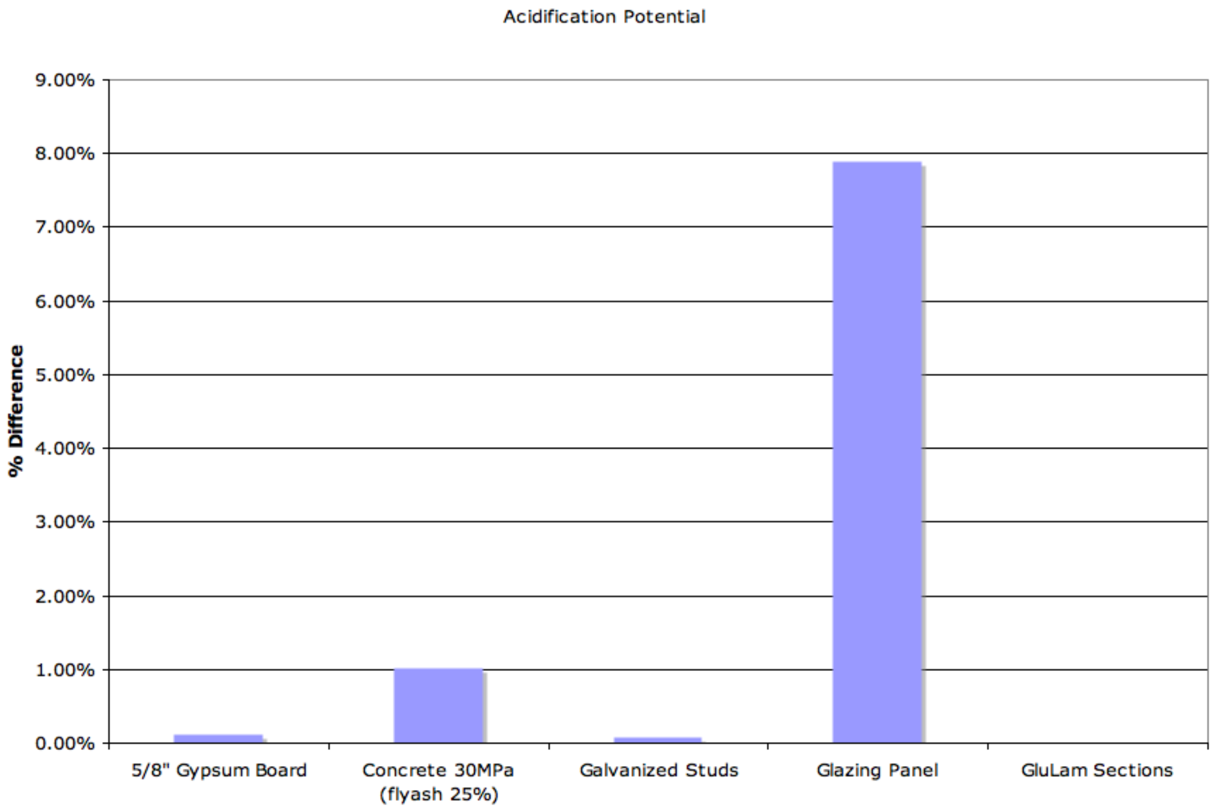


Figure 12 Sensitivity analysis results for Acidification Potential

Smog Potential is most sensitive to glazing panels, and somewhat sensitive to concrete. Again, because of the emissions from the manufacturing processes of glazing penls and concrete, they are the materials that have the greatest effect on this impact category.

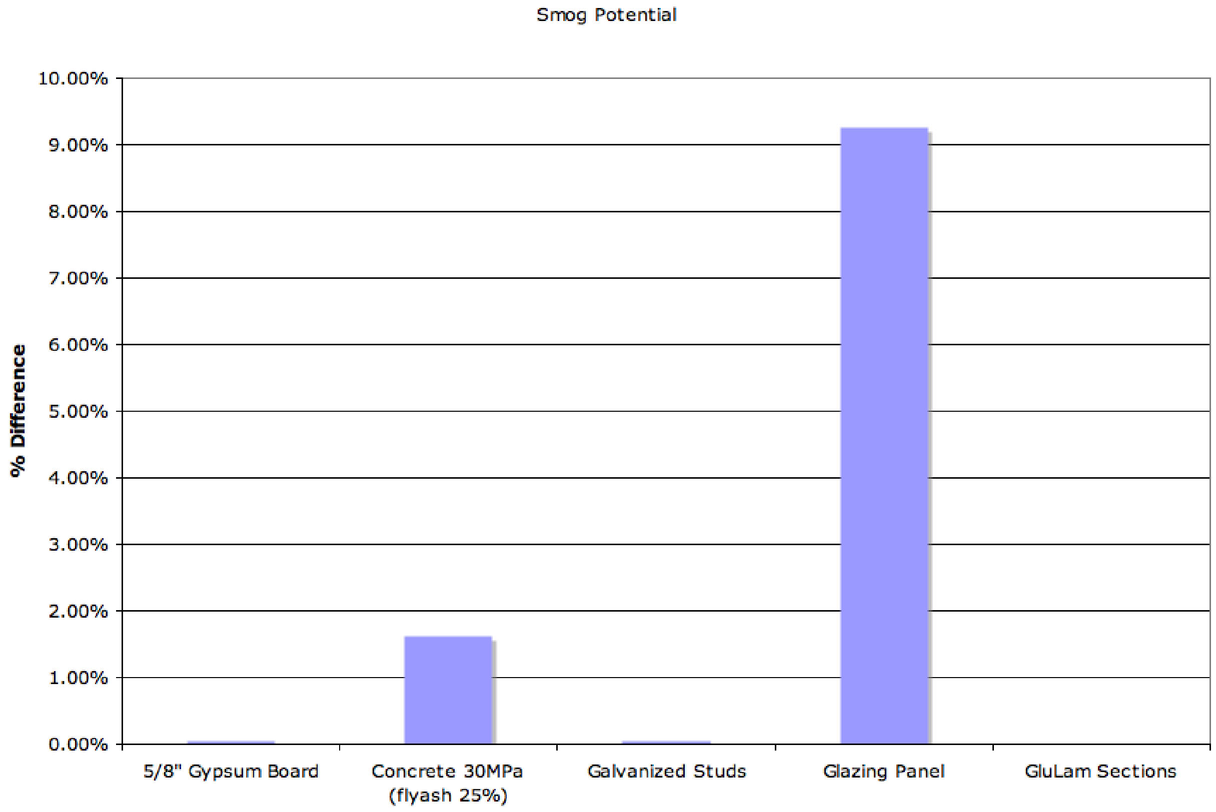


Figure 13 Sensitivity analysis results for Smog Potential.

Global warming potential is highly sensitive to the amount of glazing panels in our building. The production of glass panels requires a great deal of energy, as discussed earlier in the sensitivity for primary energy consumption. High temperatures are also involved in manufacturing. This causes a large amount of greenhouse gas emissions into the atmosphere, increasing the global warming potential.

