Life Cycle Assessment of the "Be" Building

Teresa Amiama

Andrew Lee

Manvil Lo

University of British Columbia

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PROVISIO

This study is part of a larger study – the UBC LCA Project – which is continually developing. As such, the findings contained in this report should be considered preliminary as there may have been subsequent refinements since the initial review of this report.

If further information is required or if you would like to use results from this please contact Mr. Rob Sianchuk.

2012

Review
Rob Sianchuk

Project Team
Teresa Amiama
Andrew Lee
Manvil Lo

[LIFE CYCLE ASSESSEMENT OF THE “BE” BUILDING]

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Abstract

The following document is a report describing a life cycle assessment (LCA) study performed on the BE Building. This LCA study was completed at the request of the UBC SEEDS program to understand the impact of increasing the glazing of a multi-unit residential building through its life cycle and to assist the Residential Environmental Assessment Program (REAP) in developing responsible, mandated glazing ratios. The BE Building is a multi-family residential development located on the University of British Columbia's South Campus. The development consists of a 17-storey high-rise building containing fifty-eight (58) owner-occupied units.

For this LCA study report, the ISO 14040 and 14044 formatting standards have been followed. A sensitivity analysis for five materials was performed, as well as a sensitivity analysis for fenestration ratios. The sensitivity analysis measured the change in environmental impact across the impact categories considered, after a hypothetical 10% increase in material quantity (typically mass) was imposed. Concrete stood out as a leader in the percent impact change in the categories 'weighted resource use', 'global warming potential', and 'smog potential'. Rebar comprised most of the percent change in impact in terms of 'eutrophication potential'. Also worth noting is aluminum's impact. This material has high impacts in all categories except in 'weighted resource use' (where concrete is the outstanding leader), and it has the greatest impact in 'ozone depletion potential' (where concrete is the second greatest contributor).

The result of the sensitivity analysis is a useful tool for examining specific impacts from an increase in standard glazing. A 10% increase in standard glazing didn't contribute to a significant relative change in impact. Notably, the greatest impact from an increased standard glazing was in 'HH Respiratory Effects Potential.'

The glazing ratio (76.9%) was higher than the provided energy use intensities, thus the fenestration ratio study focused on decreasing glazing ratios. The results show that for the life cycle stages "Manufacturing", "Maintenance," and "Operating Energy" a decrease in fenestration ratio decreases the net impacts; on the other hand, "Construction" and "End-of-Life" show a net increase in impacts with decreasing fenestration ratios. Finally, if all the life cycle stages are accounted for together, a decreasing fenestration ratio shows a net decrease in overall impacts.

For future implementations of LCA in residential buildings, the limitations of the IE software reference in the Uncertainties section should be modified. Reviewing impacts of glazing in residential buildings should refer to this report in making evidence-based decisions for policy.

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1.0 Introduction

The following document is a report describing a life cycle assessment (LCA) study performed on the BE Building. This study was carried out between February and March 2012 by a team of three University of British Columbia (UBC) students under the guidance of Rob Sianchuk, an LCA professional.

1.1 Background

the BE Building is a multi-family residential development located in UBC's South Campus. The development consists of a 17-storey high-rise building containing fifty-eight (58) owner-occupied units, along with seven (7) townhouse units which are structurally separate from the high-rise tower. These townhouses have been excluded from this study; thus, within this report, "the BE Building" refers only to the high-rise tower.

the BE Building is marketed as a luxury high-rise featuring sustainable environmental design. The building is accredited with a Silver rating under the Residential Environmental Assessment Program (REAP), a green building rating system developed by UBC. Described green building features include, "high-performance heating and cooling systems, low E-coated glass windows, and large wraparound balconies that shade the residences from direct sunlight in summer." (ASPAC, 2012)

The developers of the BE Building were ASPAC, a real-estate development company based in Vancouver, British Columbia. Architectural services were performed by Musson Cattell Mackey Partnership. The general contractor was Ledcor. Construction commenced in 2007 and completed in 2009.

1.2 Structural Characteristics

The primary structural and building envelope characteristics of the BE Building are summarized in Table 1, on the next page.

Table 1. Building Characteristics of the BE Building

Building System	**Specific Characteristics**
Structure	Parking levels: Concrete columns and slab-bands supporting suspended slabs Levels 1 to 17: Concrete columns supporting concrete suspended slabs
Floors	Parking levels: Concrete slab

	Levels 1 to 17: Concrete suspended slabs
Exterior Walls	Cast-in-place and steel stud assemblies
Interior Walls	Steel stud, cast-in-place, and concrete block assemblies
Windows	Standard glazing with aluminum frames
Roof	Suspended concrete slab
Mechanical	Air shafts

2.0 Goal and Scope

The Goal & Scope is critical to documenting the context and guiding an LCA study's execution. The purpose of defining the Goal of the study is to unambiguously state the context of the study, whereas the Scope details how the actual modeling of the study was carried out. For this LCA study report, the format immediately below has been used to unambiguously outline the details of the parameters outlined in ISO 14040 and 14044.

Parameter Name

Parameter definition.

Details of how this item is defined for the LCA study of the BE Building.

This format has been followed throughout the Goal & Scope in order to provide the audience with an explanation of each parameter and transparently state how it is defined for the LCA study of the BE Building.

2.1. Goal of Study

The following are descriptions for a set of parameters which unambiguously state the context of the LCA study of the BE Building.

Intended application

Describes the purpose of the LCA study.

This LCA study will be used in three ways:

- As a benchmark for similar buildings, demonstrating the environmental impacts of construction of residential buildings
- As a guide towards informing decision-making and future policy regarding glazing and fenestration and their effects on building energy consumption
- As an exemplary demonstration of the latest in environmental impact accounting methods in order to contribute to the further development of such activities.

Reasons for carrying out the study

Describes the motivation for carrying out the study.

This LCA study was completed at the request of UBC SEEDS to understand the impact of increasing the glazing of a multi-unit residential building through its life cycle and to assist the Residential Environmental Assessment Program (REAP) in developing responsible, mandated glazing ratios. Secondly, the report itself is an educational asset to help disseminate education on LCA and help further the development of this scientific method into sustainability in building construction practices at UBC and the green building industry as LCA is rapidly gaining acceptance at all scales of sustainable construction standards and corporate social responsibility policy.

Intended audience

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

The results of this study are to be primarily communicated to policymakers, while also remaining accessible to the general public. In addition, the LCA report is intended to be communicated to industry and governments groups observing and involved in green building, as LCA is an emerging topic of significance in this area.

Intended for comparative assertions

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

The results of this LCA study are intended for comparative assertions between this building and two other UBC residential buildings (LCA studies performed simultaneously by different groups) , as well as with the building LCA studies contained within the UBC LCA Database.

2.2 Scope of Study

The following are descriptions for a set of parameters that detail how the actual modeling of the study was carried out.

Product system to be studied

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

A unit process is a measurable activity that consumes inputs and emits outputs as a result of providing a product or service. The main processes that make up the product system to be studied in this LCA study are the manufacturing of construction products (Figure 1. Generic unit processes considered within Construction Product Manufacturing process by Impact Estimator software), the construction of a building (Figure 2. Generic unit processes considered within Building Construction process by Impact Estimator software), the operation and maintenance of the building (Figure 3. Generic unit processes considered within Building Maintenance process by Impact Estimator software), and the demolition of a building (Figure 4. Generic unit processes considered within Building Demolition process by Impact Estimator software). These four processes are the building blocks of the LCA models that have been developed to describe the impacts associated with the BE Building. The unit processes and inputs and outputs considered within these four main processes are outlined below.

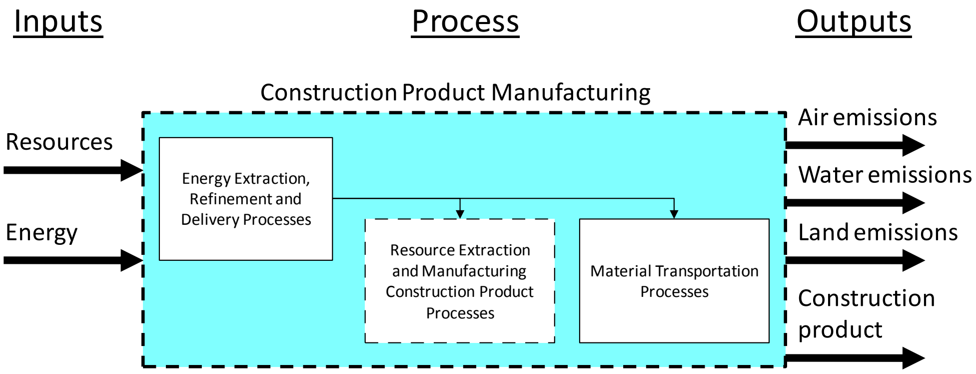

Figure 1. Generic unit processes considered within Construction Product Manufacturing process by Impact Estimator software

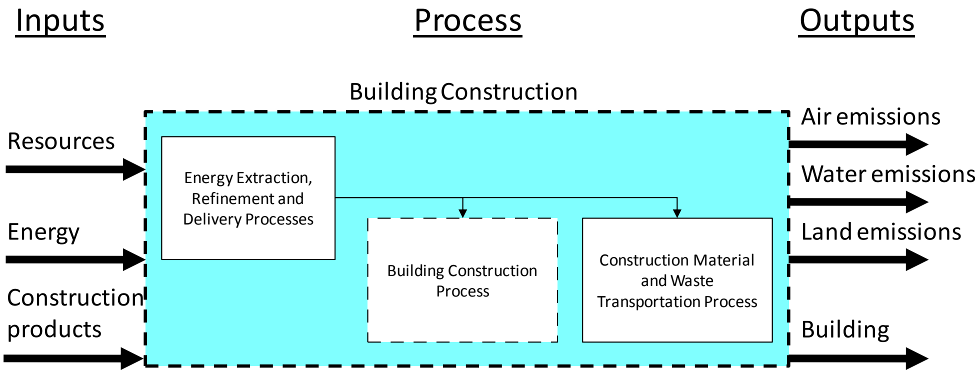

Figure 2. Generic unit processes considered within Building Construction process by Impact Estimator software

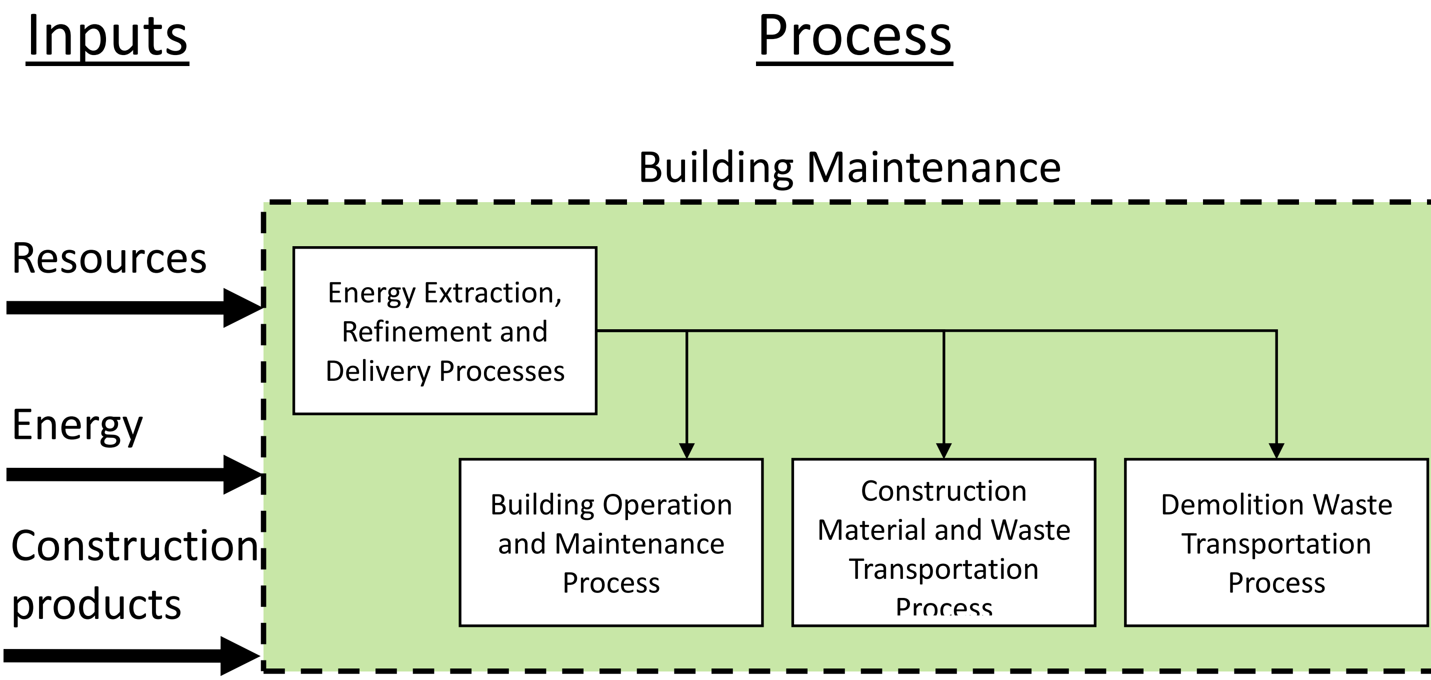

Figure 3. Generic unit processes considered within Building Maintenance process by Impact Estimator software

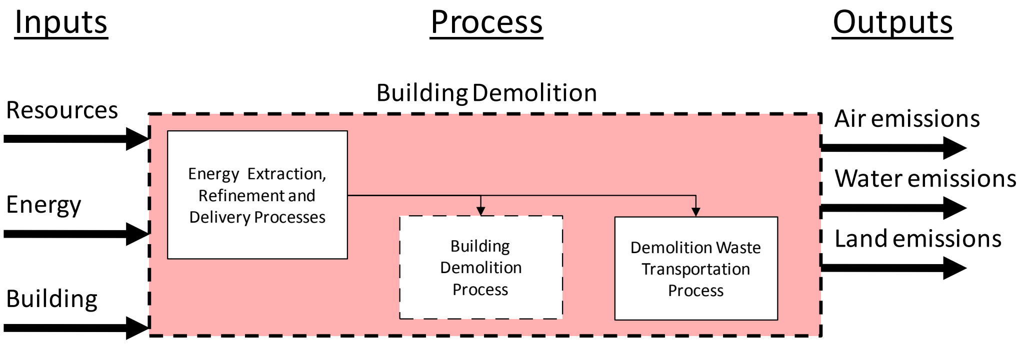

Figure 4. Generic unit processes considered within Building Demolition process by Impact Estimator software

As seen in the above figures, the inputs and outputs occurring at the various stages in a building's life cycle are captured. The organization of these processes into the product systems to describe the impacts of building construction requires the definition of a system boundary. Thus, the product system studied in this LCA study of the BE Building is further defined in the system boundary section below.

System boundary

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

The BE Building LCA study involved analysis of the cradle-to-grave life cycle of a new building. The LCA model developed to describe the impacts created by this building were created in the Impact Estimator software using the generic unit processes, within the processes, illustrated previously in Figure 1. Generic unit processes considered within Construction Product Manufacturing process by Impact Estimator software, Figure 2. Generic unit processes considered within Building Construction process by Impact Estimator software, Figure 3. Generic unit processes considered within Building Maintenance process by Impact Estimator software, and Figure 4. Generic unit processes considered within Building Demolition process by Impact Estimator software.

The product components studied are those of the BE Building high-rise building. Specifically, this study includes the construction products used to create its structure and envelope. This indicates that product components must be defined as the materials within the product studied.

The material product components (i.e. building assemblies) that were included from the product (i.e. building) are the footings, slabs on grade, walls, columns and beams, roofs, as well as all associated doors and windows, gypsum board, vapour barriers, insulation, cladding and roofing. These material product components are in turn assemblies of construction products.

