Building Life Cycle Assessment:
Marine Drive Residence at
The University of British Columbia

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Abstract

A Life Cycle Assessment of thirteen buildings on UBC campus was conducted as part of a 4th year Civil Engineering undergraduate course in order to assess the environmental impacts generated by the buildings. This paper represents one of the thirteen studies, which was conducted on the Marine Drive Student Residence. Quantity takeoffs were performed using OnScreen Takeoff software on both structural and architectural drawings to generate determine quantities and types of materials used in building construction. These assemblies were then inputted into Athena Environmental Impact Estimator (IE) software to determine the impacts generated by the building. Eight different impact categories were measured using the software and the results for Marine Drive Residence were compared with other residences studied on a per square foot basis, which indicated that this residence has exceptionally high impacts in most categories.

Assumptions, input values, and areas of uncertainty have also been outlined in the report and a sensitivity analysis has been conducted to examine the effects of errors and determine how different assemblies correlate to different impact categories. Uncertainties with column and beam assemblies are particularly uncertain. Although calculations were made to model these assemblies as accurately as possible, results seem to be much to high. This may be do to the fact that this study used a version of the IE that was not completely finished being developed (ie. build 51 of version 4).

In addition, an energy model was prepared in order to assess heat losses and the potential effects that material upgrades could have to reduce these.

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1.0 Introduction

Located near Wreck Beach on the west side of UBC's Point Grey Campus, Marine Drive Residence is the newest student residence and exhibits the urban modernity of chic glass high rises. The development has generated some controversy and was halted by Wreck Beach advocates in 2004 who refused to allow the construction of 20 -storey towers that would be in view of nudes on the beach below. The towers were then re-designed to not exceed 18 storeys and construction resumed in 2005. The residence was designed by Hotson Bakker Boniface Haden Associated Architects and structural consultation was provided by Read Jones Christoffersen Consluting Engineers. Information on the total cost of the complex was unavailable.

The residence consists of a combination of high-rise towers and lower structures (called podiums) for a total of six buildings, which includes a commons block that does not house students. The units housing students have been completed and are occupied but the commons block is still under construction and is expected to be completed this year. A summary of the buildings and their sizes is presented below.

Table 1-1 - Marine Drive Square Footage Tables

Marine Drive Sqaure Footage Tables

Building	Type	Floors	Beds	Square Ft
Building 1	Tower	18	344	126021
Building 2	Podium	5	223	202796
Building 3 (Commons Block)	Amenity	*omitted from study*		
Building 4	Tower	18	405	148119
Building 5	Tower	17	368	129297
Building 6	Podium	7	294	115120
	TOTAL =	**65**	**1634**	**721353**

There is no indication that a Life Cycle Assessment (LCA) has ever been conducted on the Marine Drive Residence before; this report will be the first evaluation of the environmental impacts created by the development. Due to limitations on resources and therefore scope, for the purpose of this study Tower 4 is the only one modeled and this model will be used to represent the entire complex on an impact per square foot basis. Tower 4 is an 18-storey high-rise with a concrete superstructure and a heavily glazed exterior. A summary of the building's composition, which forms the basis for the LCA, is presented in the table below.

Table 1-2 - Bulding Characteristics

Building System	Specific Characteristics of Marine Drive Tower 4
Structure	Concrete and structural steel columns supporting concrete suspended slabs
Floors	Basement: Concrete slab on grade; Ground: combination of Suspended slabs and slabs on grade; All other floors (Floors 2-18): Suspended slabs
Exterior Walls	Basement: Cast in place walls; Ground: Cast in place walls with concrete block cladding and acoustic batt insulation; aluminum framed curtain wall with standard glazing; steel stud exterior walls with commercial steel cladding, acoustic batt insulation; Floors Two, Three, Four, and Five: Cast in place walls with concrete block cladding and acoustic batt insulation; steel stud exterior walls with commercial steel cladding, acoustic batt insulation; All other Floors (Floors 7-18):Cast in place walls with acoustic batt insulation; steel stud exterior walls with commercial steel cladding, acoustic batt insulation
Interior Walls	Basement: cast in place concrete walls; All Other Floors (Floors Ground-18) : gypsum on steel stud walls (some double thickness) with acoustic batt insulation
Windows	All windows and curtain walls standard glazed
Roof	Floors Six and Seven: Inverted Membrane Roofing with aggregate ballast, 4" polyisocyanurate insulation on suspended concrete slab; metal roof with 4" polyisocyanurate insulation and waterproofing membrane; Floor 18 Roof: Inverted Membrane Roofing with aggregate ballast, 4" polyisocyanurate insulation on suspended concrete slab; Membrane Roofing System with 4" polyisocyanurate insulation, vapour barrier on suspended concrete slab

2.0 Goal And Scope

This life cycle analysis (LCA) of the Marine Drive Residence at the University of British Columbia was carried out as an exploratory study to determine the environmental impact of it’s design. The residence consists of five residence buildings, which are referred to collectively as Marine Drive Residence in this report. This LCA of the Marine Drive Residence is also part of a series of twelve others being carried out simultaneously on respective buildings at UBC with the same goal and scope.

The main outcomes of this LCA study are the establishment of a materials inventory and environmental impact references for the Marine Drive Residence. An exemplary application of these references are in the assessment of potential future performance upgrades to the structure and envelope of the Marine Drive Residence. When this study is considered in conjunction with the twelve other UBC building LCA studies, further applications include the possibility of carrying out environmental performance comparisons across UBC buildings over time and between different materials, structural types and building functions. Furthermore, as demonstrated through these potential applications, this Marine Drive Residence LCA can be seen as an essential part of the formation of a powerful tool to help inform the decision making process of policy makers in establishing quantified sustainable development guidelines for future UBC construction, renovation and demolition projects.

The intended core audience of this LCA study are those involved in building development related policy making at UBC, such as the Sustainability Office, who are involved in creating policies and frameworks for sustainable development on campus. Other potential audiences include developers, architects, engineers and building owners involved in design planning, as well as external organizations such as governments, private industry and other universities whom may want to learn more or become engaged in performing similar LCA studies within their organizations.

2.1 Scope of Study

The product system being studied in this LCA are the structure, envelope and operational energy usage associated with space conditioning of the Marine Drive Residence on a square foot finished floor area of residence building basis. In order to focus on design related impacts, this LCA encompasses a cradle-to-gate scope that includes the raw material extraction, manufacturing of construction materials, and construction of the structure and envelope of the Marine Drive Residence, as well as associated transportation effects throughout.

2.2 Tools, Methodology and Data

Two main software tools are to be utilized to complete this LCA study; OnCenter's OnScreen TakeOff and the Athena Sustainable Materials Institute's Impact Estimator (IE) for buildings.

The study will first undertake the initial stage of a materials quantity takeoff, which involves performing linear, area and count measurements of the building's structure and envelope. To accomplish this, OnScreen TakeOff version 3.6.2.25 is used, which is a software tool designed to perform material takeoffs with increased accuracy and speed in order to enhance the bidding capacity of its users. Using imported digital plans, the program simplifies the calculation and measurement of the takeoff process, while reducing the error associated with these two activities. The measurements generated are formatted into the inputs required for the IE building LCA software to complete the takeoff process. These formatted inputs as well as their associated assumptions can be viewed in Appendixes A and B respectively.

Using the formatted takeoff data, version 4.0.51 of the IE software, the only available software capable of meeting the requirements of this study, is used to generate a whole building LCA model for the Marine Drive Residence in the Vancouver region as an MURB rented building type. The IE software is designed to aid the building community in making more environmentally conscious material and design choices. The tool achieves this by applying a set of algorithms to the inputted takeoff data in order to complete the takeoff process and generate a Bill of Materials (BoM). This BoM then utilizes the Athena Life Cycle Inventory (LCI) Database, version 4.6, in order to generate a cradle-to-grave LCI profile for the building. In this study, LCI profile results focus on the manufacturing and transportation of materials and their installation in to the initial structure and envelope assemblies. As this study is a cradle-to-gate assessment, the expected service life of the Marine Drive Residence is set to 1 year, which results in the maintenance, operating energy and end-of-life stages of the building's life cycle being left outside the scope of assessment.

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

- Global warming potential

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

Using the summary measure results, a sensitivity analysis is then conducted in order to reveal the effect of material changes on the impact profile of the Marine Drive Residence. Finally, using the UBC Residential Environmental Assessment Program (REAP) as a guide, this study then estimates the embodied energy involved in upgrading the insulation and window R-values to REAP standards and calculates the energy payback period of investing in a better performing envelope.

The primary sources of data for this LCA are the original architectural and structural drawings from when the Marine Drive Residence was initially constructed in 2005. The assemblies of the building that are modeled include the foundation, columns and beams, floors, walls and roofs, as well as the associated envelope and openings (ie. doors and windows) within each of these assemblies. The decision to omit other building components, such as flooring, electrical aspects, HVAC system, finishing and detailing, etc., are associated with the limitations of available data and the IE software, as well as to minimize the uncertainty of the model. In the analysis of these assemblies, some of the drawings lack sufficient material details, which necessitate the usage of assumptions to complete the modeling of the building in the IE software. Furthermore, there are inherent assumptions made by the IE software in order to generate the BoM and limitations to what it can model, which necessitated further assumptions to be made. These assumptions and limitation will be discussed further as they energy in the Building Model section and, as previously mentioned, all specific input related assumption are contained in the Input Assumptions document in Annex B.

3.0 Building Model

3.1 Takeoffs

Building materials and their quantities were determined by performing quantity takeoff calculations on architectural and structural drawings of Tower 4 using OnCenter's OnScreen TakeOff software. Both sets of drawings were obtained from the UBC records department on West Mall of the Point Grey Campus. The drawings were then imported into On-Screen Takeoff Pro, a program that performs quantity takeoffs using different conditions to calculate areas, lengths, and counts of different assemblies.

The program itself is fairly intuitive and the files associated with the takeoff software are included on the CD included with this document. The names of the assemblies correspond to either a description or their names as specified in the drawings. The names are also identical to the names used in the IE input values spreadsheet (included in the Appendix A). A basic breakdown of how different assemblies were modeled is presented below. In some cases, calculations were involved to transform On-Screen Takeoff values into final input values. A complete list of these calculations is presented for reference in Appendix B.

3.1.1 On Grade and Suspended Slabs

Concrete slab areas were calculated using an area condition in On-Screen. In the cases where multiple floors were identical, one floor was modeled as a single assembly and then multiplied by the number of identical floors later on to determine the total area.

3.1.2 Ceiling

The ceiling area was calculated using an area condition. This was only done on drawings that specifically indicated extra material use in the ceilings.

3.1.3 Walls

Wall lengths were calculated using a linear condition in On-Screen. In the cases where multiple floors were identical, one floor was modeled as a single assembly and then multiplied by the number of identical floors later on to determine the total area. On-Screen was only used to determine lengths. Other dimensions such as height and thickness were translated directly from drawings into the IE.

3.1.4 Doors

Doors were categorized by type and floor set and then counted using count conditions. In the cases where floors were identical, one floor was modeled as a single assembly and then multiplied by the number of identical floors to determine the total number of doors.

3.1.5 Roofs

Roofs were broken down by type as specified by the architectural drawings. Areas were then determined using an area condition.

3.1.6 Footings

Count conditions were used to count the total number of columns of each type in the building. Dimensions for the footings were translated directly from structural drawings into the IE and are not included in On-Screen.

3.1.7 Column and Beam Assemblies

Takeoffs for columns and beams were determined in a three-step process. First, the total supported column areas were determined using an area condition. Most floors were broken into three conditions in order for areas to be more or less rectangular. The number of columns and beams were then counted using count conditions, although the location of beams was often estimated. These three conditions were then combined to determine IE software inputs.

3.1.8 Windows

Windows were counted by type and floor series using count conditions and nomenclature specified in the architectural drawings. In the cases of repeated floors, the number of windows was multiplied by the number of identical floors to determine the final IE inputs. Dimensions for the windows were also entered into On-Screen in order to produce a secondary calculation of the cumulative window area. Both the window counts and the total window areas were used to calculate final IE inputs.

3.2 Assumptions

The following sections detail the general assumptions that were made in order to model each assembly in the IE. A further detailed breakdown of both the general and assembly specific assumptions can be found in Appendix B.

Perhaps the largest assumption made in modeling the environmental impacts of the Marine Drive Residence was the method used to extrapolate impacts determined for a single building to represent the entire complex. Originally, assemblies similar between different buildings were replicated in the IE so that the software would be modeling the entire complex.

Only Tower 4 has been modeled in the IE software and the final impacts were then calculated using summary measures on a per square foot basis and then multiplied by the total complex square footage in order to determine the overall impacts. Although this will likely be a reasonably accurate means of modeling the other two towers, which are quite similar, there is significant uncertainty around how effectively this model can be extended to include the two podium buildings. Without drawings of the podium buildings it is difficult to verify any estimated degrees of uncertainty.

3.2.1 Floor Assumptions

In consistency with other concrete bodies in the structure, since there is no indication of increased fly ash content, it was assumed that all concrete contained only average concentrations of fly ash. One slight modification was made to the concrete in order to fit IE input fields: the strength of concrete was adjusted from 3500 to 4000 psi. Although this will likely result in a higher overall global warming potential in the model, the magnitude of this increase is unknown and therefore not adjusted for.

Two other general assumptions were also made due to lack of specific information available from the drawings. No floor envelope specifications were provided and since flooring such as carpeting is beyond the scope of this study, floors were assumed to not have envelopes. The other source of uncertainty is related to floor loading specifications, which were indicated in the structural drawings as having a point load of 2 kips. It is unusual to attribute a point load to a floor area, so this was assumed to translate into a uniform area load of 100 psf in order to fit IE input fields.

3.2.2 Roof Assumptions

Similarly to the floors, no unusual concrete fly ash concentrations were specified and loading specifications were also given as point loads, specifically as 0.3 kips. In an attempt to be proportionally consistent with other loading assumptions, 0.3 kips was correlated to 45 psf in the IE software. Also, roof concrete strengths were specified as 3500 psi in structural drawings but had to be rounded up to 4000 to fit IE input fields, likely resulting a slightly increased global warming potential for the overall model.

3.2.3 Column and Beam Assumptions

Due to the rigidity of the IE inputs and the non-uniformity of the column assembly within the tower, modeling this part of the structure required the largest assumptions and appears to be the greatest source of error within the model. The Athena Environmental Impact Estimator models column and beam assemblies in a grid format, which assumes that bay areas and spans are uniform. It also places minimum values on bay areas and span lengths and will round up to these minimums if an input value is outside the range.

In order to conform to this input format, the number of columns and beams were counted, the supported area was determined, and then transformed mathematically into a rectangular grid where length = 2 x width. (See Appendix B for calculation details) Since no drawings detailing beams were available the location of certain beams had to be assumed; beams were only assumed to exist if the length of a span between two columns exceeded 10 ft. Although all beams and columns counted in the quantity takeoffs are represented in the model, the values for supported spans are below the minimum required input value, which means that the software may be rounding up the lengths of beams even if this is not evident in the input fields. If rounding is occurring, span values will be rounded up to approximately 20 ft. This cannot be changed without reducing the value for bay areas, which would result in a value below the valid input range and cause the model to not function.