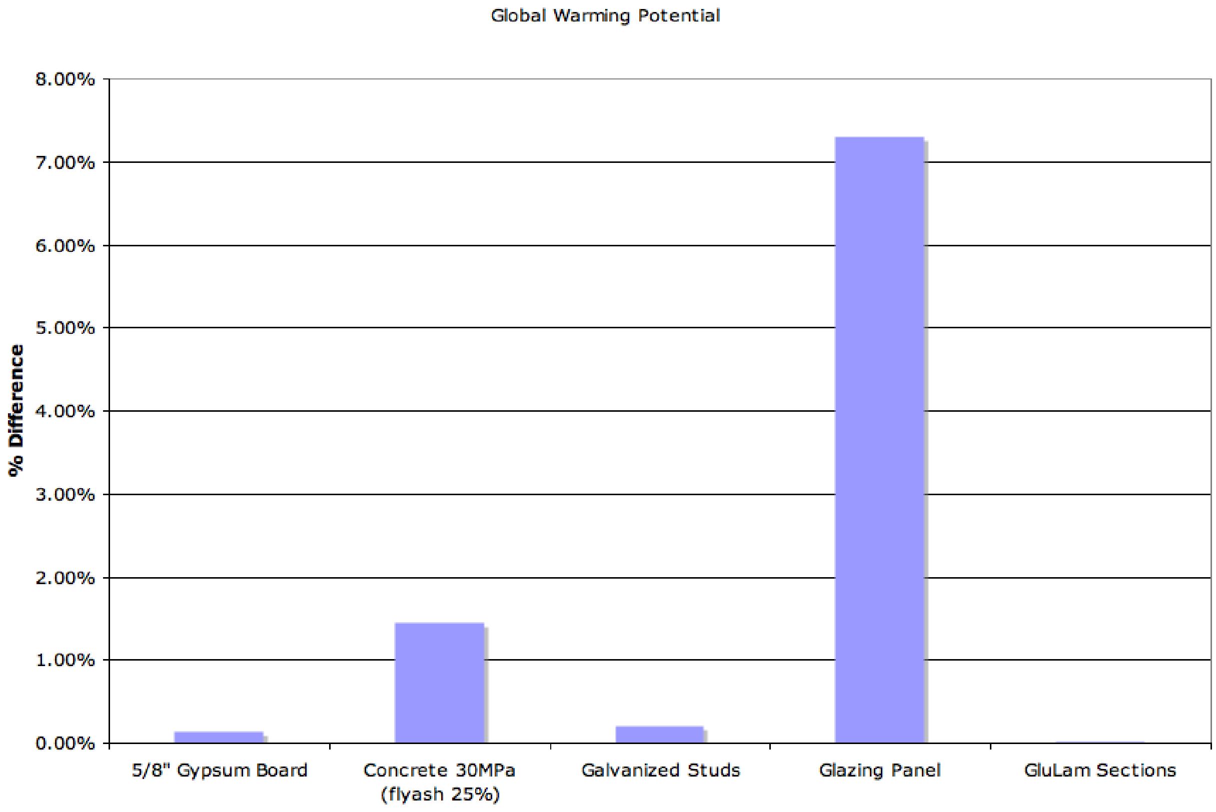


Figure 14 Sensitivity analysis results for Global Warming Potential.

Chain of Custody Inquiry

	Material	Life cycle stage	Company name	Email + Phone	Date contacted	Latitude of facility	Longitude of facility	Transportation mode to facility	Transportation mode from facility	Notes
	Sand	Extraction	Construction Aggregates Ltd.	Shelagh.Wright@paccoast.com 604-885-7595	22/03/12	49°32'35.24"N	123°41'21.16"W	Truck	Truck	
	Aggregate	Extraction	Construction Aggregates Ltd.	Shelagh.Wright@paccoast.com 604-885-7595	22/03/12	49°32'35.24"N	123°41'21.16"W	Truck	Truck	
	Cement	Manufacturing	Lehigh Northwest Materials	Shelagh.Wright@paccoast.com 604-885-7595	22/03/12	49°29'5.69"N	123°44'17.60"W	Truck	Truck	
Completed Product	Concrete Blocks	Manufacturing	Basalite Concrete Products Vancouver	Shelagh.Wright@paccoast.com 604-885-7595	22/03/12	49° 9'45.40"N	122°51'25.32"W	Truck	Truck	

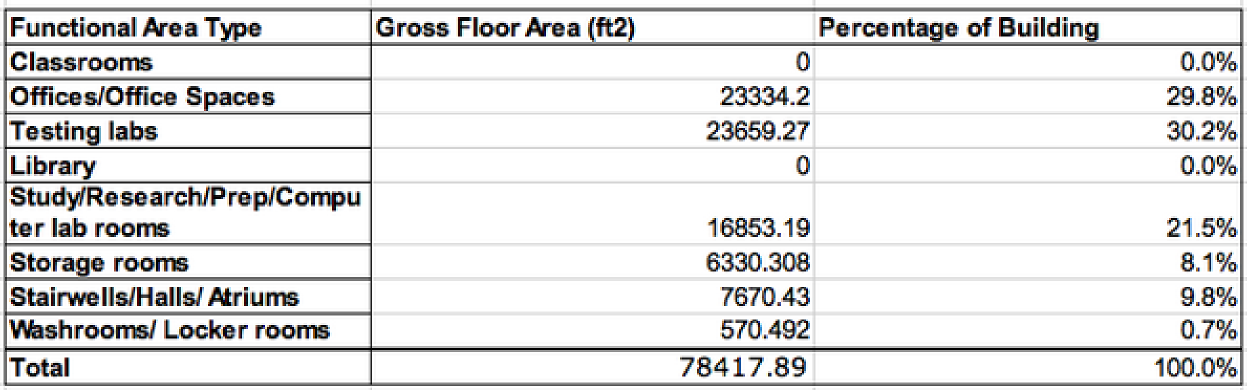
The exercise was developed for the exterior white brick cladding used in the North and East facades of the building. The exercise was executed by contacting the architects first, to know the name of the company that manufactured the product. In the architecture firm, the contact is Jana Foit, one of the head architects working on the building. An email was sent to her asking for the relevant information. She sent us back the name of the company which was Basalite Concrete Products. With this information we tracked the company on the internet and found a phone and email for inquiries. Later, Shelagh Wright, from architectural sales, was contacted. Finally, she was able to give us the information that we needed, regarding components of the product, extraction and manufacture plants location and type of transportation used.

This process was relatively short and not so difficult because we had the contribution of the architects and a representative of the brick company. It took us about 2-3 days to have the information to complete the exercise, but it would be a totally different scenario if we had to account for a greater amount of materials in the buildings. In this case the relatively simple procedure would turn to be a more complex task as it would involve many different assembly types and thus, hundreds of different materials. It would be almost impossible to account for a complete chain of custody study as it would involve a large number of hours dedicated to it and even though, it is probable that not all the information would be gathered. A more adequate approach could be to address this chain of custody for the most important materials, those contributing to the greater environmental impacts.

Functions and Impacts

Building Functions

The ESSB Building provides space for teaching, laboratories and office spaces for the department of Earth and Ocean Science (EOS), the Department of Statistics, the Pacific Institute for Mathematical Sciences (PIMS), the Dean of Science, and the Pacific Museum of the Earth (PME). Specifically there is 30% dedicated to testing labs, 30% dedicated to office spaces, and 20% for computer labs and research space. The old EOS East building was also intended to provide office and research space for faculty, but was far smaller in size.



Functional Area Type	Gross Floor Area (ft2)	Percentage of Building
Classrooms	0	0.0%
Offices/Office Spaces	23334.2	29.8%
Testing labs	23659.27	30.2%
Library	0	0.0%
Study/Research/Prep/Computer lab rooms	16853.19	21.5%
Storage rooms	6330.308	8.1%
Stairwells/Halls/ Atriums	7670.43	9.8%
Washrooms/ Locker rooms	570.492	0.7%
Total	78417.89	100.0%

Table 14 Functional Spaces of the ESSB Building

Conclusion

This LCA study on the new ESSB building was performed at an undergraduate level using only the resources available to us as students of CIVL498E at the University of British Columbia. Software such as OnScreen TakeOff, Athena Impact Estimator, and Microsoft Excel were key components in the compilation of our results. Through these software, we were able to do quantity take offs and create a building model through Impact Estimator. Results generated were the Bill of Materials and the Summary Measures Tables (by Life Cycle or by Assembly). It is important to note that to achieve resulting outputs, assumptions had to be made to account for lack of information or software limitations. These assumptions lead to uncertainties in our results, such as underestimating or overestimating a material.

Using the Bill of Materials, we are able to perform a sensitivity analysis on five materials in our building, in which we added 10% of each material to see how it would affect the environmental impact results of the building. We found that in many impact categories, the material that had the most effect on the environment were the glazing panels, followed by the amount of concrete used in the building. Glazing panels were significant effect in terms of Human Health Respiratory Effects Potiential and Smog Potential.

Through the energy use models, we established that the new ESSB building when compared to a 1997 Model National Energy Code for Buildings (MNECB) reference building, will result in over 50% of energy savings. As the old EOS East and Engineering Annex buildings that were replaced by the ESSB are prior to 1997, we could conclude that the ESSB building would be more efficient in energy use than the older buildings.

After performing this LCA study through transparent methods that can be duplicated, we are able to see the environmental impacts of the ESSB throughout its design life, and can compare these results with other buildings built for similar functions. Given the time and resources available for the compilation of this report, further analyses can be done to provide a much more detailed LCA that would have greater accuracy and reduced uncertainty. We would recommend that LCA be performed for all buildings in the future to build an abundant database that can be used for green building design.