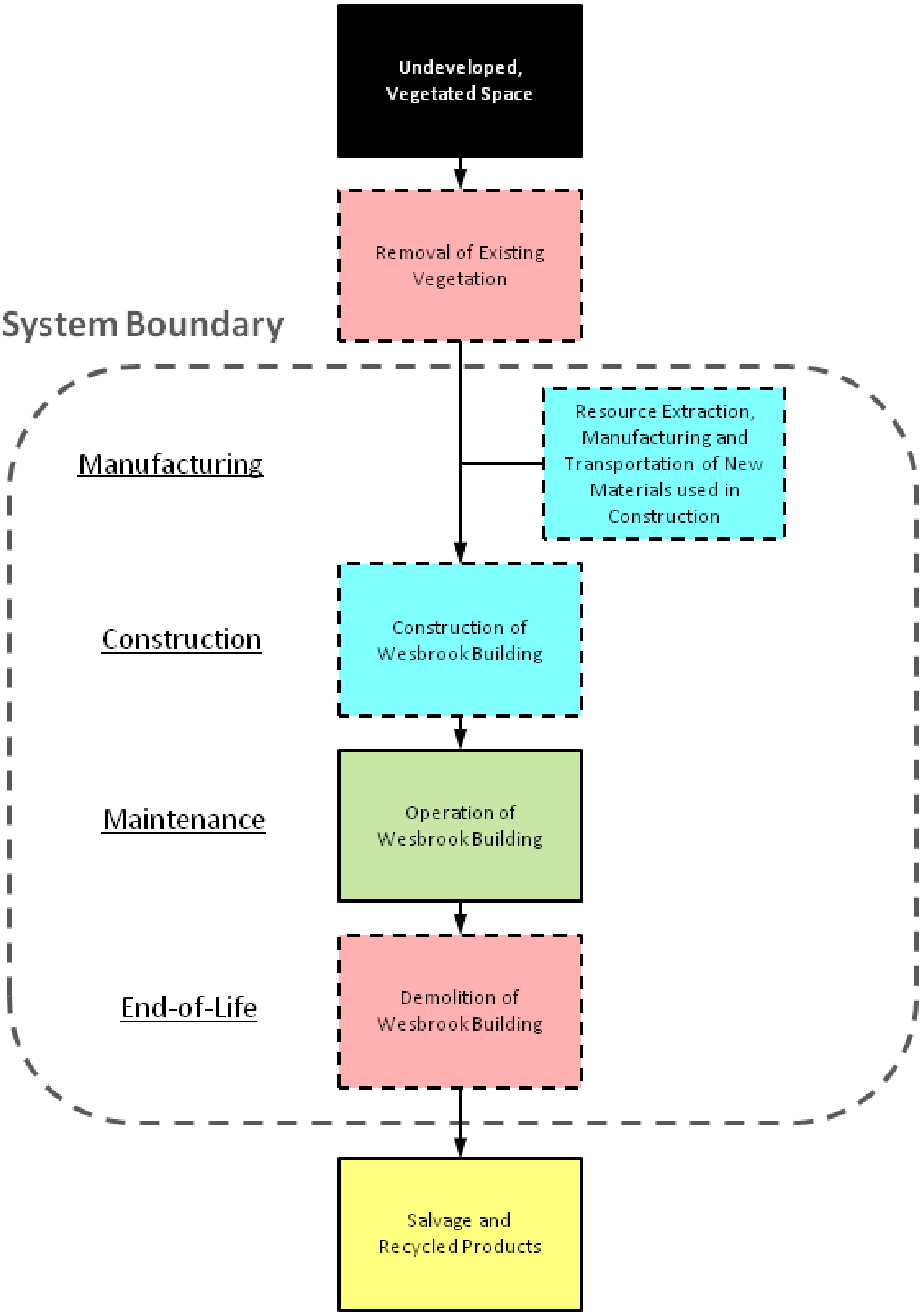

Figure 5. System Boundary

The life cycle stages considered include those spanning from cradle-to-grave. The model excludes the impacts associated with the transformation of existing vegetated space into developed land. The manufacturing phase captures resource extraction and manufacturing of construction products. The construction phase captures the building construction process. The maintenance phase includes operational impacts and periodic repair and replacement of building components. An end-of-life cycle phase captures the demolition of the BE Building and the transportation of demolition wastes. The impact of any resulting salvage or recycling beyond the demolition phase is excluded from the scope of this LCA study.

Functions of the product system

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

A description of the BE Building's major functions have been outlined in the Introduction of this report.

Functional unit

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

The functional units used in this study to normalize the LCA results for the BE Building include:

- *per generic residential building square foot constructed*
- *per specific residential building square foot constructed*
- *per residential building occupant*
- *per fenestration square foot constructed*

Further discussion of these functional units and their application are contained in the Impact Assessment sub-section under Functions and Impacts.

Allocation procedures

Describes how the input and output flows of the studied product system (and unit processes within it) are distributed between it and other related product systems.

The problem of allocation arises in three situations – i) when a process produces more than one product, ii) a waste treatment process collectively treats multiple wastes products and iii) when materials are recycled or reused in subsequent life cycles. An allocation problem arises in these situations because the input and output flows from the processes must be shared amongst the products and subsequent life cycles.

In this study, the cut-off allocation method was used, which entails that only the impacts directly caused by a product within a given life cycle stage are allocated to that product.

That is, although construction and demolitions wastes are direct outputs from this building, their potential subsequent life cycles were outside the scope of this LCA study. That is, the end of life phase ends once the wastes are transported to their end of life process, and does not include consideration of waste treatment processes or possible subsequent life cycles.

Impact assessment methodology and categories selected

State the methodology used to characterize the LCI results and the impact categories that will address the environmental and other issues of concern.

The primary impact assessment method used in the BE Building LCA study was the Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI), developed by the US Environmental Protection Agency (US EPA). An impact characterization method developed by the Athena Institute was also used to characterize weighted raw resource use and fossil fuel consumption.

The impact categories selected and the units used to express them (i.e. category indicators) are listed below:

- Global warming potential – kg CO_2 equivalents
- Ozone depletion potential – kg CFC^{-11} equivalents
- Acidification potential – H^+ mol equivalents
- Eutrophication potential – kg N equivalents
- Photochemical smog potential – kg NOx equivalents
- Human health respiratory effects potential – kg $PM_{2.5}$ equivalents
- Weighted raw resource use – kg
- Fossil fuel consumption – MJ

Short descriptions of each of these impact categories are provided in the Impact Assessment sub-section in Results and Interpretation.

Interpretation to be used

Statement of significant issues, model evaluation results and concluding remarks.

Analysis and discussions of uncertainty, sensitivity, and functional units of this LCA study are contained in the Results and Interpretation section of this report, whereas concluding remarks are contained in the Conclusion.

Assumptions

Explicit statement of all assumptions used to by the modeler to measure, calculate or estimate information in order to complete the study of the product system.

With data sources, there were two main areas where assumptions were integrated: materials takeoffs of building assemblies and assumptions contained within the Impact Estimator.

The details of the methods used in completing the material take offs on the building drawings are summarized in the Model Development section of this report.

All of the inputs and assumptions associated with interfacing these takeoffs with the Impact Estimator are documented in the Input Document (Appendix A) and the Assumptions Document (Appendix B). Assumptions were typically required in the development of building assembly information due to missing information as well as limitations in construction product LCI data and assembly characteristics in the Impact Estimator.

Assumptions regarding the completion of take offs to estimate material use, referenced LCI data and transportation networks have all been developed by the Athena Institute and are built into the Impact Estimator version 4.1.14. This information is proprietary; however, parts can be accessed through the inner workings report found on the Athena Institute webpage.[1]

Value choices and optional elements

Details the application and use of normalization, grouping, weighting and further data quality analysis used to better understand the LCA study results.

Value choices and optional elements were not included in this study due to limited time and resources, however, this report does provide sufficient documentation for its audience to carry out these types of analyses.

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[1] Athena Impact Estimator for Buildings: Software Overview – http://www.athenasmi.org/our-software-data/impactEstimator/

Limitations

Describe the extents to which the results of the modeling carried out on the product system accurately estimate the impacts created by the product system defined by the system boundary of the study.

The following limitations should be considered when interpreting the results of this LCA study.

- System Boundary – Any of the impacts created or avoided through the reuse, recycling or waste treatment of the construction or demolition wastes emitted were outside the scope of this study.
- Data Sources and Assumptions – This LCA study used original architectural and structural drawings obtained from Musson Cattell Mackey Partnership to develop information on the building assemblies in the construction of the BE Building. The resulting LCA models are specific to these buildings as their bills of materials reflect their unique designs. Furthermore, the life cycle inventory (LCI) flows and their characterization reflect averages of industry processes and their impacts for North America. This is due to the fact that those industries engaged in the North American construction market are currently not providing this LCI data. Furthermore, it was not possible to regionalize the impacts of processes and their inventory flows due to time and resource constraints in conducting this study.

Data quality requirements

Qualitative and quantitative description of the sourced data used in the study including its age, geographical and technological coverage, precision, completeness, reproducibility and uncertainty.

The sources of data used in the development of this LCA study include those used to estimate results for the bill of materials, life cycle inventory (LCI) flows and the characterization of LCI flows.

- Bill of Materials - Architectural and structural drawings were obtained from Musson Cattell Mackey Partnership (MCM) to develop information on the building assemblies in the partial construction of the BE Building. Architects at MCM also contributed information where information was either missing or unclear in the drawings. The precision of the quantity take offs does rely somewhat on the quantity takeoffs built into the Impact Estimator, as the quantity take offs from the drawings are input and completed by the Impact Estimator. However, the use of the Impact Estimator does enable these results to be reproduced due to all results being documented in the Inputs and Assumptions Documents contained in Appendix A and B in this report.

- LCI flows – The Athena LCI Database was the source of LCI data. An assessment of the quality of the data and modeling assumptions used to develop the Athena LCI Database (which is built into the Impact Estimator) was outside the time and resource constraints of this study. However, some of this information can be accessed through the inner workings report found on the Athena Institute webpage[2]. Generally speaking, this database is specific to the current North American context, and thus does create some geographic and temporal limitations on this study. For instance, i) The construction product manufacturing as well as fuel refining and production LCI data is based on North American averages ii) The transportation matrix that estimates distances and modes for construction product transportation as well as construction and demolition wastes is specific to Vancouver, British Columbia iii) The LCI data and modeling parameters in the Impact Estimator were developed by the Athena Institute to reflect current circumstances and technologies.
- Characterization factors – Documentation of the US EPA TRACI impact assessment method can be found on the US EPA website[3], and documentation for the development of the weighted resource use impact category can be found on the Athena Institute webpage[4]. Generally speaking, this method characterized LCI flows to reflect their potential to cause damage on average in North America. Qualitative discussion of the uncertainties present in the impact assessment results are contained in this report in the Impact Assessment sub-section of Results and Interpretation.

Type of critical review

A review of the methods, data, interpretations, transparency, and consistency of the LCA study.

An ISO 14044 critical review has not been completed on this report. The report content and results have received a general review by Rob Sianchuk using a standardized grading rubric developed for the course in which this study was developed. If this report is to be used outside of intended application, it is strongly advised that the authors be included in communications.

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[2] Athena Impact Estimator for Buildings: Software Overview – http://www.athenasmi.org/our-software-data/impactEstimator/

[3] US EPA TRACI documentation - http://www.epa.gov/nrmrl/std/traci/traci.html

[4] Weighted resource use impact category development - http://www.athenasmi.org/wp-content/uploads/2011/10/16_ECC_Impacts_of_Resource_Extraction.pdf

Type and format of the report required for the study

Statement of the type and format followed by the report.

The format of this report followed the report outline provided by Rob Sianchuk, the advisor and supervisor of this study.

3.0 Model Development

This section details the processes undertaken to model the components of the product system, the BE Building, and their impacts.

3.1 Structure and Envelope

3.1.1 Material Takeoff Development

Quantities takeoffs were performed using the software program, On-Screen Takeoff 3 (OST 3). Each assembly was modeled using one of the three modeling conditions available in the software program: linear, area, and count conditions.

The linear condition was used to model assemblies with variable length and uniform height and thickness. This included strip footings and walls.

The area condition was used to determine surface areas. Floor areas of different functional types and roof areas were quantified using this condition. Additionally, spread footings volumes were calculated by multiplying area takeoffs with footing thicknesses.

The count condition was used to quantify groups of objects with identical properties: columns, beams, windows, and doors.

3.1.2 Material Takeoff Assumptions

Due to the input limitations of Athena Impact Estimator or unavailability of data, a number of assumptions and approximations were necessary. Actual and measured values, stated unknowns, and corresponding input values are presented in Appendix A. Assumptions and any calculations pertaining to these assumptions are detailed in Appendix B.

Foundation

Rebar quantities are calculated by IE based solely on the input rebar size while using internally-assumed rebar spacing and configurations. All rebar sizes were specified in construction drawings using Canadian standard sizes. Because the Imperial unit system was selected as the input measurement system, only input of U.S. rebar sizes were allowed by IE. The closest corresponding sizes available; of which three rebar sizes were available in the IE, thus the maximum size was selected when the actual rebar size exceeded this maximum.

Table 2. Canadian Standard Rebar Sizes

Bar Size	Nominal Diameter (mm)
10M	11.3
15M	16
20M	19.5
25M	25.2
30M	29.9

Table 3. Allowed IE Inputs, US Standard Rebar Sizes

Bar Size	Nominal Diameter (mm)
#4	12.7
#5	15.875
#6	19.05

IE has a footing thickness limitation of 19.4 inches. Where footing thicknesses exceeded this value, the thickness was specified as 19 inches and the input footing width was adjusted accordingly to maintain the same footing volume.

Flyash content was assumed to be average where information was unavailable.

Walls

As previously stated, the wall quantities were calculated using a linear condition in OST 3. The type of information collected to input in the IE is as follows:

Wall assemblies were assumed to be an average height of 9.875 ft. In addition, they had three types of information that was required:

- The type of wall assembly: steel stud, cast-in-place, concrete block, and curtain walls for were types of assemblies used. Each type of wall assembly in turn has different inputs that are required; Table 4 is a summary of the information recorded.
- The envelope: information such as the type and thickness of insulation or type of gypsum wall board.
- The opening: number and types of windows and doors.

Table 4. Wall Assembly Types and Information Collected

Wall Assembly	Information Required	Wall Assembly	Information Required
Steel Stud	Wall type (load bearing or non-load bearing	Cast-in-Place	Concrete (20 MPa, 30 MPa, or 60 MPa)
	Stud weight (25 Ga or 20 Ga)		Thickness (8” or 12”)
	Sheathing type (none, OSB, plywood)		Reinforcement (#15 M or #20 M)
	Stud thickness (1 5/8 x 3 5/8 or 6 or 8 in)		Concrete Flyash (25% or 35%)
	Stud spacing (16 o.c. or 24 o.c.)	Concrete Block	Rebar (#10 or #15)
Wall Assembly	Information Required		
Curtain Wall	Percent Viewable Glazing (%)		
	Percent Spandrel Panel (%)		
	Thickness of insulation		
	Spandrel Panel Type (metal or opaque glass		

Several assumptions were made in this process, such as assigning the type of glazing, flyash content of concrete, and type of insulation, since information was not available; this portion of the study is a source of error.

Doors and windows were added using a count condition in OST 3. Since floors 3 through 13 were identical, one takeoff of the drawing was taken and the results multiplied by 11 in order to calculate the length of the wall assemblies in those floors.

Floors

The floor was assumed to be a suspended concrete slab. The square footage was calculated for all floors using take-offs. For floors 3 through 13, the square footage was multiplied by the number of floors, given that each of those floors are identical. Balconies were assumed to be of different thickness and concrete type. This assumption did not affect square footage, but affected the volume of concrete in the bill of materials.

Columns & Beams

Column and beam quantities were calculated internally by IE using the following inputs for a given storey: number of beams, number of columns, floor to floor height, bay size, supported span, and live load.

Loads were assumed to be distributed equally to all columns and spans on a given floor; thus, bay size and supported spans were assumed to be equal to the square root of the quotient of gross floor area divided by the number of columns of a particular storey.

Different design live loads were specified based on the function of the floor area (ie. typical residential, parking, exits and stairs). The input live load for a given storey was taken to be the area-weighted average live load.

Roof

Roofs were modeled in the IE software using the maximum span possible allowed in Athena. The area condition from OST 3 was considered in the adjustments made to roofing span. Loads were specified in the drawings, but the IE software provided a limited number of choices, so the closest load quantity was chosen to approximate the roof.

3.2 Operating Energy

The impacts of operating energy consumption were calculated internally by Impact Estimator given the following inputs: total floor area, annual electricity use intensity, and annual natural gas use intensity.

3.2.1 Energy Use Development

Annual electrical energy use intensity and natural gas use intensity were provided by the UBC Sustainability Office as a function of glazing ratio (window area / total wall area) and building floor area. A glazing ratio of 68.6% was estimated, based on the quantity takeoffs. A building floor area of 12,853 m^2 was provided by the developer, which excludes exterior or unheated areas. Typical electrical energy use intensities ($kWh/m^2/yr$) and natural gas use intensities ($m^3/m^2/yr$) for high-rise concrete structures with various glazing ratios were provided by the UBC Sustainability Office. Extrapolating, typical values of 104 $kWh/m^2/yr$ and 8.81 $m^3/m^2/yr$ were determined, respectively. This equates to an electrical energy use intensity of 1,341,807 kWh/yr and natural gas use intensity of 113,296 m^3/yr.