Also, input fields in the IE do not allow for concrete strengths to be specified, only live loads. This may be missing an important component in environmental impacts since the concrete strengths change from 25 MPa to 35 MPa from the top of the structure to the bottom respectively. Since these strengths have a significant affect on greenhouse gas emissions, the assumption that all column strengths are the same may not be valid.

3.2.4 Footings and Stairs Assumptions

Concrete fly ash content was again assumed to be average and the concrete strength of 5,333 psi had to be changed to 4,000 psi in order to match available input options for all footings. Again, this rigidity in input format contributed to inaccuracies in greenhouse gas emissions estimated by the model. In some cases, the size of rebar also had to be changed to match available input fields.

One point of uncertainty is a lack of information on footing envelopes. Structural drawings specify that some envelope material may be necessary but this decision was to be made at the discretion of geotechnical experts at the time of excavation. For the purposes of this model it was assumed that no footing envelopes existed.

There is no input category in the IE that represents stairs. Stairs were modeled as footings in order to have more control over concrete volumes and reinforcement dimensions in the model.

3.2.5 Wall Assumptions

Door types specified in the model have been confirmed through drawings and a site visit but the generic terms used in the IE make it uncertain if doors used in the model are an accurate representation of the actual ones. However, it seems likely that this assumption is a minor one since the type of materials has been confirmed and it is only the volume that remains uncertain.

Windows were accounted for by counting the number of each type of assembly and then matching them to the areas specified in the window schedule in the architectural drawings. In cases where the window assembly did not match any detailed in the window schedule, an assumption was made based on size and the number of windows and the new assembly was equated to one specified in the window schedule. A complete breakdown of these assumptions and count for the total number of windows can be referenced in Appendix B. Two more assumptions related to the window assemblies were made when the architect was unable to verify drawing ambiguities. The windows were assumed to be of standard glazing with aluminum frames.

There was also limited information about the envelopes of the metal stud walls immediately surrounding the windows. These envelopes were assumed to be the same as the single stud drywall partition envelopes that the metal stud walls join to except with a commercial grade steel exterior cladding. Also, due to a few missing specifics in the architectural drawings, steel studs in drywall partitions were assumed to be light (25 Ga) and acoustic batt insulation was interpreted as fiberglass.

3.3 Bill of Materials

The following Bill of Materials (BoM) states the estimated types and quantities of materials used in the construction of Tower 4 of the Marine Drive Residence. This BoM was generated using the IE after all assemblies had been inputted from On-Screen calculations. By doing so, material quantities are slightly higher than takeoff values and also present some slightly different materials. This is because the IE software accounts for waste material generated during construction by estimating typical waste amounts and adding this to the total quantities. It also breaks down some assemblies into smaller components that are part of their fabrication or associated with construction such as paper tape.

Table 3 - Bill of Materials

Material	Quantity	Unit
1/2" Gypsum Fibre Gypsum Board	58.2502	m2
3 mil Polyethylene	423.7181	m2
5/8" Fire-Rated Type X Gypsum B	22304.11	m2
5/8" Gypsum Fibre Gypsum Board	772.4108	m2
5/8" Moisture Resistant Gypsum B	36.3141	m2
5/8" Regular Gypsum Board	65.0757	m2
6 mil Polyethylene	191.8635	m2
Aluminium	397.0517	Tonnes
Ballast (aggregate stone)	231834	Kg
Batt. Fiberglass	46579.05	m2 (25mm)
Cold Rolled Sheet	0.2143	Tonnes
Commercial(26 ga.) Steel Claddinc	2723.986	m2
Concrete 20 MPa (flyash av)	399.8188	m3
Concrete 30 MPa (flyash av)	28407.46	m3
Concrete Blocks	13502.87	Blocks
Concrete Brick	1114.098	m2
EPDM membrane	34443.73	Kg
Foam Polyisocyanurate	882.1856	m2 (25mm)
Galvanized Sheet	1.8828	Tonnes
Galvanized Studs	48.5197	Tonnes
Glazing Panel	16.4079	Tonnes
Isocyanurate	3671.973	m2 (25mm)
Joint Compound	23.132	Tonnes
Large Dimension Softwood Lumbe	8.5693	m3
Modified Bitumen membrane	751.1945	Kg
Mortar	63.5739	m3
Nails	25.003	Tonnes
Paper Tape	0.2655	Tonnes
Polyester felt	0.817	Tonnes
Polyethylene Filter Fabric	0.2418	Tonnes
Rebar, Rod, Light Sections	1564.151	Tonnes
Screws Nuts & Bolts	2.7169	Tonnes
Small Dimension Softwood Lumbe	7.7807	m3
Softwood Plywood	3.8268	m2 (9mm)
Solvent Based Alkyd Paint	209.7064	L
Standard Glazing	15606.27	m2
Water Based Latex Paint	1483.879	L
Welded Wire Mesh / Ladder Wire	2.0728	Tonnes

Because the BoM does not use consistent units it is not immediately obvious which assemblies account for the greatest resource usage. Predictably, materials such as concrete, aggregate, rebar, glazing, and insulation are present in high quantities. Concrete, aggregate, and rebar are used throughout all assemblies in the superstructure such as columns, beams, slabs, floors, and roofs. Concrete is also used extensively for walls throughout the building. Because of the high degree of uncertainty with the concrete modeling as outlined in the assumptions, it seems likely that these numbers may be an overestimate, particularly if the IE is indeed rounding up beam spans in the estimating process.

Other than concrete and its associated components, wall materials such as fiberglass insulation, gypsum drywall, and exterior glazing accounts for the other high material use assemblies. Although assumptions were also made here, most assumptions were related to the type of materials; there is little uncertainty in the volumes used. Although fiberglass insulation thickness was estimated in the metal stud walls around window assemblies, the relative area of this is small and therefore any error would have a proportionally small impact. Similarly, with windows there is little relative uncertainty around the window areas when compared to uncertainty around material used as outlined in the window assumptions section of this document.

4.0 Summary Measures

From the final BoM compiled through the different assemblies by the IE the software cross-references an extensive database to determine estimations of environmental impacts in eight impact categories, namely:

- Global warming potential *(MJ)*
- Acidification potential (*kg*)
- Eutrophication potential *(kg CO2 eq / kg)*
- Ozone depletion potential *(moles of H+ eq / kg)*
- Photochemical smog potential *(kg PM2.5 eq / kg)*
- Human health respiratory effects potential *(kg N eq / kg)*

- Weighted raw resource use *(kg CFC-11 eq / kg)*
- Primary energy consumption *(kg NOx eq / kg)*

As described in the goal and scope section of this document, impacts are determined using mid-point impact assessment methodology, meaning that the potential for environmental harm in terms of equivalent standardized units is determined but the final impacts are not (ie. endpoint effects). Determining final impacts is heavily dependent upon context and current software lacks both the complexity and information required to undertake such a model.

As specified in the goal and scope, the impact assessment only includes the manufacturing and construction phases of the building's life cycle. Impact values for both Tower 4 and the extrapolated values representing the entire complex are presented below:

Table 4 -1 – Marine Drive Summary Measures

Impact Summary Table - Tower 4

Impact Category	Units	Manufacturing			Construction			Total Effects (Ma	
		Material	Transport-ation	Total	Material	Transport-ation	Total	Overall	Per S
Primary Energy Consumption	*MJ*	109,000,000.00	3,430,000.00	112,430,000.00	5,640,000.00	18,800,000.00	24,440,000.00	136,870,000.00	92.
Weighted Resource Use	*kg*	84,300,000.00	104,000.00	84,404,000.00	259,000.00	429,000.00	688,000.00	85,092,000.00	57.
Global Warming Potential	*(kg CO2 eq / kg)*	10,700,000.00	5,950.00	10,705,950.00	383,000.00	35,400.00	418,400.00	11,124,350.00	7.5
Acidification Potential	*(moles of H+ eq / kg)*	3,700,000.00	2,030.00	3,702,030.00	177,000.00	11,300.00	188,300.00	3,890,330.00	2.6
HH Respiratory Effects Potential	*(kg PM2.5 eq / kg)*	38,100.00	2.45	38,102.45	200.00	13.60	213.60	38,316.05	0.
Eutrophication Potential	*(kg N eq / kg)*	284.00	0.01	284.01	0.00	0.09	0.09	284.10	0.0
Ozone Depletion Potential	*(kg CFC-11 eq / kg)*	0.02	0.00	0.02	0.00	0.00	0.00	0.02	0.0
Smog Potential	*(kg NOx eq / kg)*	56,000.00	45.80	56,045.80	4,390.00	253.00	4,643.00	60,688.80	0.4

Complex Total

Impact Category	Units	Manufacturing			Construction			Total Effects (Man. +	
		Material	Transport-ation	Total	Material	Transport-ation	Total	Overall	Per S
Primary Energy Consumption	*MJ*	530,839,912.70	16,704,411.73	**547,544,324.43**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Weighted Resource Use	*kg*	410,548,666.27	506,489.46	**411,055,155.73**	1,761,353.25	[illegible]	[illegible]	[illegible]	[illegible]
Global Warming Potential	*(kg CO2 eq / kg)*	52,109,973.57	28,977.04	**52,138,950.61**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Acidification Potential	*(moles of H+ eq / kg)*	18,019,336.48	9,886.28	**18,029,222.76**	862,006.15	55,032.03	**917,038.18**	[illegible]	[illegible]
HH Respiratory Effects Potential	*(kg PM2.5 eq / kg)*	185,550.46	11.93	**185,562.40**	974.02	66.23	**1,040.25**	**186,602.65**	[illegible]
Eutrophication Potential	*(kg N eq / kg)*	1,383.11	0.07	**1,383.18**	0.00	0.42	**0.43**	**1,383.60**	0.0
Ozone Depletion Potential	*(kg CFC-11 eq / kg)*	0.09	0.00	**0.09**	0.00	0.00	**0.00**	**0.09**	0.0
Smog Potential	*(kg NOx eq / kg)*	272,725.09	223.05	**272,948.14**	21,379.70	1,232.13	**22,611.83**	**295,559.98**	[illegible]

4.1 Impact Comparisons

Even when presented in graphical format it is difficult to comprehend the true meaning of such abstract numbers. In order to add some perspective, impacts for each category have been graphed with impact values for other residences at UBC. To normalize the data, impacts have been compiled on a per square foot basis and represent both manufacturing and construction stages, the latter of which is mostly transportation. The data table of values used to generate the following graphs can be found in Appendix C.

4.1.1 Primary Energy Consumption

Primary energy consumption simply refers to the estimated amount of power consumed. In this case, the energy demand created by Marine Drive is staggering, outstripping all other residences and amounting to nearly double the average.

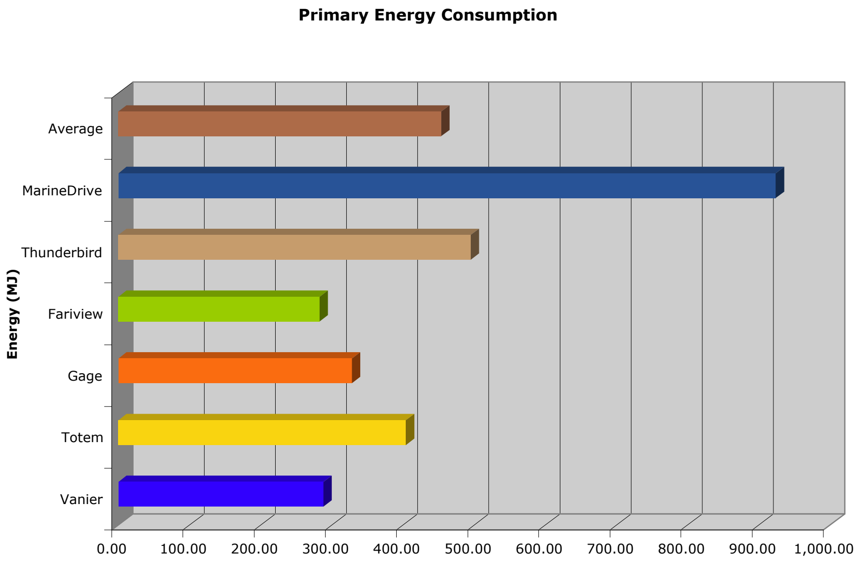

Figure 4-1 – Primary Energy Consumption

4.1.2 Weighted Resource Use

Again, Marine Drive residence dramatically outstrips the resource demand of other residences, more than doubling the average value. Although some uncertainty related to column and beam modeling may be disproportionately elevating the value for Marine

Drive's resource use, the vast difference between this complex and all other residences is too great to be attributed entirely to model error.

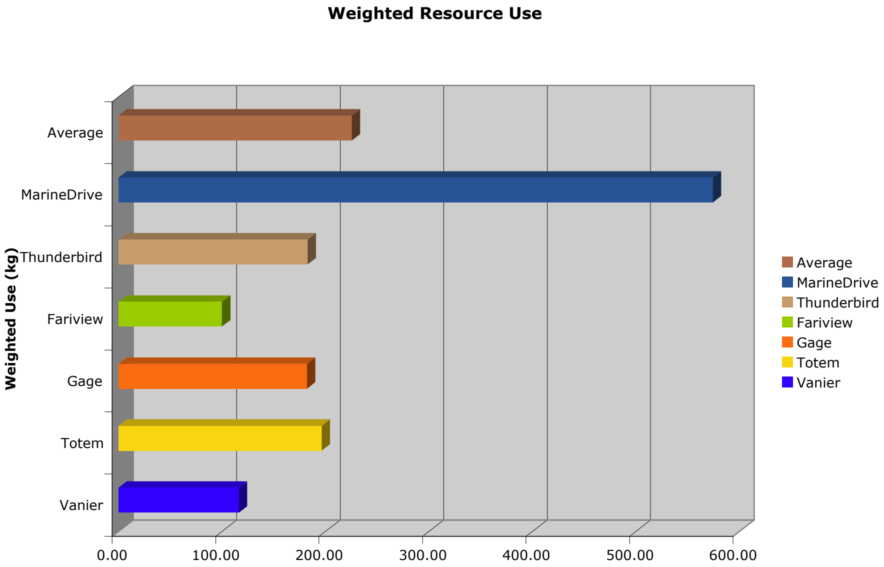

Figure 4-2 – Weighted Resource Use

4.1.3 Global Warming Potential

Global warming potential is determined by calculating the equivalent of CO_2 released into the atmosphere and is highly influenced by the amount of concrete in a structure. Again, error in concrete volume, likely attributed to column and beam assembly assumptions could be resulting in falsely high values, but the discrepancy between the Marine Drive residence and the other complexes appears to be indicating a trend.