Appendix A: IE Input Document

Assembly Group	Assembly Type	Assembly Name	Input Fields	Input Values	
				Known/ Measured	IE Inputs
1 Foundation					
	1.1 Concrete Slab-on-Grade				
		1.1.1 SOG_125mm			
			Length (m)	10.00	10.00
			Width (m)	13.60	17.00
			Thickness (mm)	125	100
			Concrete (MPa)	25	30
			Concrete flyash %	40%	35%
		1.1.2 SOG_200mm			
			Length (m)	33.60	33.60
			Width (m)	30.00	30.00
			Thickness (mm)	200	200
			Concrete (MPa)	25	30
			Concrete flyash %	40%	35%
	1.2 Concrete Footing				
		1.2.1 Footing_PF1			
			Length (m)	18.2	18.2
			Width (m)	1.4	1.4
			Thickness (mm)	350	350
			Concrete (MPa)	25	30
			Concrete flyash %	40%	35%
			Rebar	20M	20M
		1.2.2 Footing_PF2			
			Length (m)	8	8
			Width (m)	0.8	0.8
			Thickness (mm)	250	250
			Concrete (MPa)	25	30
			Concrete flyash %	40%	35%
			Rebar	15M	15M
		1.2.3. Footing_PF3			
			Length (m)	12.6	15.12
			Width (m)	1.8	1.8
			Thickness (mm)	600	500
			Concrete (MPa)	25	30
			Concrete flyash %	40%	35%
			Rebar	20M	20M
		1.2.4 Footing_PF4			
			Length (m)	32	60.8
			Width (m)	3.2	3.2
			Thickness (mm)	950	500
			Concrete (MPa)	25	30
			Concrete flyash %	40%	35%

	Rebar	25M	20M
1.2.5 Footing_PF5			
	Length (m)	12	16.8
	Width (m)	2.4	2.4
	Thickness (mm)	700	500
	Concrete (MPa)	25	30
	Concrete flyash %	40%	35%
	Rebar	25M	20M
1.2.6 Footing_PF6			
	Length (m)	19	19
	Width (m)	1	1
	Thickness (mm)	350	350
	Concrete (MPa)	25	30
	Concrete flyash %	40%	35%
	Rebar	15M	15M
1.2.7 Footing_SF1			
	Length (m)	107.046	107.05
	Width (m)	0.5	0.5
	Thickness (mm)	300	300
	Concrete (MPa)	25	30
	Concrete flyash %	40%	35%
	Rebar	15M	15M
1.2.8 Footing_SF2			
	Length (m)	87.43166667	87.4300000
	Width (m)	0.6	0.6
	Thickness (mm)	250	250
	Concrete (MPa)	25	30
	Concrete flyash %	40%	35%
	Rebar	15M	15M
1.2.9 Footing_SF3			
	Length (m)	77.628	77.63
	Width (m)	1	1
	Thickness (mm)	350	350
	Concrete (MPa)	25	30
	Concrete flyash %	40%	35%
	Rebar	15M	15M
1.2.10 Footing_SF4			
	Length (m)	83.10266667	83.10
	Width (m)	1.5	1.5
	Thickness (mm)	350	350
	Concrete (MPa)	25	30
	Concrete flyash %	40%	35%
	Rebar	15M	15M
1.2.11 Footing_SF5			
	Length (m)	44.0765	44.0765
	Width (m)	2	2
	Thickness (mm)	350	350
	Concrete (MPa)	25	30

			Concrete flyash %	40%	35%
			Rebar	15M & 25M	15M
		1.2.12 Footing_SF7			
			Length (m)	37.53688889	37.54
			Width (m)	2.7	2.7
			Thickness (mm)	350	350
			Concrete (MPa)	25	30
			Concrete flyash %	40%	35%
			Rebar	15M & 25M	15M
		1.2.13 Footing_SF8			
			Length (m)	16.95903505	16.96
			Width (m)	2.197	2.20
			Thickness (mm)	400	400
			Concrete (MPa)	25	30
			Concrete flyash %	40%	35%
			Rebar	15M & 35M	15M
		1.2.14 Footing_SF9			
			Length (m)	37.1795	37.1795
			Width (m)	2	2
			Thickness (mm)	300	300
			Concrete (MPa)	25	30
			Concrete flyash %	40%	35%
			Rebar	15M & 25M	15M
2 Walls					
	2.1 Cast In Place				
		2.1.1 Wall_Cast-in-Place_W1_200mm			
		Envelope	Length (mm)	10687	10687
			Height (mm)	4200	4200
			Thickness (mm)	200	200
			Concrete (MPa)	25	30
			Concrete flyash %	40	35
			Rebar	#15M Vert, #15M Horiz	#15M
			Category	Insulation	Insulation
			Material	Rigid Board Insulation (R20)	Polystyrene expanded
			Thickness (mm)	50	50
			Category	Vapour Barrier	Vapour Barrier
			Material	Fluid Applied Waterproofing	Polyethylene 6 mil
			Thickness	-	-
		2.1.2 Wall_Cast-in-Place_W2_250mm			
			Length (mm)	76980	96225
			Height (mm)	4200	4200
			Thickness (mm)	250	200
			Concrete (MPa)	25	30

		Envelope	Concrete flyash %	40	35
			Rebar	#15M	#15M
			Category	Insulation	Insulation
			Material	Rigid Board Insulation (R20)	Polystyrene expanded
			Thickness (mm)	50	50
			Category	Vapour Barrier	Vapour Barrier
			Material	Fluid Applied Waterproofing	Polyethylene 6 mil
			Thickness	-	-
		2.1.3 Wall_Cast-in-Place_W3_300mm			
		Envelope	Length (mm)	120247	120247
			Height (mm)	4200	4200
			Thickness (mm)	300	300
			Concrete (MPa)	25	30
			Concrete flyash %	40	35
			Rebar	#25M Vert, #15M Horiz	#20M
			Category	Insulation	Insulation
			Material	Rigid Board Insulation (R20)	Polystyrene expanded
			Thickness (mm)	50	50
			Category	Vapour Barrier	Vapour Barrier
			Material	Fluid Applied Waterproofing	Polyethylene 6 mil
			Thickness	-	-
		2.1.4 Wall_Cast-in-Place_W5_300mm			
		Envelope	Length (mm)	128089	128089
			Height (mm)	4200	4200
			Thickness (mm)	300	300
			Concrete (MPa)	25	30
			Concrete flyash %	40	35
			Rebar	#15M Vert, #15M Horiz	#15M
			Category	Insulation	Insulation
			Material	Rigid Board Insulation (R20)	Polystyrene expanded
			Thickness (mm)	50	50
			Category	Vapour Barrier	Vapour Barrier
			Material	Fluid Applied Waterproofing	Polyethylene 6 mil
			Thickness	-	-
		2.1.5 Wall_Cast-in-Place_W6_350mm			
			Length (mm)	16654	19430
			Height (mm)	4200	4200
			Thickness (mm)	350	300
			Concrete (MPa)	25	30

		Envelope	Concrete flyash %	40	35
			Rebar	#30M/20M Vert, #15M Horiz	#20M
			Category	Insulation	Insulation
			Material	Rigid Board Insulation (R20)	Polystyrene expanded
			Thickness (mm)	50	50
			Category	Vapour Barrier	Vapour Barrier
			Material	Fluid Applied Waterproofing	Polyethylene 6 mil
			Thickness	-	-
		2.1.6 Wall_Cast-in-Place_W7_300mm			
		Envelope	Length (mm)	23680	23680
			Height (mm)	4200	4200
			Thickness (mm)	300	300
			Concrete (MPa)	25	30
			Concrete flyash %	40	35
			Rebar	#25M Vert, #15M Horiz	#20M
			Category	Insulation	Insulation
			Material	Rigid Board Insulation (R20)	Polystyrene expanded
			Thickness (mm)	50	50
			Category	Vapour Barrier	Vapour Barrier
			Material	Fluid Applied Waterproofing	Polyethylene 6 mil
			Thickness	-	-
		2.1.7 Wall_Cast-in-Place_W8_300mm			
		Envelope	Length (mm)	23100	23100
			Height (mm)	4200	4200
			Thickness (mm)	300	300
			Concrete (MPa)	25	30
			Concrete flyash %	40	35
			Rebar	#15M Vert, #15M Horiz	#15M
			Category	Insulation	Insulation
			Material	Rigid Board Insulation (R20)	Polystyrene expanded
			Thickness (mm)	50	50
			Category	Vapour Barrier	Vapour Barrier
			Material	Fluid Applied Waterproofing	Polyethylene 6 mil
			Thickness	-	-
		2.1.8 Wall_Cast-in-Place_W9_300mm_4200mmHeight			
			Length (mm)	14190	14190
			Height (mm)	4200	4200
			Thickness (mm)	300	300