3.2.2 Energy Use Assumptions

An assumption had to be made in order to calculate the energy use for the BE Building. Since the glazing ratio was higher than the provided values, these values had to be extrapolated with the assumption that the relation remained linear. Figure 6 shows the energy use values provided.

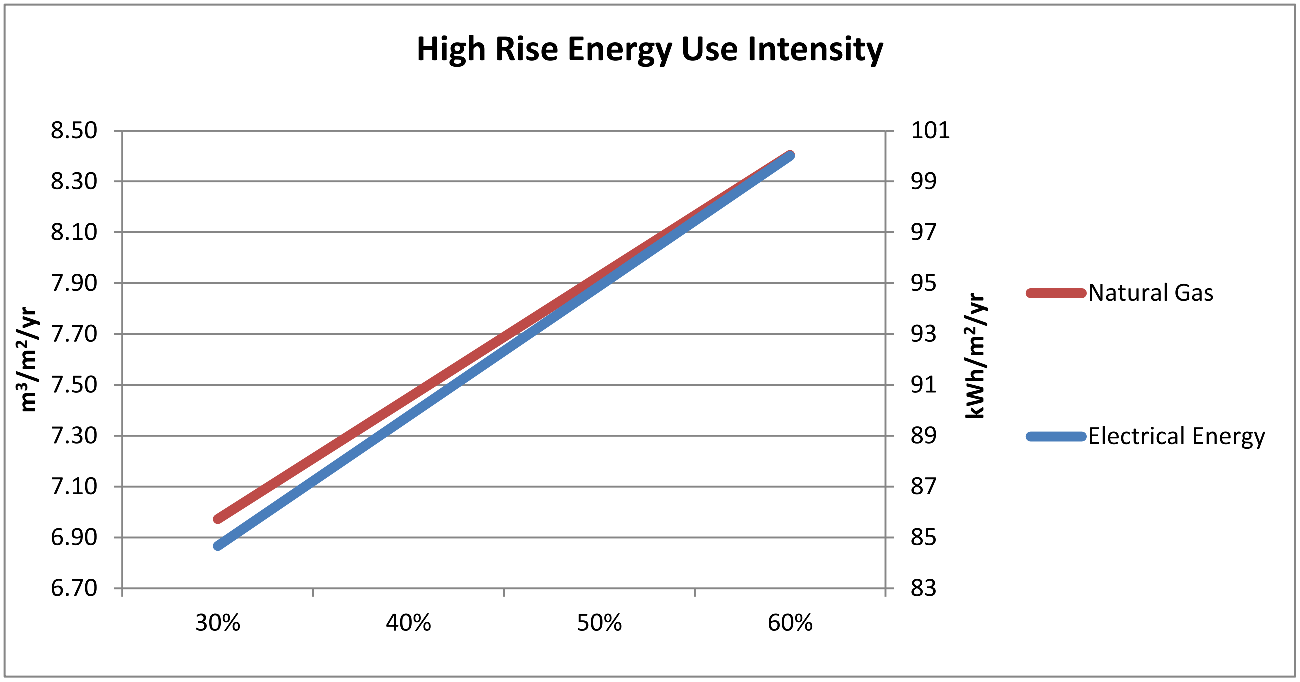


Figure 6. Natural Gas and Electrical Energy Use Values Provided

4.0 Results

4.1 Inventory Analysis

4.1.1 Bill of Materials

The Bill of Materials of the BE Building is presented in Table 5., below. Material quantities are sorted by assembly group, as well as totaled for the entire building.

Table 5. Bill of Materials

Construction Material	Units	Assembly Group					
		Foundation	Walls	Floors	Columns & Beams	Roof	Building Total
Concrete 30 MPa (flyash 35%)	m3	617.35		590.73			1,208.09
Concrete 30 Mpa (flyash av)	m3	199.55	2,232.76	2,401.79	40,355.34		45,189.44
Rebar, Rod, Light Sections	Tonnes	2.32	253.56	205.23	15,051.60	4.44	15,517.15
Concrete 20 Mpa (flyash av)	m3		20.61			66.32	86.93
#15 Organic Felt	m2		23,382.58				23,382.58
½" Fire-Rated Type X Gypsum Board	m2		1,693.00				1,693.00
½" Gypsum Fibre Gypsum Board	m2		4,159.19				4,159.19
½" Regular Gypsum Board	m2		49,915.84				49,915.84
5/8" Fire-Rated Type X Gypsum Board	m2		15,218.75				15,218.75
5/8" Regular Gypsum Board	m2		187.01				187.01
6 mil Polyethylene	m2		4,010.97				4,010.97
Aluminum	Tonnes		145.95				145.95
Batt. Fiberglass	m2 (25mm)		104,600.14				104,600.14
Blown Cellulose	m2 (25mm)		221.40				221.40
Cold Rolled Sheet	Tonnes		15.37				15.37
Concrete Blocks	Blocks		21,146.27				21,146.27
EPDM membrane (black, 60 mil)	kg		13,720.62				13,720.62
Foam Polyisocyanurate	m2 (25mm)		400.20				400.20
Galvanized Sheet	Tonnes		16.40				16.40
Galvanized Studs	Tonnes		139.62				139.62
Glazing Panel	Tonnes		986.19				986.19
Joint Compound	Tonnes		71.02				71.02
Mortar	m3		450.06				450.06
Nails	Tonnes		8.64				8.64

Natural Stone	m2		3,768.81				3,768.81
Oriented Strand Board	m2 (9mm)		267.77				267.77
Paper Tape	Tonnes		0.82				0.82
PVC	kg		18,342.41				18,342.41
Screws Nuts & Bolts	Tonnes		9.88				9.88
Small Dimension Softwood Lumber, kiln-dried	m3		9.15				9.15
Solvent Based Alkyd Paint	L		38.91				38.91
Standard Glazing	m2		4,715.13				4,715.13
Water Based Latex Paint	L		521.90				521.90

4.1.2 Energy Use

The annual and overall energy use of the BE Building was provided by the UBC Sustainability Office as annual energy use intensity of electrical and natural gas. Table 6 presents these calculated values.

Table 6. Energy Use for the BE Building

Energy Type	Annual (per year)	Total (99 years)
Electrical (kWh)	1341807	132838902
Natural Gas (m3)	113296	11216286

4.2 Impact Assessment

The outputs of Impact Estimator provide an estimate impact quantities across the eight impact categories of concern: Global Warming Potential, Ozone Layer Depletion, Acidification Potential, Eutrophication Potential, Smog Potential, Human Health Respiratory Effects, Weighted Resource Use, and Fossil Fuel Use. The impacts associated with each life cycle phase and each building assembly group are presented in Table 7 through 14.

Table 7. Global Warming Potential by Life Cycle Stage and Assembly Group

Life Cycle Stage	Process	Global Warming Potential	Assembly Group					
			Foundation	Walls	Floors	Columns & Beams	Roof	Building Total
Manufacturing	Material	kg CO2 eq	191822	2471129	905924	722464	17708	4310000
	Transportation	kg CO2 eq	7008	55022	28106	21678	583	112000
	Total	kg CO2 eq	198830	2526151	934029	744142	18291	4420000
Construction	Material	kg CO2 eq	2826	44989	41140	0	911	89900
	Transportatio	kg CO2 eq	9910	96893	37283	20298	961	165000

	n							
	Total	kg CO2 eq	12735	141882	78424	20298	1873	255000
Maintenance	Material	kg CO2 eq		1668730				1670000
	Transportation	kg CO2 eq		104642				105000
	Total	kg CO2 eq		1773371				1770000
End-of-Life	Material	kg CO2 eq	5833	24590	22791	14502	505	68200
	Transportation	kg CO2 eq	4909	25048	18499	10144	410	59000
	Total	kg CO2 eq	10742	49638	41290	24647	915	127000
Operating Energy	Annual	kg CO2 eq	321553	321553	321553	321553	321553	321553
	Total	kg CO2 eq	31833786	31833786	31833786	31833786	31833786	31833786

Table 8. Ozone Layer Depletion by Life Cycle Stage and Assembly Group

Life Cycle Stage	Process	Ozone Layer Depletion	Assembly Group					
			Foundation	Walls	Floors	Columns & Beams	Roof	Building Total
Manufacturing	Material	kg CFC-11 eq	3.88E-04	4.08E-03	1.63E-03	8.11E-04	4.66E-05	6.93E-03
	Transportation	kg CFC-11 eq	2.98E-07	2.31E-06	1.18E-06	9.02E-07	2.39E-08	4.72E-06
	Total	kg CFC-11 eq	3.88E-04	4.08E-03	1.63E-03	8.12E-04	4.66E-05	6.93E-03
Construction	Material	kg CFC-11 eq	0.00E+00	2.14E-09	0.00E+00	0.00E+00	0.00E+00	2.14E-09
	Transportation	kg CFC-11 eq	4.06E-07	3.98E-06	1.53E-06	8.31E-07	3.94E-08	6.78E-06
	Total	kg CFC-11 eq	4.06E-07	3.98E-06	1.53E-06	8.31E-07	3.94E-08	6.78E-06
Maintenance	Material	kg CFC-11 eq		2.43E-03				2.43E-03
	Transportation	kg CFC-11 eq		4.29E-06				4.29E-06
	Total	kg CFC-11 eq		2.43E-03				2.43E-03
End-of-Life	Material	kg CFC-11 eq	2.63E-07	1.11E-06	1.03E-06	6.53E-07	2.28E-08	3.07E-06
	Transportation	kg CFC-11 eq	2.01E-07	1.03E-06	7.58E-07	4.15E-07	1.68E-08	2.42E-06
	Total	kg CFC-11 eq	4.64E-07	2.13E-06	1.78E-06	1.07E-06	3.95E-08	5.49E-06
Operating Energy	Annual	kg CFC-11 eq	2.66E-07	2.66E-07	2.66E-07	2.66E-07	2.66E-07	2.66E-07
	Total	kg CFC-11 eq	2.64E-05	2.64E-05	2.64E-05	2.64E-05	2.64E-05	2.64E-05

Table 9. Acidification Potential by Life Cycle Stage and Assembly Group

Life Cycle Stage	Process	Acidification Potential	Assembly Group					
			Foundation	Walls	Floors	Columns & Beams	Roof	Building Total
Manufacturing	Material	moles of H+ eq	65451	1195290	310159	248013	4849	1824115
	Transportation	moles of H+ eq	3470	23318	12109	8229	191	47335
	Total	moles of H+ eq	68922	1218608	322268	256242	5041	1871450
Construction	Material	moles of H+ eq	1522	23069	25059	0	555	50205
	Transportation	moles of H+ eq	3125	34069	11759	6402	303	55616
	Total	moles of H+ eq	4647	57138	36818	6402	858	105822
Maintenance	Material	moles of H+ eq		977958				977958
	Transportation	moles of H+ eq		33846				33846
	Total	moles of H+ eq		1011803				1011803
End-of-Life	Material	moles of H+ eq	323	1363	1264	804	28	3782
	Transportation	moles of H+ eq	1548	7900	5835	3199	129	18612
	Total	moles of H+ eq	1872	9263	7098	4004	157	22394
Operating Energy	Annual	moles of H+ eq	134201	134201	134201	134201	134201	134201
	Total	moles of H+ eq	13285862	13285862	13285862	13285862	13285862	13285862

Table 10. Eutrophication Potential by Life Cycle Stage and Assembly Group

Life Cycle Stage	Process	Eutrophication Potential	Assembly Group					
			Foundation	Walls	Floors	Columns & Beams	Roof	Building Total
Manufacturing	Material	kg N eq	47.204	963.769	456.245	884.430	7.538	2360.597
	Transportation	kg N eq	3.682	24.568	12.769	8.621	0.199	49.858
	Total	kg N eq	50.887	988.337	469.014	893.051	7.736	2410.455
Construction	Material	kg N eq	0.945	21.481	24.981	0	0.553	47.961
	Transportation	kg N eq	3.238	35.539	12.181	6.632	0.314	57.859
	Total	kg N eq	4.183	57.019	37.163	6.632	0.868	105.820
Maintenance	Material	kg N eq		515.954				515.954
	Transportation	kg N eq		35.119				35.119
	Total	kg N eq		551.073				551.073

End-of-Life	Material	kg N eq	0.222	0.936	0.868	0.552	0.019	2.597
	Transportation	kg N eq	1.463	7.463	5.512	3.023	0.122	17.583
	Total	kg N eq	1.685	8.400	6.380	3.575	0.141	20.180
Operating Energy	Annual	kg N eq	13.234	0.001	0.001	0.001	0.001	13.234
	Total	kg N eq	1310.165	0.102	0.102	0.102	0.102	1310.165

Table 11. Smog Potential by Life Cycle Stage and Assembly Group

Life Cycle Stage	**Process**	**Smog Potential**	**Assembly Group**					
			Foundation	**Walls**	**Floors**	**Columns & Beams**	**Roof**	**Building Total**
Manufacturing	Material	kg NOx eq	969.609	9150.386	4244.151	2585.438	33.185	17018.248
	Transportation	kg NOx eq	81.084	538.659	279.929	187.897	4.290	1092.331
	Total	kg NOx eq	1050.693	9689.045	4524.080	2773.335	37.475	18110.579
Construction	Material	kg NOx eq	30.737	532.693	603.532	0	13.371	1180.333
	Transportation	kg NOx eq	69.758	768.627	262.455	142.890	6.767	1249.547
	Total	kg NOx eq	100.495	1301.320	865.987	142.890	20.138	2429.880
Maintenance	Material	kg NOx eq		8992.560				8992.560
	Transportation	kg NOx eq		757.833				757.833
	Total	kg NOx eq		9750.393				9750.393
End-of-Life	Material	kg NOx eq	4.155	17.518	16.236	10.332	0.360	48.601
	Transportation	kg NOx eq	34.557	176.327	130.224	71.411	2.886	415.404
	Total	kg NOx eq	38.713	193.844	146.460	81.742	3.246	464.005
Operating Energy	Annual	kg NOx eq	134.830	134.830	134.830	134.830	134.830	134.830
	Total	kg NOx eq	13348.181	13348.181	13348.181	13348.181	13348.181	13348.181

Table 12. Human Health Respiratory Effects by Life Cycle Stage and Assembly Group

Life Cycle Stage	**Process**	**Human Health Respiratory Effects**	**Assembly Group**					
			Foundation	**Walls**	**Floors**	**Columns & Beams**	**Roof**	**Building Total**
Manufacturing	Material	kg PM2.5 eq	459.766	13895.353	2022.013	1384.330	37.566	17797.255
	Transportation	kg PM2.5 eq	4.235	28.329	14.719	9.961	0.230	57.496

	Total	kg PM2.5 eq	464.001	13923.683	2036.732	1394.290	37.796	17854.752
Construction	Material	kg PM2.5 eq	1.071	25.766	28.308	0.000	0.627	55.772
	Transportation	kg PM2.5 eq	3.756	41.125	14.132	7.694	0.364	67.020
	Total	kg PM2.5 eq	4.827	66.891	42.440	7.694	0.992	122.791
Maintenance	Material	kg PM2.5 eq		21884.063				21884.063
	Transportation	kg PM2.5 eq		40.718				40.718
	Total	kg PM2.5 eq		21924.781				21924.781
End-of-Life	Material	kg PM2.5 eq	0.308	1.298	1.203	0.765	0.027	3.601
	Transportation	kg PM2.5 eq	1.861	9.494	7.012	3.845	0.155	22.367
	Total	kg PM2.5 eq	2.169	10.792	8.215	4.610	0.182	25.968
Operating Energy	Annual	kg PM2.5 eq	632.064	632.064	632.064	632.064	632.064	632.064
	Total	kg PM2.5 eq	62574.305	62574.305	62574.305	62574.305	62574.305	62574.305

Table 13. Weighted Resource Use by Life Cycle Stage and Assembly Group

Life Cycle Stage	Process	Weighted Resource Use	Assembly Group					
			Foundation	Walls	Floors	Columns & Beams	Roof	Building Total
Manufacturing	Material	ecologically weighted kg	2099796	9793163	8091860	4547113	175170	24703329
	Transportation	ecologically weighted kg	3619	24128	12027	8059	194	48037
	Total	ecologically weighted kg	2103415	9817291	8103886	4555172	175364	24751365
Construction	Material	ecologically weighted kg	941	14134	14419	0	319	29814
	Transportation	ecologically weighted kg	3119	34660	11735	6389	303	56164
	Total	ecologically weighted kg	4060	48795	26154	6389	622	85978
Maintenance	Material	ecologically weighted kg		2018690				2018690
	Transportation	ecologically weighted kg		33684				33684
	Total	ecologically weighted kg		2052374				2052374
End-of-Life	Material	ecologically weighted kg	2107	8882	8232	5238	182	24640

	Transportation	ecologically weighted kg	1545	7884	5823	3193	129	18575
	Total	ecologically weighted kg	3652	16766	14055	8431	311	43215
Operating Energy	Annual	ecologically weighted kg	112272	112272	112272	112272	112272	112272
	Total	ecologically weighted kg	11114889	11114889	11114889	11114889	11114889	11114889

Table 14. Fossil Fuel Use by Life Cycle Stage and Assembly Group

Life Cycle Stage	**Process**	**Fossil Fuel Use**	**Assembly Group**					
			Foundation	**Walls**	**Floors**	**Columns & Beams**	**Roof**	**Building Total**
Manufacturing	Material	MJ	1173389	25436022	7819855	11447475	187655	46024494
	Transportation	MJ	154891	1030642	513407	343242	8252	2050838
	Total	MJ	1328280	26466664	8333262	11790716	195907	48075332
Construction	Material	MJ	40604	609028	622080	0	13782	1285494
	Transportation	MJ	132379	1473925	498060	271161	12841	2386562
	Total	MJ	172983	2082952	1120140	271161	26623	3672056
Maintenance	Material	MJ		9274439				9274439
	Transportation	MJ		1430238				1430238
	Total	MJ		10704677				10704677
End-of-Life	Material	MJ	89474	377195	349596	222458	7747	1046470
	Transportation	MJ	65580	334616	247127	135517	5476	788316
	Total	MJ	155054	711811	596723	357975	13223	1834786
Operating Energy	Annual	MJ	5701275	5701275	5701275	5701275	5701275	5701275
	Total	MJ	564426191	564426191	564426191	564426191	564426191	564426191

4.2.1 Difference in Impacts due to Different Glazing Ratios

The SEEDS program intended this LCA to be a study for changes in impacts with increasing glazing ratios (window area/total wall area); by modifying the building characteristics in the IE's inputs to change the glazing ratio of the building, we can identify the change in the impacts on the building's life cycle. Due to the BE Building's high glazing ratio of 76.9% and the availability of limited energy use intensity data, we have looked at decreasing the ratio to 70%, 60%, 50%, and 40%. The basis of comparison used is percentage difference from base case (original fenestration ratio) for all impacts for the different fenestration ratio scenarios.

