UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Life Cycle Assessment: Earth Sciences Building

Joshua Power

University of British Columbia

CIVL 498C

November 01, 2013

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

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Executive Summary

This study, a life cycle assessment (LCA) of the Earth Sciences Building (ESB) serves as a contribution to the on-going process of creating a LCA building database at UBC while also showing the environmental impacts associated with the product and construction process stages of the building. These stages include: raw material extraction, transportation of materials to the manufacturer, manufacturing, transportation to the construction site, and the construction-installation process.

On-Screen Takeoff and the Athena Impact Estimator for Buildings software were utilized to measure material quantities in the ESB and estimate the environmental impacts of these materials. The building materials were classified according to the Canadian Institute of Quantity Surveyors Level 3 Elements format in order to standardize the elements in a way that enables comparison and analysis.

The results of the assessment show that the Earth Sciences building contributes higher to all impact categories compared to the class benchmark, excluding Ozone Layer Depletion. The ESB performs relatively well when comparing cost to GWP for various buildings on campus. To improve the previous model and recommend future improvements, data adjustments and substitutions were made and uncertainties in the analysis were discussed.

Table of Contents

List of Figures

List of Tables

1.0 General Information on the Assessment

1.1 Purpose of the Assessment

Performing a life cycle assessment on the Earth Sciences Building is an effective method of quantifying the environmental performance of the building.

1.1.1 Intended Use of the Assessment

The intended use of this assessment, alongside other LCA assessments from the CIVL 489C class, is to contribute to the UBC LCA benchmark for the construction of new buildings at the University of British Columbia.

1.1.2 Reasons for Carrying Out the Study

This study was completed to promote the development of the UBC LCA database and is intended to provide future scholars and green building practitioners with the necessary information to carry out similar LCA studies.[1]

1.1.3 Intended Audience

The results of this study are intended for building practitioners and policy makers at UBC as well as students and professionals who will be continuing the advancement of the UBC LCA database. This study may also be useful for external organizations interested in developing LCA framework for buildings.

1.1.4 Intended for Comparative Assertions

This study will contribute to the UBC LCA database and is intended for comparative assertions alongside other UBC building LCAs in the creation of a UBC building benchmark. By using the Athena Impact Estimator for Buildings (IE), and conforming to the same goal and scope, the studies created as part of the contribution to the UBC LCA database are comparable because the assumptions and context of each of these studies are equivalent.[2]

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[1] ESSB Final Report 2012
[2] Life cycle assessment- Requirements and guidelines (ISO 14044:2006)

1.2 Identification of Building

Located at 2202 Main Mall, the Earth Sciences Building is one of the newest additions to UBC. Construction on the $75 million project began in Fall 2010[3] and was completed in September 2012. The architects for the project were Busby and Associates Architects and Maple Argo Architects. The general contractor was Bird Construction Company and the Environmental Construction Engineer was ACM Environmental Corporation.[4]

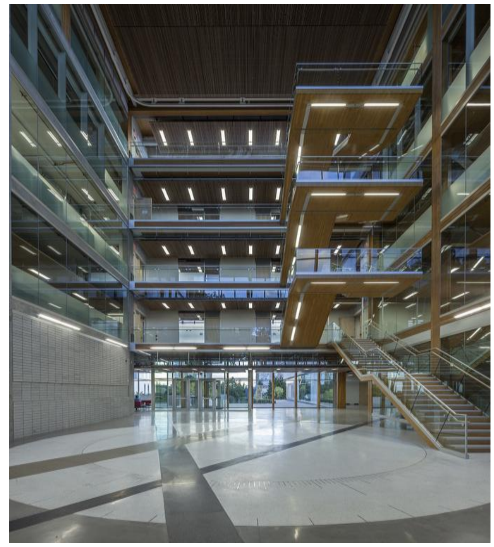

Figure 1: ESB Atrium

The ESB is a 5 storey mid-rise, with 2 below ground floors, and a gross square area of 15,238 m^2. The site boundary is defined by a 12 m setback from the Main Mall oak trees to the East, a 30.5 m setback from the Scarfe building to the North, alignment with the South face of the Beaty Biodiversity Whale Pavilion to the South, and the EOS Main building to the West.[5]

Constructed to LEED Gold standards, the ESB is the largest panelized wood building and the largest application of cross-laminated timber in North America.[6] This institutional building is home to 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).[7]

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[3] UBC Planning http://planning.ubc.ca/vancouver/projects-consultations/completed/academic-lands/earth-sciences-building-esb
[4] ESSB Final Report 2012
[5] UBC Planning http://planning.ubc.ca/vancouver/projects-consultations/completed/academic-lands/earth-sciences-building-esb
[6] UBC Earth Science Building: http://science.ubc.ca/about/esb
[7] UBC Properties: http://www.ubcproperties.com/portfolio_detail.php?category=Location&list=Vancouver&id=Earth%20Science%20Building

1.3 Other Assessment Information

Table 1: Summary of Assessment Information

Client for assessment	**Completed as coursework in Civil Engineering technical elective course at the University of British Columbia**
Name and qualification of the assessor	First author: Joshua Power – Clean Energy Engineering Previous authors: Robert Baumann, Hilda Ho and Maria Jose Valdebenito
Impact assessment method	Athena Impact Estimator for Buildings Version 4.2 (Public Release)
Point of assessment	1 year
Period of validity	5 years
Date of assessment	Completed in December, 2013
Verifier	Student work, study not verified

2.0 General Information on the Object of Assessment

2.1 Functional Equivalent

Functional units allow the systems under consideration to be compared on an equivalent basis by providing a reference to which the input and output data are normalized.[8] The metric chosen is based on some performance characteristic of the system, and comparisons between systems are made on the basis of fulfilling the same function, quantified by the same functional unit.[9] In order to compare the environmental impacts of one building relative to another, or relative to a benchmark database, the functional units across the buildings under review need to be explicit and consistent.

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[8] Life cycle assessment- Requirements and guidelines (ISO 14044:2006)
[9] Life cycle assessment- Requirements and guidelines (ISO 14044:2006)

Table 2: Functional Equivalent

Aspect of Object of Assessment	Description
Building type	Institutional
Technical and functional requirements	[1] BC Technical Guidelines - serve as the code of quality and performance for the design, construction and renovation of University-owned institutional buildings.[10] [2] National Building Code [3] BC Building Code
Pattern of use	[1] The Earth Science Building (ESB) includes teaching, laboratory, and office spaces. [2] Occupant load of 1628 people.[11]
Required service life[12]	[1] 100 year service life for the structure and the exterior envelope [2] 25 years for interior components and systems, and designed to facilitate change and adaptability [3] Roof systems shall have a minimum 30 year life

2.2 Reference Study Period

According to EN 15978, a standard methodology for reporting construction sector environmental data in Europe,[13] the default value for the reference study period is the required service life of the building. At UBC, the service life for key building systems is 100 years for the structure and the exterior envelope.[14]

This LCA study excludes the use stage, end of life stage and benefits and loads beyond the system boundary, modules B, C and D respectively because they are outside the specified scope of the project due to time restrictions. For this study, the emphasis was on sorting the materials during the Product and Construction stages.

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10 UBC Technical Guidelines http://www.technicalguidelines.ubc.ca/
11 Building architectural drawings
12 UBC Technical Guidelines – Performance Objectives: http://www.technicalguidelines.ubc.ca/technical/performance_obj.html
13 Athena News: http://www.athenasmi.org/first-north-american-building-declaration-to-en-15978/
14 UBC Technical Guidelines – Performance Objectives: http://www.technicalguidelines.ubc.ca/technical/performance_obj.html

2.3 Object of Assessment Scope

2.3.1 Description of Building Materials[15]

The ESB foundation and columns are made up mostly of rebar and concrete with the exception of a smaller number of wood columns through the building. The 3-tier floors are mostly made of concrete, insulation and wood. The roof assembly consists of two different levels: the first level is referred to as the deck of the fifth floor, and the roof of the building itself is on top of the fifth floor. The main structural component of the roof is cross-laminated timber. The wall assemblies 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 made of reinforced concrete.

Previously, it was reported that the decision to omit other building components, such as electrical aspects, HVAC system, finishing and detailing, etc., is associated with the limitations of available data and the IE software.[16] In this project, major components of the building were broken down into Level 3 Elemental format as established by the Canadian Institute of Quantity Surveyors (CIQS), in order to standardize the elements in a way that enables comparison and analysis. The building components included in each Level 3 Element are shown and a description and quantity of each metric used to normalize the results of impact categories by Level 3 Element are shown in Table 3: Building Definition.