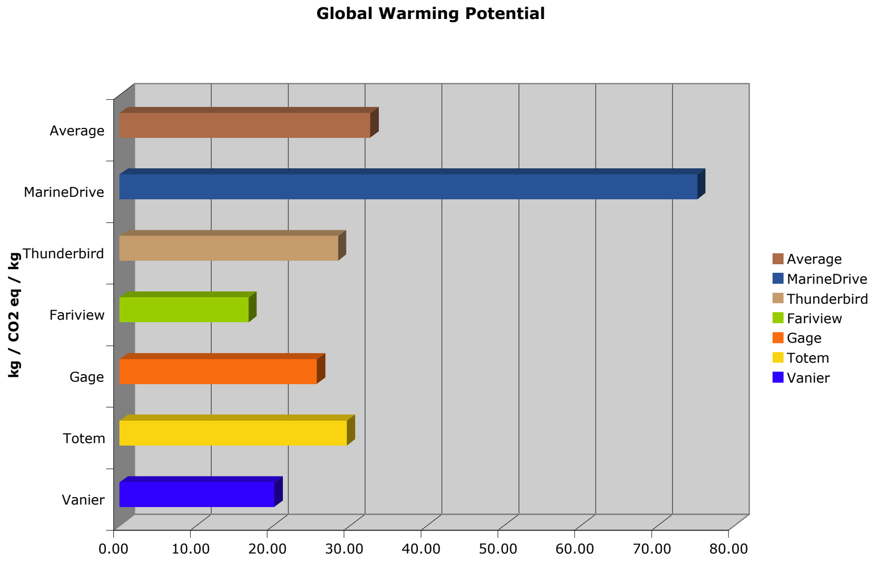

Figure 4-3 – Global Warming Potential

4.1.4 Acidification Potential

Acidification potential refers to the equivalent estimated amount of H^{+} released into the environment. This value is also exceptionally high for the Marine Drive residence with more than double the value of the average.

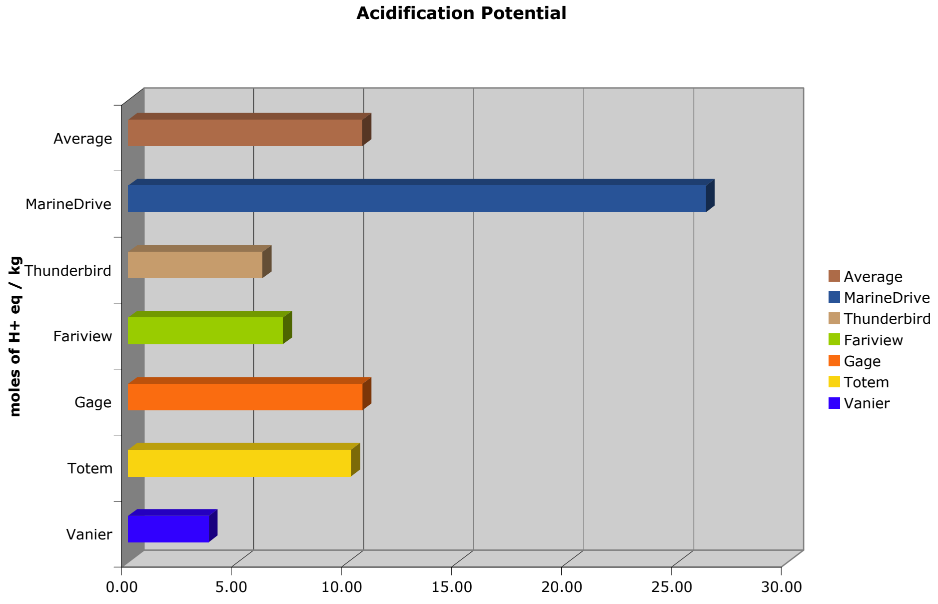

Figure 4-4 – Acidification Potential

4.1.5 HH Respiratory Effects Potential

This index measures the potential for human health respiratory effects as quantified by PM2.5 eq kg. Once again, the impact created by the Marine Drive residence is significantly above that of any other residence at UBC.

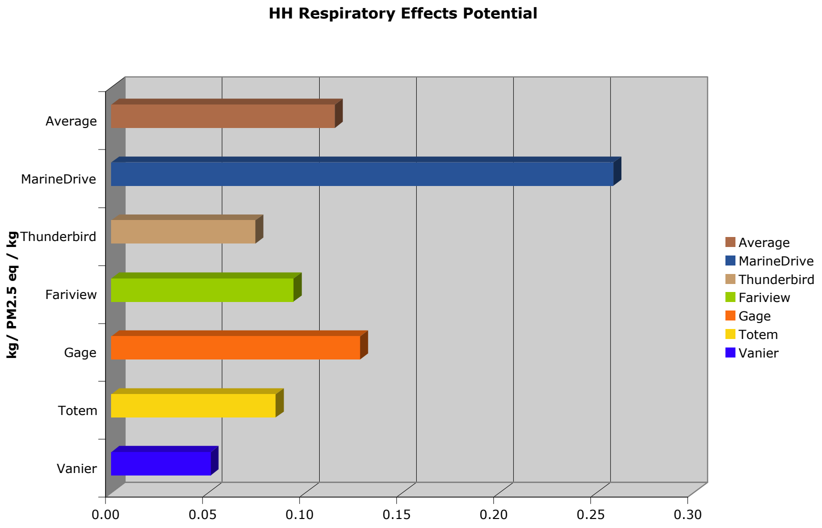

Figure 4-5 – HH Respiratory Effects Potential

4.1.6 Eutrophication Potential

Eutrophication potential refers to the likelihood that the release of nitrogen into an aquatic environment will promote plant an algae growth to the point where the nutrients that were previously scarce are consumed so rapidly that other life is “choked out”. In this case, Thunderbird residence exceeds Marine Drive’s potential for impact, which also may suggest that data in other categories might not be unacceptably skewed.

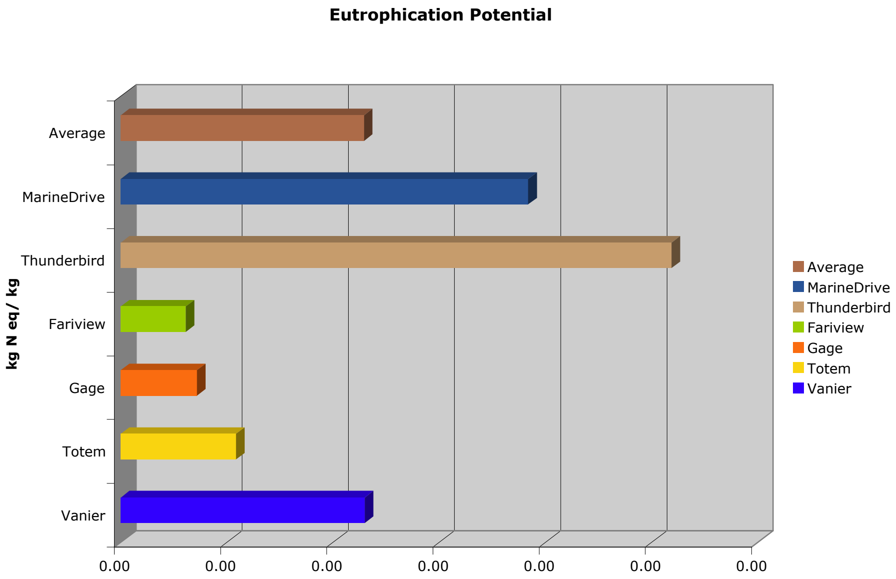

Figure 4-6 – Eutrophication Potential

4.1.7 Ozone Depletion Potential

Although impact values are relatively low in this category, Marine Drive residence appears to be closer to the expected average value. However, it still seems somewhat surprising that the value is above average. With advancements in material technology aimed at reducing ozone depletion (such as reduction of CFC use) it seems logical to assume that ozone depletion potential should be lower than the average especially when compared to older buildings.

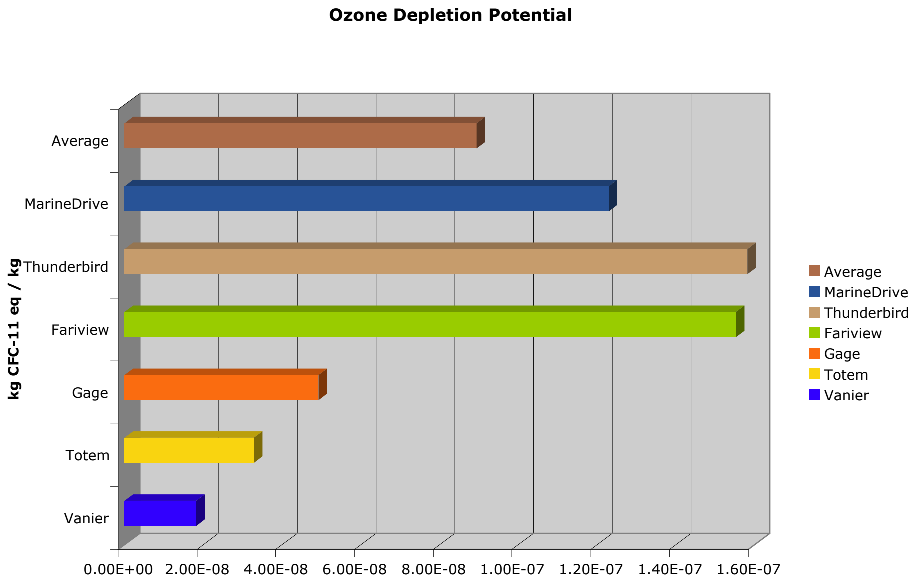

Figure 4-7 – Ozone Depletion Potential

4.1.8 Smog Potential

The final impact category, smog potential, once again shows Marine Drive as having the most significant potential for impact. Although it is the newest of the residences, it appears to be having the most significant environmental effects.

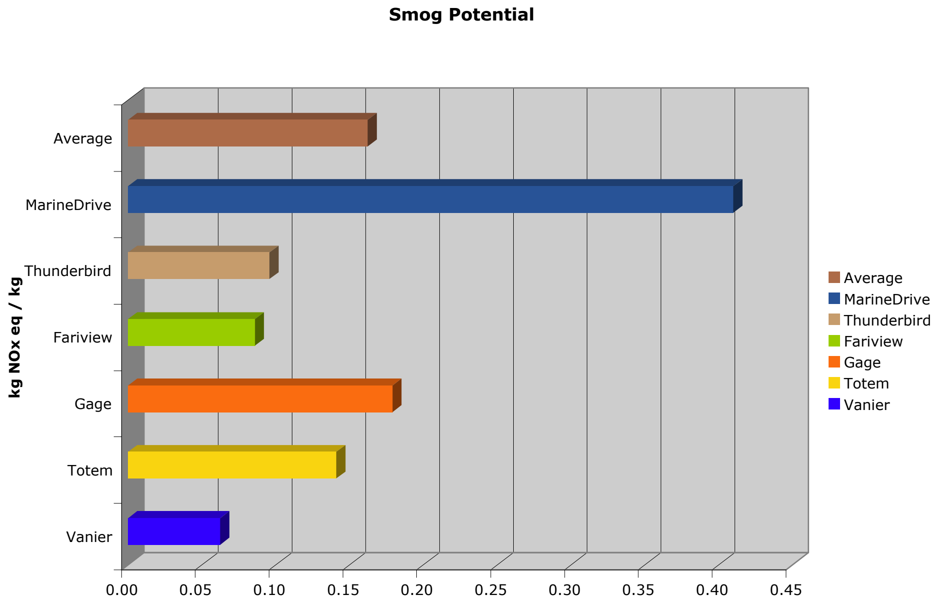

Figure 4-8 – Smog Potential

4.2 Impacts By Assembly

Impacts were also categorized by assembly type, which allows for comparisons between different parts of the building. A summary of the values generated is presented in the table below. These values are the initial outputs and therefore only represent Tower 4.

Table 4-2– Impacts by Assembly Type

Material ID	Foundations	Walls	Beams and Columns	Roofs	Floors	Extra Basic Mater	Total
Primary Energy Consumption MJ	2036179.0	1469052	-584660.71	19797647	7141874	298616.0428	1601587
Weighted Resource Use kg	2690477.0	9783018	-49652.66	7534894	65958388	412785.343	8428442
Global Warming Potential (kg CO2 e	521319.3	27084204	-35653.37	81407001	15231942	84229.25422	2429304
Acidification Potential (moles of H+ (	347296.8	6545763	-15424.86	5906098.	97824409	56217.91803	1666436
HH Respiratory Effects Potential (kg	259177.8	3554619	-17671.30	7697988	5.7568992	41834.21128	1210683
Eutrophication Potential (kg N eq / k	8840.926	8816455.1	-2015.299	0338481.9	5066911.7	1411.584918	710055.9
Ozone Depletion Potential (kg CFC-	258571.14	3824049	-17648.12	9896981	167552454	41734.44095	120572
Smog Potential (kg NOx eq / kg)	259952.74	37554027	-17634.87	17301216	7589458	41953.78588	1212897

However, all output values for beams and columns appear as negative numbers, which indicates that an error is occurring somewhere in the software. This seems unusual since all other aspects of the model appear to be functioning properly and producing seemingly reasonable impact estimations. Because of this abnormality, comparisons by assembly type were not explored more thoroughly.

4.3 Impact Assessment Uncertainties

In addition to uncertainties resulting from the assumptions made while conducting this study, uncertainty is further generated during the stage of impact assessment in a variety of ways. This next section outlines some of the uncertainty generated in the process of determining impacts from values inputted into the IE.

Impact assessment software aims to be as comprehensive and sophisticated as possible but is limited by the amount that can be packed into a program and the memory storage capacity of a computer. Impact assessment experiences tension in two opposing directions since it attempts to simultaneously be sophisticated while being accessible to the average person and therefore the average PC. This broader limitation results in three key areas of uncertainty being generated.

The first, as touched on previously in this document, is related to spatial linking. Not only does the database of supporting information need to exist, but a program capable of compiling such information through a geographical information system would be required to assess the related impacts of a specific material source located 20km away over a windy mountain road as compared to a similar facility 100km away across rolling plains. While impact estimators such as IE do take location into account, the true modeling potential that could be realized with more advanced software and processing capacity is not achieved.

There is also issue of modeling techniques, which are also limited by the processing capacity of the average PC. Ideally, the most advanced modeling techniques would be used for each impact category, but the depth of each technique varies depending on the history of research in each respective field. One example of advanced modeling that the average computer may not be capable of is related to toxicology. While it may be relatively easy to quantify toxicity released from a given process, further translating that into health impacts and contamination potential is dependent upon determining the probability of toxicity migration through available pathways. This step, from outputs to impacts, is much more difficult to make and consequently outputs are commonly deemed sufficient impact estimation results. However, this means that, even though quantities of a contaminant released may be known, there remains a great deal of uncertainty as to how this will impact either human or environmental health without pathway modeling.

The final limitation of software is related to actually modeling uncertainty itself using such techniques as the Monte Carlo simulation. As has been pointed out previously, certain aspects of an LCA make even uncertainty difficult to quantify, but in order to maintain transparency, both uncertainty and a sensitivity analysis should be modeled. If two products were being compared for environmental impact and ranked similarly but the uncertainty of each study could be modeled with reasonable accuracy, this would provide valuable insights for decision makers choosing between the two. However, due to both available data and PC processing capacity, advanced modeling techniques in this field are not currently feasible.

It should also be noted that the background research in each impact category is not consistent across all fields. Certain areas such as toxicology have much more supporting research than resource usage, which is still emerging. Because of this, it should be recognized that the modeling that impact assessment software uses could be based on new or uncertain research that may prove to be flawed in the future as more is learned in that field. For example, current indicators for resource usage may prove to be incorrect in coming years, which would cause impacts estimated from previous LCA's to be incorrect as well. This type of uncertainty, uncertainty in the very science impact estimation is base on, is difficult to quantify.

Typically, uncertainty tends to propagate as impacts become more specific. The terminology used to address this is commonly midpoint versus endpoint selection. For example, ozone depletion potential is relatively easy to quantify provided that data on such chemical omissions is correct. This would be considered a midpoint case with the endpoint being the true impact on human health such as potential for skin cancer. Since the science correlating to the latter point is less certain, most impact estimators assess impacts based on midpoint criteria. The true effects on human or environmental health remain somewhat uncertain.