In order to modify the building characteristics the following steps were followed:

1. Copy exterior steel stud wall, take away all windows and doors, and adjust length to that of curtain wall
2. Reduce curtain wall height
3. Adjust height of exterior steel stud wall to compensate for the reduction in the curtain wall
4. Adjust energy use intensity values for target glazing ratio
5. Reproduce summary report
6. Repeat steps 2 – 5 for all glazing ratios
7. Calculate percent difference from base case for all scenarios

Figures 7 through 12 provide charts summarizing the results of the procedure detailed above.

The results show that for the life cycle stages “Manufacturing”, “Maintenance,” and “Operating Energy” a decrease in fenestration ratio decreases the net impacts. Maintenance stood out from the other categories as it has the largest percent difference from the other life cycle stages (e.g.: Operating Energy is approximately 70% of Maintenance across all glazing ratios). On the other hand, “Construction” and “End-of-Life” show a net increase in impacts with decreasing fenestration ratios. Construction is approximately 3X larger than End-of-Life. Finally, if all the life cycle stages are accounted for together, a decreasing fenestration ratio shows a net decrease in overall impacts.

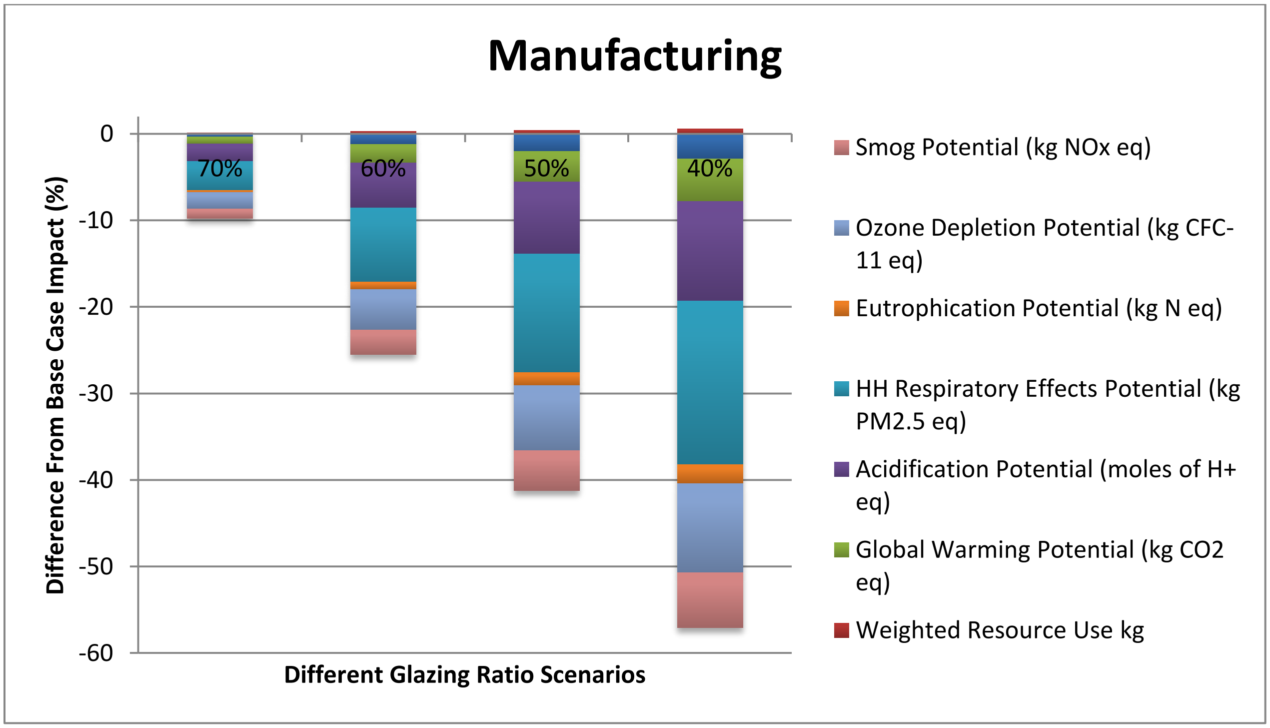


Figure 7. Manufacturing: Difference from base case impact per scenario

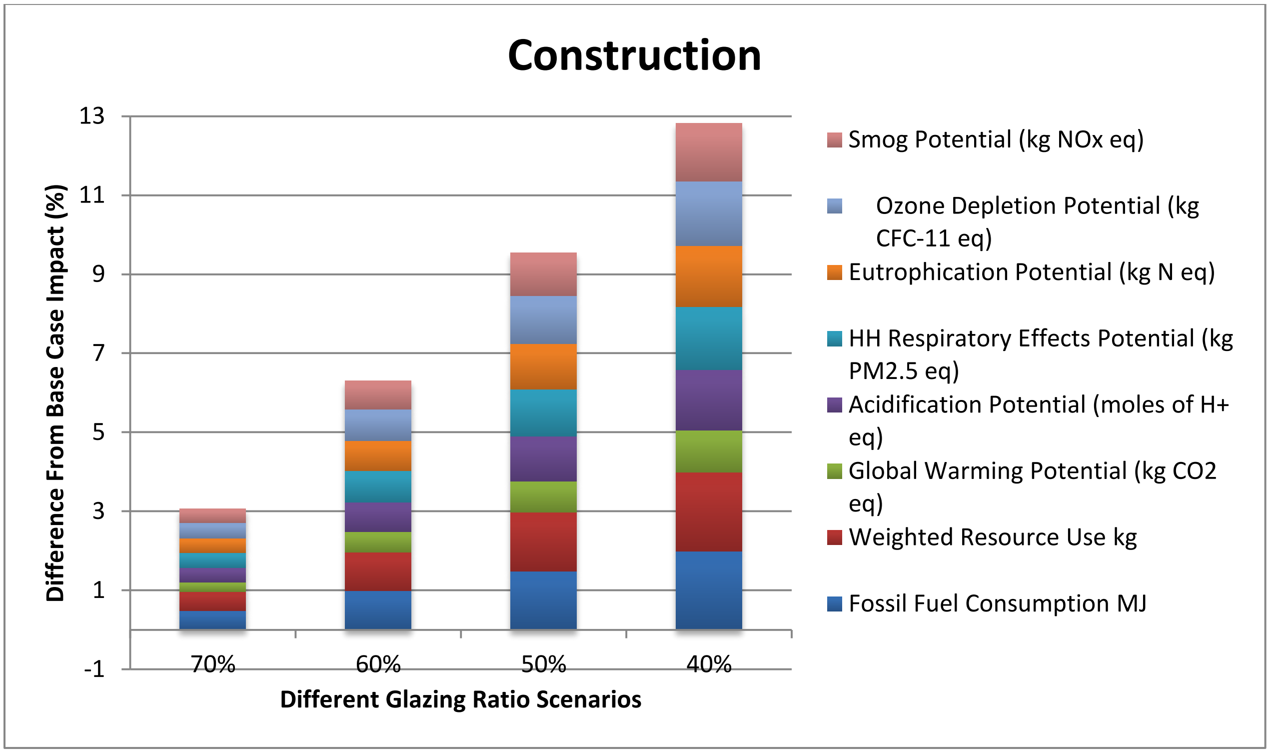


Figure 8. Construction: Difference from base case impact per scenario

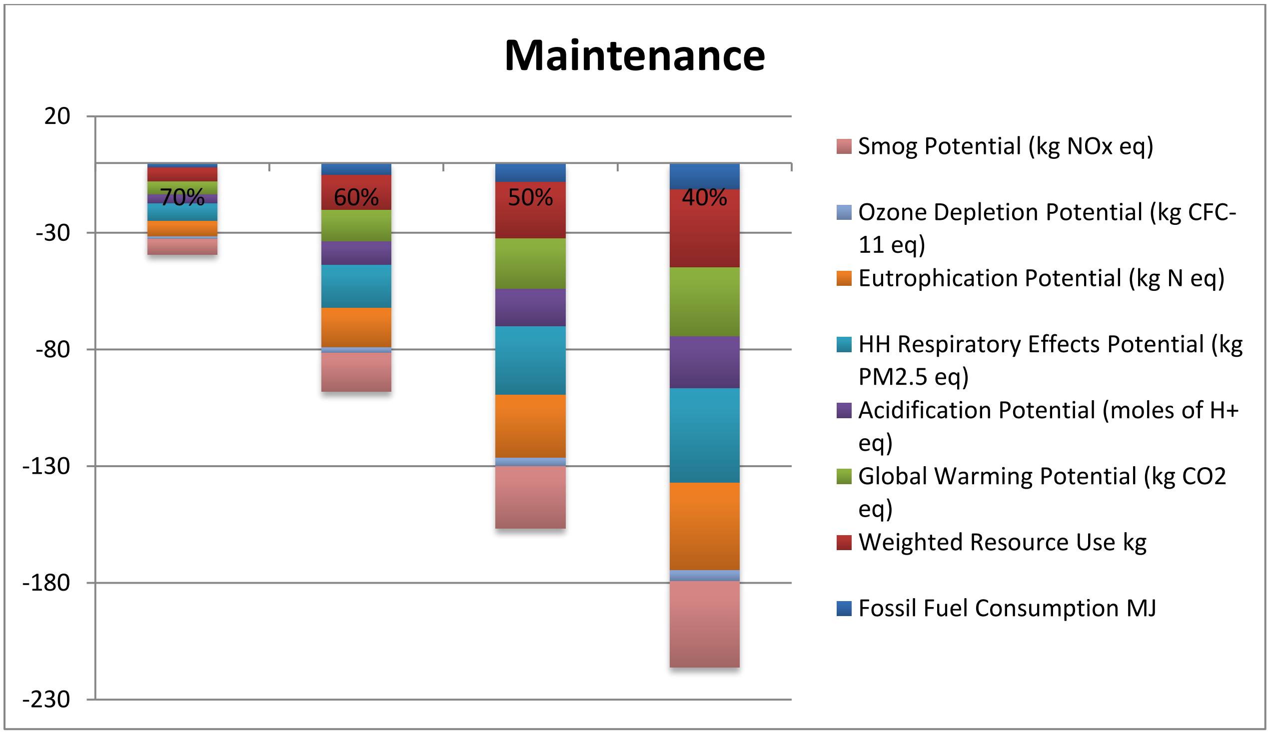


Figure 9. Maintenance: Difference from base case impact per scenario

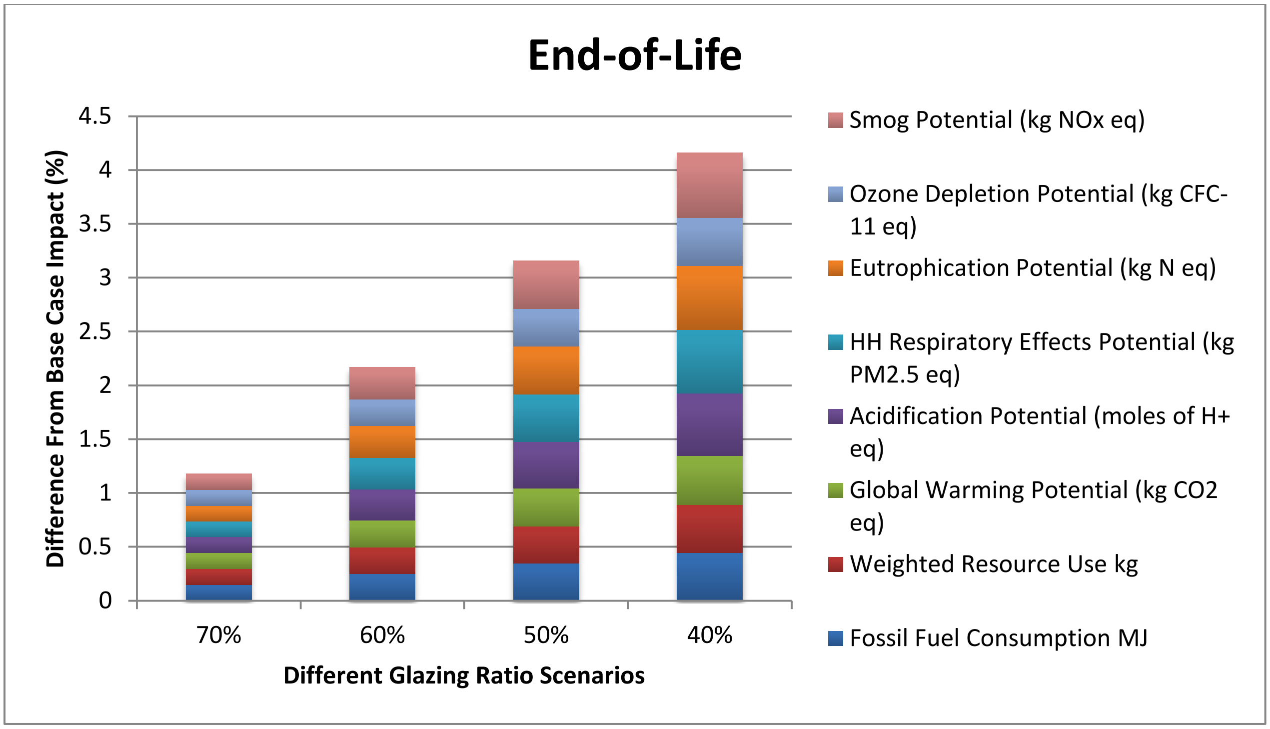


Figure 10. End-of-Life: Difference from base case impact per scenario

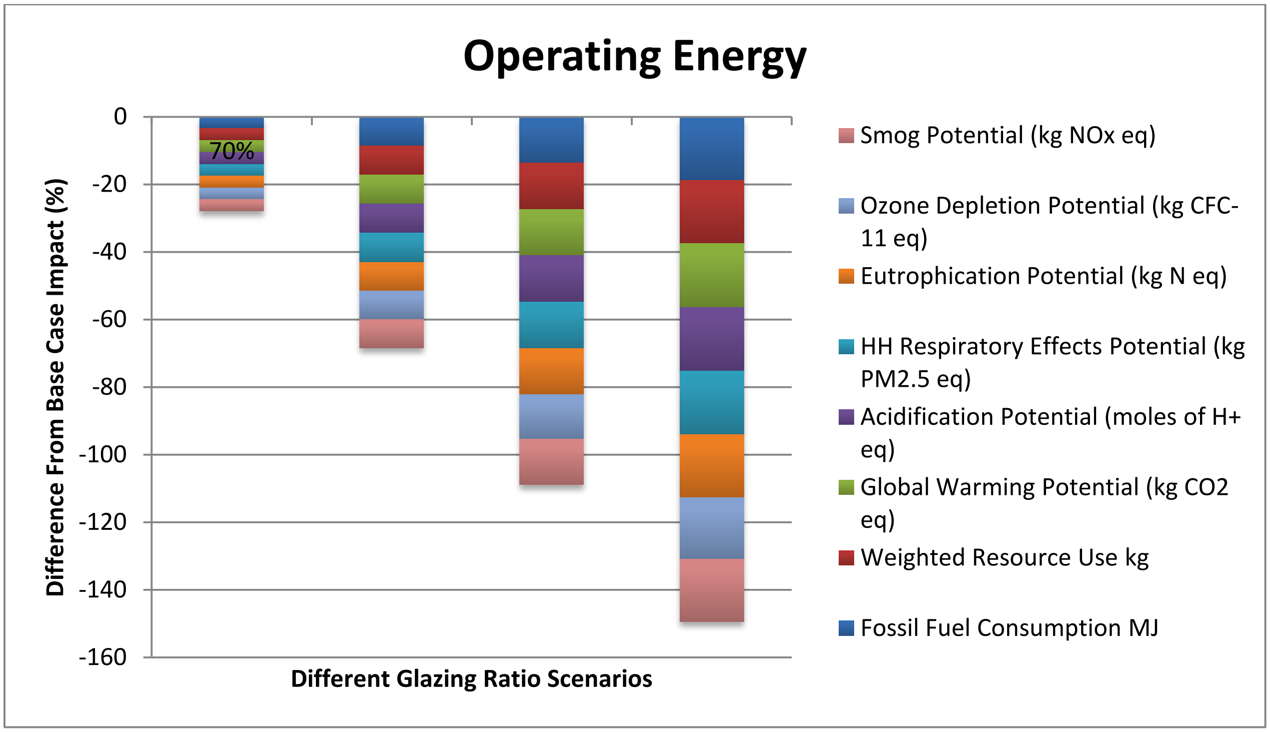


Figure 11. Operating Energy: Difference from base case impact per scenario

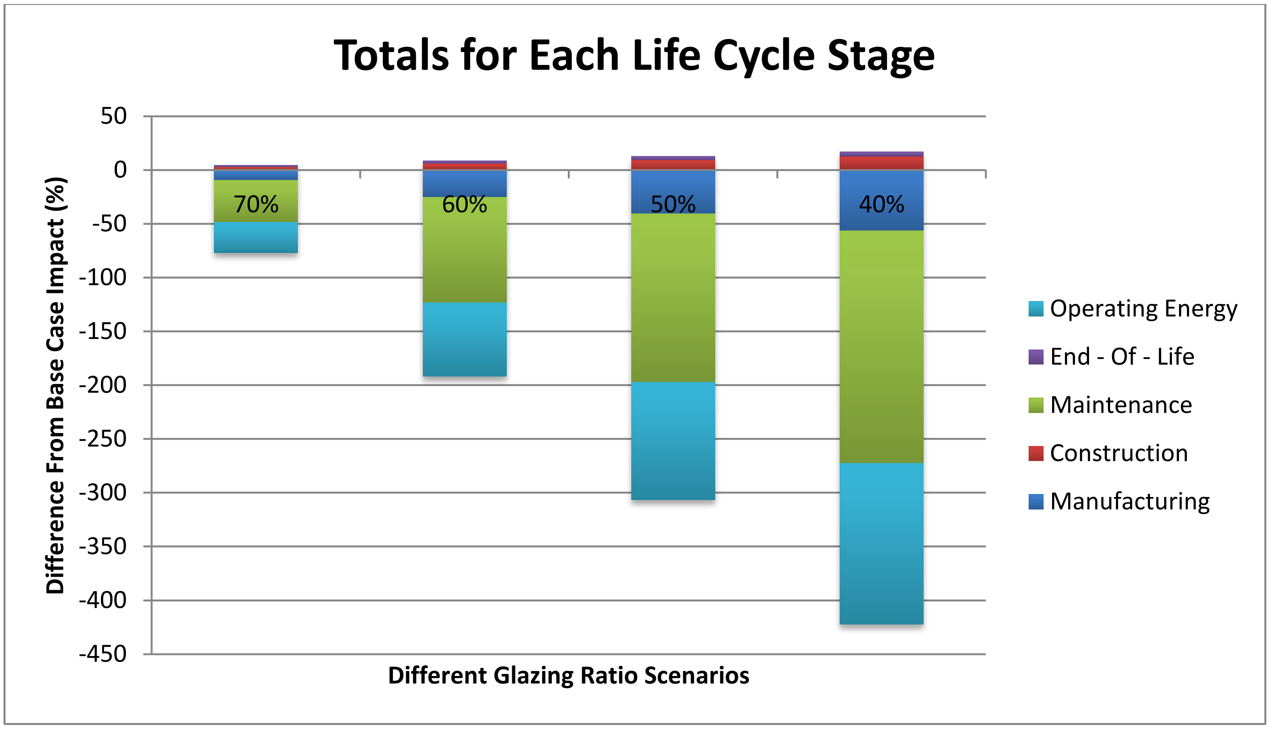


Figure 12. Total percent difference from base case impact for each life cycle stage of the building

4.2.2 Uncertainty

Some uncertainty is attributed to assumptions made in the development of this LCA study. In material take-offs, linear and area conditions relied on the accuracy of drawings and precision of the take-off tools. The take-off process also presents the possibility of human error.

Uncertainty is also present in impact estimation modeling. Actual rebar sizes were specified in Canadian standard sizes, but US standard rebar sizes closest to the specified size were used for impact estimator inputs. Limitations existed in impact estimation that required an adjustment of footing widths. Furthermore, live load of columns was approximated as the area-averaged live load imposed by the various floor-use types on the slab of the storey above. Similar limitations existed for floor volume quantification, and slab width was approximated to work with such limitations. Wall assemblies were also a source of error when approximation for assembly items such as widths of gypsum boards and stud weights were needed. Also, finishings of the walls was not part of the scope of this project, which affects the results (although this effect is most likely to be negligible).

Little uncertainty existed in the data vintage. The BE Building, being a new building, left little uncertainty in terms of whether the actual building still reflects the drawings. However, being a young building also carries with it other uncertainties. Maintenance cycles may not be fully developed for a building without experienced users. In the future the maintenance of the building may change as components age, remodeling takes place, or unforeseen circumstances affect these cycles.