[15] ESSB Final Report 2012: Inventory Analysis
[16] ESSB Final Report 2012

Table 3: Building Definition

CIVL 498c Level 3 Elements	Description	Quantity	Units
A11 Foundations	Total area of the slab-on-grade	1178	m^2
A21 Lowest Floor Construction	Total area of the slab-on-grade	1178	m^2
A22 Upper Floor Construction	Sum of the total area of all upper floors measured from the outside face of the exterior walls	7,524.7	m^2
A23 Roof Construction	Sum of the total area of the roofs measured from the outside face of the exterior walls	708	m^2
A31 Walls Below Grade	Sum of the total surface area of the exterior walls above grade	1,953.7	m^2
A32 Walls Above Grade	Sum of the total surface area of the exterior walls below grade	6,221.9	m^2
B11 Partitions	Sum of the total surface area of the interior walls	9,863.1	m^2

Standard Foundations	• Wall and column footings (eg. strip and pad footings) • Pile caps, column pedestrals and grade beams • Perimeter insulation • Crawl space walls
Special Foundations	• Piling • Caissons • Raft foundation • Ground and rock anchors • Underpinning • Special dewatering • Any other special foundations • Shoring to special foundations

Figure 2: A11 Foundations

	• Structural frame • Suspended roofs and decks • Fireproofing and fire stopping • Miscellaneous metals relating to the roof structure • Skylight structural framing • Waterproofing and vapour barrier • Insulation • Roofing membrane • Skylights
Columns & Beams	• All columns and beams supporting roofs

Figure 3: A23 Roof Construction

Fixed Partitions	• Interior fixed partition walls including wallboard • Balustrades and railings • Interior balcony fronts • Sound attenuation • Interior windows and storefronts • Interior glazed partitions • Interior glazed balustrades and screens • All miscellaneous metals, rough carpentry, sealing, caulking, shielding and protection within the wall assembly
Movable Partitions	• Demountable partitions • Retractable and movable partitions • Operable partitions
Structural Partitions	• Loadbearing partitions
Doors	• All interior doors including finish • Door frames • Door hardware • Access doors • Door opening elements

Figure 4: B11 Partitions

	• Slabs on grade • Waterproofing and vapour barrier • Insulation • Slab thickening below interior bearing walls

Figure 5: A21 Lowest Floor Construction

Walls Below Grade	• Exterior wall construction below grade and above lowest floor slab on grade • Interior furring, wallboard • Insulation and vapour barrier • All miscellaneous metals, wood blocking, sealing and caulking etc. within the wall assembly • Windows and doors
Structural Walls Below Grade	• Structural components of walls below grade

Figure 6: A31 Walls Below Grade

Upper Floor Construction	• Structural frame • Suspended floors and decks (including exterior balcony slabs) • Inclined and stepped floors • Expansion and contraction joints • Suspended ramps • Structural and non-structural toppings • Sound attenuation/insulation in floors • Special floor construction (ex. catwalks, space frames, etc.) • Miscellaneous metals relating to the floor structure • Fireproofing and firestopping
Columns & Beams	• All columns and beams supporting floors
Stair Construction	• Stair structure

Figure 7: A22 Upper Floor Construction

Walls Above Grade	• Exterior wall construction with facing materials, exterior applied finishes, back-up construction, framing, wallboard, insulation and vapour barriers • All miscellaneous metals, relieving angles, wood blockings, sealing and caulking, etc. within the wall assembly • Windows and doors
Structural Walls Above Grade	• Structural components of walls above grade
Curtain Walls	• Curtain walls

Figure 8: A32 Walls Above Grade

3.0 Statement of Boundaries and Scenarios Used in the Assessment

3.1 System Boundary

This LCA study is limited to the product stage and construction process stage, module A and B respectively shown in Table 4: Life Cycle Stages for Building Products; however, it is expected this study will be expanded upon in the future to make use of Athena's software capability to break impacts down into 6 life cycle phases;[17]

- Resource extraction
- Product manufacturing
- Construction of the building
- Building occupancy and maintenance
- Building demolition
- Materials disposition (disposal or transfer for recycling or reuse)

Table 4: Life Cycle Stages for Building Products According to EN 15978

BUILDING LIFE CYCLE INFORMATION				**SUPPLEMENTARY INFORMATION**
A 1-3	A 4-5	B 1-7	C 1-4	D
PRODUCT stage	CONSTRUCTION PROCESS stage	USE stage	END OF LIFE stage	Benefits and loads beyond the system boundary
A1: Raw material supply	A4: Transport	B1: Use	C1: De-construction demolition	Reuse-recovery-recycling-potential
A2: Transport	A5: Construction-installation process	B2: Maintenance	C2: Transport	
A3: Manufacturing		B3: Repair	C3: Waste Processing	
		B4: Replacement	C4: Disposal	
		B5: Refurbishment		
		B6: Operational Energy Use		
		B7: Operational Water Use		

[17] Athena LCA summary page

The upstream process of the product stage begins with raw material supply and ends with the downstream process of manufacturing. The construction process begins with the transportation of the finished products from the product stage to the construction site, and ends with the downstream process of construction and installation.

3.2 Product Stage

3.2.1 Raw Material Supply

The life cycle phase Resources Extraction in the IE includes, extraction of raw resources, tracking of energy use, emissions to air, water and land per unit of resource extracted. Raw material supply also includes data from activities such as reforestation and beneficiation.[18] Electricity use is based on the grid characteristics of the location selected.

3.2.2 Transport

The Resources Extraction phase also includes the transportation of raw resources to the location where they're processed, defining the boundary between extraction and manufacturing.[19] Transportation distances and modes reflect regional averages and each material has a transportation distance associated with it.[20]

3.2.3 Manufacturing

The manufacturing process begins with raw resources and other materials being delivered to the plant gate and ends with the finished product ready for shipment. The IE follows international guidelines for product LCAs addressing secondary components and assemblies, data sources and verification, and system boundaries.[21] Note that to the extent possible to the extent possible, all offshore products are

[18] Athena LCA summary page: www.athenasmi.org
[19] Athena LCA summary page: www.athenasmi.org
[20] Athena FAQ: http://calculatelca.com/faqs/#ie4b_databases
[21] Athena LCA summary page: www.athenasmi.org

treated as though they were manufactured in North America.[22] Electricity use is based on the grid characteristics of the location selected.

3.3 Construction Stage

3.3.1 Transport

In the IE tool, the On-Site Construction stage begins with the transportation of individual products and sub-assemblies from manufacturing facilities to distributors. The average transportation distances to building sites within each city are calculated based on regional surveys.[23, 24]

3.3.2 Construction-Installation Process

The construction process takes into account the energy used to construct the structural elements of the building and creates an inventory of the associated emissions to air, water and land. Other processes included are waste generation, energy use of machines such as cranes (energy required to lift materials an average distance of half of the height of the building) and mixers, the transportation of equipment to and from the site, concrete form work, and temporary heating and ventilation.[25, 26] Again, electricity use is based on the grid characteristics of the selected location within the IE.

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[22] Impact Estimator Software And Database Overview
[23] Athena LCA summary page: www.athenasmi.org
[24] Impact Estimator Software And Database Overview
[25] Athena LCA summary page: www.athenasmi.org
[26] Impact Estimator Software And Database Overview

4.0 Environmental Data

4.1 Data Sources

Life cycle inventory (LCI) involves the process of collecting and calculating the flows associated with the product system. These flows include raw resources or materials, energy, water, and emissions to air, water and land.[27]

The Impact Estimator draws information about building materials and products from the Athena LCI Database. The database has been developed as a result of continuing research from the Athena Institute, the managing body, a non-profit research organization specializing in LCA. Database development comes from LCIs or LCAs of specific industries, product groups, transportation, construction processes, and maintenance tasks in accordance with LCA standards such as ISO 14040 and ISO 14044 as well as internal/external peer review.[28]

Another LCI database that the Impact Estimator draws from, in this case for information on energy combustion/pre-combustion processes for electricity generation and transportation, is the US LCI Database. This database is publicly available and is maintained by the National Renewable Energy Laboratory's (NREL) High-Performance Buildings research group alongside government stakeholders and industry partners.[29] The database project began in 2001, and since its inception has been supported and funded by a wide variety of stakeholders including the U.S Department of Energy, the American Chemistry Council, and the U.S. Green Building Council, to name a few.[30] Currently, the database is developed and maintained by U.S. Life Cycle Inventory (LCI) Database project management team.

[27] Athena LCA summary page: www.athenasmi.org
[28] LCI Background Data: http://calculatelca.com/software/impact-estimator/lca-database-reports/
[29] U.S. Life Cycle Inventory Database: http://www.nrel.gov/lci/about.html
[30] U.S. Life Cycle Inventory Database: http://www.nrel.gov/lci/about.html

4.2 Data adjustments and Substitutions

A few IE inputs with a high contribution to Global Warming Potential (GWP) were investigated to uncover potential inaccuracies. Improvement strategies for these inaccuracies are recommended in Table 5: Potential Inaccuracies.

Table 5: Potential Inaccuracies

Level 3 Element	**Element and Material Modeling Review**		
	Type and Property Selection (ex. concrete strength, rebar size, roof/floor loading, etc.)		
	IE Inputs (GWP hotspots)	**Description of Inaccuracy(ies)**	**Improvement Strategy(ies)**
A11 Foundations	A11 Foundations- Footing_PF4	known rebar of 25M, IE input of 20M	search for a supplementary LCI database containing this input
		known concrete flyash of 40%, IE input of 35%	search for a supplementary LCI database containing this input
		known concrete MPa of 25, IE input of 30	search for a supplementary LCI database containing this input
A21 Lowest Floor Construction		known length and thickness values adjusted in IE to account for changes	known values can be inputted once other restrictions are addressed (see assumptions from previous model)
	A11 Foundations- Footing_SF4	known concrete MPa of 25, IE input of 30	search for a supplementary LCI database containing this input
		known concrete flyash of 40%, IE input of 35%	search for a supplementary LCI database containing this input
A22 Upper Floor Construction	A21 Lowest Floor Construction- Concrete_SOG_200	known concrete MPa of 25, IE input of 30	search for a supplementary LCI database containing this input
		known concrete flyash of 40%, IE input of 35%	search for a supplementary LCI database containing this input
	A22 Upper Floor Construction- Concrete_Beam_N/A_Base ment	known supported area of 86.29m2, IE input of 86.31m2	change IE input
A23 Roof Construction	A31 Walls Below Grade- Wall_Cast-in-Place_W6_350mm	known concrete MPa of 25, IE input of 30	search for a supplementary LCI database containing this input
		known concrete flyash of 40%, IE input of 35%	search for a supplementary LCI database containing this input

		known length and thickness values adjusted in IE to account for changes	known values can be inputted once other restrictions are addressed (see assumptions from previous model)
A31 Walls Below Grade	B11 Partitions-Curtain_Wall_Interior_2700 mm Height	thickness of insulation unknown and no IE input	review drawings
		spandrel type unknown and no IE input	review drawings
A32 Walls Above Grade			
B11 Partitions			