		Envelope	Concrete (MPa)	25	30
			Concrete flyash %	40	35
			Rebar	#15M	#15M
			Category	Insulation	Insulation
			Material	Rigid Board Insulation (R20)	Polystyrene expanded
			Thickness (mm)	50	50
			Category	Vapour Barrier	Vapour Barrier
			Material	Fluid Applied Waterproofing	Polyethylene 6 mil
			Thickness	-	-
		2.1.9 Wall_Cast-in-Place_W9_300mm_5000mmHeight			
		Envelope	Length (mm)	14040	14040
			Height (mm)	5000	5000
			Thickness (mm)	300	300
			Concrete (MPa)	25	30
			Concrete flyash %	40	35
			Rebar	#15M	#15M
			Category	Insulation	Insulation
			Material	Rigid Board Insulation (R20)	Polystyrene expanded
			Thickness (mm)	50	50
			Category	Vapour Barrier	Vapour Barrier
			Material	Fluid Applied Waterproofing	Polyethylene 6 mil
			Thickness	-	-
		2.1.10 SW1_350m_4200mmHeight			
			Length (mm)	37119	43306
			Height (mm)	4200	4200
			Thickness (mm)	350	300
			Concrete (MPa)	35	30
			Concrete flyash %	35	35
			Rebar	#15M Vert, #15M Horiz	#15M
		2.1.11 SW1_350mm_5000mmHeight			
			Length (mm)	1020	1190
			Height (mm)	5000	5000
			Thickness (mm)	350	300
			Concrete (MPa)	35	30
			Concrete flyash %	35	35
			Rebar	#15M Vert, #15M Horiz	#15M
		2.1.12 SW5_430mm_4200mmHeight			
			Length (mm)	25345	36328
			Height (mm)	4200	4200

		Thickness (mm)	430	300
		Concrete (Mpa)	35	30
		Concrete flyash %	35	35
		Rebar	#15M Vert, #15M Horiz	#15M
	2.1.13 SW5_430mm_5000mmHeight			
		Length (mm)	5420	7769
		Height (mm)	5000	5000
		Thickness (mm)	430	300
		Concrete (MPa)	35	30
		Concrete flyash %	35	35
		Rebar	#15M Vert, #15M Horiz	#15M
2.2 Concrete Block Wall				
	2.2.1 Wall_E6.2_ConcreteBlock_152mmSteelStud			
		Length mm)	10760	10760
		Height (mm)	5000	5000
		Rebar	#15M	#15M
		Sheathing Type	-	-
		Stud Spacing	-	-
		Stud Weight	-	-
		Stud Thickness (mm)	39 x 152	39 x 152
	Envelope	Category	Insulation	Insulation
		Material	Mineral Wool Blanket Insulation	
		Thickness	150mm	
		Category	Vapour Barrier	Vapour Barrier
		Material	Vapour Retarder	Polyethylene 6 mil
		Thickness	-	-
		Category	Gypsum Board	Gypsum Board
		Material	Gypsum Board, GWB	
		Thickness	16mm	
	2.2.2 Wall_16_2H_CMU_Wall			
		Length (mm)	365593	365593
		Height (mm)	4786	4786
		Rebar	#15M	#15M
	Envelope	Category	Paint	Paint
		Material	-	Latex Water Based
	Door Opening	Number of Doors	71	71
		Door Type	Hollow Metal Door	Steel Interior Door
2.3 Curtain Wall				

2.3.1 Wall_CurtainWall_AllGlazing_12800mm Height			
Window Opening	Length (mm)	37560	37560
	Height (mm)	12800	12800
	Percent Viewable Glazing	100	100
	Percent Spandrel Panel	0	0
	Thickness of Insulation (mm)	-	-
	Spandrel Type (Metal/Glass)	Opaque Glass	Opaque Glass
	Number of Windows	27	24
	Total Window Area (m2)	39	39
	Frame Type	Aluminum Frame	Aluminum Frame
	Glazing Type	Low E Glazing 2SSG	Low E T in Glazing
	Operable/Fixed	Operable	Operable
2.3.2 Wall_CurtainWall_AllGlazing_14400mm Height			
Window Opening	Length (mm)	11540	11540
	Height (mm)	14400	14400
	Percent Viewable Glazing	100	100
	Percent Spandrel Panel	0	0
	Thickness of Insulation (mm)	-	-
	Spandrel Type (Metal/Glass)	Opaque Glass	Opaque Glass
	Number of Windows	12	12
	Total Window Area (m2)	17	17
	Frame Type	Aluminum Frame	Aluminum Frame
	Glazing Type	Low E Glazing 2SSG	Low E T in Glazing
	Operable/Fixed	Operable	Operable
2.3.3 Wall_CurtainWall_AllGlazing_17700mm Height			
	Length (mm)	5570	5570
	Height (mm)	17700	17700
	Percent Viewable Glazing	100	100
	Percent Spandrel Panel	0	0
	Thickness of Insulation (mm)	-	-
	Spandrel Type (Metal/Glass)	Opaque Glass	Opaque Glass
2.3.4 Wall_CurtainWall_Opaque Glass Spandrel_5090mm Height			
	Length (mm)	147630	147630
	Height (mm)	5090	5090

			Percent Viewable Glazing	79	79
			Percent Spandrel Panel	21	21
			Thickness of Insulation (mm)	140	140
			Spandrel Type (Metal/Glass)	Opaque Glass	Opaque Glass
		Door Opening	Number of Doors	16	16
			Door Type	Aluminum Glazed Door	Aluminum Exterior Door, 80% glazing
		2.3.5 Wall_CurtainWall_Opaque Glass Spandrel_4100mm Height			
			Length (mm)	171510	171510
			Height (mm)	4100	4100
			Percent Viewable Glazing	61	61
			Percent Spandrel Panel	39	39
			Thickness of Insulation (mm)	140	140
			Spandrel Type (Metal/Glass)	Opaque Glass	Opaque Glass
		Door Opening	Number of Doors	15	15
			Door Type	Aluminum Glazed Door	Aluminum Exterior Door, 80% glazing
		2.3.6 Wall_CurtainWall_Opaque Glass Spandrel_4410mm Height			
			Length (mm)	191496	191496
			Height (mm)	4410	4410
			Percent Viewable Glazing	54	54
			Percent Spandrel Panel	46	46
			Thickness of Insulation (mm)	140	140
			Spandrel Type (Metal/Glass)	Opaque Glass	Opaque Glass
		Window Opening	Number of Windows	28	28
			Total Window Area (m2)	40	40
			Frame Type	Aluminum Frame	Aluminum Frame
			Glazing Type	Low E Glazing 2SSG	Low E T in Glazing
			Operable/Fixed	Operable	Operable
		Door Opening	Number of Doors	7	7
			Door Type	Aluminum Glazed Door	Aluminum Exterior Door, 80% glazing
		2.3.7 Wall_CurtainWall_Opaque Glass Spandrel_2390mm Height			
			Length (mm)	647574	647574

			Height (mm)	2390	2390
			Percent Viewable Glazing	73	73
			Percent Spandrel Panel	27	27
			Thickness of Insulation (mm)	140	140
			Spandrel Type (Metal/Glass)	Opaque Glass	Opaque Glass
		Window Opening_Strip window	Number of Windows	196	196
			Total Window Area (m2)	294	294
			Frame Type	Aluminum Frame	Aluminum Frame
			Glazing Type	Low E Glazing 2SSG	Low E T in Glazing
			Operable/Fixed	Operable	Operable
		2.3.8 Curtain_Wall_Interior_4786mm_Height			
			Length (mm)	27920	27920
			Height (mm)	4786	4786
			Percent Viewable Glazing	100	100
			Percent Spandrel Panel	0	0
			Thickness of Insulation (mm)	-	-
			Spandrel Type (Metal/Glass)	-	-
		Door Opening	Number of Doors	7	7
			Door Type	Aluminum Glazed Door	Aluminum Exterior Door, 80% glazing
		2.3.9 Curtain_Wall_Interior_2700mm_Height			
			Length (mm)	223330	223330
			Height (mm)	2700	2700
			Percent Viewable Glazing	100	100
			Percent Spandrel Panel	0	0
			Thickness of Insulation (mm)	-	-
			Spandrel Type (Metal/Glass)	-	-
		Door Opening	Number of Doors	35	35
			Door Type	Solid Core Wood Door	Solid Wood Door
	2.4 Steel Stud				
		2.4.1 Wall 1.1_92mm_SteelStud			
			Length (mm)	360100	360100

		Envelope	Height (mm)	2700	2700
			Sheathing Type	None	None
			Stud Spacing	-	400 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 92	39 x 92
			Category	Gypsum Board	Gypsum Board
			Material	Type X Gypsum Board	Gypsum Fire Rated Type X 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Acustic Insulation	Fiberglass Balt
			Thickness	89mm	89mm
			Category	Gypsum Board	Gypsum Board
			Material	Type X Gypsum Board	Gypsum Fire Rated Type X 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Paint	Paint
			Material	-	Latex Water Based
		Door Opening_Metal Doors	Number of Doors	87	87
			Door Type	Hollow Metal Door	Steel Interior Door
		2.4.2 Wall 1.1_92mm_SteelStud			
		Envelope	Length (mm)	771481	771481
			Height (mm)	2700	2700
			Sheathing Type	None	None
			Stud Spacing	-	400 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 92	39 x 92
			Category	Gypsum Board	Gypsum Board
			Material	Type X Gypsum Board	Gypsum Fire Rated Type X 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Acustic Insulation	Fiberglass Balt
			Thickness	89mm	89mm
			Category	Gypsum Board	Gypsum Board
			Material	Type X Gypsum Board	Gypsum Fire Rated Type X 5/8"