Finally, the weighting of different impact categories will have an overall effect on the final impact assigned during an assessment. After data is normalized and characterized it is typically grouped into high, medium, and low impact categories and then sometimes aggregated in order to produce a single impact index value. Either a panel of experts of through stakeholder input typically determines weighting of priorities. Regardless, of the method, a high degree of subjectivity is involved at this stage and if the incorrect impact categories are selected as low impact the true validity of the entire study may be thrown into question. Uncertainty could be reduced if anthropocentric prioritization was omitted but, since use of the study will likely rest upon decision makers at some point, this omission may achieve little in the overall reduction of uncertainty.

5.0 Sensitivity Analysis

A sensitivity analysis was conducted on five of the most commonly used materials in the structure in order to estimate the overall sensitivity of the model to errors from assumptions. Conversely, sensitivity can be used to optimize design in order to minimize environmental impacts most effectively. A sensitivity analysis can clearly indicate how significantly different assemblies affect different impacts. For example, if it is found that ozone depletion potential is very sensitive to the use of polyisocyanurate insulation, this may guide a decision to use less of this kind of insulation, resulting in a significant decrease in ozone depletion potential.

To conduct the sensitivity analysis 10% material was added as extra basic material and impact summary measures were generated using the IE in separate models. Changes were then plotted as percent differences to show sensitivity. The x-axis represents the percent change in material and the y-values represent the corresponding percent change in impact values for each impact category. The most sensitive impacts can be identified as the ones having the steepest slopes.

Table 5-1 – Materials Added for Sensitivity Analysis

Material	**Quantity**	**Addition (+10%)**	**Units**
5/8" Fire-Rated Type X Gypsum Board	22304.1	2230.41	m^2
Batt. Fiberglass	46579.1	4657.91	m^2 (25mm)
Concrete 30 MPa (flyash av)	3354664	335466.4	m^3
Rebar, Rod, Light Sections	1152869	115287	tonnes
Standard Glazing	15606.3	1560.63	m^2

5.1 Gypsum Board Sensitivity

Using the method described above, gypsum sensitivity was analyzed, yielding the following results.

Table 5-2 – Gypsum Board Sensitivity Results

		Overall Impacts		
Impact Category	**Units**	**Initial**	**+ 10% Material**	**% Difference**
Primary Energy Consumption	MJ	142,760,000.00	142,300,000.00	-0.32
Weighted Resource Use	kg	88,460,000.00	88,553,000.00	0.11
Global Warming Potential	(kg CO2 eq / kg)	11,535,160.00	11,529,000.00	-0.05
Acidification Potential	(moles of H+ eq / kg)	4,004,100.00	4,012,000.00	0.20
HH Respiratory Effects Potential	(kg PM2.5 eq / kg)	39,120.14	39,218.00	0.25
Eutrophication Potential	(kg N eq / kg)	295.12	295.10	-0.01
Ozone Depletion Potential	(kg CFC-11 eq / kg)	0.02	0.02	0.00
Smog Potential	(kg NOx eq / kg)	62,476.40	62,530.00	0.09

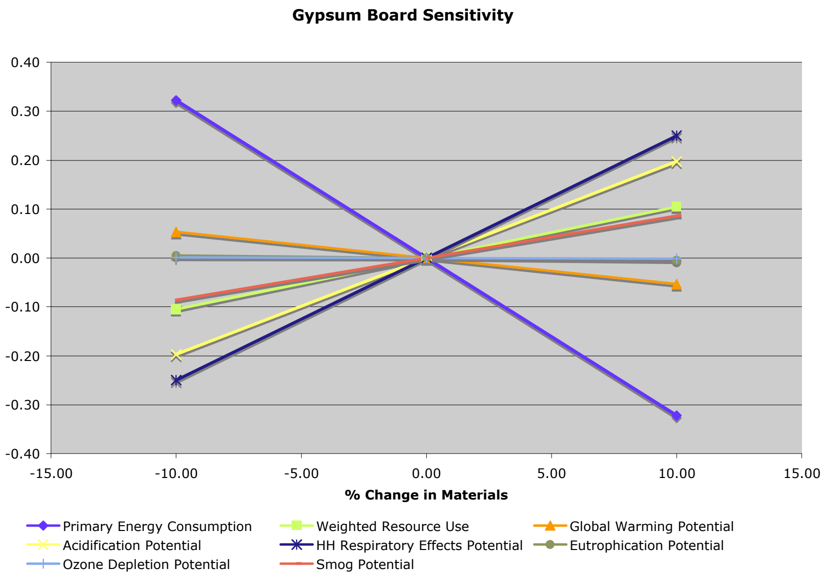

Figure 5-1 - Gypsum Board Sensitivity

The results are both interesting and unexpected since the magnitude of impacts should only increase as the amount of materials used increases. However, it should be recognized that the percent changes in impacts are very small – all less than 1%. Therefore it can likely be concluded that impacts are not very sensitive to the amount of gypsum used and the negative slopes are possibly the result of internal rounding errors within the IE software.

5.2 Fiberglass Sensitivity

The following results were found after running a sensitivity analysis on the material.

Table 5-3 – Fiberglass Sensitivity Results

		Overall Impacts		
Impact Category	**Units**	**Initial**	**+ 10% Material**	**% Difference**
Primary Energy Consumption	MJ	142,760,000.00	142,300,000.00	-0.32
Weighted Resource Use	kg	88,460,000.00	88,553,000.00	0.11
Global Warming Potential	(kg CO2 eq / kg)	11,535,160.00	11,529,000.00	-0.05
Acidification Potential	(moles of H+ eq / kg)	4,004,100.00	4,012,000.00	0.20
HH Respiratory Effects Potential	(kg PM2.5 eq / kg)	39,120.14	39,218.00	0.25
Eutrophication Potential	(kg N eq / kg)	295.12	304.00	3.01
Ozone Depletion Potential	(kg CFC-11 eq / kg)	0.02	16.90	89,308.85
Smog Potential	(kg NOx eq / kg)	62,476.40	62,530.00	0.09

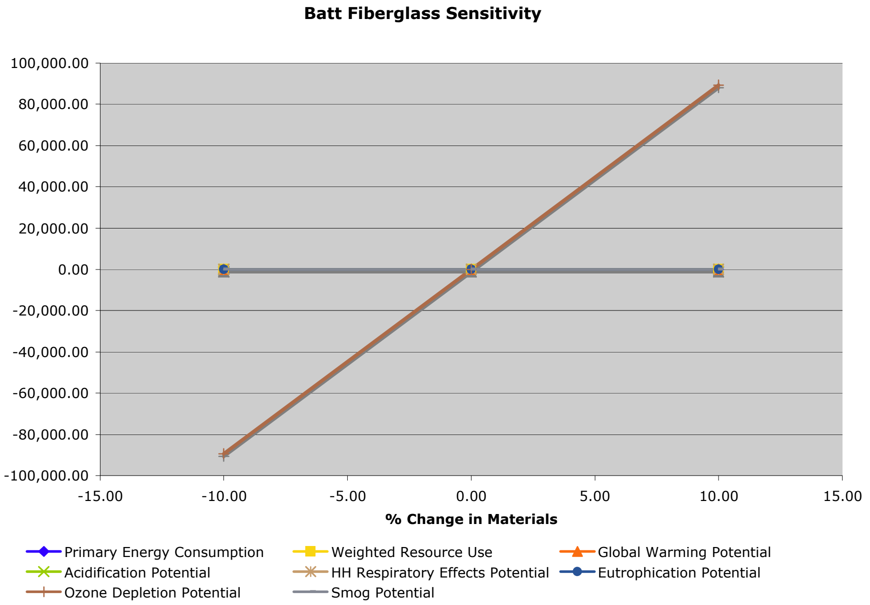

Figure 5-2 - Batt Fiberglass Sensitivity

All impacts appear to be fairly unaffected by changes in batt fiberglass insulation volumes with the exception of ozone depletion potential. At an incredible change in impact magnitude of almost 90,000 %, the value seems erroneous. However, the input was checked repeatedly; if an error is occurring it is within the IE estimator in the category.

In the event that this output is in fact correct then it is clear that the volume of fiberglass batt insulation in a structure dramatically affects the ozone depletion potential, perhaps more so than any other material. Changes in other impacts appear to be almost negligible in comparison.

5.3 Concrete Sensitivity

Concrete sensitivity was analyzed and found to yield the following results.

Table 5-4– Concrete Sensitivity Results

		Overall Impacts		
Impact Category	**Units**	**Initial**	**+ 10% Material**	**% Difference**
Primary Energy Consumption	MJ	142,760,000.00	778,800,000.00	445.53
Weighted Resource Use	kg	88,460,000.00	1,031,810,000.00	1,066.41
Global Warming Potential	(kg CO2 eq / kg)	11,535,160.00	106,519,000.00	823.43
Acidification Potential	(moles of H+ eq / kg)	4,004,100.00	36,420,000.00	809.57
HH Respiratory Effects Potential	(kg PM2.5 eq / kg)	39,120.14	262,252.00	570.38
Eutrophication Potential	(kg N eq / kg)	295.12	345.32	17.01
Ozone Depletion Potential	(kg CFC-11 eq / kg)	0.02	0.22	1,058.64
Smog Potential	(kg NOx eq / kg)	62,476.40	555,360.00	788.91

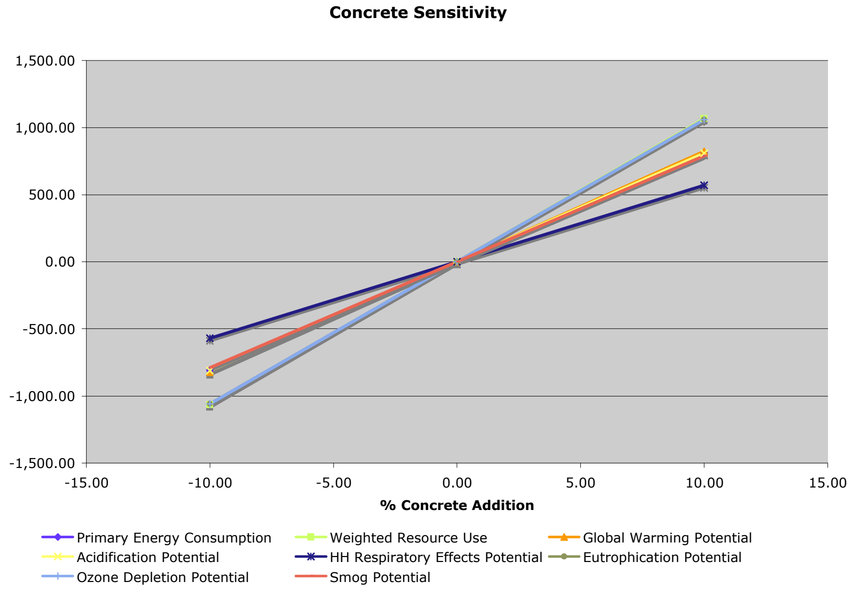

Figure 5-3 - Concrete Sensitivity

From the above graph and table values, it is clear that concrete has a significant impact on all impacts; a rather small difference in concrete added results in higher all around impacts. This suggests that potentially invalid assumptions made as a result of the rigidity of the input fields for assemblies such as concrete beams and columns could be a serious challenge in accurately assessing a building's impacts. Conversely, this data highlights how smart design resulting in either reduced concrete volumes or more environmentally forms of concrete can significantly reduce the environmental impacts associated with a project.

5.4Rebar, Rod, and Light Sections Sensitivity

An analysis of the sensitivity of rebar, rod, and light sections yielded the following results.

Table 5-5 – Rebar, Rod, and Light Sections Sensitivity Results

		Overall Impacts		
Impact Category	**Units**	**Initial**	**+ 10% Material**	**% Difference**
Primary Energy Consumption	MJ	142,760,000.00	2,373,000,000.00	1,562.23
Weighted Resource Use	kg	88,460,000.00	296,290,000.00	234.94
Global Warming Potential	(kg CO2 eq / kg)	11,535,160.00	80,207,000.00	595.33
Acidification Potential	(moles of H+ eq / kg)	4,004,100.00	5,151,000.00	28.64
HH Respiratory Effects Potential	(kg PM2.5 eq / kg)	39,120.14	127,324.00	225.47
Eutrophication Potential	(kg N eq / kg)	295.12	20,600.78	6,880.58
Ozone Depletion Potential	(kg CFC-11 eq / kg)	0.02	0.02	0.59
Smog Potential	(kg NOx eq / kg)	62,476.40	10,490.00	-83.21

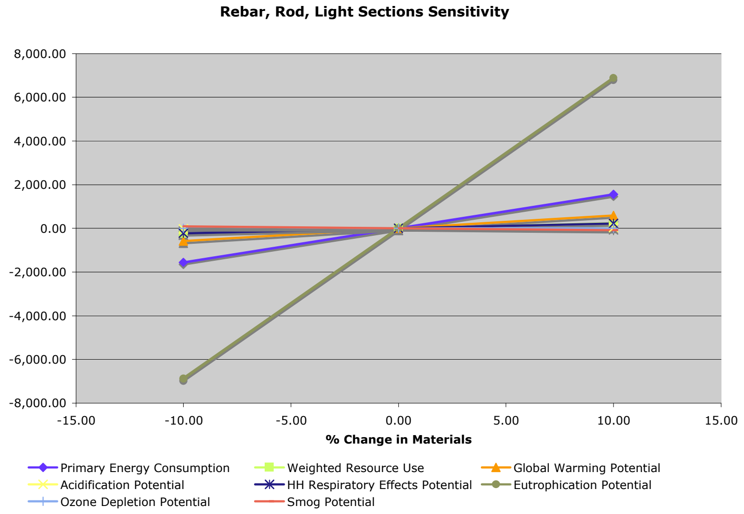

Figure 5-4 – Rebar, Rod, and Light Sections Sensitivity

Although eutrophication potential clearly stands out as an impact highly sensitive to changes in rebar, rod, and light section material volumes, the magnitude of other changes should also be noted. For example, the change in global warming potential, 595%, is nothing to be overlooked. There is also the unusual negative slope of change in smog potential, which seems highly counterintuitive and may suggest that certain bugs embedded in the program are affecting output values.

It appears that reductions in rebar, rod, and light section usage in buildings also have high potential for reducing overall building impacts.

5.5 Glazing Sensitivity

The final assembly analyzed for sensitivity was glazing, yielding the following results.