4.3 Data Quality

4.3.1 Types of Uncertainty

Table 6: Types of Uncertainty at Each LCA stage[31]

Type	Description	Goal & Scope	Inventory Analysis	Impact Assessment
Data uncertainty	Uncertainty introduced due to the nature of the data itself.		1. Collection 2. Allocation methods use to create data 3. Inaccuracies 4. No data	1. Uncertainty in lifetimes of substances 2. Travel potential
Model uncertainty	Uncertainty introduced from the use of modeling.		5. Linear vs. non-linear modeling	3. Characterization factors not known or uncertain
Uncertainty due to choices	Uncertainty introduced into the assessment due to the choices of the LCA practitioner.	1. Functional unit 2. System boundary 3. Service life 4. Maintenance cycles 5. Methods 6. Tools used in modeling 7. Choice of allocation methods 8. IA methods 9. IA categories		
Temporal variability	Uncertainty introduced due to the changes to relevant LCA information with time.		6. Difference in yearly factory emissions 7. Data vintage	4. Interpretation of impacts over time 5. Effect of climate

[31] CIVL 498C Class Notes: Week 8

Spatial variability	Uncertainty introduced due to the changes in relevant LCA conditions over space.		8. Regional differences between factories	6. Regional differences in environmental sensitivity 7. Distribution of emissions
Variability between objects/sources	Uncertainty due to inconsistencies between LCA processes and interactions.		9. Difference between factories 10. Technologies which produce the same product	8. Difference in human exposure patterns
Mistakes	Uncertainty due to mistakes made by the LCA practitioner.	10. Any	11. Any	9. Any

It is impossible to completely remove the uncertainty from a LCA, but it is possible to minimize the uncertainty introduced into the study with clear and comparable studies and databases. The LCI databases used in the study, the Athena LCI Database and the US LCI Database are updated frequently to remain current as new data is obtained. In the case of the Athena Database, most of the research at Athena goes into developing, verifying and updating the databases that form the basis of the Athena software tools.[32]

[32] Athena LCI Database: http://www.athenasmi.org/our-software-data/lca-databases/

4.3.2 Data Uncertainty

An example of data uncertainty in this study is the use of survey sheets sent to companies to collect data to obtain an average of industry values. Uncertainty is introduced when specific companies are chosen or choose to participate in the data collection process. The IE uses average values for generic building profiles rather than manufacturer specific data.

4.3.3 Model Uncertainty

A specific example of model uncertainty in this study is the characterization factors associated with the global warming impact category. The global warming potentials associated with various compounds are based on the amount of infrared absorption a substance has relative to carbon dioxide over a certain time period. The GWP being considered changes depending on the reference time period, but there is also uncertainty (some compounds more than others) in the lifetimes of these substances in the atmosphere which affects the utilized GWP values in the software.

4.3.4 Temporal Variability

An example of temporal variability is the effect of the climate on the impact assessment phase of the study. The IE can model impact assessment specifically for Vancouver, but depending on the time of year that emissions are released, the impacts can vary widely. For example, Smog Potential is greatly influence by climate inversions keeping the pollution low to the ground and these inversions are likely to change throughout the year.

4.3.5 Spatial Variability

An example of spatial variability affecting the inventory analysis is the regional difference between factories. For example, human health impacts could be very different between a factory that is located in a densely populated region compared to a factory located where emissions are blown out over the ocean. In the IE, these factories are modeled the same way as long as they're located in Vancouver.

4.3.6 Variability Between Objects/Sources

An example of variability between sources for impact assessment is the difference in human exposure patterns. Some people may have a different threshold for certain pollutants, but exposure is modeled the same way.

Impact Category	Category Indicator	Possible Endpoint Impacts

5.0 List of Indicators Used for Assessment & Expression of Results

5.1 Impact Assessment Method

The impact assessment stage of the study characterizes the LCI input and output flows into relevant environmental impacts. The Impact Estimator 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).[33] TRACI is the North American standard for life cycle assessment, and the IE software is adjusted each time the US EPA updates TRACI.[34]

5.2 Impact Categories

In developing TRACI, the impact categories that were ultimately included in the tool were narrowed down from a large list of impact categories identified in a preliminary study by the US EPA. This manageable list was selected for a variety of reasons, including consistency with existing regulations and policies, perceived importance, and ease of modeling.[35] See Table 7: Impact Assessment Categories for the TRACI impact assessment categories available in the IE that are included in this study as well as their respective category indicators and possible endpoint impacts. Additional information on individual impact categories is provided in the sections following.

[33] ESSB previous report
[34] Athena Sustainable Materials Institute News: http://www.athenasmi.org/impact-estimator-for-buildings-version-4-2-build-02-press-release/
[35] US EPA TRACI User's Manual: http://www.pre-sustainability.com/download/TRACI_2_1_User_Manual.pdf

Fossil fuel consumption	MJ	- Decreased fossil fuel reserves - Increased difficulty in extraction
Global warming potential	kg CO_2 eq	- Increased coastal area damage from SLR - Damaged ecosystems - Agricultural effects
Acidification potential	kg SO_2 eq	- Ecosystem damage - Building damage
Human health respiratory effects potential	kg PM2.5 eq	- Toxicological human health impacts - Decreased productivity - Increased stresses on hospital system
Eutrophication potential	kg N eq	- Impacts boaters, swimmers, fishermen - Creates lake hypoxia, impacting ecosystem - Impacts agriculture industry - Potential toxicity to humans
Ozone depletion potential	kg CFC-11 eq	- Skin cancer - Crop damage - Marine-life damage
Smog potential	kg O_3 eq	- Health impacts on vulnerable populations - Plant mortality

Table 7: Impact Assessment Categories

5.2.1 Fossil Fuel Consumption

Fossil fuel consumption describes the total energy used to transport and transform raw materials into products. It includes the energy involved in extraction, processing, manufacturing, construction, and indirect energies from processing or transforming this energy.[36]

5.2.2 Global Warming Potential

Global Warming Potential is a measure of the ability of a gas to contribute to global warming relative to carbon dioxide. This potential is based on the radiative forcing and residence time of gases released into the atmosphere. TRACI uses GWPs with 100-year time horizons and utilizes a hierarchy of data sources consistent with international acceptance.[37] Emissions with high GWP come from activities such as burning fossil fuels for electricity, and cement production.

36 ESSB Final Report 2012

37 TRACI User Manual: http://www.pre-sustainability.com/download/TRACI_2_1_User_Manual.pdf

5.2.3 Acidification Potential

Acidification potential is a measure of the increasing concentration of hydrogen ions (acidity) relative to sulfur dioxide. In TRACI 2.1, an acidification model incorporates increased hydrogen ion potential within the environment.[38] The release of acidic emissions into the atmosphere from agriculture and fossil fuel combustion results in acid rain.

5.2.4 Human Health Respiratory Effects Potential (HH Particulate)

HH Particulate is a measure of the particulate matter in ambient that form as a result of chemical processes in the air, or are released during combustion. The two groups of concern are inhalable coarse particles (between 2.5 micrometers and 10 micrometers in diameter) and fine particles (smaller than or equal to 2.5 micrometers in diameter). The latter are often products of combustion processes.[39]

5.2.5 Eutrophication Potential

Eutrophication potential is a measure of a product's ability to enrich an aquatic ecosystem with nutrients, thereby increasing the growth of algae biomass. These nutrients, phosphorus and nitrogen among the most potent, are introduced into aquatic ecosystems through wastewater treatment processes and fertilizer runoff from agricultural practices. Eutrophication often leads to hypoxic (depleted oxygen) regions resulting in dead zones for other aquatic life.

5.2.6 Ozone Depletion Potential

Ozone depletion potential is a measure of a chemical's ability to react in the atmosphere and breakdown stratospheric ozone. Substances linked to this breakdown are chlorofluorocarbons that are used as refrigerants, foam blowing agents, solvents, and

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[38] TRACI User Manual: http://www.presustainability.com/download/TRACI_2_1_User_Manual.pdf
[39] TRACI User Manual: http://www.presustainability.com/download/TRACI_2_1_User_Manual.pdf

halons that are used as fire extinguishing agents.[40] Once released, these compounds react in the upper atmosphere in a series of chain reactions that result in the breakdown of ozone.

5.2.7 Smog Potential

Unrelated to stratospheric ozone, smog potential is a measure of the ground level ozone formation as a result of photochemical oxidation. Compounds such as volatile organic compounds and nitrogen oxides from the combustion process in vehicles react with sunlight to create smog pollution.

[40] TRACI User Manual: http://www.presustainability.com/download/TRACI_2_1_User_Manual.pdf

6.0 Model Development

Before modeling the ESB in Athena, takeoff quantities from the digital building drawings were imported into On-Screen Takeoff 3 (OST) to document the area, linear, and count quantities. Originally, the inputs were organized into an excel Inputs Document into the following Assembly Groups: [1] Foundation, [2] Walls, [3] Columns and Beams, [4] Floors, [5] Roof, and [6] Extra Basic Materials. The Inputs Document was accompanied by various assumptions documents that have since been aggregated and organized into one IE Assumptions document. Both the updated IE Inputs and IE Assumptions documents are available in

Table 18: Graduate Attributes

Graduate Attribute			
Name	Description	Content Code	Which of the CEAB graduate attributes you believe you had to demonstrate during your final project experience.
Knowledge Base	Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.	IA = introduced & applied	LCA framework and standards were introduced in class and then applied to our individual building.
Problem Analysis	An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.	I = introduced	Introduced work arounds within the Impact Estimator to add new material types.