		Door Opening_Wood Doors	Thickness	16mm	25.381mm-507.614mm
			Category	Paint	Paint
			Material	-	Latex Water Based
			Number of Doors	220	220
			Door Type	Solid Core Wood Door	Solid Wood Door
		2.4.3 Wall 1.2_152mm_SteelStud			
		Envelope	Length (mm)	97289	97289
			Height (mm)	2700	2700
			Sheathing Type	None	None
			Stud Spacing	-	400 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 152	39 x 152
			Category	Gypsum Board	Gypsum Board
			Material	Type X Gypsum Board	Gypsum Fire Rated Type X 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Acustic Insulation	Fiberglass Balt
			Thickness	89mm	89mm
			Category	Gypsum Board	Gypsum Board
			Material	Type X Gypsum Board	Gypsum Fire Rated Type X 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Paint	Paint
			Material	-	Latex Water Based
		Door Opening	Number of Doors	20	20
			Door Type	Solid Core Wood Door	Solid Wood Door
		2.4.4 Wall 2_152mm_SteelStud_ At Washrooms			
		Envelope	Length (mm)	39142	39142
			Height (mm)	2700	2700
			Sheathing Type	None	None
			Stud Spacing	-	400 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 152	39 x 152
			Category	Gypsum Board	Gypsum Board
			Material	Glass Mat Gypsum Tile Backer Board	Gypsum Moisture Resistant 5/8"

			Thickness	16mm	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Acustic Insulation	Fiberglass Balt
			Thickness	150mm	150mm
			Category	Gypsum Board	Gypsum Board
			Material	Type X Gypsum Board	Gypsum Moisture Resistant 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Paint	Paint
			Material	-	Latex Water Based
		Door Opening	Number of Doors	1	1
			Door Type	Solid Core Wood Door	Solid Wood Door
		2.4.5 Wall 3_92mm_SteelStud			
		Envelope	Length (mm)	145114	145114
			Height (mm)	2700	2700
			Sheathing Type	None	None
			Stud Spacing	-	600 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 92	39 x 92
			Sheathing Type	None	None
			Stud Spacing	-	400 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	Furring Channel	39 x 92
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Acustic Insulation	Fiberglass Balt
			Thickness	89mm	89mm
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Paint	Paint

		Door Opening	Material	-	Latex Water Based
			Number of Doors	23	23
			Door Type	Solid Core Wood Door	Solid Wood Door
		2.4.6 Wall 4_92mm_SteelStud			
		Envelope	Length (mm)	24888	24888
			Height (mm)	2700	2700
			Sheathing Type	None	None
			Stud Spacing	-	400 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 92	39 x 92
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Acustic Insulation	Fiberglass Balt
			Thickness	89mm	89mm
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Paint	Paint
			Material	-	Latex Water Based
		Door Opening_Metal Doors	Number of Doors	6	6
			Door Type	Hollow Metal Door	Steel Interior Door
		2.4.7 Wall 4_92mm_SteelStud			
		Envelope	Length (mm)	586627	586627
			Height (mm)	2700	2700
			Sheathing Type	None	None
			Stud Spacing	-	400 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 92	39 x 92
			Category	Gypsum Board	Gypsum Board

			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Acustic Insulation	Fiberglass Balt
			Thickness	89mm	89mm
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Paint	Paint
			Material	-	Latex Water Based
		Door Opening_Wood Doors	Number of Doors	7	7
			Door Type	Solid Core Wood Door	Solid Wood Door
		2.4.8 Wall 5_152mm_SteelStud			
		Envelope	Length (mm)	94592	94592
			Height (mm)	3986	3986
			Sheathing Type	None	None
			Stud Spacing	-	400 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 152	39 x 152
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Acustic Insulation	Fiberglass Balt
			Thickness	89mm	89mm
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm

			Category	Paint	Paint
			Material	-	Latex Water Based
		Door Opening	Number of Doors	4	4
			Door Type	Solid Core Wood Door	Solid Wood Door
		2.4.9 Wall 7_152mm_SteelStud_ At Washrooms			
		Envelope	Length (mm)	54365	54365
			Height (mm)	2700	2700
			Sheathing Type	None	None
			Stud Spacing	-	400 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 152	39 x 152
			Category	Gypsum Board	Gypsum Board
			Material	Glass Mat Gypsum Tile Backer Board	Gypsum Moisture Resistant 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Acustic Insulation	Fiberglass Balt
			Thickness	89mm	89mm
			Category	Gypsum Board	Gypsum Board
			Material	Glass Mat Gypsum Tile Backer Board	Gypsum Moisture Resistant 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Paint	Paint
			Material	-	Latex Water Based
		2.4.10 Wall 8_203mm_SteelStud_ Plumbing Chase			
		Envelope	Length (mm)	25123	25123
			Height (mm)	2700	2700
			Sheathing Type	None	None
			Stud Spacing	-	400 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 92	39 x 92
			Sheathing Type	None	None
			Stud Spacing	-	400 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 92	39 x 92
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm

			Category	Gypsum Board	Gypsum Board
			Material	Glass Mat Gypsum Tile Backer Board	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Acustic Insulation	Fiberglass Balt
			Thickness	89mm	89mm
			Category	Insulation	Insulation
			Material	Acustic Insulation	Fiberglass Balt
			Thickness	89mm	89mm
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Paint	Paint
			Material	-	Latex Water Based
		2.4.11 Wall 9_152mm_SteelStud_BrickCladding			
		Envelope	Length (mm)	69307	69307
			Height (mm)	3986	3986
			Sheathing Type	MDF Paneling	OSB
			Stud Spacing	-	400 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 152	39 x 152
			Category	Cladding	Cladding
			Material	Brick Veneer Masonry	Brick-
			Thickness (mm)	90	90
			Category	Insulation	Insulation
			Material	Acustic Insulation	Fiberglass Balt
			Thickness	150mm	150mm
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Paint	Paint
			Material	-	Latex Water Based
		Door Opening	Number of Doors	2	2
			Door Type	Solid Core Wood Door	Solid Wood Door
		2.4.12 Wall 9.1_152mm_SteelStud_BrickCladding			
			Length (mm)	29357	29357

		Envelope	Height (mm)	3986	3986
			Sheathing Type	MDF Paneling	OSB
			Stud Spacing	-	400 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 152	39 x 152
			Category	Cladding	Cladding
			Material	Brick Veneer Masonry	Brick-
			Thickness (mm)	90	90
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Acustic Insulation	Fiberglass Balt
			Thickness	150mm	150mm
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Paint	Paint
			Material	-	Latex Water Based
		Door Opening	Number of Doors	3	3
			Door Type	Solid Core Wood Door	Solid Wood Door
		2.4.13 Wall 9.4_92mm_SteelStud_BrickCladding			
		Envelope	Length (mm)	8804	8804
			Height (mm)	3986	3986
			Sheathing Type	MDF Paneling	OSB
			Stud Spacing	-	400 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 92	39 x 92
			Category	Cladding	Cladding
			Material	Brick Veneer Masonry	Brick-
			Thickness	90	90
			Category	Insulation	Insulation
			Material	Acustic Insulation	Fiberglass Balt
			Thickness	150mm	150mm
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWS	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-

			507.614mm
2.4.14 Wall 10_64mm_SteelStud			
Envelope	Length (mm)	272373	272373
	Height (mm)	2700	2700
	Sheathing Type	None	None
	Stud Spacing	-	600 o.c.
	Stud Weight	-	25Ga
	Stud Thickness (mm)	39 x 64	39 x 92
	Category	Gypsum Board	Gypsum Board
	Material	25mm Type X Gypsum Board	Gypsum Fire Rated Type X 5/8"
	Thickness	25mm	25.381mm-507.614mm
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Board, GWB	Gypsum Regular 5/8"
	Thickness	16mm	25.381mm-507.614mm
	Category	Paint	Paint
	Material	-	Latex Water Based
Door Opening	Number of Doors	54	54
	Door Type	Hollow Metal Door	Steel Interior Door
2.4.15 Wall 11.1_92mm_SteelStud			
Envelope	Length (mm)	126760	126760
	Height (mm)	2700	2700
	Sheathing Type	None	None
	Stud Spacing	-	400 o.c.
	Stud Weight	-	25Ga
	Stud Thickness (mm)	39 x 92	39 x 92
	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Board, GWB	Gypsum Regular 5/8"
	Thickness	16mm	25.381mm-507.614mm
	Category	Paint	Paint
	Material	-	Latex Water Based
Door Opening	Number of Doors	2	2
	Door Type	Solid Core Wood Door	Solid Wood Door
2.4.16 Wall 11.2_152mm_SteelStud			
	Length (mm)	139379	139379
	Height (mm)	2700	2700
	Sheathing Type	None	None
	Stud Spacing	-	400 o.c.