Table 5-6 - Glazing Sensitivity Results

		Overall Impacts		
Impact Category	**Units**	**Initial**	**+ 10% Material**	**% Difference**
Primary Energy Consumption	MJ	142,760,000.00	142,300,000.00	-0.32
Weighted Resource Use	kg	88,460,000.00	88,553,000.00	0.11
Global Warming Potential	(kg CO2 eq / kg)	11,535,160.00	11,529,000.00	-0.05
Acidification Potential	(moles of H+ eq / kg)	4,004,100.00	4,032,000.00	0.70
HH Respiratory Effects Potential	(kg PM2.5 eq / kg)	39,120.14	39,718.00	1.53
Eutrophication Potential	(kg N eq / kg)	295.12	295.10	-0.01
Ozone Depletion Potential	(kg CFC-11 eq / kg)	0.02	0.02	0.00
Smog Potential	(kg NOx eq / kg)	62,476.40	62,730.00	0.41

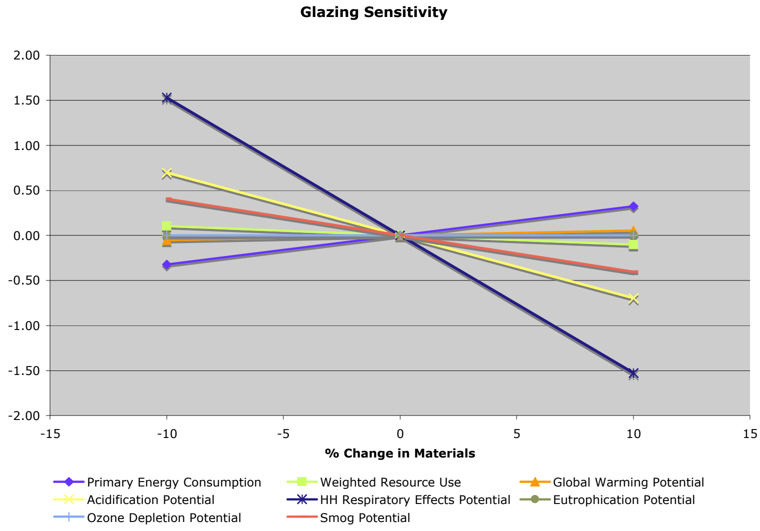

Figure 5-5 – Glazing Sensitivity

Similarly to the gypsum board sensitivity analysis, glazing sensitivity shows a range of different slopes that are all relatively minor (mostly with changes less than 1%) but some of these are negative. Once again, it is uncertain whether or not this is due to internal rounding within the IE impact generation calculations or if there may be a bug within the software somewhere.

Interestingly, changes in window surface area appear to do little to affect the overall impact of a building. However, it should be noted that the impacts generated are only analyzing the manufacturing and construction phases of life cycles and windows will have a much larger effect on building energy consumption during the operating phase of a building's life as a result of heat loss. The next section of this report will explore building performance as related to heat loss through exterior surfaces and their materials.

6.0 Building Performance

The LCA for Marine Drive Residence does not account for operating life or end of life disposal. However, energy usage during operation is still significant and has not been overlooked. The average estimated energy consumption for Tower 1, which is quite similar to Tower 4, is shown here.

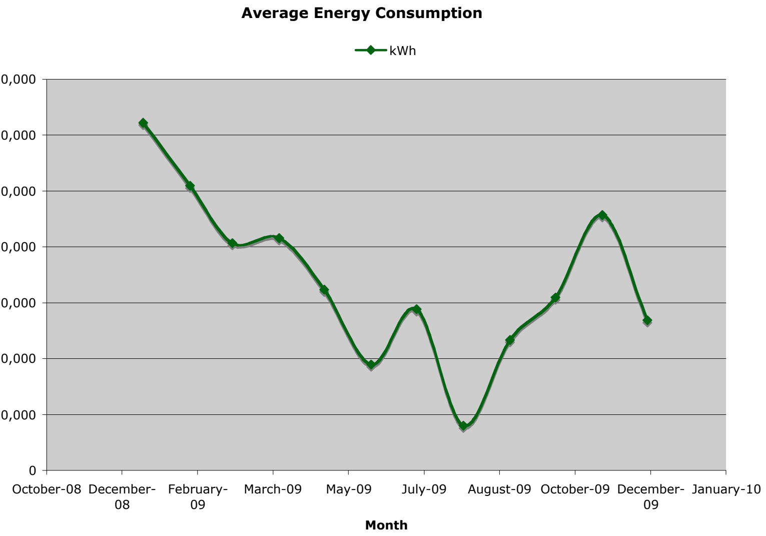

Figure 6-1 – Average Energy Consumption

Building performance for the operating life of Tower 4 is modeled using a heat loss equation and the areas and types of building envelope materials. Because accurate exterior envelope information was only available for Tower 4, results here are not extrapolated to include the entire complex.

In this model, the existing building is compared with another "idealized" building with a few material upgrades that reduce the rate of building heat loss. The idealized building has all of the same material volumes and areas; only the kind of material has been substituted. The two buildings are compared to determine energy savings and the energy payback period of installing upgraded materials.

Heat loss is calculated using the following equation:

$$Q = (1/R) \times A \times \Delta T$$

Where:

R = Calculated R-Value in ft^2 °F h/BTU (Imperial units)

A = Assembly of interest ft^2

ΔT = Inside Temperature – Outside Temperature in °

The following table outlines the R-values used calculating heat losses in both the old and improved buildings:

Table 6-6 – Material R-Values

Material	R-Values
3" Fiberglass Batt Insulation	9.42
4" Polyisocyanurate Insulation	21.6
Low E silver argon filled glazing (3mm glass with 1/2" airspace)	3.75
Standard glazing (double panes, 1/2″ airspace)	2.04

Using values from the table above, the exterior envelope of Tower 4 can be summarized as follows.

Table 7 - Exterior Assembly Areas

	Area (ft^2)	R-value
South Windows	6131	2.04
North Windows	6414	2.04
East Windows	10673	2.04
West Windows	11171	2.04
TOTAL	**34389**	
North Walls	6694	9.42
South Walls	7378	9.42
East Walls	7815	9.42
West Walls	7432	9.42
TOTAL	**29319**	
Roof 1	2278	28.8
Roof 3	2026	28.8
Roof 4	7376	28.8
TOTAL	**11680**	

Two changes have been made to the existing structure to create the 'Improved' building, which was then modeled to determine both embedded energy in material production and heat losses over time. All heating values and surface areas were kept the same but two materials were substituted:

- 3" polyisocyanurate insulation was substituted for fiberglass batt insulation in all exterior walls
- all exterior windows with standard glazing were substituted with low E silver argon filled glazing

The resulting changes in R-values due to these substitutions are summarized in the table below:

Table 8 – Current and Improved R-Values

	R-value: Old Building	**R-Value New Building**
Windows	2.04	3.75
Walls	9.42	21.6

Embedded energy was calculated by creating two new IE models that contained only window and insulation assemblies: one for the current building and one for the improved building. The first table shows how the two insulation types were initially compared to ensure that they used the same waste percent additions and therefore could have their volumes interchanged without adjustments having to be made.

Table 9 – Insulation Wastes

Material	**input amount**	**output amount**	**waste addition**
Batt Fiberglass	100 m^2	105m^2	5%
Polyisocyanurate	100 m^2	105m^2	5%

Then, the energy difference between the two sets of basic materials was calculated and added to the embedded energy in the current building to determine the embedded energy in the improved structure. A summary of these values is presented in the table below.

Table 10 – Embedded Energy

Embedded Energy	**kWh**	**Joules**
Current Basic Materials	1370000	4.932E+12
Improved Basic Materials	1550000	5.58E+12
Current Building	8548250	3.07737E+13
Improved Building	8728250	3.14217E+13

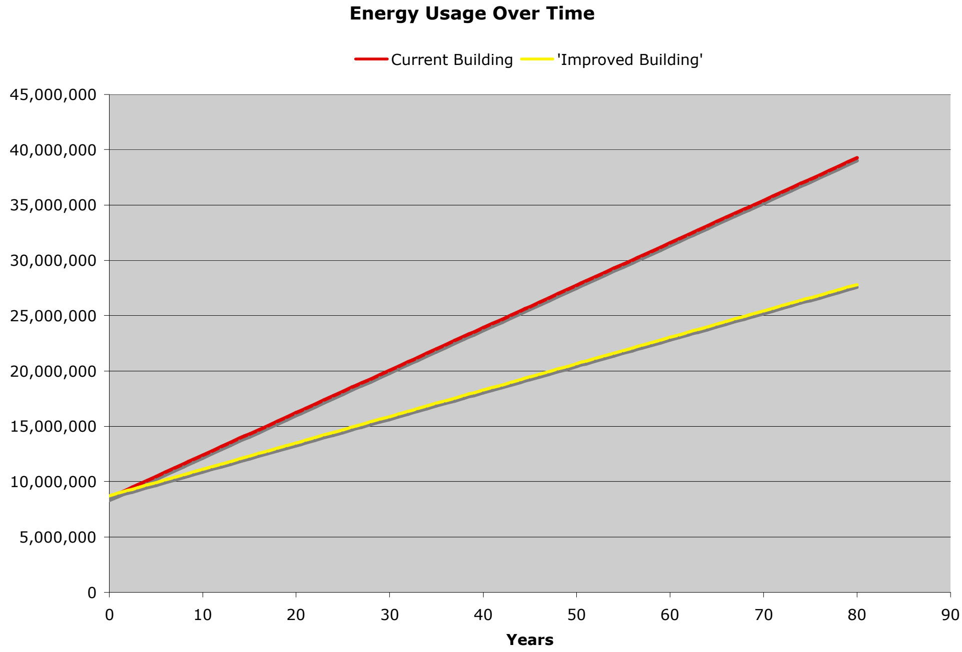

Figure 6-2 – Energy Usage Over Time

From the graph showing cumulative energy usage over time, it is apparent that the energy payback period is almost instantaneous; net energy begins to be saved immediately. However, although this does appear appealing from an energy perspective, this does not account for other factors such as initial cost and overall environmental impacts. Furthermore, even though it is clear that using better exterior envelope materials can save that energy, it would have to be further investigated to figure out whether it is financially, practically, or environmentally beneficial to replace existing materials with improved ones at this point since construction has already been completed.

7.0 Conclusions

There is an appreciable utility in determining average baseline impacts for residences. There is the potential that future decisions on new developments may be able to draw on these results as an environmental reference point. Furthermore, assumptions and methodologies documented in this report may be used to provide insight on how future LCAs might be conducted.

From impact comparisons, the Marine Drive Residence appears to be responsible for significantly larger environmental impacts than any other residence at UBC. This is surprising since, being the newest residence, one would expect it to be the most environmentally friendly since building policies at UBC continue to shift in that direction. Although uncertainty in the model makes it difficult to draw firm conclusions, it appears that concrete high rises with extensive exterior glazing are the worst option from an environmental perspective, regardless of how modern the technologies or designs incorporated are.

Appendix A: EIE Input Tables

All input values are specified for only Tower 4, not the entire complex. Highlighted cells indicate an assumption.

General Description					
	Project Location	Vancouver			
	Building Life Expectancy	1 year			
	Building Type	Residential			
Assembly Group	**Assembly Type**	**Input Fields**	**Ideal Inputs**	**Ideal Building Tota**	**EIE Input**
SLABS	8" 10M reinforced slab				
		Length (ft)	103.6	103.6	103.6
		Width (ft)	103.6	103.6	103.6
		Thickness (inches)	8	8	8
		Concrete (psi)	3000	3000	3000
		Concrete flyash %	average	average	average
	8" slab on grade				
		Length (ft)	74.6	74.6	74.6
		Width (ft)	74.6	74.6	74.6
		Thickness (inches)	8	8	8
		Concrete (psi)	3000	3000	3000
		Concrete flyash %	average	average	average
	4" Slab on Grade unreinforced				
	*basement level	Length (ft)	91.6	91.6	91.6
		Width (ft)	91.6	91.6	91.6
		Thickness (inches)	4	4	4
		Concrete (psi)	3000	3000	3000
		Concrete flyash %	average	average	average
FOOTINGS	Footing F1	Length (ft)	7.5	15	30
	* 2 per building	Width (ft)	7.5	7.5	7.5
		Thickness (inches)	26	26	13
		Concrete (psi)	5333	5333	4000
		Concrete flyash %	average	average	average
		Rebar	#6	#6	#6
	Footing F2				
	* 6 per building	Length (ft)	7.5	45	45
		Width (ft)	6	6	6
		Thickness (inches)	18	18	18
		Concrete (psi)	5333	5333	4000
		Concrete flyash %	average	average	average
		Rebar	#5	#5	#5
	Footing F8				
		Length (ft)	5.25	5.25	21
		Width (ft)	14.5	14.5	14.5
		Thickness (inches)	48	48	16
		Concrete (psi)	5333	5333	4000
		Concrete flyash %	average	average	average
		Rebar	#9, #6, #5	#9, #6, #5	#6
	Footing F9				
		Length (ft)	5.5	5.5	5.5
		Width (ft)	3.5	3.5	3.5
		Thickness (inches)	16	16	16
		Concrete (psi)	5333	5333	4000
		Concrete flyash %	average	average	average
		Rebar	#5	#5	#5
	Footing F11				
		Length (ft)	9	9	18
		Width (ft)	7	7	7
		Thickness (inches)	30	30	15
		Concrete (psi)	5333	5333	4000
		Concrete flyash %	average	average	average
		Rebar	#6	#6	#6
	Footing F13				
	* 2 per building	Length (ft)	8	16	32
		Width (ft)	8	8	8
		Thickness (inches)	28	28	14
		Concrete (psi)	5333	5333	4000
		Concrete flyash %	average	average	average
		Rebar	#6	#6	#6
	Footing F14				
	* 2 per building	Length (ft)	13	26	78
		Width (ft)	11	11	11
		Thickness (inches)	42	42	14
		Concrete (psi)	5333	5333	4000
		Concrete flyash %	average	average	average
		Rebar	#7	#7	#6

Footing F15				
	Length (ft)	6.5	6.5	6.5
	Width (ft)	5.5	5.5	5.5
	Thickness (inches)	18	18	18
	Concrete (psi)	5333	5333	4000
	Concrete flyash %	average	average	average
	Rebar	#5	#5	#5
Footing F16				
	Length (ft)	7	7	14
	Width (ft)	8.5	8.5	8.5
	Thickness (inches)	30	30	15
	Concrete (psi)	5333	5333	4000
	Concrete flyash %	average	average	average
	Rebar	#6	#6	#6
Footing F20				
* 9 per building	Length (ft)	5.5	49.5	49.5
	Width (ft)	4.5	4.5	4.5
	Thickness (inches)	16	16	16
	Concrete (psi)	5333	5333	4000
	Concrete flyash %	average	average	average
	Rebar	#5	#5	#5
Footing F21				
	Length (ft)	6.5	6.5	6.5
	Width (ft)	4.5	4.5	4.5
	Thickness (inches)	12	12	12
	Concrete (psi)	5333	5333	4000
	Concrete flyash %	average	average	average
	Rebar	#5	#5	#5
Footing F22				
* 5 per building	Length (ft)	9	45	45
	Width (ft)	4.25	4.25	4.25
	Thickness (inches)	18	18	18
	Concrete (psi)	5333	5333	4000
	Concrete flyash %	average	average	average
	Rebar	#5	#5	#5
Footing F23				
* 4 per building	Length (ft)	7.5	30	60
	Width (ft)	7.5	7.5	7.5
	Thickness (inches)	30	30	15
	Concrete (psi)	5333	5333	4000
	Concrete flyash %	average	average	average
	Rebar	#7	#7	#6
Footing F24				
	Length (ft)	15	15	30
	Width (ft)	10	10	10
	Thickness (inches)	36	36	18
	Concrete (psi)	5333	5333	4000
	Concrete flyash %	average	average	average
	Rebar	#7	#7	#6
Footing F25				
	Length (ft)	8.5	8.5	17
	Width (ft)	8	8	8
	Thickness (inches)	30	30	15
	Concrete (psi)	5333	5333	4000
	Concrete flyash %	average	average	average
	Rebar	#6	#6	#6
Footing SF1				
* 11 per building	Length (ft)	9	99	99
	Width (ft)	1.5	1.5	1.5
	Thickness (inches)	10	10	10
	Concrete (psi)	5333	5333	4000
	Concrete flyash %	average	average	average
	Rebar	#5	#5	#5
Footing SF2				
* 7 per building	Length (ft)	8	56	56
	Width (ft)	3.5	3.5	3.5
	Thickness (inches)	12	12	12
	Concrete (psi)	5333	5333	4000
	Concrete flyash %	average	average	average
	Rebar	#5	#5	#5
Footing SF3				
* 5 per building	Length (ft)	7	35	35
	Width (ft)	5.25	5.25	5.25
	Thickness (inches)	18	18	18
	Concrete (psi)	5333	5333	4000
	Concrete flyash %	average	average	average
	Rebar	#5	#5	#5