Similarly, spatial and temporal variability provide uncertainties. The proximity of a regional park may have affected the weight of each impact. The distance between the BE Building and the source of electricity and water is such that considerations ought to be given to the impact of this region. Furthermore, the elevation of the UBC area in relation to the Metro Vancouver region requires water pumping and re-chlorination. Temporal variability may also create uncertainty in the progression of climate change and which impacts ought to be weighted higher.

Data quality is another source of error. Data collection is an imprecise exercise, with limitations on accuracy and data availability, and therefore introduces uncertainties. Data collection by multiple parties, despite agreed upon methods, may also lead to discrepancies and uncertainties.

Also, difference in yearly factory emissions need to be accounted for. Factories may produce different emissions with the same product output, due to climate conditions, accidents or natural disasters, and other factors. This leads to uncertainty regarding how to determine typical impacts.

Furthermore, the interpretation of impacts over time is difficult to understand and evaluate. The effects of emissions and impacts over time may vary from analysis to analysis, which leads to uncertainty about how to value short and long term impacts.

Differences in human exposure patterns is one of the more controversial ones. Lack of data or precedent can create uncertainty in how human health is affected by different and long-term exposure patterns.

Overall, recognizing these uncertainties helps to retain the transparency of this report. If all these uncertainties were explored and mitigated, it would not be conducive to building a cohesive and structured report given the scope.

4.2.3 Sensitivity Analysis

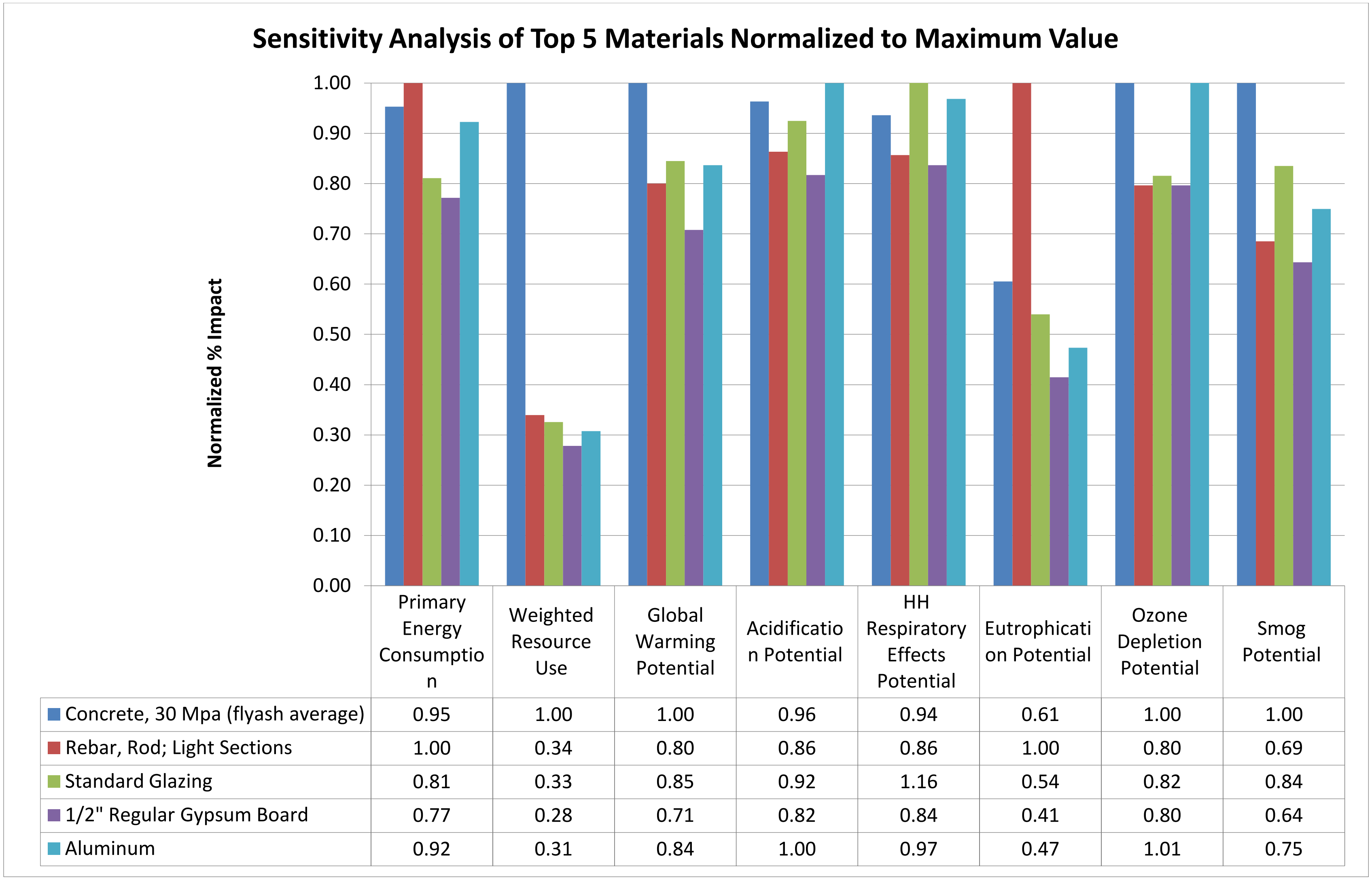
Five materials of significant abundance were selected to test the sensitivity of the model to changes in these material quantities. The aim of this sensitivity analysis is to measure the change in environmental impact across the impact categories that we are concerned with. The sensitivity analysis illuminates the relationships between material quantity and impact, or lack thereof, for each of the materials chosen. Figure 13. Sensitivity Analysis below displays graphically the percent change in each impact category given a 10% increase in material quantity for five materials. The graph is normalized to the maximum value in each impact category in order to highlight the differences between each type of material and their contributions in relation to each other.

Concrete stood out as a leader in the percent impact change in the categories 'weighted resource use', 'global warming potential', and 'smog potential'. Rebar comprised most of the percent change in impact in terms of 'eutrophication potential'.

Contrary to the normalized sensitivity analysis, Figure 14. Sensitivity Analysis of Select Materials (non-normalized) provides insight into the overall change in impact if 10% of the material quantity is increased for each of the 5 materials. Concrete again, not surprisingly, stood out as a leader in the percent impact change in the categories ' weighted resource use', 'global warming potential', and 'smog potential'.

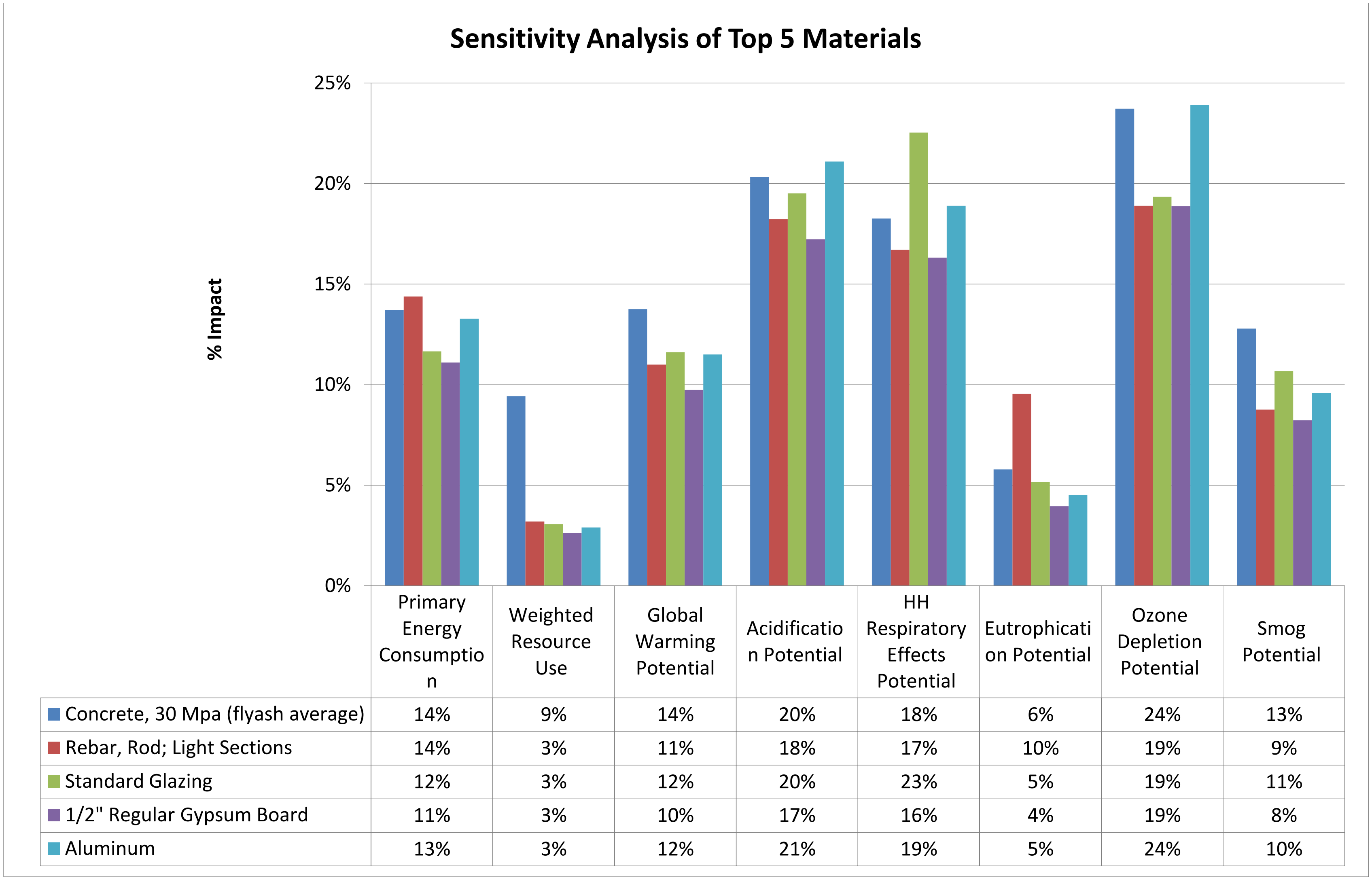
Also worth noting is aluminum's impact. This material has high impacts in all categories except in 'weighted resource use' (where concrete is the outstanding leader), and it has the greatest impact in 'ozone depletion potential' (where concrete is the second greatest contributor).