			Stud Weight	-	25Ga
			Stud Thickness (mm)	39 x 152	39 x 152
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWB	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
			Category	Paint	Paint
			Material	-	Latex Water Based
		2.4.17 Wall 12.1_22mm_FurringChannel			
			Length (mm)	58685	58685
			Height (mm)	4200	4200
			Sheathing Type	None	None
			Stud Spacing	-	600 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	22mm Furring Channel	39 x 92
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWB	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
		Door Opening	Number of Doors	6	6
			Door Type	Solid Core Wood Door	Solid Wood Door
		2.4.18 Wall 12.2_38mm_FurringChannel			
			Length (mm)	133371	133371
			Height (mm)	4200	4200
			Sheathing Type	None	None
			Stud Spacing	-	600 o.c.
			Stud Weight	-	25Ga
			Stud Thickness (mm)	38mm Furring Channel	39 x 92
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWB	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
		Door Opening	Number of Doors	4	4
			Door Type	Hollow Metal Door	Steel Interior Door
		2.4.19 Wall E3_152mm_SteelStud_12600mmHeight			
			Length (mm)	12830	12830
			Height (mm)	12600	12600
			Sheathing Type	Exterior Sheathing	OSB
			Stud Spacing	-	400 o.c.
			Stud Weight	-	20Ga
			Stud Thickness	39 x 152	39 x 152

			(mm)		
		Envelope	Category	Cladding	Cladding
			Material	Brick Veneer Masonry	Brick-
			Thickness	90	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Mineral Wool Board Insulation (R20)	Rockwool Batt
			Thickness	70.00	70.00
			Category	Vapour Barrier	Vapour Barrier
			Material	Air Vapour Moisture Barrier	Polyethylene 6mil
			Thickness	-	
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWB	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
		2.4.20 Wall E3_152mm_SteelStud_1810mmHeight			
		Envelope	Length (mm)	393570	393570
			Height (mm)	1810	1810
			Sheathing Type	Exterior Sheathing	OSB
			Stud Spacing	-	400 o.c.
			Stud Weight	-	20Ga
			Stud Thickness (mm)	39 x 152	39 x 92
			Category	Cladding	Cladding
			Material	Brick Veneer Masonry	Brick-
			Thickness (mm)	90	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Mineral Wool Board Insulation (R20)	Rockwool Batt
			Thickness	70.00	70.00
			Category	Vapour Barrier	Vapour Barrier
			Material	Air Vapour Moisture Barrier	Polyethylene 6mil
			Thickness	-	
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWB	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
		2.4.21 Wall E3_152mm_SteelStud_910mmHeight			
			Length (mm)	11352	11352
			Height (mm)	910	910

		Envelope	Sheathing Type	Exterior Sheathing	OSB
			Stud Spacing	-	400 o.c.
			Stud Weight	-	20Ga
			Stud Thickness (mm)	39 x 152	39 x 92
			Category	Cladding	Cladding
			Material	Brick Veneer Masonry	Brick-
			Thickness (mm)	90	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Mineral Wool Board Insulation (R20)	Rockwool Batt
			Thickness	70.00	70.00
			Category	Vapour Barrier	Vapour Barrier
			Material	Air Vapour Moisture Barrier	Polyethylene 6mil
			Thickness	-	
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWB	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
		2.4.22 Wall E4_152mm_SteelStud_12600mmHeight			
		Envelope	Length (mm)	3606	3606
			Height (mm)	12600	12600
			Sheathing Type	Exterior Sheathing	OSB
			Stud Spacing	-	400 o.c.
			Stud Weight	-	20Ga
			Stud Thickness (mm)	39 x 152	39 x 92
			Category	Cladding	Cladding
			Material	Composite Cement Panels	Fiber Cement Siding
			Thickness (mm)	25	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Mineral Wool Board Insulation (R20)	Rockwool Batt
			Thickness	70.00	70.00
			Category	Vapour Barrier	Vapour Barrier
			Material	Air Vapour Moisture Barrier	Polyethylene 6mil
			Thickness	-	

			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWB	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
		2.4.23 Wall E4_152mm_SteelStud_1810mmHeight			
		Envelope	Length (mm)	386616	386616
			Height (mm)	1810	1810
			Sheathing Type	Exterior Sheathing	OSB
			Stud Spacing	-	400 o.c.
			Stud Weight	-	20Ga
			Stud Thickness (mm)	39 x 152	39 x 92
			Category	Cladding	Cladding
			Material	Composite Cement Panels	Fiber Cement Siding
			Thickness (mm)	25	25.381mm-507.614mm
			Category	Insulation	Insulation
			Material	Mineral Wool Board Insulation (R20)	Rockwool Batt
			Thickness (mm)	70.00	70.00
			Category	Vapour Barrier	Vapour Barrier
			Material	Air Vapour Moisture Barrier	Polyethylene 6mil
			Thickness	-	
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board, GWB	Gypsum Regular 5/8"
			Thickness	16mm	25.381mm-507.614mm
3 Columns and Beams					
	3.1 Concrete Columns				
		3.1.1 Column_Concrete_Beam_N/A_Basement			
			Number of Beams	0	0
			Number of Columns	55	55
			Floor to floor height (m)	4.2	4.2
			Bay sizes (m)	9.29	9.29
			Supported span (m)	9.29	9.29
			Supported Area (m2)	86.29	86.31
			Live load (kPa)	4.8	4.8
		3.1.2 Column_Concrete_Beam_Level1			
			Number of Beams	16	16
			Number of Columns	34	34

			Floor to floor height (m)	5	5
			Bay sizes (m)	5.53	5.53
			Supported span (m)	5.53	5.53
			Supported Area (m2)	30.63	30.63
			Live load (kPa)	4.8	4.8
		3.1.3 Column_Concrete_Beam_N/A_Level2			
			Number of Beams	0	0
			Number of Columns	30	30
			Floor to floor height (m)	4.2	4.2
			Bay sizes (m)	6.95	6.95
			Supported span (m)	6.95	6.95
			Supported Area (m2)	48.34	48.34
			Live load (kPa)	3.6	3.6
		3.1.4 Column_Concrete_Beam_N/A_Level3			
			Number of Beams	0	0
			Number of Columns	38	38
			Floor to floor height (m)	4.2	4.2
			Bay sizes (m)	6.30	6.30
			Supported span (m)	6.30	6.30
			Supported Area (m2)	39.67	39.7
			Live load (kPa)	3.6	3.6
		3.1.5 Column_Concrete_Beam_N/A_Level4			
			Number of Beams	0	0
			Number of Columns	38	38
			Floor to floor height (m)	4.2	4.2
			Bay sizes (m)	6.30	6.30
			Supported span (m)	6.30	6.30
			Supported Area (m2)	39.67	39.7
			Live load (kPa)	3.6	3.6
	3.2 Wood Columns				
		3.2.1 Column_GL_Wood_Level1			
			Number of Beams	0	0
			Number of Columns	67	67
			Floor to floor height (m)	5	5
			Bay sizes (m)	5.53	5.53
			Supported span (m)	5.53	5.53
			Supported Area (m2)	30.63	30.63
			Live load (kPa)	4.80	4.8
		3.2.2 Column_GL_Wood_Level2			
			Number of Beams	0	0