Investigation	An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.	IDA = introduced, developed & applied	Interpretation of comparisons between buildings i.e. class benchmarking.
Design	An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.	N/A = not applicable	
Use of Engineering Tools	An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.	IA = introduced & applied	Using Athena Impact Estimator for Buildings to model the environmental performance of the ESB. Limitations of the IE were a main topic of discussion and investigation throughout the class.
Individual and Team Work	An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.	DA = developed & applied	Team work throughout class exercises led to a better understanding of LCA concepts such as functional unit and product life cycle stages. Individual work was carried out to complete each of the stages and the final project.
Communication	An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.	IA = introduced & applied	Assignment 1 - 'Getting into the know' was an effective way to learn about LCA and communicate some of the barriers and successes associated with LCA in practice. The final report is also requires the effective communication of results and reflection.

Professionalism	An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.	N/A = not applicable	
Impact of Engineering on Society and the Environment	An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.	IDA = introduced, developed & applied	In class we talked about possible end point impacts associated with impact categories that bring the LCA down to the social level. We were also introduced to Life Cycle Costing (LCC) and how this can play a major role in decision-making.
Ethics and Equity	An ability to apply professional ethics, accountability, and equity.	N/A = not applicable	
Economics and Project Management	An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.	I = introduced	Again, in LCC we touched on net present value, the discounting of future costs and how this affects project decisions.
Life-long Learning	An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.	IDA = introduced, developed & applied	LCA is an emerging field and the information and framework is always changing. Our projects and research will put us on par with similar efforts around the world. The UBC LCA building database will help give decision makers a tool to compare new projects on campus.

Annex D – Impact Estimator Inputs and Assumptions.

6.1 Previous Model Development[41]

For the foundation, the areas of footings were found using the area conditions in 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 to find the number of columns and beams on each floor. The floor-to-floor heights were calculated from the elevations of each floor from the structural drawings.

The areas of each floor were also estimated using OST. Several take-offs were performed depending on the number of 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. 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 OST. The assembly of each wall was determined through architectural plans, sections and elevations. The drawings provided specific details for each type of wall, describing structural components as well as interior and exterior finish schedules. For concrete walls, the information was provided by the structural drawings, containing shear walls and retaining walls. Doors and windows were associated with each type of wall using a count condition in OST.

6.2 Improving the Model's Accuracy

The updated IE Inputs document is sorted into Level 3 Elemental format as established by CIQS. To improve the accuracy of the model in this new sorting

[41] ESSB Final Report 2012: Material Takeoff Development

format, the changes outlined in Table 8: Improving the Model were undertaken. The table highlights the Extra Basic Materials in the original model and matches them with their corresponding assemblies. These materials were then sorted according to Level 3 Elemental format and added accordingly to the improved model in Athena IE.

Table 8: Improving the Model

Extra Basic Material in original model		**Material's corresponding Level 3 Element**	**Corresponding assembly name in IE Inputs**
Name	Amount		
Glulam Sections	17.03 m^3	A23	6.2.1 Columns_GL_Wood(Total Sum) EXTRA BASIC MATERIAL
Hollow Structural Steel	23.33 tonnes	A22	6.1.1 Columns_HSS_350W(Total Sum) EXTRA BASIC MATERIAL
Laminated Veneer Lumber	107.616 m^3	A23	5.2.1Roof_CrossLaminatedTimber EXTRA BASIC MATERIAL
Parallel Strand Lumber	271.984 m^3	A22	4.1.2 Floor_Wood_SuspendedSlab_89mm EXTRA BASIC MATERIAL
Polyiso Foam Board (unfaced)	6,686 m^2	A22	4.1.3 Floor_Insulation_SuspendedSlab_25mm EXTRA BASIC MATERIAL
		A23	5.1.1 Roof_insulation EXTRA BASIC MATERIAL

Note that the area of polyiso foam board estimated for the entire building was originally 6,686 m^2. For Level 3 sorting, this area was separated into the insulation present in the roof, and the insulation present in the floor. Insulation is present as a sublayer of the floor in between concrete and wood and the roof is composed mainly of cross-laminated timber and insulation.[42] The area of polyiso insulation in the IE is 3056 m^2 and 3590 m^2 respectively.

[42] ESSB Final Report 2012

One assembly name that was included in the original inputs document, but not included in the model was a below ground concrete block wall, denoted as 2.2.1 Wall_E6.2_ConcreteBlock_152mmSteelStud. This assembly was added to the improved model under the same assembly name into A21 Lowest Floor Construction.

Once the inputs were organized, Athena Impact Estimator for Buildings was used to complete a life cycle assessment of the ESB. The model achieves this by applying a set of algorithms to the inputted takeoff data to generate a bill of materials (BoM). This BoM utilizes the built in Athena Life Cycle Inventory (LCI) Database, in order to estimate a cradle-to-grave LCI profile for the building.[43] For this project, the cradle-to-gate LCI profile of the ESB is being considered.

6.3 Reference Flow and Bill of Materials

A reference flow is a quantified amount of the product(s), including product parts, necessary for a specific product system to deliver the performance described by the functional unit.[44] These are the flows associated with a product system that allow comparison between other product systems with the same functional unit. The BoMs for the ESB for each Level 3 Element are presented below.

Table 9: BoM A11 Foundations

Material	Quantity	Unit
Concrete 30 MPa (flyash 35%)	361.2324	m3
Rebar, Rod, Light Sections	4.1779	Tonnes

Table 10: BoM A21 Lowest Floor Construction

Material	Quantity	Unit
Concrete 20 MPa (flyash av)	11.298	m3
Concrete 30 MPa (flyash 35%)	229.53	m3

43 ESSB Final Report 2012
44 The Product, Functional Unit and Reference Flows in LCA: http://www2.mst.dk/Udgiv/Publications/2004/87-7614-233-7/pdf/87-7614-234-5.PDF

Rebar, Rod, Light Sections	0.3997	Tonnes
Welded Wire Mesh / Ladder Wire	1.0646	Tonnes

Table 11: BoM A22 Upper Floor Construction

Material	Quantity	Unit
Concrete 30 MPa (flyash 25%)	1547.2385	m3
Concrete 30 MPa (flyash av)	401.7851	m3
GluLam Sections	20.1125	m3
Hollow Structural Steel	23.5633	Tonnes
Parallel Strand Lumber	274.7038	m3
Polyiso Foam Board (unfaced)	3250.8	m2 (25mm)
Rebar, Rod, Light Sections	267.1474	Tonnes

Table 12: BoM A23 Roof Construction

Material	Quantity	Unit
GluLam Sections	19.3205	m3
Laminated Veneer Lumber	108.6922	m3
Polyiso Foam Board (unfaced)	753.9	m2 (25mm)

Table 13: BoM A31 Walls Below Grade

Material	Quantity	Unit
6 mil Polyethylene	2794.4744	m2
Concrete 30 MPa (flyash 35%)	782.659	m3
Expanded Polystyrene	5378.3634	m2 (25mm)
Nails	0.1628	Tonnes
Rebar, Rod, Light Sections	24.4376	Tonnes

Table 14: BoM A32 Walls Above Grade

Material	Quantity	Unit
#15 Organic Felt	849.5761	m2
5/8" Regular Gypsum Board	1792.5246	m2
6 mil Polyethylene	1728.6455	m2
Aluminum	63.6087	Tonnes
Cold Rolled Sheet	0.1786	Tonnes
Double Glazed Hard Coated Air	299.8641	m2
EPDM membrane (black, 60 mil)	1222.2277	kg
FG Batt R11-15	12200.4791	m2 (25mm)
Fiber Cement	819.7396	m2
Galvanized Sheet	4.6633	Tonnes
Galvanized Studs	10.8348	Tonnes
Glazing Panel	126.0137	Tonnes
Joint Compound	1.789	Tonnes
Mortar	25.7429	m3
MW Batt R11-15	4636.3693	m2 (25mm)
Nails	0.697	Tonnes
Ontario (Standard) Brick	928.5675	m2
Oriented Strand Board	2275.7105	m2 (9mm)
Paper Tape	0.0205	Tonnes

Screws Nuts & Bolts	2.1444	Tonnes
Water Based Latex Paint	88.1742	L

Table 15: BoM B11 Partitions

Material	Quantity	Unit
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	10921.0693	m2
Aluminum	8.278	Tonnes
Cold Rolled Sheet	0.0848	Tonnes
Concrete 30 MPa (flyash 35%)	119.4662	m3
EPDM membrane (black, 60 mil)	109.391	kg
FG Batt R11-15	22637.5623	m2 (25mm)
Galvanized Sheet	9.3489	Tonnes
Galvanized Studs	27.5522	Tonnes
Glazing Panel	24.6493	Tonnes
Joint Compound	18.1792	Tonnes
Mortar	12.2171	m3
Nails	1.4843	Tonnes
Ontario (Standard) Brick	440.6813	m2
Oriented Strand Board	586.1111	m2 (9mm)
Paper Tape	0.2086	Tonnes
Rebar, Rod, Light Sections	2.8178	Tonnes
Screws Nuts & Bolts	1.7713	Tonnes
Small Dimension Softwood Lumber, kiln-dried	25.4275	m3
Solvent Based Alkyd Paint	44.5118	L
Water Based Latex Paint	1075.4168	L

7.0 Communication of Assessment Results

7.1 Life Cycle Results

7.1.1 Summary Measures

The summary measures for the Product and Construction life cycle stages for each impact category organized by whole building and Level 3 Element sorting are presented in this section.