The result of the sensitivity analysis is a useful tool for examining specific impacts from an increase in standard glazing. A 10% increase in standard glazing didn't contribute to a significant relative change in impact. Notably, the greatest impact from an increased standard glazing was in 'HH Respiratory Effects Potential.' Three other minor contributions were observed to 'global warming potential', 'acidification potential', and 'smog potential'. These results may prompt interesting discussion surrounding why standard glazing has an impact on these categories, and relatively lower to the other materials.



	Primary Energy Consumption	Weighted Resource Use	Global Warming Potential	Acidification Potential	HH Respiratory Effects Potential	Eutrophication Potential	Ozone Depletion Potential	Smog Potential
🟦 Concrete, 30 Mpa (flyash average)	0.95	1.00	1.00	0.96	0.94	0.61	1.00	1.00
🟥 Rebar, Rod; Light Sections	1.00	0.34	0.80	0.86	0.86	1.00	0.80	0.69
🟩 Standard Glazing	0.81	0.33	0.85	0.92	1.16	0.54	0.82	0.84
🟪 1/2" Regular Gypsum Board	0.77	0.28	0.71	0.82	0.84	0.41	0.80	0.64
🟦 Aluminum	0.92	0.31	0.84	1.00	0.97	0.47	1.01	0.75

Figure 13. Sensitivity Analysis of Select Materials Normalized to Maximum Value

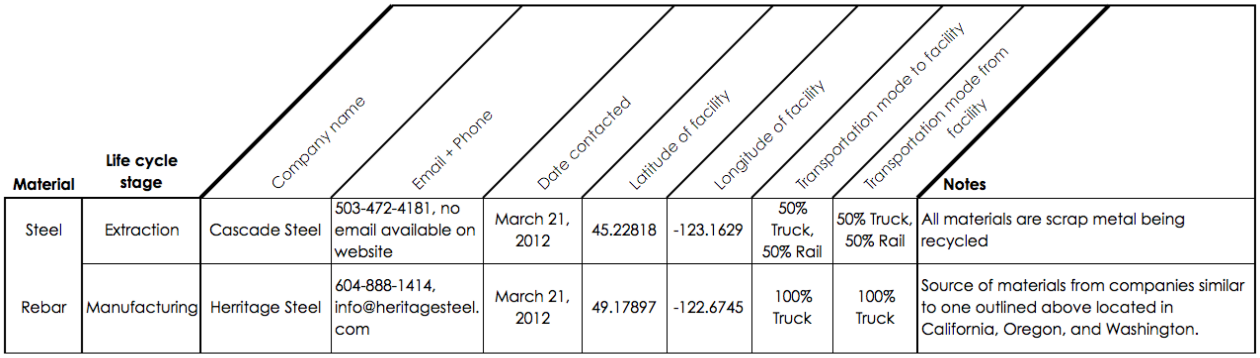


	Primary Energy Consumption	Weighted Resource Use	Global Warming Potential	Acidification Potential	HH Respiratory Effects Potential	Eutrophication Potential	Ozone Depletion Potential	Smog Potential
🟦 Concrete, 30 Mpa (flyash average)	14%	9%	14%	20%	18%	6%	24%	13%
🟥 Rebar, Rod; Light Sections	14%	3%	11%	18%	17%	10%	19%	9%
🟩 Standard Glazing	12%	3%	12%	20%	23%	5%	19%	11%
🟪 1/2" Regular Gypsum Board	11%	3%	10%	17%	16%	4%	19%	8%
■ Aluminum	13%	3%	12%	21%	19%	5%	24%	10%

Figure 14. Sensitivity Analysis of Select Materials

4.2.4 Chain of Custody Inquiry

Rebar was selected as the construction material to complete a chain of custody exercise. The goal of the exercise was to obtain information on the extraction and manufacturing processes involved with producing the rebar. The structural engineering company, Jones Kwong Kishi, associated with the BE Building was intended to be the starting point. However, a local rebar manufacturing company, Heritage Steel, was contacted as a first step in order to get the information, since efforts to contact Thomas Woo, the structural engineer for the BE Building, at Jones Kwong Kishi failed. Heritage Steel was assumed to be a typical supplier to contractors in the area. The steel to manufacture rebar at Heritage Steel is supplied by three recycling operations in the United States located in California, Oregon and Washington State. An example of the information obtained from this exercise is shown in Figure 15.



Material	Life cycle stage	Company name	Email + Phone	Date contacted	Latitude of facility	Longitude of facility	Transportation mode to facility	Transportation mode from facility	Notes
Steel	Extraction	Cascade Steel	503-472-4181, no email available on website	March 21, 2012	45.22818	-123.1629	50% Truck, 50% Rail	50% Truck, 50% Rail	All materials are scrap metal being recycled
Rebar	Manufacturing	Herritage Steel	604-888-1414, info@heritagesteel.com	March 21, 2012	49.17897	-122.6745	100% Truck	100% Truck	Source of materials from companies similar to one outlined above located in California, Oregon, and Washington.

Figure 15. Information obtained about Rebar from Chain of Custody exercise

4.2.5 Functions and Impacts

Table 15. Building Functions

Room Type	Area (sq. ft of typical floor)	Percentage of Total Building Area
Bedroom	21696	12.2
Bathroom	8800	4.9
Kitchen	9152	5.1
Living Area/Balconies	54928	30.8
Hallway/Stairwell/Elevator	22960	12.9
Parking	48098	27.0
Storage/Mechanical/Operational	12496	7.0

5.0 Conclusions

This document is a report describing a life cycle assessment (LCA) study performed on the BE Building. This LCA study will be used as a benchmark for similar buildings, as a guide towards informing decision-making and future policy regarding glazing and fenestration and as an exemplary demonstration of the latest in environmental impact accounting methods.

This LCA includes life cycle stages such as manufacturing, transportation and construction. The parameters explored within these life cycle stages are Foundations, Beams and Columns, Walls, Roofs and Floors.

For the top 5 most abundant materials by mass in these parameters, a sensitivity analysis was conducted. The sensitivity analysis measured the change in environmental impact across the impact categories that we are concerned with after a hypothetical 10% increase in material quantity was imposed. Concrete stood out as a leader in the percent impact change in the categories ‘ weighted resource use’, ‘global warming potential’, ‘acidification potential’, ‘HH respiratory effects potential’, ‘ozone depletion potential’ and ‘smog potential’. Rebar comprised most of the percent change in impact in terms of ‘primary energy consumption’ and ‘eutrophication potential’. A 10% increase in standard glazing didn’t contribute to a significant relative change in impact. Interestingly, the greatest impact from an increased standard glazing was in ‘HH Respiratory Effects

Potential.' Three other minor contributions were observed to 'global warming potential', 'acidification potential', and 'smog potential' from a 10% increase in standard glazing.

Additionally, a fenestration ratio study was performed. The SEEDS program intended this LCA to be a study for changes in impacts with increasing glazing ratio; however, the glazing ratio (76.9%) was higher than the provided energy use intensities, thus the study focused on decreasing glazing ratios. The results show that for the life cycle stages "Manufacturing", "Maintenance," and "Operating Energy" a decrease in fenestration ratio decreases the net impacts; on the other hand, "Construction" and "End-of-Life" show a net increase in impacts with decreasing fenestration ratios. Finally, if all the life cycle stages are accounted for together, a decreasing fenestration ratio shows a net decrease in overall impacts.

For future implementations of LCA in residential buildings, the limitations of the IE software reference in the Uncertainties section should be modified. Reviewing impacts of glazing in residential buildings should refer to this report in making evidence-based decisions for policy.

Appendix A - Impact Estimator Inputs

Assembly Group	Assembly Type	Assembly Name	Input Fields	Known/Measured	IE Inputs
1 Foundation					
	1.2 Concrete Footings				
		1.2.1 Footing_F0_26"			
			Length (ft)	9@7.5	67.5
			Width (ft)	6	8.21
			Thickness (in)	26	19
			Concrete (psi)	3625	4000
			Concrete flyash %	Unknown	Average
			Rebar	20M	#6
		1.2.2 Footing_F1_28"			
			Length (ft)	15@8	120
			Width (ft)	6.5	9.58
			Thickness (in)	28	19
			Concrete (psi)	3625	4000
			Concrete flyash %	Unknown	Average
			Rebar	20M	#6
		1.2.3 Footing_F2_38"			
			Length (ft)	5@11	55
			Width (ft)	9	18.00
			Thickness (in)	38	19
			Concrete (psi)	3625	4000
			Concrete flyash %	Unknown	Average
			Rebar	25M	#6
		1.2.4 Footing_F3_42"			
			Length (ft)	5@12	60
			Width (ft)	10	22.11
			Thickness (in)	42	19
			Concrete (psi)	3625	4000
			Concrete flyash %	40	35
			Rebar	30M	#6
		1.2.5 Footing_F4_42"			
			Length (ft)	4@21	84
			Width (ft)	9.5	21.00
			Thickness (in)	42	19
			Concrete (psi)	3625	4000
			Concrete flyash %	40	35
			Rebar	30M	#6
		1.2.6 Footing_F5_38"			
			Length (ft)	3@18	54

			Width (ft)	9	18.00
			Thickness (in)	38	19
			Concrete (psi)	3625	4000
			Concrete flyash %	Unknown	Average
			Rebar	25M	#6
		1.2.7 Footing_F6_32"			
			Length (ft)	3@9	27
			Width (ft)	7.5	12.63
			Thickness (in)	32	19
			Concrete (psi)	3625	4000
			Concrete flyash %	Unknown	Average
			Rebar	25M	#6
		1.2.8 Footing_F7_48"			
			Length (ft)	13	13
			Width (ft)	11	27.79
			Thickness (in)	48	19
			Concrete (psi)	3625	4000
			Concrete flyash %	40	35
			Rebar	30M	#6
		1.2.9 Footing_F8_52"			
			Length (ft)	15	15
			Width (ft)	12	32.84
			Thickness (in)	52	19
			Concrete (psi)	3625	4000
			Concrete flyash %	40	35
			Rebar	30M	#6
		1.2.10 Footing_F9_42"			
			Length (ft)	14	14
			Width (ft)	9	19.89
			Thickness (in)	42	19
			Concrete (psi)	3625	4000
			Concrete flyash %	40	35
			Rebar	25M	#6
		1.2.11 Footing_F10_72"			
			Length (ft)	44	44
			Width (ft)	50	189.47
			Thickness (in)	72	19
			Concrete (psi)	3625	4000
			Concrete flyash %	40	35
			Rebar	30M	#6
		1.2.12 Footing_SF1_12"			

			Length (ft)	830	830
			Width (ft)	1.5	1.5
			Thickness (in)	12	12
			Concrete (psi)	3625	4000
			Concrete flyash %	Unknown	Average
			Rebar	10M	#4
2 Walls					
	2.1 Steel Stud Walls				
		2.1.1 Wall_Steel Stud_G2			
		Envelope	Length (ft)	2060	2060
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	3 5/8"	3 5/8"
			Stud Spacing (in o.c.)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	3 5/8"	3 5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
		Door Opening	Number of Doors	78	78
			Door Type	-	Steel Interior Door
		2.1.2 Wall_Steel Stud_G4			
			Length (ft)	291	291
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	2 1/2	3 5/8

		Steel Stud	Stud Spacing (in o.c.)	16	24
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	2 1/2	3 5/8
			Stud Spacing (in o.c.)	16	24
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	2 1/2"	2 1/2"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	2 1/2"	2 1/2"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
		2.1.3 Wall_Steel Stud_G5			
		Steel Stud	Length (ft)	1579	1579
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	2 1/2	3 5/8
			Stud Spacing (in o.c.)	16	24
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	3 5/8"	3 5/8"
			Stud Spacing (in o.c.)	16	16

		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	2 1/2"	2 1/2"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	3 5/8"	3 5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
		2.1.4 Wall_Steel Stud_G6			
		Envelope	Length (ft)	181	181
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	2 1/2	3 5/8"
			Stud Spacing (in o.c.)	16	24
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	1/2"	1/2"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	2 1/2	2 1/2

			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	1/2"	1/2"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
		2.1.4 Wall_Steel Stud_G11			
		Envelope	Length (ft)	177	177
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	3 5/8"	3 5/8"
			Stud Spacing (in o.c.)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	1/2"	1/2"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	3 5/8"	3 5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	1/2"	1/2"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
		2.1.5 Wall_Steel Stud_G12			
			Length (ft)	51	51
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none

		Envelope	Stud Thickness	6"	6"
			Stud Spacing (in o.c.)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	1/2"	1/2"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	6"	6"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	1/2"	1/2"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
		2.1.6 Wall_Steel Stud_G14			
		Steel Stud	Length (ft)	104	104
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	2 1/2"	3 5/8
			Stud Spacing (in o.c.)	16	24
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	2 1/2"	3 5/8
			Stud Spacing (in o.c.)	16	24
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X

			Thickness	5/8"	5/8"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	2 1/2"	2 1/2"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	2 1/2"	2 1/2"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
		2.1.7 Wall_Steel Stud_P1			
		Envelope	Length (ft)	10	10
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	3 5/8"	3 5/8"
			Stud Spacing (in o.c.)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Regular	Regular
			Thickness	1/2"	1/2"
			Category	Gypsum Board	Gypsum Board
			Material	Regular	Regular
			Thickness	1/2"	1/2"
		2.1.8 Wall_Steel Stud_P2			
		Envelope	Length (ft)	3605	3605
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	3 5/8"	3 5/8"
			Stud Spacing (in o.c.)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X

			Thickness	1/2"	1/2"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	1/2"	1/2"
		Door Opening	Number of Doors	251	251
			Door Type	-	Hollow Core Wood Interior Door
		2.1.9 Wall_Steel Stud_P2a			
		Envelope	Length (ft)	11061	11061
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	3 5/8"	3 5/8"
			Stud Spacing (in o.c.)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	1/2"	1/2"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	3 5/8"	3 5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	1/2"	1/2"
		Door Opening	Number of Doors	437	437
			Door Type	-	Hollow Core Wood Interior Door
		2.1.10 Wall_Steel Stud_P3			
		Envelope	Length (ft)	13	13
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	20
			Sheathing Type	-	none
			Stud Thickness	6"	6"
			Stud Spacing (in o.c.)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Regular	Regular

			Thickness	1/2"	1/2"
			Category	Gypsum Board	Gypsum Board
			Material	Regular	Regular
			Thickness	1/2"	1/2"
		2.1.11 Wall_Steel Stud_P3a			
		Envelope	Length (ft)	4452	4452
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	20
			Sheathing Type	-	none
			Stud Thickness	6"	6"
			Stud Spacing (in o.c.)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Regular	Regular
			Thickness	1/2"	1/2"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	6"	6"
			Category	Gypsum Board	Gypsum Board
			Material	Regular	Regular
			Thickness	1/2"	1/2"
		Door Opening	Number of Doors	51	51
			Door Type	-	Hollow Core Wood Interior Door
		2.1.12 Wall_Steel Stud_P4			
		Envelope	Length (ft)	221	221
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	20
			Sheathing Type	-	none
			Stud Thickness	6"	6"
			Stud Spacing (in o.c.)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Regular	Regular
			Thickness	1/2"	1/2"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	6"	6"
			Category	Gypsum Board	Gypsum Board

			Material	Regular	Regular
			Thickness	1/2"	1/2"
		2.1.13 Wall_Steel Stud_P5			
			Length (ft)	280	280
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	3 5/8"	3 5/8"
			Stud Spacing (in o.c.)	16	16
		Steel Stud	Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	3 5/8"	3 5/8"
			Stud Spacing (in o.c.)	16	16
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Regular	Regular
			Thickness	1/2"	1/2"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	3 5/8"	3 5/8"
			Category	Insulation	Insulation
			Material	-	Fibreglass Batt
			Thickness	3 5/8"	3 5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Regular	Regular
			Thickness	1/2"	1/2"
		2.1.14 Wall_Steel Stud_S1			
			Length (ft)	5	5
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	2 1/4"	3 5/8"
			Stud Spacing (in o.c.)	24	24
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	ULC Rated GWB	Gypsum Fire Rated Type X
			Thickness	3/4"	1/2"
			Category	Gypsum Board	Gypsum Board