			Number of Columns	34	34
			Floor to floor height (m)	4.2	4.2
			Bay sizes (m)	6.95	6.95
			Supported span (m)	6.95	6.95
			Supported Area (m2)	48.34	48.34
			Live load (kPa)	3.6	3.6
		3.2.3 Column_GL_Wood_Level3			
			Number of Beams	0	0
			Number of Columns	40	40
			Floor to floor height (m)	4.2	4.2
			Bay sizes (m)	6.30	6.30
			Supported span (m)	6.30	6.30
			Supported Area (m2)	39.67	39.67
			Live load (kPa)	3.6	3.6
		3.2.4 Column_Wood_Level4			
			Number of Beams	0	0
			Number of Columns	40	40
			Floor to floor height (m)	4.2	4.2
			Bay sizes (m)	6.30	6.30
			Supported span (m)	6.30	6.30
			Supported Area (m2)	39.67	39.67
			Live load (kPa)	3.6	3.6
		3.2.5 Column_Wood_Level5			
			Number of Beams	0	0
			Number of Columns	34	34
			Floor to floor height (m)	4.2	4.2
			Bay sizes (m)	7.23	7.23
			Supported span (m)	7.23	7.23
			Supported Area (m2)	52.21	52.21
			Live load (kPa)	3.6	3.6
4 Floors					
	4.1 Insulated suspended slab				
		4.1.1 Floor_Concrete_Suspendedslab_193mm			
			Width(m)	88	88.05128205
			Span (m)	9.75	9.75
			Concrete (Mpa)	35	35
			Concrete flyash %	0.25	0.25
			Live load (kPa)	4.8	4.80
		4.1.2 Floor_Wood_SuspendedSlab_89mm			

			Thickness (m)	0.089	0.089
			Area (m2)	3056	3056
			Volume (m3)	271.984	271.984
			Live load (kPa)	3.3	3.3
		4.1.3 Floor_Insulation_SuspendedSlab_25mm			
			Thickness(m)	0.025	0.025
			Area(m2)	3096	3096
			Live load (kPa)	3.3	3.3
		4.1.4 Floor_Concrete_SuspendedSlab_100mm			
			Width(m)	370.2769231	370.2769231
			Span (m)	9.75	9.75
			Concrete (Mpa)	35	35
			Concrete flyash %	0.25	0.25
			Live load (kPa)	3.3	3.30
5 Roof					
	5.1 Roof insulation				
		5.1.1 Roof_insulation			
			Area (m2)	718	
			Thckness	0.125	
			thickness125=25x5 - Area(m2)	3590	
			Live load (psf)	1.3	
	5.2 Cross laminated timber				
		5.2.1 Roof_CrossLaminatedTimber			
			Area (m2)	708	
			Thickness	0.152	
			Volume	107.616	
			Life load (kPa)	1.3	
6 Extra Basic Materials					
	6.1 Steel				
		6.1.1 Columns_HSS_350W(Total Sum)			
			Hollow Structural Steel (tonnes)	23.33	23.33
	6.2 Wood				
		6.2.1 Columns_GL_Wood(Total Sum)			
			Glulam Beams (m3)	17.03	17.03

Appendix B: IE Input Assumptions Document

Assembly Group	Assembly Type	Assembly Name	Specific Assumptions
2 Walls	The length of the concrete cast-in-place walls needed adjusting to accommodate the wall thickness limitation in the Impact Estimator. It was assumed that interior steel stud walls were light gauge (25Ga) and exterior steel stud walls were heavy gauge (20Ga). According to the general notes in the structural plans, normal weight concrete for retaining walls is 25MPa and for shear walls 35Mpa. The IE allowed for 20, 30 or 60MPa, so 30MPa was used to model concrete walls. In the other hand, fly ash content for retaining walls was modeled as 40%, which was the closest value for the actual content of 35%.		
	2.1 Cast In Place		
		2.1.6 Wall_Cast-in-Place_W2_250mm	This wall was increased by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/200mm] = (76980) * [(250)/200] = 96225 mm
		2.1.7 Wall_Cast-in-Place_W6_350mm	This wall was increased by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/300mm] = (16654) * [(350)/300] = 19430 mm
		2.1.8 Wall_Cast-in-Place_SW1_350mm_4200mmHeight	This wall was increased by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/300mm] = (37119) * [(350)/300] = 43306 mm

	2.1.8 Wall_Cast-in-Place_SW1_350mm_5000mmHeight	This wall was increased by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/300mm] = (1020) * [(350)/300] = 1190 mm
	2.1.8 Wall_Cast-in-Place_SW5_430mm_4200mmHeight	This wall was increased by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/300mm] = (5420) * [(430)/300] = 7769 mm
	2.1.8 Wall_Cast-in-Place_SW5_430mm_5000mmHeight	This wall was increased by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/300mm] = (25345) * [(430)/300] = 36328 mm
2.2 Concrete Block Wall		
	2.2.1 Wall_E6.2_ConcreteBlock_152mmSteelStud	Polyethylene was assumed to be 6mil because the this is a below ground wall.
	2.2.2 Wall_16_2H_CMU_Wall	Steel Interior Door was the closest estimation to the observed doors in this wall. Latex Water Based was the painting assumed to be used as finishing material.
2.3 Curtain Wall		
	2.3.4 Wall_CurtainWall_Opaque Glass Spandrel_5090mm Height	Aluminum Door with 80% glazing was the closest estimtation to the observed doors in this wall.
	2.3.5 Wall_ CurtainWall_Opaque Glass Spandrel_4100mm Height	Aluminum Door with 80% glazing was the closest estimtation to the observed doors in this wall.
	2.3.6 Wall_CurtainWall_Opaque Glass Spandrel_4410mm Height	Aluminum Door with 80% glazing was the closest estimtation to the observed doors in this wall.
	2.3.8 Wall_Curtain_Wall_Interior_4786mm_Height	Aluminum Door with 80% glazing was the closest estimtation to the observed doors in this wall.
2.4 Steel		

	Stud		
		2.4.1 Wall 1.1_92mm_SteelStud	Since this was an interior wall, no sheathing was considered. Gypsum Fire Rated Type X 5/8'' was the gypsum type used in the IE to model this wall. This type of wall had 87 hollow metal doors and 220 solid wood doors, so the total length of this wall was divided proporcionally to account for the two different type of doors. Acoustic insulation was modeled as fiberglass batt, as it was the closest surrogate to this kind of material. Latex Water Based was the painting assumed to be used as finishing material.
		2.4.4 Wall 2_152mm_SteelStud_ At Washrooms	Since this was an interior wall, no sheathing was considered. Gypsum Moisture Resistant 5/8''' was the closest element found in the IE to model this wall. Acoustic insulation was modeled as fiberglass batt, as it was the closest surrogate to this kind of material.
		2.4.5 Wall 3_92mm_SteelStud	Since this was an interior wall, no sheathing was considered. Acoustic insulation was modeled as fiberglass batt, as it was the closest surrogate to this kind of material. Latex Water Based was the painting assumed to be used as finishing material. Furring channel was replaced by a 92mm stud, as this is theclosest thickness provided by IE.
		2.4.6 Wall 4_92mm_SteelStud	Since this was an interior wall, no sheathing was considered. Acoustic insulation was modeled as fiberglass batt, as it was the closest surrogate to this kind of material. Latex Water Based was the painting assumed to be used as finishing material.
		2.4.7 Wall 4_92mm_SteelStud	Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate. Since this was an interior wall, no sheathing was considered. No information was provided for the type of painting used, so Latex Water Based was assumed to be used when painting was indicated in the architectural plans.
		2.4.8 Wall 5_152mm_SteelStud	Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate. Since this was an interior wall, no sheathing was considered. Latex Water Based was the painting assumed to be used as finishing material.
		2.4.9 Wall 7_152mm_SteelStud_ At Washrooms	Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate. Since this was an interior wall, no sheathing was considered. No information was provided for the type of painting used, so Latex Water Based was assumed to be used when painting was indicated in the architectural plans.

		2.4.10 Wall 8_203mm_SteelStud_ Plumbing Chase	Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate. Since this was an interior wall, no sheathing was considered. Latex Water Based was the painting assumed to be used as finishing material.
		2.4.11 Wall 9_152mm_SteelStud_BrickCladding	Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate. MDF Panelling sheathing was replaced by OSB sheating type in the IE. No information was provided for the type of painting used, so Latex Water Based was assumed to be used when painting was indicated in the architectural plans.
		2.4.12 Wall 9.1_152mm_SteelStud_Brick Cladding	Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate. MDF Panelling sheathing was replaced by OSB sheating type in the IE. No information was provided for the type of painting used, so Latex Water Based was assumed to be used when painting was indicated in the architectural plans.
		2.4.13 Wall 9.4_92mm_SteelStud_Brick Cladding	Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate. MDF Panelling sheathing was replaced by OSB sheating type in the IE. No information was provided for the type of painting used, so Latex Water Based was assumed to be used when painting was indicated in the architectural plans.
		2.4.14 Wall 10_64mm_SteelStud	64mm steel stud was replaced by a 92mm stud, as this is the closest thickness provided by IE. Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate. Gypsum Fire Rated Type X 5/8'' was the gypsum type used in the IE to model this wall. No information was provided for the type of painting used, so Latex Water Based was assumed to be used when painting finishing was indicated in the architectural plans.
		2.4.15 Wall 11.1_92mm_SteelStud	Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate. Since this was an interior wall, no sheathing was considered. No information was provided for the type of painting used, so Latex Water Based was assumed to be used when painting was indicated in the architectural plans.