Life Cycle Stage	Process Module	Fossil Fuel Consumption (MJ)	Global Warming (kg CO2eq)	Acidification (moles of H+eq)	Human Health (kg PM10eq)	Eutrophication (kg Neq)	Ozone Layer (kg CFC-11eq)	Smog (kg O3eq)
PRODUCT	Manufacturing	21248593.69	1969786.969	17175.59385	10653.75468	983.3774168	0.009518242	219854.8078
	Transport	958364.418	52230.4695	340.5235041	9.416464846	23.71331599	2.12987E-06	12054.04479
	Total	**22206958.11**	**2022017.439**	**17516.11735**	**10663.17114**	**1007.090733**	**0.009520372**	**231908.8526**
CONSTRUCTION	Construction-	1262272.862	107919.217	828.7519742	132.2869255	49.94900266	0.000334459	22842.29952
	Transport	1365531.578	98615.95894	484.2952468	14.68002427	34.70321483	3.93749E-06	17124.83028
	Total	**2627804.439**	**206535.176**	**1313.047221**	**146.9669497**	**84.65221749**	**0.000338397**	**39967.1298**
USE	Replacement							
	Replacement							
	Operational Energy							
	Total							
END OF LIFE	Material							
	Transport							
	Total							
TOTAL EFFECTS	Non-Transport	22,510,866.55	2,077,706.19	18,004.35	10,786.04	1,033.33	0.01	242,697.11
	Transport	2,323,896.00	150,846.43	824.82	24.10	58.42	0.00	29,178.88
	Operational Energy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	24,834,762.55	2,228,552.61	18,829.16	10,810.14	1,091.74	0.01	271,875.98

Figure 9: Summary Measure ESB Building

Life Cycle Stage	Process Module	Fossil Fuel (MJ)	Global Warming (kg CO2eq)	Acidification (moles of H+eq)	Human Health (kg PM10eq)	Eutrophication (kg Neq)	Ozone Layer (kg CFC-11eq)	Smog (kg O3eq)
PRODUCT	Manufacturing	518449.1801	78449.50136	514.7949275	214.1362323	25.59930972	0.000459555	10719.92977
	Transport	70969.3835	3135.798178	24.97616987	0.653535028	1.711105753	1.29845E-07	884.4251074
	Total	**589418.5636**	**81585.29954**	**539.7710974**	**214.7897673**	**27.31041547**	**0.000459685**	**11604.35488**
CONSTRUCTION	Construction-	41283.69395	5077.379709	31.66852474	10.75072066	1.469104315	2.29776E-05	783.06343
	Transport	62262.04828	4673.411941	22.11652879	0.679671758	1.591837067	1.86509E-07	782.1048172
	Total	**103545.7422**	**9750.79165**	**53.78505354**	**11.43039241**	**3.060941381**	**2.31641E-05**	**1565.168247**
USE	Replacement							
	Replacement							
	Operational Energy							
	Total							
END OF LIFE	Material							
	Transport							
	Total							
TOTAL EFFECTS	Non-Transport	559,732.87	83,526.88	546.46	224.89	27.07	0.00	11,502.99
	Transport	133,231.43	7,809.21	47.09	1.33	3.30	0.00	1,666.53
	Operational Energy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	692,964.31	91,336.09	593.56	226.22	30.37	0.00	13,169.52

Figure 10: Summary Measures A11 Foundations

Life Cycle Stage	Process Module	Fossil Fuel (MJ)	Global Warming (kg CO2eq)	Acidification (moles of H+eq)	Human Health (kg PM10eq)	Eutrophication (kg Neq)	Ozone Layer (kg CFC-11eq)	Smog (kg O3eq)
PRODUCT	Manufacturing	330548.954	51954.30601	339.9460832	142.4024425	15.02364434	0.000304539	7079.949697
	Transport	46155.06398	2047.995445	16.26057966	0.425834707	1.114273618	8.47925E-08	575.8033147
	Total	**376704.018**	**54002.30146**	**356.2066629**	**142.8282772**	**16.13791796**	**0.000304624**	**7655.753011**
CONSTRUCTION	Construction-	70140.01957	6217.087155	46.5388486	7.410429981	2.579319801	1.52269E-05	1423.998193
	Transport	42454.39192	3126.14439	15.07051238	0.459968052	1.082296273	1.2481E-07	532.9287358
	Total	**112594.4115**	**9343.231545**	**61.60936098**	**7.870398033**	**3.661616074**	**1.53517E-05**	**1956.926929**
USE	Replacement							
	Replacement							
	Operational Energy							
	Total							
END OF LIFE	Material							
	Transport							
	Total							
TOTAL EFFECTS	Non-Transport	400,688.97	58,171.39	386.48	149.81	17.60	0.00	8,503.95
	Transport	88,609.46	5,174.14	31.33	0.89	2.20	0.00	1,108.73
	Operational Energy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	489,298.43	63,345.53	417.82	150.70	19.80	0.00	9,612.68

Figure 11: Summary Measures A21 Lowest Floor Construction

		Fossil Fuel	Global Warming	Acidification	Human Health	Eutrophication	Ozone Layer	Smog
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)	(moles of H+eq)	(kg PM10eq)	(kg Neq)	(kg CFC-11eq)	(kg O3eq)
PRODUCT	Manufacturing	8768121.768	692269.5746	4787.707537	1411.078731	549.4261419	0.003105223	83140.17982
	Transport	468257.7468	27228.14898	168.929037	4.742083923	11.81750139	1.107E-06	5979.495769
	Total	**9236379.515**	**719497.7236**	**4956.636574**	**1415.820815**	**561.2436433**	**0.00310633**	**89119.67559**
CONSTRUCTION	Construction-	662645.7477	56883.85105	447.4550852	69.08543881	28.29525535	0.00015561	13342.2437
	Transport	398571.1286	28803.47984	141.5318221	4.289415267	10.14121602	1.15028E-06	5004.719277
	Total	**1061216.876**	**85687.33089**	**588.9869072**	**73.37485407**	**38.43647136**	**0.00015676**	**18346.96297**
USE	Replacement							
	Replacement							
	Operational Energy							
	Total							
END OF LIFE	Material							
	Transport							
	Total							
TOTAL EFFECTS	Non-Transport	9,430,767.52	749,153.43	5,235.16	1,480.16	577.72	0.00	96,482.42
	Transport	866,828.88	56,031.63	310.46	9.03	21.96	0.00	10,984.22
	Operational Energy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	10,297,596.39	805,185.05	5,545.62	1,489.20	599.68	0.00	107,466.64

Figure 12: Summary Measures A22 Upper Floor Construction

		Fossil Fuel	Global Warming	Acidification	Human Health	Eutrophication	Ozone Layer	Smog
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)	(moles of H+eq)	(kg PM10eq)	(kg Neq)	(kg CFC-11eq)	(kg O3eq)
PRODUCT	Manufacturing	1011565.806	64589.39279	511.3505968	81.18458022	17.29675175	6.67855E-05	3453.662627
	Transport	29211.94862	2203.31683	10.37373935	0.319357774	0.74707532	8.78551E-08	366.812206
	Total	**1040777.755**	**66792.70962**	**521.7243361**	**81.50393799**	**18.04382707**	**6.68733E-05**	**3820.474833**
CONSTRUCTION	Construction-	18159.72182	1176.475144	11.47598352	0.995464793	0.58655384	3.35016E-06	251.4071825
	Transport	15209.44758	559.9060848	5.296559945	0.132409869	0.358195816	2.28389E-08	187.2242828
	Total	**33369.1694**	**1736.381229**	**16.77254347**	**1.127874662**	**0.944749656**	**3.373E-06**	**438.6314653**
USE	Replacement							
	Replacement							
	Operational Energy							
	Total							
END OF LIFE	Material							
	Transport							
	Total							
TOTAL EFFECTS	Non-Transport	1,029,725.53	65,765.87	522.83	82.18	17.88	0.00	3,705.07
	Transport	44,421.40	2,763.22	15.67	0.45	1.11	0.00	554.04
	Operational Energy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	1,074,146.92	68,529.09	538.50	82.63	18.99	0.00	4,259.11

Figure 13: Summary Measures A23 Roof Construction

Process Module	Fossil Fuel (MJ)	Global Warming (kg CO2eq)	Acidification (moles of H+eq)	Human Health (kg PM10eq)	Eutrophication (kg Neq)	Ozone Layer (kg CFC-11eq)	Smog (kg O3eq)
Manufacturing	1575500.741	188797.4848	1214.950391	471.0966355	78.56414246	0.000995978	24574.0365
Transport	157397.6283	7066.230313	55.41938102	1.455889528	3.801133638	2.92201E-07	1962.385356
Total	**1732898.37**	**195863.7151**	**1270.369772**	**472.552525**	**82.3652761**	**0.00099627**	**26536.42186**
Construction-	243474.7719	21278.713	161.2165779	24.40279388	9.214450224	4.97939E-05	4968.798423
Transport	136922.1465	10255.61125	48.63302669	1.493420241	3.499497123	4.09301E-07	1719.800801
Total	**380396.9184**	**31534.32425**	**209.8496046**	**25.89621412**	**12.71394735**	**5.02032E-05**	**6688.599224**
Replacement							
Replacement							
Operational Energy							
Total							
Material							
Transport							
Total							
Non-Transport	1,818,975.51	210,076.20	1,376.17	495.50	87.78	0.00	29,542.83
Transport	294,319.77	17,321.84	104.05	2.95	7.30	0.00	3,682.19
Operational Energy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	2,113,295.29	227,398.04	1,480.22	498.45	95.08	0.00	33,225.02