			Material	ULC Rated GWB	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
		2.1.15 Wall_Steel Stud_S2			
		Envelope	Length (ft)	450	450
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	2 1/4"	3 5/8"
			Stud Spacing (in o.c.)	24	24
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	1"	1/2" X 2
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
			Category	Gypsum Board	Gypsum Board
			Material	Gypsum Fire Rated Type X	Gypsum Fire Rated Type X
			Thickness	5/8"	5/8"
		2.1.13 Wall_Steel Stud_F2			
		Envelope	Length (ft)	86	86
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	7/8"	3 5/8"
			Stud Spacing (in o.c.)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Regular	Regular
			Thickness	1/2"	1/2"
		2.1.14 Wall_Steel Stud_F3			
			Length (ft)	10454	10454
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	1 5/8"	3 5/8"

		Envelope	Stud Spacing (in o.c.)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Regular	Regular
			Thickness	1/2"	1/2"
		Door Opening	Number of Doors	6	6
			Door Type	-	Hollow Core Wood Interior Door
		2.1.15 Wall_Steel Stud_F4			
		Envelope	Length (ft)	1223	1223
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	2 1/2"	3 5/8"
			Stud Spacing (in o.c.)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Regular	Regular
			Thickness	1/2"	1/2"
		2.1.16 Wall_Steel Stud_F5			
		Envelope	Length (ft)	820	820
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	3 5/8"	3 5/8"
			Stud Spacing (in o.c.)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Regular	Regular
			Thickness	1/2"	1/2"
		2.1.17 Wall_Steel Stud_F6			
		Envelope	Length (ft)	392	392
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	20
			Sheathing Type	-	none
			Stud Thickness	6"	6"
			Stud Spacing (in o.c.)	16	16
			Category	Gypsum Board	Gypsum Board
			Material	Regular	Regular

			Thickness	1/2"	1/2"
		2.1.18 Wall_Steel Stud_F7			
			Length (ft)	1354	1354
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	20
			Sheathing Type	-	none
			Stud Thickness	3 5/8"	3 5/8"
			Stud Spacing (in o.c.)	-	16
		2.1.19 Wall_Steel Stud_F8			
			Length (ft)	341	341
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	20
			Sheathing Type	-	none
			Stud Thickness	3 5/8"	3 5/8"
			Stud Spacing (in o.c.)	-	16
		2.1.20 Wall_Steel Stud_E7			
		Envelope	Length (ft)	4277	4277
			Height (ft)	9.875	9.875
			Wall Type	-	load-bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	-	3 5/8"
			Stud Spacing (in o.c.)	-	16
			Category	Cladding	Gypsum Board
			Material	Natural Stone	Regular
			Thickness	-	-
			Category	Vapour & Air Barrier	Vapour & Air Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
			Category	Insulation	Insulation
			Material	R 18 Cavity Wall Insulation	Fibreglass Batt
			Thickness	-	-
			Category	Gypsum Board	Gypsum Board
			Material	Exterior Glass-Mat Gypsum Sheathing	Gypsum Fibre BD
			Thickness	1/2"	1/2"
		2.1.21 Wall_Steel Stud_E12			

		Pre-engineered Metal Envelope	Length (ft)	209	209
			Height (ft)	9.875	9.875
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	-	3 5/8"
			Stud Spacing (in o.c.)	-	16
			Wind Average	-	High (11.4 psf)
			Category	Insulation	Insulation
			Material	-	Polylsocyanurate Foam
			Thickness	2 1/2"	2 1/2"
			Category	Vapour & Air Barrier	Vapour & Air Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
			Category	Gypsum Board	Gypsum Board
			Material	Exterior Glass-Mat Gypsum Sheathing	Gypsum Fibre BD
			Thickness	1/2"	1/2"
	2.2 Curtain Wall				
		2.2.1 Wall_Curtain			
			Length (ft)	8246	8246
			Height (ft)	9.875	9.875
			Percent Viewable Glazing (%)	-	98
			Percent Spandrel Panel (%)	-	2
			Thickness of Insulation (mm)	-	2 in
			Spandrel Type	-	metal
		Door Opening	Number of Doors	159	159
			Door Type	-	Aluminum Exterior Door, 80% glazing
		Window Opening	Number of Windows	213	213
			Total Windown Area (ft^2)	5112	5112
			Fixed vs Operable	Operable	Operable
			Frame Type	-	PVC Frame

		Glazing Type	-	Standard Glazing
2.3 Cast in Place				
	2.3.1 Wall_Cast in Place_C			
	Door Opening	Length (ft)	984	984
		Height (ft)	9.875	9.875
		Thickness (in)	8	8
		Concrete (Mpa)	-	30
		Concrete flyash %	-	Average
		Reinforcement	-	#15M
		Number of Doors	5	5
		Door Type	-	Steel Interior Door
	2.3.2 Wall_Cast in Place_E1			
		Length (ft)	1007	1007
		Height (ft)	9.875	9.88
		Thickness (in)	8	8
		Concrete (Mpa)	-	30
		Concrete flyash %	-	Average
		Reinforcement	-	#15M
	2.3.3 Wall_Cast in Place_E2			
		Length (ft)	107	107
		Height (ft)	9.875	9.875
		Thickness (in)	8	8
		Concrete (Mpa)	-	20
		Concrete flyash %	-	Average
		Reinforcement	-	#15M
2.4 Basic Materials				
	2.4.1 Wall_Basic Materials_F1			
		Assembly Type	GWB	Regular Gypsum Board
		Thickness (in)	1/2"	1/2"
		Area (ft^2)	88.875	88.875
2.5 Concrete Block				
	2.5.1 Wall_Concrete Block_B			
	Opening	Length (ft)	60	60
		Height (ft)	9.875	9.875
		Rebar #	#15	#15
		Number of Doors	3	3
		Door Type	-	Steel Interior Door
	2.5.2 Wall_Concrete Block_B1			

			Length (ft)	34	34
			Height (ft)	9.875	9.875
			Rebar #	#15	#15
		2.5.3 Wall_Concrete Block_B2			
		Steel Stud *(Mistake)*	Length (ft)	567	567
			Height (ft)	9.875	9.875
			Rebar #	#15	#15
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	2 1/2"	3 5/8
			Stud Spacing (in o.c.)	16	24
		Opening	Number of Doors	16	16
			Door Type	-	Steel Interior Door
		2.5.4 Wall_Concrete Block_B3			
		Steel Stud *(Mistake)*	Length (ft)	623	623
			Height (ft)	9.875	9.875
			Rebar #	#15	#15
			Wall Type	non-load bearing	non-load bearing
			Stud Weight (Ga)	-	25
			Sheathing Type	-	none
			Stud Thickness	2 1/2"	3 5/8
			Stud Spacing (in o.c.)	16	24
3 Columns and Beams					
	3.1 Concrete Column				
		3.1.1 Columns_P2			
			Number of Beams	42	42
			Number of Columns	54	54
			Floor to floor height (ft)	9	9
			Bay sizes (ft)	21.55	21.55
			Supported span (ft)	21.55	21.55
			Supported area (ft2)	464.48	464.48
			Live load (psf)	50	50
		3.1.2 Columns_P1			
			Number of Beams	49	49
			Number of Columns	53	53
			Floor to floor height (ft)	14.46	14.46
			Bay sizes (ft)	24.25	24.25
			Supported span (ft)	24.25	24.25
			Supported area (ft2)	588.15	588.15

	Live load (psf)	100	100
3.1.3 Column_L1			
	Number of Beams	0	0
	Number of Columns	28	28
	Floor to floor height (ft)	10.46	10.46
	Bay sizes (ft)	17.12	17.12
	Supported span (ft)	17.12	17.12
	Supported area (sq ft)	293.14	293.14
	Live load (psf)	52.2	50
3.1.4 Column_L2			
	Number of Beams	0	0
	Number of Columns	28	28
	Floor to floor height (ft)	9.63	9.63
	Bay sizes (ft)	18.00	18.00
	Supported span (ft)	18.00	18.00
	Supported area (sq ft)	324.11	324.11
	Live load (psf)	52.1	50
3.1.5 Column_L3			
	Number of Beams	0	0
	Number of Columns	28	28
	Floor to floor height (ft)	9.63	9.63
	Bay sizes (ft)	18.00	18.00
	Supported area (sq ft)	18.00	18.00
	Live load (psf)	52.1	50
3.1.6 Column_L4			
	Number of Beams	0	0
	Number of Columns	28	28
	Floor to floor height (ft)	9.63	9.63
	Bay sizes (ft)	18.00	18.00
	Supported span (ft)	18.00	18.00
	Supported area (sq ft)	324.11	324.11
	Live load (psf)	52.1	50
3.1.7 Column_L5			
	Number of Beams	0	0
	Number of Columns	28	28
	Floor to floor height (ft)	9.63	9.63
	Bay sizes (ft)	18.00	18.00
	Supported span (ft)	18.00	18.00
	Supported area (sq ft)	324.11	324.11
	Live load (psf)	52.1	50
3.1.8 Column_L6			

	Number of Beams	0	0
	Number of Columns	28	28
	Floor to floor height (ft)	9.63	9.63
	Bay sizes (ft)	18.00	18.00
	Supported span (ft)	18.00	18.00
	Supported area (sq ft)	324.11	324.11
	Live load (psf)	52.1	50
3.1.9 Column_L7			
	Number of Beams	0	0
	Number of Columns	28	28
	Floor to floor height (ft)	9.63	9.63
	Bay sizes (ft)	18.00	18.00
	Supported span (ft)	18.00	18.00
	Supported area (sq ft)	324.11	324.11
	Live load (psf)	52.1	50
3.1.10 Column_L8			
	Number of Beams	0	0
	Number of Columns	28	28
	Floor to floor height (ft)	9.63	9.63
	Bay sizes (ft)	18.00	18.00
	Supported span (ft)	18.00	18.00
	Supported area (sq ft)	324.11	324.11
	Live load (psf)	52.1	50
3.1.11 Column_L9			
	Number of Beams	0	0
	Number of Columns	28	28
	Floor to floor height (ft)	9.63	9.63
	Bay sizes (ft)	18.00	18.00
	Supported span (ft)	18.00	18.00
	Supported area (sq ft)	324.11	324.11
	Live load (psf)	52.1	50
3.1.12 Column_L10			
	Number of Beams	0	0
	Number of Columns	28	28
	Floor to floor height (ft)	9.63	9.63
	Bay sizes (ft)	18.00	18.00
	Supported span (ft)	18.00	18.00
	Supported area (sq ft)	324.11	324.11
	Live load (psf)	52.1	50
3.1.13 Column_L11			
	Number of Beams	0	0

		Number of Columns	28	28
		Floor to floor height (ft)	9.63	9.63
		Bay sizes (ft)	18.00	18.00
		Supported span (ft)	18.00	18.00
		Supported area (sq ft)	324.11	324.11
		Live load (psf)	52.1	50
	3.1.14 Column_L12			
		Number of Beams	0	0
		Number of Columns	28	28
		Floor to floor height (ft)	9.63	9.63
		Bay sizes (ft)	18.00	18.00
		Supported span (ft)	18.00	18.00
		Supported area (sq ft)	324.11	324.11
		Live load (psf)	52.1	50
	3.1.15 Column_L13			
		Number of Beams	0	0
		Number of Columns	28	28
		Floor to floor height (ft)	9.63	9.63
		Bay sizes (ft)	17.89	17.89
		Supported span (ft)	17.89	17.89
		Supported area (sq ft)	320.07	320.07
		Live load (psf)	52.4	50
	3.1.16 Column_L14			
		Number of Beams	0	0
		Number of Columns	26	26
		Floor to floor height (ft)	10.63	10.63
		Bay sizes (ft)	18.12	18.12
		Supported span (ft)	18.12	18.12
		Supported area (sq ft)	328.38	328.38
		Live load (psf)	54.5	50
	3.1.17 Column_L15			
		Number of Beams	0	0
		Number of Columns	25	25
		Floor to floor height (ft)	10.63	10.63
		Bay sizes (ft)	16.18	16.18
		Supported span (ft)	16.18	16.18
		Supported area (sq ft)	261.92	261.92
		Live load (psf)	60.2	50
	3.1.18 Column_L16			
		Number of Beams	0	0
		Number of Columns	10	10

		Floor to floor height (ft)	11.08	11.08
		Bay sizes (ft)	22.36	22.36
		Supported span (ft)	22.36	22.36
		Supported area (sq ft)	500.00	500.00
		Live load (psf)	49.0	50
	3.1.19 Column_L17			
		Number of Beams	0	0
		Number of Columns	10	10
		Floor to floor height (ft)	11.38	11.38
		Bay sizes (ft)	22.36	22.36
		Supported span (ft)	22.36	22.36
		Supported area (sq ft)	499.80	499.80
		Live load (psf)	48.4	50
	3.1.20 Column_L18			
		Number of Beams	0	N/A
		Number of Columns	0	N/A
		Floor to floor height (ft)	22	N/A
		Bay sizes (ft)	0	N/A
		Supported span (ft)	0	N/A
		Supported area (sq ft)	0.00	N/A
		Live load (psf)	40	N/A
4 Floors				
4.1 Concrete Suspended Slab Floor				
	4.1.1 Floors_P2			
		Floor area (sq ft)	25170	25170
		Concrete (psi)	3625	4000
		Flyash (%)	unknown	average
		Live load (psf)	50	50
	4.1.2 Floors_P1			
		Floor area (sq ft)	37505	37505
		Concrete (psi)	3625	4000
		Flyash (%)	unknown	average
		Live load (psf)	50	50
	4.1.3 Floors_L1			
		Floor area (sq ft)	9534	9534
		Concrete (psi)	3625	4000
		Flyash (%)	unknown	average
		Live load (psf)	40	50
	4.1.4 Floors_L2			
		Floor area (sq ft)	7113	7113
		Concrete (psi)	3625	4000

	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.5 Floors_L3			
	Floor area (sq ft)	9000	9000
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.6 Floors_L4			
	Floor area (sq ft)	9000	9000
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.7 Floors_L5			
	Floor area (sq ft)	9000	9000
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.8 Floors_L6			
	Floor area (sq ft)	9000	9000
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.9 Floors_L7			
	Floor area (sq ft)	9000	9000
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.10 Floors_L8			
	Floor area (sq ft)	9000	9000
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.11 Floors_L9			
	Floor area (sq ft)	9000	9000
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.12 Floors_L10			
	Floor area (sq ft)	9000	9000
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average

	Live load (psf)	40	50
4.1.13 Floors_L11			
	Floor area (sq ft)	9000	9000
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.14 Floors_L12			
	Floor area (sq ft)	9000	9000
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.15 Floors_L13			
	Floor area (sq ft)	9000	9000
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.16 Floors_L14			
	Floor area (sq ft)	8988	8988
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.17 Floors_L15			
	Floor area (sq ft)	8405	8405
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.18 Floors_L16			
	Floor area (sq ft)	7265	7265
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.19 Floors_L17			
	Floor area (sq ft)	4853	4853
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	40	50
4.1.5 Floors_Balcony_L3			
	Floor area (sq ft)	818	818
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	100	100

4.1.6 Floors_Balcony_L4			
	Floor area (sq ft)	818	818
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	100	100
4.1.7 Floors_Balcony_L5			
	Floor area (sq ft)	818	818
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	100	100
4.1.8 Floors_Balcony_L6			
	Floor area (sq ft)	818	818
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	100	100
4.1.9 Floors_Balcony_L7			
	Floor area (sq ft)	818	818
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	100	100
4.1.10 Floors_Balcony_L8			
	Floor area (sq ft)	818	818
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	100	100
4.1.11 Floors_Balcony_L9			
	Floor area (sq ft)	818	818
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	100	100
4.1.12 Floors_Balcony_L10			
	Floor area (sq ft)	818	818
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	100	100
4.1.13 Floors_Balcony_L11			
	Floor area (sq ft)	818	818
	Concrete (psi)	3625	4000
	Flyash (%)	unknown	average
	Live load (psf)	100	100
4.1.14 Floors_Balcony_L12			

			Floor area (sq ft)	818	818
			Concrete (psi)	3625	4000
			Flyash (%)	unknown	average
			Live load (psf)	100	100
		4.1.15 Floors_Balcony_L13			
			Floor area (sq ft)	818	818
			Concrete (psi)	3625	4000
			Flyash (%)	unknown	average
			Live load (psf)	100	100
		4.1.16 Floors_Balcony_L14			
			Floor area (sq ft)	818	818
			Concrete (psi)	3625	4000
			Flyash (%)	unknown	average
			Live load (psf)	100	100
		4.1.17 Floors_Balcony_L15			
			Floor area (sq ft)	818	818
			Concrete (psi)	3625	4000
			Flyash (%)	unknown	average
			Live load (psf)	100	100
5 Roofs					
	5.1 Concrete Suspended Slab Roof				
		5.1.1 Roofs_L18			
			Roof area (sq ft)	4840	
			Concrete (psi)	3625	4000
			Flyash (%)	unknown	average
			Live load (psf)	40	50

Appendix B - Impact Estimator Assumptions

Assembly Group	Assembly Type	Assembly Name	Input Assumptions
1 Foundation			
	1.2 Concrete Footings		
	Spread footing takeoffs were performed using area conditions in OnScreen Takeoff to determine the total surface area of each footing type. The thicknesses of each footing type were input as specified in the drawings. Strip footing takeoffs were performed using the linear condition in OnScreen Takeoff to determine the cumulative length of each strip footing type. The thicknesses and widths of each footing type were input as specified in the drawings. Actual rebar sizes were specified in Canadian standard sizes, but US standard rebar sizes closest to the specified size were used for Impact Estimator inputs.		
		1.1.1 Footing_F0_26"	The width of this footing was adjusted to accommodate the footing thickness limitation of Impact Estimator. = (Measured Width) x (Measured Thickness)/(Input Thickness) = 6 ft x 26"/19" = 8.21 ft
		1.1.2 Footing_F1_28"	The width of this footing was adjusted to accommodate the footing thickness limitation of Impact Estimator. = (Measured Width) x (Measured Thickness)/(Input Thickness) = 6.5 ft x 28"/19" = 9.58 ft
		1.1.3 Footing_F2_38"	The width of this footing was adjusted to accommodate the footing thickness limitation of Impact Estimator. = (Measured Width) x (Measured Thickness)/(Input Thickness) = 9 ft x 38"/19" = 18.00 ft Impact Estimator's maximum allowable rebar size (#6) was selected because the specified rebar size (25M, approximately #8) could not be input.