	Footing SF4				
		Length (ft)	15	15	15
		Width (ft)	2.5	2.5	2.5
		Thickness (inches)	10	10	10
		Concrete (psi)	5333	5333	4000
		Concrete flyash %	average	average	average
		Rebar	#5	#5	#5
	Footing SF5				
	* 3 per building	Length (ft)	19	57	114
		Width (ft)	9	9	9
		Thickness (inches)	36	36	18
		Concrete (psi)	5333	5333	4000
		Concrete flyash %	average	average	average
		Rebar	#7	#7	#6
	Footing SF6				
	* 3 per building	Length (ft)	24	72	72
		Width (ft)	4	4	4
		Thickness (inches)	18	18	18
		Concrete (psi)	5333	5333	4000
		Concrete flyash %	average	average	average
		Rebar	#6	#6	#6
	Core Footing				
		Length (ft)	44	44	176
	*assumed to only exist in the tower	Width (ft)	44	44	44
	(3 in total complex)	Thickness (inches)	60	60	15
		Concrete (psi)	5333	5333	4000
		Concrete flyash %	average	average	average
		Rebar	#5	#5	#5
	18" footing w/ 20M				
	* 2 per building	Length (ft)	24	48	48
		Width (ft)	4	8	8
		Thickness (inches)	18	18	18
		Concrete (psi)	5333	5333	4000
		Concrete flyash %	average	average	average
		Rebar	#6	#6	#6
STAIRS	Stairs				
		Length (ft)	14	69.0	69
		Width (ft)	4	19.7	19.7
		Thickness (inches)	8	8	8
		Concrete (psi)	3500	3500	4000
		Concrete flyash %	average	average	average
		Rebar	#5	#5	#5
	Stairs Floors 3-5				
		Length (ft)	14	117.6	117.6
		Width (ft)	4	11.2	11.2
		Thickness (inches)	8	8	8
		Concrete (psi)	3500	3500	4000
		Concrete flyash %	average	average	average
		Rebar	#5	#5	#5
	Stairs floors 8-17				
		Length (ft)	14	24.4	244
		Width (ft)	4	7.0	7
		Thickness (inches)	8	8	8
		Concrete (psi)	3500	3500	4000
		Concrete flyash %	average	average	average
		Rebar	#5	#5	#5
	Stairs 18+				
		Length (ft)	14	33.9	33.9
		Width (ft)	4	9.7	9.7
		Thickness (inches)	8	8	8
		Concrete (psi)	3500	3500	4000
		Concrete flyash %	average	average	average
		Rebar	#5	#5	#5

General Description				
	Project Location	Vancouver		Complex Multiplier
	Building Life Expectancy	1 year		Complex Multiplier
	Building Type	Residential		

Assembly Group	Assembly Type	Input Fields	Ideal Inputs	Building Total	EIE Input
WALLS	concrete walls floors 8-17				
Concrete Cast In Place		Length (ft)	224	2240	2240
		Height (ft)	9	9	9
		Thickness (inches)	8	8	8
		Concrete (Mpa)	4000	4000	4000
		Concrete Flyash %	average	average	average
		Reinforcement	#5	#5	#5
	concrete walls 18+				
		Length (ft)	596	596	596
		Height (ft)	9	9	9
		Thickness (inches)	8	8	8
		Concrete (Mpa)	4000	4000	4000
		Concrete Flyash %	average	average	average
		Reinforcement	#5	#5	#5
	thick wall				
		Length (ft)	363	363	363
		Height (ft)	9	9	9
		Thickness (inches)	16	16	12
		Concrete (Mpa)	4000	4000	4000
		Concrete Flyash %	average	average	average
		Reinforcement	#5	#5	#5
		Door Type	-	-	Steel Interior Door
		Number of Doors	25	25	25
	thick walls floors 3-5				
		Length (ft)	94	282	282
		Height (ft)	9	9	9
		Thickness (inches)	16	16	12
		Concrete (Mpa)	4000	4000	4000
		Concrete Flyash %	average	average	average
		Reinforcement	#5	#5	#5
		Door Type	-	-	Steel Interior Door
		Number of Doors	8	24	24
	thick walls floors 8-17				
		Length (ft)	97	970	970
		Height (ft)	9	9	9
		Thickness (inches)	16	16	12
		Concrete (Mpa)	4000	4000	4000
		Concrete Flyash %	average	average	average
		Reinforcement	#5	#5	#5
		Door Type	-	-	Steel Interior Door
		Number of Doors	5	50	50
	thick walls 18+				
		Length (ft)	139	139	139
		Height (ft)	9	9	9
		Thickness (inches)	16	16	12
		Concrete (Mpa)	4000	4000	4000
		Concrete Flyash %	average	average	average
		Reinforcement	#5	#5	#5
		Door Type	-	-	Steel Interior Door
		Number of Doors	4	4	4
	Concrete Wall floors 3-5				
		Length (ft)	459	1377	1377
		Height (ft)	9	9	9
		Thickness (inches)	8	8	8
		Concrete (Mpa)	4000	4000	4000
		Concrete Flyash %	average	average	average
		Reinforcement	#5	#5	#5
	Concrete Wall				
		Length (ft)	2580	2580	2580
		Height (ft)	9	9	9
		Thickness (inches)	8	8	8
		Concrete (Mpa)	4000	4000	4000
		Concrete Flyash %	average	average	average
		Reinforcement	#5	#5	#5
	Concrete block wall				
		Envelope	crete Brick Cladding	rete Brick Cladding	crete Brick Cladding
		Length (ft)	1269	1269	1269
		Height (ft)	9	9	9
		Rebar (m)	#7	#7	**#5**

Steel Stud	Metal Stud Wall				
		Wall Type	Exterior	Exterior	Exterior
		Length (ft)	1027	1027	1027
		Height (ft)	9	9	9
		Door Type	wooden door	wooden door	wooden door
		Number of Doors	6	6	38
		Total opening area (ft ^{2})	6688	6688	42335.0
		Number of window units	716	716	4532
		Frame Type	-	-	Aluminum Frame
		Glazing Type	-	-	Standard Glazing
		Sheathing type	none	none	none
		Stud thickness	1 5/8 x 3 5/8	1 5/8 x 3 5/8	1 5/8 x 3 5/8
		Stud spacing	16 o.c.	16 o.c.	16 o.c.
		Stud weight	-	-	Light (25 Ga)
		Category	Insulation	Insulation	insulation
		Material	-	-	fiberglass
		Type	batt	batt	batt
		Thickness (inches)	3	3	3
	Metal Stud wall 3-5				
		Wall Type	Exterior	Exterior	Exterior
		Length (ft)	379	1137	1137
		Height (ft)	9	9	9
		Total opening area (ft ^{2})	2888	8664	8664
		Number of window units	288	864	864
		Frame Type	-	-	Aluminum Frame
		Glazing Type	-	-	Standard Glazing
		Sheathing type	none	none	none
		Stud thickness	1 5/8 x 3 5/8	1 5/8 x 3 5/8	1 5/8 x 3 5/8
		Stud spacing	16 o.c.	16 o.c.	16 o.c.
		Stud weight	-	-	Light (25 Ga)
		Category	Insulation	Insulation	insulation
		Material	-	-	fiberglass
		Type	batt	batt	batt
		Thickness (inches)	3	3	3
	Metal Stud Wall 8- 17				
		Wall Type	Exterior	Exterior	Exterior
		Length (ft)	226	2260	2260
		Height (ft)	9	9	9
		Total opening area (ft ^{2})	1641	16410	16410
		Number of window units	168	1680	1680
		Frame Type	-	-	Aluminum Frame
		Glazing Type	-	-	Standard Glazing
		Sheathing type	none	none	none
		Stud thickness	1 5/8 x 3 5/8	1 5/8 x 3 5/8	1 5/8 x 3 5/8
		Stud spacing	16 o.c.	16 o.c.	16 o.c.
		Stud weight	-	-	Light (25 Ga)
		Category	Insulation	Insulation	insulation
		Material	-	-	fiberglass
		Type	batt	batt	batt
		Thickness (inches)	3	3	3
	Metal Stud Wall lv 18				
		Wall Type	Exterior	Exterior	Exterior
		Length (ft)	238	238	238
		Height (ft)	9	9	9
		Total opening area (ft ^{2})	1503	1503	4509
		Frame Type	-	-	Aluminum Frame
		Glazing Type	-	-	Standard Glazing
		Number of window units	174	174	174
		Sheathing type	none	none	none
		Stud thickness	1 5/8 x 3 5/8	1 5/8 x 3 5/8	1 5/8 x 3 5/8
		Stud spacing	16 o.c.	16 o.c.	16 o.c.
		Stud weight	-	-	Light (25 Ga)
		Category	Insulation	Insulation	insulation
		Material	-	-	fiberglass
		Type	batt	batt	batt
		Thickness (inches)	3	3	3
Metal Stud - interior	Drywall Partition				
		Wall Type	interior - steel stud	interior - steel stud	interior - steel stud
		Length (ft)	2832	2832	2832
		Height (ft)	9	9	9
		Door Type	Core Wood Interior	Core Wood Interior	Core Wood Interior
		Number of Doors	165	165	165
		Sheathing type	none	none	none
		Stud thickness	1 5/8 x 3 5/8	1 5/8 x 3 5/8	1 5/8 x 3 5/8
		Stud spacing	-	-	24 o.c.
		Stud weight	-	-	Light (25 Ga)
		Category	Gypsum Board	Gypsum Board	Gypsum Board
		Material	Gypsum Type X 5/8"	Gypsum Type X 5/8"	Gypsum Type X 5/8"
		Category	Insulation	Insulation	insulation
		Material	-	-	fiberglass
		Type	batt	batt	batt
		Thickness (inches)	3	3	3

	Drywall Partition 3-5				
		Wall Type	interior - steel stud	interior - steel stud	interior - steel stud
		Length (ft)	1143	3429	3429
		Height (ft)	9	9	9
		Door Type	Core Wood Interior	ore Wood Interior	Hollow Core Wood Interior
		Number of Doors	69	207	207
		Sheathing type	none	none	none
		Stud thickness	1 5/8 x 3 5/8	1 5/8 x 3 5/8	1 5/8 x 3 5/8
		Stud spacing	-	-	24 o.c.
		Stud weight	-	-	Light (25 Ga)
		Category	Gypsum Board	Gypsum Board	Gypsum Board
		Material	Gypsum Type X 5/8"	Gypsum Type X 5/8"	Gypsum Type X 5/8"
		Category	Insulation	Insulation	insulation
		Material	-	-	fiberglass
		Type	batt	batt	batt
		Thickness (inches)	3	3	3
	Drywall Partition 8-17	Wall Type	interior - steel stud	interior - steel stud	interior - steel stud
		Length (ft)	556	1668	1668
		Height (ft)	9	9	9
		Door Type	Core Wood Interior	ore Wood Interior	Hollow Core Wood Interior
		Number of Doors	36	108	108
		Sheathing type	none	none	none
		Stud thickness	1 5/8 x 3 5/8	1 5/8 x 3 5/8	1 5/8 x 3 5/8
		Stud spacing	-	-	24 o.c.
		Stud weight	-	-	Light (25 Ga)
		Category	Gypsum Board	Gypsum Board	Gypsum Board
		Material	Gypsum Type X 5/8"	Gypsum Type X 5/8"	Gypsum Type X 5/8"
		Category	Insulation	Insulation	insulation
		Material	-	-	fiberglass
		Type	batt	batt	batt
		Thickness (inches)	3	3	3
	Drywal partition lv 18				
		Wall Type	interior - steel stud	interior - steel stud	interior - steel stud
		Length (ft)	304	304	304
		Height (ft)	9	9	9
		Door Type	Core Wood Interior	ore Wood Interior	Hollow Core Wood Interior
		Number of Doors	30	30	30
		Sheathing type	none	none	none
		Stud thickness	1 5/8 x 3 5/8	1 5/8 x 3 5/8	1 5/8 x 3 5/8
		Stud spacing	-	-	24 o.c.
		Stud weight	-	-	Light (25 Ga)
		Category	Gypsum Board	Gypsum Board	Gypsum Board
		Material	Gypsum Type X 5/8"	Gypsum Type X 5/8"	Gypsum Type X 5/8"
		Category	Insulation	Insulation	Insulation
		Material	-	-	fiberglass
		Type	batt	batt	batt
		Thickness (inches)	-	-	3
	Double Stud Drywall				
		Wall Type	interior - steel stud	interior - steel stud	interior - steel stud
		Length (ft)	2220	2220	2220
		Height (ft)	9	9	9
		Door Type	Core Wood Interior	ore Wood Interior	Hollow Core Wood Interior
		Stud thickness	1 5/8 x 3 5/8	1 5/8 x 3 5/8	1 5/8 x 3 5/8
		Stud spacing	-	-	24 o.c.
		Stud weight	-	-	Light (25 Ga)
		Category	Gypsum Board	Gypsum Board	Gypsum Board
		Material	Gypsum Type X 5/8"	Gypsum Type X 5/8"	Gypsum Type X 5/8"
		Category	Insulation	Insulation	Insulation
		Material	-	-	fiberglass
		Type	batt	batt	batt
		Thickness (inches)	-	-	3
	Double Stud Drywall 3-5				
		Wall Type	interior - steel stud	interior - steel stud	interior - steel stud
		Length (ft)	918	2754	2754
		Height (ft)	9	9	9
		Sheathing type	none	none	none
		Stud thickness	1 5/8 x 3 5/8	1 5/8 x 3 5/8	1 5/8 x 3 5/8
		Stud spacing	-	-	24 o.c.
		Stud weight	-	-	Light (25 Ga)
		Category	Gypsum Board	Gypsum Board	Gypsum Board
		Material	Gypsum Type X 5/8"	Gypsum Type X 5/8"	Gypsum Type X 5/8"
		Category	Insulation	Insulation	insulation
		Material	-	-	fiberglass
		Type	batt	batt	
		Thickness (inches)	-	-	3
	Double Stud Drywall 8-17				
		Wall Type	interior - steel stud	interior - steel stud	interior - steel stud
		Length (ft)	456	4560	4560
		Height (ft)	9	9	9
		Sheathing type	none	none	none
		Stud thickness	1 5/8 x 3 5/8	1 5/8 x 3 5/8	1 5/8 x 3 5/8
		Stud spacing	-	-	24 o.c.
		Stud weight	-	-	Light (25 Ga)
		Category	Gypsum Board	Gypsum Board	Gypsum Board
		Material	Gypsum Type X 5/8"	Gypsum Type X 5/8"	Gypsum Type X 5/8"
		Category	Insulation	Insulation	insulation
		Material	-	-	fiberglass
		Type	batt	batt	batt
		Thickness (inches)	-	-	3
	Double Stud Drywall lvl 18				
		Wall Type	interior - steel stud	interior - steel stud	interior - steel stud
		Length (ft)	366	366	366
		Height (ft)	9	9	9
		Sheathing type	none	none	none
		Stud thickness	1 5/8 x 3 5/8	1 5/8 x 3 5/8	1 5/8 x 3 5/8
		Stud spacing	-	-	24 o.c.
		Stud weight	-	-	Light (25 Ga)
		Category	Gypsum Board	Gypsum Board	Gypsum Board
		Material	Gypsum Type X 5/8"	Gypsum Type X 5/8"	Gypsum Type X 5/8"
		Category	Insulation	Insulation	insulation
		Material	-	-	fiberglass
		Type	batt	batt	batt
		Thickness (inches)	-	-	3
Curtain Wall	Ground Floor Curtain Wall				
		Wall Type	Exterior	Exterior	Exterior
		Length (ft)	125	125	125
		Height (ft)	14.91	14.91	14.91
		Total opening area (ft ^{2})	6405	6405	6405
		Number of window units	138	138	138
		Number of Doors	3	3	3
		Door Type	wooden door	wooden door	wooden door
		Panel Type	metal spandrel panel	etal spandrel panel	metal spandrel panel
		Percent Viewable Glazing	71.5	71.5	71.5
		Percent Spandrel Panel	28.5	28.5	28.5
		Thickness of Insulation (inches)	-	-	3