Figure 14: Summary Measures A31 Walls Below Grade

Life Cycle Stage	Process Module	Fossil Fuel (MJ)	Global Warming (kg CO2eq)	Acidification (moles of H+eq)	Human Health (kg PM10eq)	Eutrophication (kg Neq)	Ozone Layer (kg CFC-11eq)	Smog (kg O3eq)
PRODUCT	Manufacturing	6018455.354	635289.8849	7806.120889	6901.375524	185.2331713	0.003266638	71140.86546
	Transport	65587.90369	3907.320611	23.53699457	0.666286602	1.650787106	1.57927E-07	832.7465658
	Total	**6084043.258**	**639197.2055**	**7829.657884**	**6902.04181**	**186.8839584**	**0.003266796**	**71973.61202**
CONSTRUCTION	Construction-	75375.59265	5916.3285	50.51081018	7.580055464	2.60750663	3.08243E-05	918.760309
	Transport	450226.5233	33643.4318	159.8416123	4.904180101	11.49858222	1.34179E-06	5651.926235
	Total	**525602.116**	**39559.7603**	**210.3524225**	**12.48423557**	**14.10608885**	**3.21661E-05**	**6570.686544**
USE	Replacement							
	Replacement							
	Operational Energy							
	Total							
END OF LIFE	Material							
	Transport							
	Total							
TOTAL EFFECTS	Non-Transport	6,093,830.95	641,206.21	7,856.63	6,908.96	187.84	0.00	72,059.63
	Transport	515,814.43	37,550.75	183.38	5.57	13.15	0.00	6,484.67
	Operational Energy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	6,609,645.37	678,756.97	8,040.01	6,914.53	200.99	0.00	78,544.30

Figure 15: Summary Measures A32 Walls Above Grade

Life Cycle Stage	Process Module	Fossil Fuel (MJ)	Global Warming (kg CO2eq)	Acidification (moles of H+eq)	Human Health (kg PM10eq)	Eutrophication (kg Neq)	Ozone Layer (kg CFC-11eq)	Smog (kg O3eq)
PRODUCT	Manufacturing	2904155.751	253481.9592	1979.797617	1436.175181	111.7982798	0.001065764	19571.85259
	Transport	121948.9097	6713.318222	41.46573213	1.165839511	2.902136427	2.73162E-07	1467.889359
	Total	**3026104.661**	**260195.2774**	**2021.26335**	**1437.341021**	**114.7004162**	**0.001066037**	**21039.74195**
CONSTRUCTION	Construction-	147539.1925	11295.09463	80.22443902	12.25566865	5.244266632	4.39879E-05	1197.0338
	Transport	253358.87	17050.99348	89.48656468	2.649011192	6.364181273	6.81917E-07	3164.140628
	Total	**400898.0625**	**28346.08811**	**169.7110037**	**14.90467984**	**11.60844791**	**4.46698E-05**	**4361.174428**
USE	Replacement							
	Replacement							
	Operational Energy							
	Total							
END OF LIFE	Material							
	Transport							
	Total							
TOTAL EFFECTS	Non-Transport	3,051,694.94	264,777.05	2,060.02	1,448.43	117.04	0.00	20,768.89
	Transport	375,307.78	23,764.31	130.95	3.81	9.27	0.00	4,632.03
	Operational Energy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	3,427,002.72	288,541.37	2,190.97	1,452.25	126.31	0.00	25,400.92

Figure 16: Summary Measures B11 Partition

7.1.2 Hotspots

Identifying hotspots in the Product and Construction stages of the product system, and at the elemental level is a useful way to identify which processes and individual assemblies are contributing the majority of the environmental impacts in the ESB. The IE has a built in tool to show the percent contribution of each assembly in the project to a given impact category. As a class, GWP was voted as the impact category of highest concern and the GWP hotspots for ESB are identified in Table 16: GWP Hotspots by Level 3 Element, and Table 17: GWP Hotspots by Life Cycle Stage and Process Module. Further discussion is included in the Annexes.

Table 16: GWP Hotspots by Level 3 Element

Level 3 Element	Life Cycle Stage	IE Inputs document Assembly Name	Contribution to GWP (%)
A11	A11 Foundations-Footing_PF4	1.2.4 Footing_PF4	27.89
A21	21 Lowest Floor Construction-Concrete_SOG_200	1.1.2 SOG_200mm	87.86
A22	A22 Upper Floor Construction-Floor_concrete_suspendedslab_100mm	4.1.4 Floor_Concrete_SuspendedSlab_100mm	48.25
A23	A23 Roof Construction-Extra Basic Materials	[1] 6.2.1 Columns_GL_Wood(Total Sum) EXTRA BASIC MATERIAL [2] 5.2.1 Roof_CrossLaminatedTimber EXTRA BASIC MATERIAL [3] 5.1.1 Roof_insulation EXTRA BASIC MATERIAL	99.45
A31	A31 Walls Below Grade-Wall_Cast-in-Place_W6_350mm	2.1.5 Wall_Cast-in-Place_W6_350mm	32.95
A32	A32 Walls Above Grade-Wall_CurtainWall_Opaque Glass Spandrel_2390mm Height	2.3.7 Wall_CurtainWall_Opaque Glass Spandrel_2390mm Height	32.04
B11	B11 Partitions-Curtain_Wall_Interior_2700mm Height	2.3.9 Curtain_Wall_Interior_2700mm_Height	23.87

Table 17: GWP Hotspots by Life Cycle Stage and Process Module

Level 3 Element	Life Cycle Stage	Contribution to GWP (%)	Process Module within hotspot Life Cycle Stage	Contribution to GWP (%)
A11	Product	89.32	Manufacturing	96.16
A21	Product	85.25	Manufacturing	87.75
A22	Product	89.36	Manufacturing	96.22
A23	Product	97.47	Manufacturing	96.70
A31	Product	86.13	Manufacturing	96.39
A32	Product	94.17	Manufacturing	98.92
B11	Product	90.18	Manufacturing	95.97

Annex A – Interpretation of Assessment Results

Benchmark Development

Benchmarking in LCA is a way to assess the environmental impacts of a product system in away that makes sense relative to other product systems with the same function. It is impossible to justify the sustainable construction of new buildings and to demonstrate that improvements have been made if there is no standard against which to measure the improved buildings.[45] Benchmarking allows for a meaningful interpretation of LCA results, that would otherwise stand alone.

According to ISO guidelines, in a comparative study, product systems shall be compared using the same functional unit and equivalent methodological considerations, such as performance, system boundary, data quality, allocation procedures, decision rules on evaluating inputs, and outputs and impact assessment.[46] Basically, the studies being compared need to have a common goal and scope so that they can be compared on an equivalent basis.

The functional equivalence of the benchmark assures that all buildings in the benchmark are used to fulfill the same purpose over the same length of time. At UBC, all buildings are subject to the same codes and technical guidelines; however, differences will arise in standards due to the time in which the buildings were constructed.

UBC Academic Building Benchmark

The ESB is higher in all impact categories compared to the class benchmark, excluding Ozone Layer Depletion. The comparison between the ESB and benchmark can be seen by whole building and by Level 3 Element.

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[45] Using LCAs for Benchmarking: http://www.bousteadusa.com/UsingLCAs/benchmarking.html
[46] Life cycle assessment- Requirements and guidelines (ISO 14044:2006)

Note that the contribution to each impact category for the class benchmark is 100% and the percent difference of the ESB compared to this benchmark is displayed in Figure 17: Percent Difference in Environmental Impacts Between ESB and Class Benchmark by Whole Building.

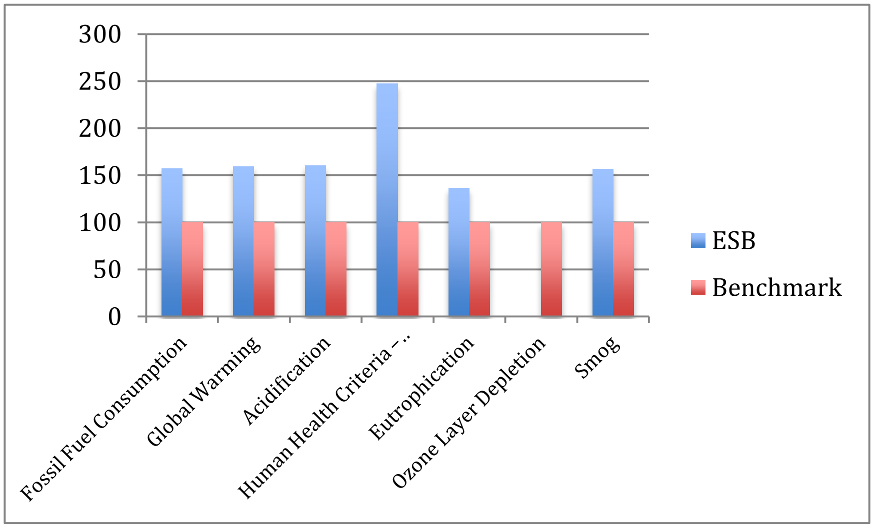

Figure 17: Percent Difference in Environmental Impacts Between ESB and Class Benchmark by Whole Building

Note that the contribution to each impact category for each Level 3 Element is 100% for the class benchmark and the percent difference of the ESB by Level 3 Element compared to the benchmark is displayed in Figure 18: Percent Difference in Environmental Impacts Between ESB and Class Benchmark by Level 3 Element.