		1.1.4 Footing_F3_42"	The width of this footing was adjusted to accommodate the footing thickness limitation of Impact Estimator. = (Measured Width) x (Measured Thickness)/(Input Thickness) = 10 ft x 42"/19" = 22.11 ft Impact Estimator's maximum allowable rebar size (#6) was selected because the specified rebar size (30M, approximately #9) could not be input.
		1.1.5 Footing_F4_42"	The width of this footing was adjusted to accommodate the footing thickness limitation of Impact Estimator. = (Measured Width) x (Measured Thickness)/(Input Thickness) = 9.5 ft x 42"/19" = 21.00 ft Impact Estimator's maximum allowable rebar size (#6) was selected because the specified rebar size (30M, approximately #9) could not be input.
		1.1.6 Footing_F5_38"	The width of this footing was adjusted to accommodate the footing thickness limitation of Impact Estimator. = (Measured Width) x (Measured Thickness)/(Input Thickness) = 9 ft x 38"/19" = 18.00 ft Impact Estimator's maximum allowable rebar size (#6) was selected because the specified rebar size (25M, approximately #8) could not be input.

		1.1.7 Footing_F6_32"	The width of this footing was adjusted to accommodate the footing thickness limitation of Impact Estimator. = (Measured Width) x (Measured Thickness)/(Input Thickness) = 7.5 ft x 32"/19" = 12.63 ft Impact Estimator's maximum allowable rebar size (#6) was selected because the specified rebar size (25M, approximately #8) could not be input.
		1.1.8 Footing_F7_48"	The width of this footing was adjusted to accommodate the footing thickness limitation of Impact Estimator. = (Measured Width) x (Measured Thickness)/(Input Thickness) = 11 ft x 48"/19" = 27.79 ft Impact Estimator's maximum allowable rebar size (#6) was selected because the specified rebar size (30M, approximately #9) could not be input.
		1.1.9 Footing_F8_52"	The width of this footing was adjusted to accommodate the footing thickness limitation of Impact Estimator. = (Measured Width) x (Measured Thickness)/(Input Thickness) = 12 ft x 52"/19" = 32.84 ft Impact Estimator's maximum allowable rebar size (#6) was selected because the specified rebar size (30M, approximately #9) could not be input.

		1.1.10 Footing_F9_42"	The width of this footing was adjusted to accommodate the footing thickness limitation of Impact Estimator. = (Measured Width) x (Measured Thickness)/(Input Thickness) = 9 ft x 42"/19" = 19.89 ft Impact Estimator's maximum allowable rebar size (#6) was selected because the specified rebar size (25M, approximately #8) could not be input.
		1.1.11 Footing_F10_72"	The width of this footing was adjusted to accommodate the footing thickness limitation of Impact Estimator. = (Measured Width) x (Measured Thickness)/(Input Thickness) = 50 ft x 72"/19" = 189.47 ft Impact Estimator's maximum allowable rebar size (#6) was selected because the specified rebar size (30M, approximately #9) could not be input.
		1.1.12 Footing_SF1_12"	The rebar size (#3) was increased to accommodate the minimum rebar size (#4) accepted by Impact Estimator.
2 Walls			
	2.1 Steel Stud Walls		
	Stud Weight: when not provided. If stud thickness is < 6", then weight was assumed to be "light" (25 Ga) If stud thickness is >= 6", then weight was assumed to be "heavy" (20 Ga) Sheathing Type: assumed to be "none" since none were specified. Stud Thickness: Smallest stud size in IE is 3 5/8"; all studs < 3 5/8" were put at 24 o.c. instead of 16 o.c. when possible. Insulation: All "batt" insulation was assumed to be fibreglass batt insulation Exterior Glass-Mat Gypsum Sheathing replaced by Gypsum Fibre BD		
		2.1.1 Wall_Steel Stud_G2	Doors assumed to be "Steel Interior Doors"
		2.1.2 Wall_Steel	

		Stud_G4	
		2.1.3 Wall_Steel Stud_G5	
		2.1.4 Wall_Steel Stud_G6	
		2.1.4 Wall_Steel Stud_G11	
		2.1.5 Wall_Steel Stud_G12	
		2.1.6 Wall_Steel Stud_G14	
		2.1.7 Wall_Steel Stud_P1	
		2.1.8 Wall_Steel Stud_P2	Doors assumed to be "Hollow Core Wood Interior Doors"
		2.1.9 Wall_Steel Stud_P2a	Doors assumed to be "Hollow Core Wood Interior Doors"
		2.1.10 Wall_Steel Stud_P3	
		2.1.11 Wall_Steel Stud_P3a	Doors assumed to be "Hollow Core Wood Interior Doors"
		2.1.12 Wall_Steel Stud_P4	
		2.1.13 Wall_Steel Stud_P5	
		2.1.14 Wall_Steel Stud_S1	
		2.1.15 Wall_Steel Stud_S2	
		2.1.13 Wall_Steel Stud_F2	
		2.1.14 Wall_Steel Stud_F3	Doors assumed to be "Hollow Core Wood Interior Doors"
		2.1.15 Wall_Steel Stud_F4	
		2.1.16 Wall_Steel Stud_F5	
		2.1.17 Wall_Steel Stud_F6	
		2.1.18 Wall_Steel Stud_F7	Assumed tiles on thin set mortar was assumed to have negligent impacts, thus not included since there is no similar material in IE
		2.1.19 Wall_Steel Stud_F8	Assumed tiles on thin set mortar was assumed to have negligent impacts, thus not included since there is no similar material in IE
		2.1.20 Wall_Steel Stud_E7	Doors assumed to be "Aluminum Exterior Doors, 80% glazing" Windows assumed to be "Aluminum Frame" and have "Standard

			Glazing"
		2.1.21 Wall_Steel Stud_E12	Wind Average assumed to be "High" since E12 was used as exterior walls in the top floors of the building
	2.2 Curtain		
	Percent Viewable Glazing (%): assumed to be 98%. Percent Viewable Spandrel (%): assumed to be 2% Insulation Thickness: assumed to be 2". Spandrel Type: assumed to be metal.		
		2.2.1 Wall_Curtain	Doors assumed to be "Aluminum Exterior Doors, 80% glazing" Windows assumed to be "PVC Frame"
	2.3 Cast in Place		
	Flyash Percentage: assumed to be average percentage. Reinforcement: assumed to be #15M		
		2.3.1 Wall_Cast in Place_C	Concrete strength assumed to be 30 Mpa Doors assumed to be "Steel Interior Doors"
		2.3.2 Wall_Cast in Place_E1	Concrete strength assumed to be 30 Mpa
		2.3.3 Wall_Cast in Place_E2	Concrete strength assumed to be 20 Mpa
	2.4 Basic Materials		
		2.4.1 Wall_Basic Materials_F1	
	2.5 Concrete Block		
	Rebar: assumed to be #15M Mistakes in B2 and B3: the assembly included a steel stud component that was not present in the original assembly.		
		2.5.1 Wall_Concrete Block_B	Doors assumed to be "Steel Interior Doors"
		2.5.2 Wall_Concrete Block_B1	
		2.5.3 Wall_Concrete	Doors assumed to be "Steel Interior Doors"

		Block_B2	
		2.5.4 Wall_Concrete Block_B3	
3 Columns and Beams			
	3.1 Concrete Column		
	Substructure columns (P1 & P2) were counted in OnScreen Takeoff using a count condition. Superstructure columns were tallied as specified in the column schedule provided in the drawings (S106). Bay size and span length for a particular storey is simply the square root of the gross area of that storey divided by the number of columns on that storey. (Span Length) = (Bay Size) = SQRT((Gross Floor Area of Storey)/(Number of Columns of Storey)) Supported area of a particular storey is assumed to be the the gross floor area divided by the number of columns on that storey. (Supported Area) = (Gross Area)/(Number of Columns of Storey) This building was constructed using a Slab Band Design instead of a traditional Beam-Column Design. Because slab band takeoffs cannot be input into Impact Estimator, slab band spans between columns were counted and input as beams. Live loads were dependant on the floor usage type, as specified in the drawings (S101). Live loads are associated with the slab, thus columns of a particular storey resist the loads determined by the floor usage type of the storey immediately above the columns.		
		3.1.1 Columns_P2	Supported area is the floor area of P2
		3.1.2 Columns_P1	Supported area is the floor area of P1
		3.1.3 Columns_L1	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(6539 SF x 40 PSF) + (621 SF x 100 PSF) + (1048 SF x 100 PSF)] / (8208 SF) = 52.2 PSF

		3.1.4 Columns_L2	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(7243 SF x 40 PSF) + (810 SF x 100 PSF) + (1022 SF x 100 PSF)] / (9075 SF) = 52.1 PSF
		3.1.5 Columns_L3	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(7243 SF x 40 PSF) + (810 SF x 100 PSF) + (1022 SF x 100 PSF)] / (9075 SF) = 52.1 PSF
		3.1.6 Columns_L4	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(7243 SF x 40 PSF) + (810 SF x 100 PSF) + (1022 SF x 100 PSF)] / (9075 SF) = 52.1 PSF

		3.1.7 Columns_L5	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(7243 SF x 40 PSF) + (810 SF x 100 PSF) + (1022 SF x 100 PSF)] / (9075 SF) = 52.1 PSF
		3.1.8 Columns_L6	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(7243 SF x 40 PSF) + (810 SF x 100 PSF) + (1022 SF x 100 PSF)] / (9075 SF) = 52.1 PSF
		3.1.9 Columns_L7	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(7243 SF x 40 PSF) + (810 SF x 100 PSF) + (1022 SF x 100 PSF)] / (9075 SF) = 52.1 PSF

		3.1.10 Columns_L8	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(7243 SF x 40 PSF) + (810 SF x 100 PSF) + (1022 SF x 100 PSF)] / (9075 SF) = 52.1 PSF
		3.1.11 Columns_L9	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(7243 SF x 40 PSF) + (810 SF x 100 PSF) + (1022 SF x 100 PSF)] / (9075 SF) = 52.1 PSF
		3.1.12 Columns_L10	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(7243 SF x 40 PSF) + (810 SF x 100 PSF) + (1022 SF x 100 PSF)] / (9075 SF)
		3.1.13 Columns_L11	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(7243 SF x 40 PSF) + (810 SF x 100 PSF) + (1022 SF x 100 PSF)] / (9075 SF) = 52.1 PSF

		3.1.14 Columns_L12	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(7243 SF x 40 PSF) + (810 SF x 100 PSF) + (1022 SF x 100 PSF)] / (9075 SF) = 52.1 PSF
		3.1.15 Columns_L13	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(7109 SF x 40 PSF) + (825 SF x 100 PSF) + (1028 SF x 100 PSF)] / (8962 SF) = 52.4 PSF
		3.1.16 Columns_L14	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(6481 SF x 40 PSF) + (1028 SF x 100 PSF) + (1029 SF x 100 PSF)] / (8538 SF) = 54.5 PSF

		3.1.17 Columns_L15	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(4344 SF x 40 PSF) + (0 SF x 100 PSF) + (2204 SF x 100 PSF)] / (6548 SF) = 60.2 PSF
		3.1.18 Columns_L16	Live load was approximated as the area-averaged live load imposed by the various floor-use types imposed on the slab of the storey above. (Live Load) = [(Residential Floor Area) x (Residential Live Load) + (Balcony Area) x (Balcony Live Load) + (Exits and Stairs Floor Area) x (Exits and Stairs Live Load)] / (Total Area) = [(4252 SF x 40 PSF) + (0 SF x 100 PSF) + (748 SF x 100 PSF)] / (5000 SF) = 49.0 PSF
		3.1.19 Columns_L17	Live load was approximated as the area-averaged live load imposed by the mechanical room and roof of the slab above. (Live Load) = [(Roof Area) x (Roof Live Load) + (Mechanical Area) x (Mechanical Live Load)] / (Total Area) = [(3803 SF x 40 PSF) + (1195 SF x 75 PSF)] / (4998 SF) = 48.4 PSF
		3.1.20 Columns_L18	
4 Floors			
	4.1 Concrete Suspended Slab Floor **Assumed 4000 psi**		

	4.1.1 Floors_P2	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 50psf was used. Parking floor area use may also be allocated to nearby townhouses, but it is assumed to be solely for the purpose of high-rise residents.
	4.1.2 Floors_P1	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 50psf was used. Parking floor area use may also be allocated to nearby townhouses, but it is assumed to be solely for the purpose of high-rise residents.
	4.1.3 Floors_L1	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.4 Floors_L2	Flyash concentration assumed 35% Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.5 Floors_L3	Flyash concentration assumed 35% Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.6 Floors_L4	Flyash concentration assumed 35% Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.7 Floors_L5	Flyash concentration assumed 35% Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.8 Floors_L6	Flyash concentration assumed 35% Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.

	4.1.9 Floors_L7	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.10 Floors_L8	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.11 Floors_L9	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.12 Floors_L10	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.13 Floors_L11	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.14 Floors_L12	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.15 Floors_L13	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.16 Floors_L14	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.17 Floors_L15	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.

	4.1.18 Floors_L16	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.19 Floors_L17	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.
	4.1.5 Floors_Balcony_L3	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 100psf used for all exterior balconies. All exterior balconies and patios assumed equal.
	4.1.6 Floors_Balcony_L4	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 100psf used for all exterior balconies. All exterior balconies and patios assumed equal.
	4.1.7 Floors_Balcony_L5	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 100psf used for all exterior balconies. All exterior balconies and patios assumed equal.
	4.1.8 Floors_Balcony_L6	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 100psf used for all exterior balconies. All exterior balconies and patios assumed equal.
	4.1.9 Floors_Balcony_L7	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 100psf used for all exterior balconies. All exterior balconies and patios assumed equal.
	4.1.10 Floors_Balcony_L8	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 100psf used for all exterior balconies. All exterior balconies and patios assumed equal.

	4.1.11 Floors_Balcony_L9	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 100psf used for all exterior balconies. All exterior balconies and patios assumed equal.
	4.1.12 Floors_Balcony_L10	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 100psf used for all exterior balconies. All exterior balconies and patios assumed equal.
	4.1.13 Floors_Balcony_L11	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 100psf used for all exterior balconies. All exterior balconies and patios assumed equal.
	4.1.14 Floors_Balcony_L12	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 100psf used for all exterior balconies. All exterior balconies and patios assumed equal.
	4.1.15 Floors_Balcony_L13	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 100psf used for all exterior balconies. All exterior balconies and patios assumed equal.
	4.1.16 Floors_Balcony_L14	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 100psf used for all exterior balconies. All exterior balconies and patios assumed equal.
	4.1.17 Floors_Balcony_L15	Flyash concentration is unknown. Assume average flyash concentration. Live load was approximated using specified design loads. Live load of 100psf used for all exterior balconies. All exterior balconies and patios assumed equal.
5 Roofs		
	5.1 Concrete Suspended Slab Roof **Storeys delineated as encapsulating the air ventalation system of the building were not counted as area use.**	

		Flyash concentration is unknown. Assume average flyash concentration.
	5.1.1 Roofs_L18	Live load was approximated using specified design loads. Live load of 40 was not an option in Athena, so 50psf was used.