Assembly Group	Assembly Type	Input Fields	Ideal Inputs	Ideal Building Total	EIE Input
			1		
FLOORS	Concrete Suspended Slab Floor2 Total				
		Floor width (ft)	64	64	272.43
		Span (ft)	127.7	127.7	30
		Live load (kips)	2	2	100 psf
		Type	Floor	Floor	Floor
		Concrete (psi)	3500	3500	4000
		Concrete Flyash %	Average	Average	Average
		Envelope	none	none	none
	Concrete Suspended Slab Floor3-5				
		Floor width (ft)	78.6	235.8	235.8
		Span (ft)	157.2	471.6	471.6
		Live load (kips)	2	2	100 psf
		Type	Floor	Floor	Floor
		Concrete (psi)	3500	3500	4000
		Concrete Flyash %	Average	Average	Average
		Envelope	none	none	none
	Concrete Suspended Slab Floor6 & 7 Total				
		Floor width (ft)	88	88	88
		Span (ft)	176	176	176
		Live load (kips)	2	2	100 psf
		Type	Floor	Floor	Floor
		Concrete (psi)	3500	3500	4000
		Concrete Flyash %	Average	Average	Average
		Envelope	none	none	none
	Concrete Suspended Slab Floor 8-17				
		Floor width (ft)	55.5	555	555
		Span (ft)	111	1110	1110
		Live load (kips)	2	2	100 psf
		Type	Floor	Floor	Floor
		Concrete (psi)	3500	3500	4000
		Concrete Flyash %	Average	Average	Average
		Envelope	none	none	none
	Concrete Suspended Slab Floor18+				
		Floor width (ft)	72.8	72.8	72.8
		Span (ft)	145.5	145.5	145.5
		Live load (kips)	2	2	100 psf
		Type	Floor	Floor	Floor
		Concrete (psi)	3500	3500	4000
		Concrete Flyash %	Average	Average	Average
		Envelope	none	none	none
ROOFING	R4 Type Roofing				
		Roofing Type	uspended Slab	e Suspended Slab	Suspended Slab
		Floor width (ft)	85.9	85.9	85.9
		Span (ft)	85.9	85.9	85.9
		Live load (kips)	0.3	0.3	0.3
		Concrete (psi)	3500	3500	4000
		Concrete Flyash %	Average	Average	Average
		Envelope	Roof envelope	Roof envelope	Roof envelope
		Material	egate stones)	ggregate stones)	gregate stones)
		Envelope	EPDM Inverted	EPDM Inverted	EPDM Inverted
		Material	Polyisocyanurate	Polyisocyanurate	Polyisocyanurate
		Thickness	4"	4"	4"
	R3 Type Roofing				
		Roofing Type	uspended Slab	e Suspended Slab	Suspended Slab
		Floor width (ft)	21	31.82	31.82
		Span (ft)	48.2	63.63	63.63
		Live load (kips)	0.3	0.3	0.3
		Concrete (psi)	3500	3500	4000
		Concrete Flyash %	Average	Average	Average
		Envelope	Vapour Barrier	Vapour Barrier	Vapour Barrier
		Material	-	-	3mil Poly
		Envelope	EDPM Membrane	EDPM Membrane	EDPM Membrane
		Material	Polyisocyanurate	Polyisocyanurate	Polyisocyanurate
		Thickness	4"	4"	4"
	R1 Type Roofing				
		Roofing Type	uspended Slab	e Suspended Slab	Suspended Slab
		Floor width (ft)	33.7	33.7	33.7
		Span (ft)	67.5	67.5	67.5
		Live load (kips)	0.3	0.3	0.3
		Concrete (psi)	3500	3500	4000
		Concrete Flyash %	Average	Average	Average
		Envelope	Vapour Barrier	Vapour Barrier	Vapour Barrier
		Material	-	-	3mil Poly
		Envelope	Insulation	Insulation	Insulation
		Material	Polyisocyanurate	Polyisocyanurate	Polyisocyanurate
		Thickness	4"	4"	4"
		Envelope	eel Roof System	Steel Roof System	Steel Roof System
		Material	-	-	Commercial
	Trellis Soffit				
		Roof Width (ft)	10	10	10
		Roof Length (ft)	74	74	74
		Decking	none	none	none
		Live load (psf)	-	-	45

Assembly Group	Assembly Type	Input Fields	Ideal Inputs	Building Total	EIE Input
COLUMNS Concrete Beams and Columns	Ground Floor South Podium				
		Number of columns	9	9	9
		Number of beams	8	8	8
		Floor to floor height (ft)	9	9	9
		Bay sizes (ft)	10.97	10.97	10.97
		Supported span	4.87	4.87	4.87
		Live load (kips)	2	2	100 psf
	Ground Floor Tower Center				
		Number of columns	14	14	14
		Number of beams	11	11	11
		Floor to floor height (ft)	9	9	9
		Bay sizes (ft)	10	10	10
		Supported span	3.91	3.91	3.91
		Live load (kips)	2	2	100 psf
	Ground Floor North Podium				
		Number of columns	7	7	7
		Number of beams	8	8	8
		Floor to floor height (ft)	9	9	9
		Bay sizes (ft)	10	10	10
		Supported span	5.21	5.21	5.21
		Live load (kips)	2	2	100 psf
	Floor 2 South Podium				
		Number of columns	9	9	9
		Number of beams	5	5	5
		Floor to floor height (ft)	9	9	9
		Bay sizes (ft)	10	10	10
		Supported span	4.43	4.43	4.43
		Live load (kips)	2	2	100 psf
	Floor 2 Tower Center				
		Number of columns	7	7	7
		Number of beams	5	5	5
		Floor to floor height (ft)	9	9	9
		Bay sizes (ft)	20.94	20.94	20.94
		Supported span	7.48	7.48	7.48
		Live load (kips)	2	2	100 psf
	Floor 2 North Podium				
		Number of columns	10	10	10
		Number of beams	9	9	9
		Floor to floor height (ft)	9	9	9
		Bay sizes (ft)	10	10	10
		Supported span	4.11	4.11	4.11
		Live load (kips)	2	2	100 psf
	Floors 3-5 South Podium				
		Number of columns	9	27	27
		Number of beams	7	21	21
		Floor to floor height (ft)	9	9	9
		Bay sizes (ft)	11.39	11.39	11.39
		Supported span	4.43	4.43	4.43
		Live load (kips)	2	2	100 psf
	Floors 3-5 Tower Center				
		Number of columns	17	51	51
		Number of beams	11	33	33
		Floor to floor height (ft)	9	9	9
		Bay sizes (ft)	10.84	10.84	10.84
		Supported span	3.51	3.51	3.51
		Live load (kips)	2	2	100 psf
	Floors 3-5 North Podium				
		Number of columns	6	18	18
		Number of beams	6	18	18
		Floor to floor height (ft)	9	9	9
		Bay sizes (ft)	12.11	12.11	12.11
		Supported span	6.05	6.05	6.05
		Live load (kips)	2	2	100 psf
	Floor 6 South Podium				
		Number of columns	13	13	13
		Number of beams	5	5	5
		Floor to floor height (ft)	9	9	9
		Bay sizes (ft)	11.46	11.46	11.46
		Supported span	4.46	4.46	4.46
		Live load (kips)	2	2	100 psf

Floor 6 Tower Center				
	Number of columns	15	15	15
	Number of beams	9	9	9
	Floor to floor height (ft)	9	9	9
	Bay sizes (ft)	12.69	12.69	12.69
	Supported span	3.81	3.81	3.81
	Live load (kips)	2	2	100 psf
Floor 6 North Podium				
	Number of columns	5	5	5
	Number of beams	7	7	7
	Floor to floor height (ft)	9	9	9
	Bay sizes (ft)	10	10	10
	Supported span	6.63	6.63	6.63
	Live load (kips)	2	2	100 psf
Floors 7 South Podium				
	Number of columns	10	9	9
	Number of beams	10	8	8
	Floor to floor height (ft)	9	9	9
	Bay sizes (ft)	11.63	10.97	10.97
	Supported span	3.5	4.87	4.87
	Live load (kips)	2	2	100 psf
Floors 7 Tower Center				
	Number of columns	17	9	57
	Number of beams	6	5	32
	Floor to floor height (ft)	9	9	9
	Bay sizes (ft)	19.2	17	17
	Supported span	3.39	18	18
	Live load (kips)	2	2	100 psf
Floors 8-17 Tower Center				
	Number of columns	17	170	170
	Number of beams	9	90	90
	Floor to floor height (ft)	9	9	9
	Bay sizes (ft)	12.84	12.84	12.84
	Supported span	3.4	3.4	3.4
	Live load (kips)	2	2	100 psf
Floor 18 Tower Center				
	Number of columns	16	9	57
	Number of beams	8	5	32
	Floor to floor height (ft)	9	9	9
	Bay sizes (ft)	14.06	17	17
	Supported span	3.52	18	18
	Live load (kips)	2	2	100 psf

Assembly Group	Assembly Type	Input Fields	Ideal Inputs 1	Building Total	EIE Input
EXTRA BASIC MATERIALS	5c Gypsum Board				
		1/2" regular gypsum board (ft^2)	570	570	570
		4000 psi Average Flyash Concrete (yrd^3)	194.89	194.89	194.89

Appendix B: Detailed Assumptions

Assembly Group	Assembly Type	Assembly Name	Specific Assumptions
COLUMNS	Due to the rigidity of the impact modeling software and the non-uniformity of the column assembly within the tower, modeling this part of the structure required the largest assumptions and appears to be the greatest source of error within the model. Athena Impact Estimator models column and beam assemblies in a grid format, which assumes that bay areas and spans are uniform. It also places minimum values on bay areas and span lengths and will round up to these minimums if an input value is outside the range. In order to conform to this input format, the number of columns and beams were counted, the supported area was determined, and then transformed mathematically into a rectangular grid where length = 2 x width. Since no drawings detailing beams were available the location of certain beams had to be assumed; beams were only assumed to exist if the length of a span between two columns exceeded 10 ft. Although all beams and columns counted in the quantity takeoffs are represented in the model, the values for supported spans are below the minimum required input value, which means that the software may be rounding up the lengths of beams even if this is not evident in the input fields. If rounding is occurring, span values will be rounded up to approximately 20 ft. This cannot be changed without reducing the value for bay areas, which would result in a value below the valid input range and cause the model to not function. Also, input fields in Athena do not allow for concrete strengths to be specified, only live loads. This may be missing an important component in environmental impacts since the concrete strengths change from 25 MPa to 35 MPa from the top of the structure to the bottom. Since these strengths have a significant affect on greenhouse gas emissions, the assumption that all column strengths are the same may not be valid.		
	Concrete Beams and Columns	Ground Floor South Podium	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(3847/2) / 9 = 4.87 ft 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(3847/2) / 8 = 10.97 ft
		Ground Floor Tower Center	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(6006/2) / 14 = 3.91 ft 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(6006/2) / 11 = 10 ft
		Ground Floor North Podium	The number of columns and supported areas were determined in onscreen, as well as the number of beams, whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(2659/2) / 7 = 5.21 ft 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(2659/2) / 8 = 10 ft
		Floor 2 South Podium	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(3184/2) / 9 = 4.43 ft 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(3184/2) / 5 = 10 ft
		Floor 2 Tower Center	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(5484/2) / 7 = 7.48 ft 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(5484/2) / 5 = 20.94 ft
		Floor 2 North Podium	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(3376/2) / 10 = 4.11 ft 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(3376/2) / 9 = 10 ft
		Floor 3-5 South Podium	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(3179/2) / 9 = 4.43 ft 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(3179/2) / 7 = 11.39 ft Since this represents one of three identical floors, the number of beams and columns were each multiplied by three to get the final input.