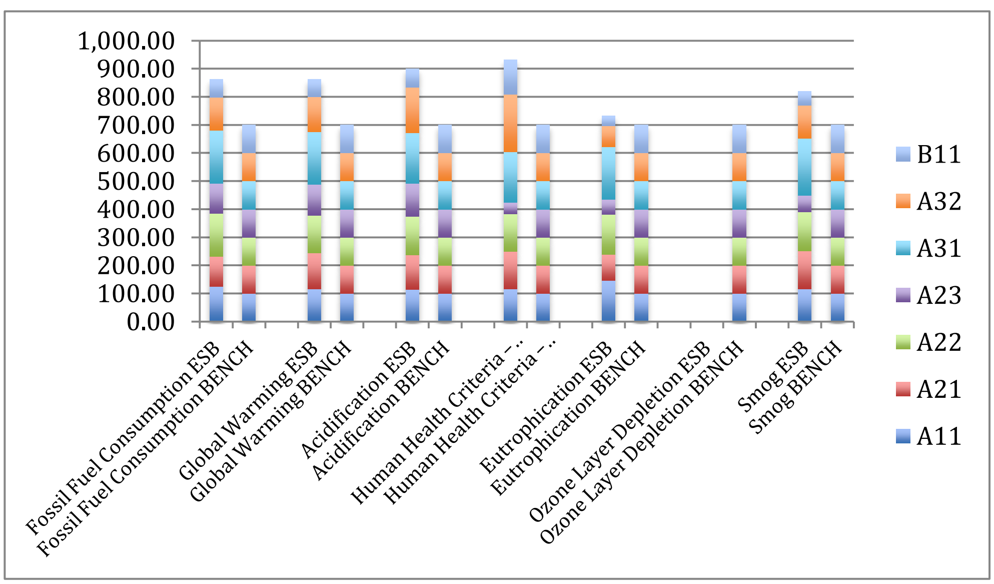

Figure 18: Percent Difference in Environmental Impacts Between ESB and Class Benchmark by Level 3 Element

Figure 19: Cost vs. GWP of Class Studies, highlights the cost of each building in the study against its respective contribution to global warming potential. The ESB is the most expensive building among those compared, and relative to its cost compares fairly well against the other buildings. For example, at 395 kg CO_2 eq for a price of $75M, the ESB contributes only 25% more to GWP at about 7 times the cost compared to AERL.

The supported GWP measure in the IE currently treats biogenic carbon as climate change neutral, but does not credit sequestered carbon in any material.[47] If the sequestered carbon from the wood materials were taken into account the building might be modeled to have a better performance since the ESB uses over 1,300 tons of BC sourced and engineered cross laminated timber, and it's estimated that the wood materials used in the building will sequester about 2,600 tons of CO_2.[48]

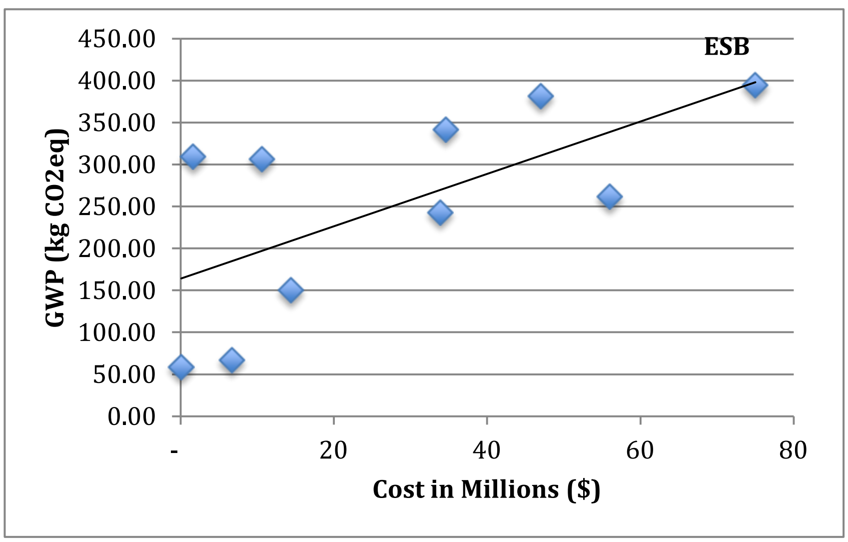

Figure 19: Cost vs. GWP of Class Studies

[47] Impact Estimator Software and Database Overview
[48] UBC's Earth Sciences Building: http://science.ubc.ca/about/esb

Annex B – Recommendations for LCA Use

Life Cycle Modules and Building Design

It's important to highlight that this LCA study only includes the Process and Construction stages and not the Use and End-of-Life stages. These additional stages have their own considerations that could have a huge impact on the overall LCA of the ESB. For example, the ESB, as one of the newest buildings on campus, is built to LEED Gold Standard, and it is very likely that energy conservation measures in the design of the building will result in notable energy use differences throughout its service life compared to the class benchmark. These energy improvements will lead to smaller environmental impacts in a variety of impact categories such as fossil fuel consumption and global warming potential.

The use of LCA in the design phase of a building has many benefits. Since most of a building's materials, energy, and environmental loading are established in the design phase and environmental impacts occur largely during the use phase[49], it is most beneficial to use a LCA framework earlier on in the process to maximize its benefit. The IE software has the ability to show the environmental impacts of different material mixes and design choices, allowing the user to consider the trade-offs in their design. This is extremely useful when starting off with a baseline design and then looking into how changes in building materials can improve its environmental performance.[50]

LCA in Practice

LCA is making its way into mainstream practice. The USGBC's latest update to the LEED system now incorporates LCA into two available credits for smaller components of the building. One credit is the Building Product Disclosure and Optimization – Environmental Product Declarations (EPDs) that aims to promote the use of materials for which life-cycle information is available and that have preferable life-cycle impacts. The second credit

[49] BD&C White Paper: Life Cycle Assessment and Sustainability
[50] Impact Estimator Software And Database Overview

is the Building Life Cycle Impact Reduction that seeks to encourage the reuse of materials to optimize their environmental performance.[51]

Some confusion in LCA arises due to the fact that there is no one all encompassing LCA standard. LCA standardization is moving forward in two directions; one is through testing professionals with a competency exam enabling them to practice professionally, and another is through the development of EPDs. LCA provides the science-based background behind EPDs that must meet and comply with specific methodological requirements defined in Product Category Rules (PCRs)[52] that standardize the goal and scope of various product categories.

The following steps are recommended in order to operationalize LCA methods, data and their use in practice at UBC:

- Promote education programs for faculty and students
- Follow consistent LCA framework across UBC to make studies transparent and easy to replicate
- Make studies available
- Promote access and training to suitable software

Issues in Application

One issue in application is the prioritization of impact categories among various stakeholders. One way to determine which impact categories should be considered in an analysis (other than by surveying stakeholders) is to include all categories within the model and to normalize each impact category relative to the background impacts in that category, i.e. regional or global. The highest contributing impacts in the model can then be chosen as the areas of focus.

[51] EarthShift: Environmental Product Declarations and LCA To Earn LEED Points
[52] EarthShift: Product Category Rules, Environmental Product Declarations, and Eco-Labels

Annex C – Author Reflection

Reflections on the Final Project and LCA

Before taking this course, other than learning about a few concepts, I had very little experience with LCA. Although I found parts of the project difficult, overall I had good experience working on a practical LCA project. Many of the concepts that I'd heard about became a lot clearer in actually being thrown into a project. The format of the course, and the topics covered in class, generally followed the LCA framework and in my mind, helped to give an otherwise overwhelming process some order.

The course began with a general introduction to life cycle assessment including history and standards, and moved on to cover goal and scope in depth. The time spent covering goal and scope development was appropriate since the goal and scope of the project have numerous considerations and dictate the rest of the LCA process. We then talked about life cycle inventory analysis, life cycle impact assessment and uncertainty in results.

After learning about LCA in this class, it seemed like one of the most obvious tools that decision makers should be using. I was surprised to find out that LCA is still in the development stage, and really just how complex the LCA process is. The main sticking point for me after taking this class is the fact that it doesn't make sense to have conversations about sustainability without taking a systems view approach. Claims around sustainability can't be justified if the conversation isn't on an equivalent basis. In the case of our buildings, it's difficult to have any meaningful conversation around the impacts associated with that building without having a benchmark to compare to.

I also like the idea that LCA has a wide variety of applications that can be integrated into any engineering discipline. Although the focus in this course was civil-related, as an environmental engineering student, I'll be able to take away the LCA framework and approach to apply it to other systems I encounter.

CEAB Graduate Attributes

Table 18: Graduate Attributes

Graduate Attribute			
Name	Description	Content Code	Which of the CEAB graduate attributes you believe you had to demonstrate during your final project experience.
Knowledge Base	Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.	IA = introduced & applied	LCA framework and standards were introduced in class and then applied to our individual building.
Problem Analysis	An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.	I = introduced	Introduced work arounds within the Impact Estimator to add new material types.
Investigation	An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.	IDA = introduced, developed & applied	Interpretation of comparisons between buildings i.e. class benchmarking.

Design	An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.	N/A = not applicable	
Use of Engineering Tools	An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.	IA = introduced & applied	Using Athena Impact Estimator for Buildings to model the environmental performance of the ESB. Limitations of the IE were a main topic of discussion and investigation throughout the class.
Individual and Team Work	An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.	DA = developed & applied	Team work throughout class exercises led to a better understanding of LCA concepts such as functional unit and product life cycle stages. Individual work was carried out to complete each of the stages and the final project.
Communication	An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.	IA = introduced & applied	Assignment 1 - 'Getting into the know' was an effective way to learn about LCA and communicate some of the barriers and successes associated with LCA in practice. The final report is also requires the effective communication of results and reflection.
Professionalism	An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.	N/A = not applicable	

Impact of Engineering on Society and the Environment	An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.	IDA = introduced, developed & applied	In class we talked about possible end point impacts associated with impact categories that bring the LCA down to the social level. We were also introduced to Life Cycle Costing (LCC) and how this can play a major role in decision-making.
Ethics and Equity	An ability to apply professional ethics, accountability, and equity.	N/A = not applicable	
Economics and Project Management	An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.	I = introduced	Again, in LCC we touched on net present value, the discounting of future costs and how this affects project decisions.
Life-long Learning	An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.	IDA = introduced, developed & applied	LCA is an emerging field and the information and framework is always changing. Our projects and research will put us on par with similar efforts around the world. The UBC LCA building database will help give decision makers a tool to compare new projects on campus.