2.4.16 Wall 11.1_92mm_SteelStud	Acoustic Batt insulation was not available in the Impact Estimator so Fiberglass Batt was selected as the closest surrogate. Since this was an interior wall, no sheathing was considered. No information was provided for the type of painting used, so Latex Water Based was assumed to be used when painting was indicated in the architectural plans.
2.4.17 Wall 12.1_22mm_FurringChannel	22mm Furring channel was replaced by a 92mm stud, as this is the closest thickness provided by IE. Since this was an interior wall, no sheathing was considered. No information was provided for the type of painting used, so Latex Water Based was assumed to be used when painting was indicated in the architectural plans.
2.4.18 Wall 12.2_38mm_FurringChannel	38mm Furring channel was replaced by a 92mm stud, as this is the closest thickness provided by IE. Since this was an interior wall, no sheathing was considered. No information was provided for the type of painting used, so Latex Water Based was assumed to be used when painting was indicated in the architectural plans.
2.4.19 Wall E3_152mm_SteelStud_12600mmHeight	Mineral Wool Board Insulation (R20) was not available in the Impact Estimator so Rockwool Batt was selected as the closest surrogate. Exterior sheating indicated in the plans was assumed to be OSB. Air Vapour Moisture Barrier was assumed to be Polyethylene 6mil.
2.4.20 Wall E3_152mm_SteelStud_1810mmHeight	Mineral Wool Board Insulation (R20) was not available in the Impact Estimator so Rockwool Batt was selected as the closest surrogate. Exterior sheating indicated in the plans was assumed to be OSB. Air Vapour Moisture Barrier was assumed to be Polyethylene 6mil.
2.4.21 Wall E3_152mm_SteelStud_910mmHeight	Mineral Wool Board Insulation (R20) was not available in the Impact Estimator so Rockwool Batt was selected as the closest surrogate. Exterior sheating indicated in the plans was assumed to be OSB. Air Vapour Moisture Barrier was assumed to be Polyethylene 6mil.
2.4.22 Wall E4_152mm_SteelStud_12600mmHeight	In the cladding category Composite Cement Panels were not available in the IE so Fiber Cement Siding were selected as the closest surrogate. Mineral Wool Board Insulation (R20) was not available in the Impact Estimator so Rockwool Batt was selected as the closest surrogate. Exterior sheating indicated in the plans was assumed to be OSB. Air Vapour Moisture Barrier was assumed to be Polyethylene 6mil.
2.4.23 Wall E4_152mm_SteelStud_1810mmHeight	In the cladding category Composite Cement Panels were not available in the IE so Fiber Cement Siding were selected as the closest surrogate. Mineral Wool Board Insulation (R20) was not available in the Impact Estimator so Rockwool Batt was selected as the closest surrogate. Exterior sheating indicated in the plans was assumed to be OSB. Air Vapour Moisture Barrier was assumed to be Polyethylene 6mil.

3 Columns and Beams			
		3.1 Concrete Columns	
			3.1.1 Column_Concrete_Beam_N/A_Basement
			Bay size & supported span are found using the square root of the total floor area divided by the number of columns. ie: Square root(Total floor area/number of coloumns).
			3.1.2 Column_Concrete_Beam_Level1
			Same assumption as 3.1.1. Floor is supported by two types of columns, so the supported span and bay size are adjusted to be proportional to fraction of total amount of columns that this type of column makes up.
			3.1.3 Column_Concrete_Beam_N/A_Level2
			Same assumption as 3.1.2.
			3.1.4 Column_Concrete_Beam_N/A_Level3
			Same assumption as 3.1.2.
			3.1.5 Column_Concrete_Beam_N/A_Level4
			Same assumption as 3.1.2.
		3.2 Wood Columns	
			3.2.1 Column_GL_Wood_Level1
			Same assumption as 3.1.2.
			3.2.2 Column_GL_Wood_Level2
			Same assumption as 3.1.2.
			3.2.3 Column_GL_Wood_Level3
			Same assumption as 3.1.2.
			3.2.4 Column_Wood_Level4
			Same assumption as 3.1.2.
			3.2.5 Column_Wood_Level5
			Same assumption as 3.1.1.

Assembly Group	Assembly Type	Assembly Name	Specific Assumptions
4 Floor			
	4.1 Insulated Suspended Slab		
		4.1.1 Floor_Concrete_Suspendedslab_193mm	
			Weighted average thickness calculation

<table>
<tr><td></td><td></td><td></td><td>
<table>
<tr><td></td><td>Thick</td><td>Length</td><td></td></tr>
<tr><td>south</td><td>300</td><td>=8*6</td><td>down to basement</td></tr>
<tr><td>north</td><td>365</td><td>=3.5*6</td><td></td></tr>
<tr><td>north</td><td>250</td><td>=2.5*6</td><td></td></tr>
<tr><td></td><td></td><td>=SUM (F80:F83)</td><td></td></tr>
<tr><td></td><td></td><td>=F80/F$9</td><td>=E80*F85</td></tr>
<tr><td></td><td></td><td>=F81/F$9</td><td>=E81*F86</td></tr>
<tr><td></td><td></td><td>=F82/F$9</td><td>=E82*F87</td></tr>
<tr><td></td><td>Weighted Average</td><td>=SUM (G85:G90)</td><td></td></tr>
</table>
Different thickness in same floor. Floors overlap for 6 meters. Weighted average thickness taken depending on length of thickness on level

Wood - Composite shear connector not taken into account (pg 73 struc)

Area is taken from multipliers of length and width
Shear connector not accounted in between floors because the overall volume of the materials are the same for concrete and wood. Composite not measured because unsure of its components.

Composition
<table>
<tr><td>Concrete</td><td>193</td></tr>
<tr><td>Rigid insulation</td><td>25</td></tr>
<tr><td>Laminated stramb lumber</td><td>89</td></tr>
</table>
</td></tr>
</table>

			Weighted average floor thickness =SUM (E96:E98) Extra thickness completed with concrete
		4.1.2 Floor_Wood_SuspendedSlab_89mm	
			Composition **Concrete** **193** Rigid insulation 25 Laminated stramb lumber 89 Weighted average floor thickness =SUM (E105:E107) Different thickness in same floor. Floors overlap for 6 meters. Weighted average thickness taken depending on length of thickness on level Wood - Composite shear connector not taken into account (pg 73 struc) Area is taken from multipliers of length and width Shear connector not accounted in between floors because the overall volume of the materials are the same for concrete and wood. Composite not measured because unsure of its components. Wood stairs accounted in the floor with same characteristics
		4.1.3 Floor_Insulation_SuspendedSlab_25mm	
			Composition

		Concrete 193 Rigid insulation 25 Laminated stramb lumber 89 Weighted average floor thickness =SUM (E117:E119) Different thickness in same floor. Floors overlap for 6 meters. Weighted average thickness taken depending on length of thickness on level Wood - Composite shear connector not taken into account (pg 73 struc) Area is taken from multipliers of length and width Shear connector not accounted in between floors because the overall volume of the materials are the same for concrete and wood. Composite not measured because unsure of its components. Rigid Board Insulation: Foam Polyisocyanurate
	4.1.4 Floor_Concrete_SuspendedSlab_100mm	
		Wood - Composite shear connector not taken into account (pg 73 struc) Auditorium stairs accounted in concrete. Same conditions. Floor thickness 214mm Concrete 100 Rigid insulation 25 Laminated stramb lumber 89
4.2 Slab on grade		

		4.2.1 Concrete_SOB_200mm	
			Span and width taken as total average due to several area segments. Concrete in basement is treated as foundation concrete for Flyash content and Strength Auditorium SOB thickness 200mm Stairs accunted together for the whole building.
		4.2.2 Concrete_SOB_125mm	
			Span and width taken as total average due to several area segments. Concrete in basement is treated as foundation concrete for Flyash content and Strength Auditorium SOB thickness 200mm Stairs accunted together for the whole building.
5 Roof			
	5.1 Roof insulation		
		5.1.1 Roof_insulation	
			Future green roof is same composition as rest of roof but covered with vegetation material not taken into account. Insulation material: Foam Polyisocyanurate
	5.2 Cross laminated timber		
		5.2.1 Roof_CrossLaminatedTimber	
			Cross laminated timber is used throughout the roof. No concrete on structural drawings Concrete was not used because architectural and structural drawings are incomplete. Two types of roofs were showned in the deck of level 5 accounted as roof. Future green roof type of roof was selected.