Annex D – Impact Estimator Inputs and Assumptions

Impact Estimator Inputs

Table 19: IE Inputs

Level 3 Element	Quantity	Units	Assembly Type	Assembly Name	Input Fields	Input Values	
						Known/Measured	IE Inputs
A11 Foundation	1178	m2					
			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
A21 Lowest Floor Construction	1178	m2					
			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%
A22 Upper Floor Construction	4468.7	m2					
			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	39.67	39.7

					(m2)		
					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
			6.1 Steel				
				6.1.1 Columns_HSS_350W(Total Sum) EXTRA BASIC MATERIAL			
					Hollow Structural Steel (tonnes)	23.33	23.33
			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
		4.1 Insulated suspended slab floor				
			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 EXTRA BASIC MATERIAL			
					Thickness (m)	0.089	
					Area (m2)	3056	
					Volume (m3)	271.984	271.984
					Live load (kPa)	3.3	
				4.1.3 Floor_Insulation_SuspendedSlab_25mm EXTRA BASIC MATERIAL			
					Thickness(m)	0.025	
					Area(m2)	3096	3096
					Live load (kPa)	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

A23 Roof Construction	708.00	m2					
			5.1 Roof insulation				
				5.1.1 Roof_insulation EXTRA BASIC MATERIAL			
					Area (m2)	718	718
					Thckness	0.125	
					thickness125=25x5 - Area(m2)	3590	
					Live load (psf)	1.3	
			5.2 Cross laminated timber				
				5.2.1 Roof_CrossLaminatedTimber EXTRA BASIC MATERIAL			
					Area (m2)	708	
					Thickness	0.152	
					Volume	107.616	107.62
					Life load (kPa)	1.3	
			3.2 Wood Columns				
				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
			6.2 Wood				
				6.2.1 Columns_GL_Wood(Total Sum) EXTRA BASIC MATERIAL			
					Glulam Beams (m3)	17.03	17.03

A31 Walls Below Grade	1953.7	m2					
			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
					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	
				Envelope	Thickness	16mm	
			2.1 Cast In Place				
				2.1.1 Wall_Cast-in-Place_W1_200mm			
					Length (mm)	10687	10687
					Height (mm)	4200	4200
					Thickness (mm)	200	200
				Envelope	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
					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
				Envelope	Thickness	-	-
				2.1.3 Wall_Cast-in-Place_W3_300mm			
					Length (mm)	120247	120247
					Height (mm)	4200	4200
				Envelope	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			
					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
				Envelope	Thickness	-	-
				2.1.5 Wall_Cast-in-Place_W6_350mm			
					Length (mm)	16654	19430
				Envelope	Height (mm)	4200	4200

					Thickness (mm)	350	300
					Concrete (MPa)	25	30
					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			
					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
				Envelope	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
					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
				Envelope	Thickness	-	-
				2.1.9 Wall_Cast-in-Place_W9_300mm_5000mmHeight			

					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
				Envelope	Thickness	-	-
A32 Walls Above Grade	6221.9	m2					
			2.3 Curtain Wall				
				2.3.1 Wall_CurtainWall_AllGlazing_12800mm Height			
					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
				Window Opening	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			
					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
				Window Opening	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
			2.4 Steel Stud				
				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 (mm)	39 x 152	39 x 152
					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''
				Envelope	Thickness	16mm	25.381mm-507.614mm
				2.4.20 Wall E3_152mm_SteelStud_1810mmHeight			
					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
				Envelope	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
					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
				Envelope	Material	Air Vapour Moisture	Polyethylene 6mil

					Thickness	Barrier -	
					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			
					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''
				Envelope	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
B11 Partitions	9863.1	m2					
			2.3 Curtain Wall				
				2.3.8 Curtain_Wall_Interior_4786mm_Height			
					Length (mm)	27920	27920
					Height (mm)	4786	4786
					Percent Viewable Glazing	100	100
				Door Opening	Percent Spandrel	0	0

					Panel		
					Thickness of Insulation (mm)	-	-
					Spandrel Type (Metal/Glass)	-	-
					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)	-	-
					Number of Doors	35	35
				Door Opening	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
					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
				Envelope	Category	Gypsum Board	Gypsum Board
					Material	Type X Gypsum Board	Gypsum Fire Rated Type X 5/8''

					Thickness	16mm	25.381mm-507.614mm
					Category Material Thickness	Insulation Acustic Insulation 89mm	Insulation Fiberglass Balt 89mm
					Category Material Thickness	Gypsum Board Type X Gypsum Board 16mm	Gypsum Board Gypsum Fire Rated Type X 5/8'' 25.381mm-507.614mm
					Category Material	Paint -	Paint Latex Water Based
				Door Opening_Metal Doors	Number of Doors Door Type	87 Hollow Metal Door	87 Steel Interior Door
				2.4.2 Wall 1.1_92mm_SteelStud2			
				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 Material Thickness	Gypsum Board Type X Gypsum Board 16mm	Gypsum Board Gypsum Fire Rated Type X 5/8'' 25.381mm-507.614mm
					Category Material Thickness	Insulation Acustic Insulation 89mm	Insulation Fiberglass Balt 89mm
					Category Material	Gypsum Board Type X Gypsum Board	Gypsum Board Gypsum Fire Rated Type X 5/8''

					Thickness	16mm	25.381mm-507.614mm
					Category	Paint	Paint
					Material	-	Latex Water Based
				Door Opening_Wood Doors	Number of Doors	220	220
					Door Type	Solid Core Wood Door	Solid Wood Door
				2.4.3 Wall 1.1_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			

	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
Envelope	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			
	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
				Envelope	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	23	23
					Door Type	Solid Core Wood Door	Solid Wood Door
				2.4.6 Wall 4_92mm_SteelStud			
					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

				Envelope	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_SteelStud2			
					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
				Envelope	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			

					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
				Envelope	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
					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

				Envelope	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			
					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
				Envelope	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			
	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
				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
				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
			2.1 Cast In Place				
				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

Impact Estimator Assumptions

Table 20: IE Assumptions

Assembly Type	Assembly Name	Specific Assumptions
1.1 Concrete Slab-on-Grade		
	1.1.1 SOG_125mm	
		Input for slab thickness is 100mm instead of 125mm due to limited options in Impact Estimator. The size of the slab is adjusted to be the same volume as the volume from real take-off measurements. Flyash% and Concrete strength inputted differ from the actual because of limited options in IE. Closest number was chosen for the study.
	1.1.2 SOG_200mm	
		Flyash% and Concrete strength inputted differ from the actual because of limited options in IE. Closest number was chosen for the study.
1.2 Concrete Footing		
	1.2.1 Footing_PF1	
		The length has been adjusted to account for the number of this type of footing in the building (ie: Length = # of footings x length of 1 footing) Impact Estimator has limited numbers to choose from for Flyash %, Concrete Strength, and Rebar. The numbers put into IE are therefore the closest available ones

	to the measured values.
1.2.2 Footing_PF2	
	Same assumption as 1.2.1 Footing_PF1.
1.2.3. Footing_PF3	
	Same assumption as 1.2.1 Footing_PF1. Input values are adjusted to account for the upper limit of 500mm thickness allowed by IE, so that the input values have the same volume as the measured values.
1.2.4 Footing_PF4	
	Same assumption as 1.2.3 Footing_PF3.
1.2.5 Footing_PF5	
	Same assumption as 1.2.3 Footing_PF3.
1.2.6 Footing_PF6	

		Same assumption as 1.2.1 Footing_PF1.
	1.2.7 Footing_SF1	
		Length of footing determined using total area of all footings of this type divided by the width of one of these footings.
	1.2.8 Footing_SF2	
		Same assumption as 1.2.7 Footing_SF1
	1.2.9 Footing_SF3	
		Same assumption as 1.2.7 Footing_SF1
	1.2.10 Footing_SF4	
		Same assumption as 1.2.7 Footing_SF1
	1.2.11 Footing_SF5	
		Same assumption as 1.2.7 Footing_SF1 Only one type of rebar is allowed for Impact Estimator, hence only 15M was chosen.
	1.2.12 Footing_SF7	
		Same assumption as 1.2.11 Footing_SF5
	1.2.13 Footing_SF8	
		Same assumption as 1.2.11 Footing_SF5
	1.2.14 Footing_SF9	
		Same assumption as 1.2.11 Footing_SF5
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_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.
2.4.13 Wall 9.4_92mm_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.

2.4.14 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.
3.1 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.

4.1 Insulated Suspended Slab					
	4.1.1 Floor_Concrete_Suspendedslab_193mm				
		Weighted average thickness calculation			
			Thick	Length	
		south	300	48	down to basement
		north	365	21	
		north	250	15	
				84	
				2.3	685.7
				1.0	365.0
				0.7	178.6
			Weighted Average		307.3
		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

Concrete	**193**		
Rigid insulation	25		
Laminated stramb lumber	89		
Weighted average floor thickness	307		

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	307		

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	307		
		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.
5.1 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.