Floor 3-5 Tower Center	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(7111/2) / 17 = 3.51 ft 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(7111/2) / 11 = 10.84 ft Since this represents one of three identical floors, the number of beams and columns were each multiplied by three to get the final input
Floor 3-5 North Podium	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(2638/2) / 6 = 6.05 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(2638/2) / 6 = 12.11 ft
Floor 6 South Podium	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(3220/2) / 13 = 4.46 ft 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(3220/2) / 5 = 11.46 ft
Floor 6 Tower Center	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(6525/2) / 15 = 3.81 ft 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(6525/2) / 9 = 12.69 ft
Floor 6 North Podium	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(2201/2) / 5 = 6.63 ft 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(2201/2) / 7 = 10 ft
Floor 7 South Podium	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(3179/2) / 10 = 3.5 ft 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(3179/2) / 10 = 11.63 ft
Floor 7 Tower Center	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(6637/2) / 17 = 3.39 ft 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(6637/2) / 6 = 19.2 ft
Floors 8-17 Tower Center	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(6678/2) / 17 = 3.4 ft 2 x sqrt(area/2) / # of beams = Bay Size 2 x sqrt(6678/2) / 9 = 12.84 ft
Floor 18 Tower Center	The number of columns and supported areas were determined in onscreen, as well as the number of beams whose positions were approximated. The assembly was modeled as a grid with dimensions calculated in the following way to ensure that values were within acceptable ranges for EIE input software (ie bay size > 10ft). sqrt(area/2) / # of columns = Span sqrt(6327/2) / 16 = 3.52

Assembly Group	Assembly Type	Assembly Name	Specific Assumptions
FLOORS	In consistency with other concrete bodies in the structure, since there is no indication of increased fly ash content it was assumed that all concrete contained only average concentrations of flyash. One slight modification was made to the concrete in order to fit EIE input fields: the strength of concrete was adjusted from 3500 to 4000 psi. Although this will likely result in a higher overall global warming potential in the model, the magnitude of this increase is unknown and therefore not adjusted for. Two other general assumptions were also made due to lack of specific information available from the drawings. No floor envelope specifications were provided and since flooring such as carpeting is beyond the scope of this study, floors were assumed to not have envelopes. The other source of uncertainty is related to floor loading specifications, which were indicated in the structural drawings as having a point load of 2 kips. It is unusual to attribute a point load to a floor area, so this was assumed to translate into a uniform area load of 100 psf in order to fit EIE input fields.		
	Concrete Suspended Slab	Concrete Suspended Slab Floor2 Total	
			The slab was area was determined in the takeoffs and then adjusted in size to fit within the parameters of the impact estimation software, which limits the span to no more than 30 ft. Span Length = Area / 30 ft = 8172.9 ft^2 / 30 ft = 272.43 ft
		Concrete Suspended Slab Floor3-5	
			The slab was area was determined in the takeoffs and then adjusted in size to fit within the parameters of the impact estimation software, which limits the span to no more than 30 ft. The area modeled in the takeoff software represents one of three identical floors so the area of one floor has been multiplied by 3 to obtain the final area. Area x 3 = Total Area 37067.8 ft^2 x 3 = 111203.4 Span Length = Total Area / 30 ft = 111203.4 ft^2 / 30 ft
		Concrete Suspended Slab Floor6 & 7 Total	
			The slab was area was determined in the takeoffs and then adjusted in size to fit within the parameters of the impact estimation software, which limits the span to no more than 30 ft. Span Length = Area / 30 ft = 15488.1 ft^2 / 30 ft = 516.27 ft
		Concrete Suspended Slab Floor 8-17 x 10	
			The slab was area was determined in the takeoffs and then adjusted in size to fit within the parameters of the impact estimation software, which limits the span to no more than 30 ft. The area modeled in the takeoff software represents one of ten identical floors so the area of one floor has been multiplied by 10 to obtain the final area. Area x 10 = Total Area 205350 ft^2 x 10 = 616050 ft^2 Span Length = Total Area / 30 ft = 616050 ft^2 / 30 ft
		Concrete Suspended Slab Floor18+	
			The slab was area was determined in the takeoffs and then adjusted in size to fit within the parameters of the impact estimation software, which limits the span to no more than 30 ft. Span Length = Area / 30 ft = 10592.4 ft^2 / 30 ft = 353.08 ft
ROOFING	Similarly to the floors, no unusual concrete flyash concentrations were specified and loading specifications were also given as point loads, specifically as 0.3 kips. In an attempt to be proportionally consistent with other loading assumptions, 0.3 kips was correlated to 45 psf in the EIE software. Also, roof concrete strengths were specified as 3500 psi in structural drawings but had to be rounded up to 4000 to fit EIE input fields, likely resulting a slightly increased global warming potential for the overall model.		
	Concrete Suspended Slab	R4 Type Roofing	
		* approximated to be a square	Roof schedules are well detailed in architectural drawings. Area determined in takeoff software was approximated as a square for EIE input. Sqrt(area) = length sqrt(7378.8 ft^2) = 85.9 ft
		R3 Type Roofing	
		* 2 slabs of this	Roof schedules are well detailed in architectural drawings. The vapour barrier was assumed to be made of 3 mil poly. Area determined in takeoff software was approximated as a rectangle of 2w = l for EIE input. The total area of two identical slabs was found by multiplying the dimensions of one by a factor of 2. area x 2 = total area 1012.2 x2 = 2024.4 ft^2 Sqrt(total area /2) = width sqrt(2024.4 ft^2) = 31.82 ft l = 2 x w = 63.63 ft
		R1 Type Roofing	Roof schedules are well detailed in architectural drawings. The vapour barrier was assumed to be made of 3 mil poly. Area determined in takeoff software was approximated as a square for EIE input. Sqrt(area) = length sqrt(ft2) = 85.9 ft
	Trellis Soffit	Trellis Soffit	The trellis soffit is a decorative structure arching over the tower entrance. It has no decking and carries no load, but a minimum load of 45 psf was specified in order to comply with EIE input fields.

Assembly Group	Assembly Type	Assembly Name	Specific Assumptions
WALLS	Door types specified in the model have been confirmed through drawings and a site visit but the generic terms used in the EIE make it uncertai doors used in the model are an accurate representation of the actual ones. However, it seems likely that this assumption is a minor one since the type of materials has been confirmed and it is only the volume that remains uncertain.		
	Windows were accounted for by counting the number of each type of assembly and then matching them to the areas specified in the window schedule in the architectural drawings. In cases where the window assembly did not match any detailed in the window schedule, an assumption was made based on size and the number of windows and the new assembly was equated to one specified in the window schedule. A complete breakdown of these assumptions and count for the total number of windows can be referenced later in this Appendix. Two more assumptions related to the window assemblies were made when the architect was unable to verify drawing ambiguities. The windows were assumed to be of standard glazing with aluminum frames.		
	There was also limited information about the envelopes of the metal stud walls immediately surrounding the windows. These envelopes were assumed to be the same as the single stud drywall partition envelopes that the metal stud walls join to except with a commercial grade steel exterior cladding. Also, due to a few missing specifics in the architectural drawings, steel studs in drywall partitions were assumed to be light (2 Ga) and acoustic batt insulation was interpreted as fiberglass.		
		concrete walls floors 8-17	This wall represents one of 10 identical floors. Total wall length was multiplied by 10 to account for all repeated wall units. Length * 10 = Input Length 224 ft * 10 = 2240 ft
		thick wall	Wall thicknesses are limited to 8" or 12" in the EIE input fields. To account for the extra concrete in this 16" wall, the missing volume was added to extra basic materials. Length * (4/3 ft - 1 ft) * height = volume added 363 ft * 1/3 ft * 9 ft = 1089 ft^3
		thick walls floors 3-5 * 3 identical floors per building	This wall represents one of 3 identical floors. Total wall length was multiplied by 3 to account for all repeated wall units. Length * 3 = Input Length 224 94ft * 3 = 282 ft Wall thicknesses are limited to 8" or 12" in the EIE input fields. To account for the extra concrete in this 16" wall, the missing volume was added to extra basic materials. Length * (4/3 ft - 1 ft) * height = volume added 282 ft * 1/3 ft * 9 ft = 846 ft^3
		thick walls floors 8-17 * 10 identical floors per tower	This wall represents one of 10 identical floors. Total wall length was multiplied by 10 to account for all repeated wall units. Length * 10 = Input Length 97 * 10 = 970 ft Wall thicknesses are limited to 8" or 12" in the EIE input fields. To account for the extra concrete in this 16" wall, the missing volume was added to extra basic materials. Length * (4/3 ft - 1 ft) * height = volume added 970 ft * 1/3 ft * 9 ft = 2910 ft^3
		thick walls 18+ *floor 18 and roof	Wall thicknesses are limited to 8" or 12" in the EIE input fields. To account for the extra concrete in this 16" wall, the missing volume was added to extra basic materials. Length * (4/3 ft - 1 ft) * height = volume added 139 ft * 1/3 ft * 9 ft = 417 ft^3
		Concrete Wall floors 3-5 * 3 identical floors per building	This wall represents one of 3 identical floors. Total wall length was multiplied by 3 to account for all repeated wall units. Length * 3 = Input Length 459ft * 3 = 1377 ft
		Concrete block wall	Rebar is specified as #7 in drawings but was rounded down to the maximum input value of #5 in the EIE.

	Metal Stud	Double Stud Drywall * the wall is double thickness (ie 2 stu modeled by doubling the length of the *consequently, only one layer of dryw	This wall is twice the thickness of the standard drywall partitions, which has been modeled by doubling the length of the wall determined through takeoffs. Consequently, gypsum board drywall has only been modeled on one side of the wall. Length * 2 = input length 1110 ft * 2 = 2220 ft The thickness of insulation, 3", was assumed to be consistent with that of the single stud drywall partitions.
		Double Stud Drywall 3-5 *3 identical floors per building * the wall is double thickness (ie 2 stu modeled by doubling the length of the	This wall is twice the thickness of the standard drywall partitions, which has been modeled by doubling the length of the wall determined through takeoffs. Consequently, gypsum board drywall has only been modeled on one side of the wall. Length * 2 = input length 459 ft * 2 = 918 ft Since this represents one of three identical floors, this length was multiplied by three to obtain the final input. Input length * 3 = final input 918 ft * 3 = 2754 ft The thickness of insulation, 3", was assumed to be consistent with that of the single stud drywall partitions.
		Double Stud Drywall 8-17 * 10 identical floors per tower * the wall is double thickness (ie 2 stu modeled by doubling the length of the	This wall is twice the thickness of the standard drywall partitions, which has been modeled by doubling the length of the wall determined through takeoffs. Consequently, gypsum board drywall has only been modeled on one side of the wall. Length * 2 = input length 228 ft * 2 = 456 ft Since this represents one of three identical floors, this length was multiplied by three to obtain the final input. Input length * 3 = final input 456 ft * 10 = 4560 ft The thickness of insulation, 3", was assumed to be consistent with that of the single stud drywall partitions.
		Double Stud Drywall lvl 18 * the wall is double thickness (ie 2 stu modeled by doubling the length of the	This wall is twice the thickness of the standard drywall partitions, which has been modeled by doubling the length of the wall determined through takeoffs. Consequently, gypsum board drywall has only been modeled on one side of the wall. Length * 2 = input length 183 ft * 2 = 366 ft Thickness of insulation was assumed to be consistent with that of the single stud drywall partitions.
		Ground Floor Curtain Wall	The thickness of insulation was assumed to be consistent with that of the other metal walls surrounding windows: 3"

Assembly Group	Assembly Type	Assembly Name	Specific Assumptions
SLABS	Concrete flyash content was again assumed to be average and the concrete strength of 5333 psi had to be changed to 4000 psi in order to match available input options for all footings. Again, this rigidity in input format is contributing to inaccuracies in greenhouse gas emissions estimated by the model. In some cases, the size of rebar also had to be changed to match available input fields. There is no input category in the EIE that represents stairs. Stairs were modeled as footings in order to have more control over concrete volumes and reinforcement dimensions in the model.		
	Slab On Grade	8" 10M reinforced slab	Since there are no rebar inputs in the modeling software, it was assumed that all concrete slabs on grade contain minimum reinforcement in the form of #10M bars. Modeled as a square area. Sqrt (area) = length = width sqrt(10733 ft^{2}) = 103.6 ft
		8" slab on grade	Modeled as a square area. Sqrt (area) = length = width sqrt(5565 ft^{2}) = 74.6 ft
		4" Slab on Grade unreinforced	Modeled as a square area. Sqrt (area) = length = width sqrt(8391 ft2) = 91.6 ft
FOOTINGS	Concrete Footing	Footing F1	Limitations on maximum footing thickness forced changes in footing dimensions. The volume of concrete within the footing has been kept constant by increasing footing length and reducing footing thickness simultanously. original thickness / = input thickness original length * = input length 26 in. / 2 = 13 in. 7.5 ft *2 = 15 ft Since there are two identical footings, the length is muliplied by 2 to find the final input length. input length * 2 = final input length 15 ft * 2 = 30 ft
		Footing F2	Since there are six identical footings, the length is muliplied by 6 to find the final input length. input length * 6 = final input length 7.5 ft * 6 = 45 ft
		Footing F8	This footing has a combination of different rebar sizes that were averaged to #6 size.Limitations on maximum footing thickness forced changes in footing dimensions. The volume of concrete within the footing has been kept constant by increasing footing length and reducing footing thickness simultanously. original thickness / = input thickness original length * = input length 48 in. / 4 = 16 in. 5.25 ft *4 = 21 ft
		Footing F11	Limitations on maximum footing thickness forced changes in footing dimensions. The volume of concrete within the footing has been kept constant by increasing footing length and reducing footing thickness simultanously. original thickness / = input thickness original length * = input length 30 in. / 2 = 15 in. 9 ft *2 = 18 ft
		Footing F13	Limitations on maximum footing thickness forced changes in footing dimensions. The volume of concrete within the footing has been kept constant by increasing footing length and reducing footing thickness simultanously. original thickness / = input thickness original length * = input length 28 in. / 2 = 14 in. 8 ft *2 = 16 ft Since there are two identical footings, the length is muliplied by 2 to find the final input length. input length * 2 = final input length 16 ft * 2 = 32 ft
		Footing F14	Limitations on maximum footing thickness forced changes in footing dimensions. The volume of concrete within the footing has been kept constant by increasing footing length and reducing footing thickness simultanously. original thickness / = input thickness original length * = input length 42 in. / 3 = 14 in. 13 ft *3 = 39 ft Since there are two identical footings, the length is muliplied by 2 to find the final input length. input length * 2 = final input length 39 ft * 2 = 78 ft
		Footing F16	Limitations on maximum footing thickness forced changes in footing dimensions. The volume of concrete within the footing has been kept constant by increasing footing length and reducing footing thickness simultanously. original thickness / = input thickness original length * = input length 30 in. / 2 = 15 in. 7 ft *2 = 14 ft

Footing F20	Since there are nine identical footings, the length is muliplied by 9 to find the final input length. length * 9 = final input length 5.5 ft * 9 = 49.5 ft
Footing F22	Since there are five identical footings, the length is muliplied by 5 to find the final input length. length * 5 = final input length 9 ft * 5 = 45 ft
Footing F23	Limitations on maximum footing thickness forced changes in footing dimensions. The volume of concrete within the footing has been kept constant by increasing footing length and reducing footing thickness simultanously. original thickness / = input thickness original length * = input length 30 in. / 2 = 15 in. 7.5 ft *2 = 15 ft Since there are four identical footings, the length is muliplied by 4 to find the final input length. input length * 4 = final input length 15 ft * 4 = 60 ft
Footing F24	Limitations on maximum footing thickness forced changes in footing dimensions. The volume of concrete within the footing has been kept constant by increasing footing length and reducing footing thickness simultanously. original thickness / = input thickness original length * = input length 36 in. / 2 = 18 in. 15 ft *2 = 30 ft
Footing F25	Limitations on maximum footing thickness forced changes in footing dimensions. The volume of concrete within the footing has been kept constant by increasing footing length and reducing footing thickness simultanously. original thickness / = input thickness original length * = input length 30 in. / 2 = 15 in. 8.5 ft *2 = 17 ft
Footing SF1 * 11 per building	Since there are eleven identical footings, the length is muliplied by 11 to find the final input length. length * 11 = final input length 9 ft * 11 = 99 ft
Footing SF2 * 7 per building	Since there are seven identical footings, the length is muliplied by 7 to find the final input length. length * 7 = final input length 8 ft * 7 = 56 ft
Footing SF3 * 5 per building	Since there are five identical footings, the length is muliplied by 5 to find the final input length. length * 5 = final input length 7 ft * 5 = 35 ft
Footing SF5 * 3 per building	Limitations on maximum footing thickness forced changes in footing dimensions. The volume of concrete within the footing has been kept constant by increasing footing length and reducing footing thickness simultanously. original thickness / = input thickness original length * = input length 36 in. / 2 = 18 in. 19 ft *2 = 38 ft Since there are three identical footings, the length is muliplied by 3 to find the final input length. input length * 3 = final input length 38 ft * 3 = ft
Footing SF6 * 3 per building	Since there are three identical footings, the length is muliplied by 3 to find the final input length. length * 3 = final input length 24 ft * 3 = 72 ft

		Core Footing	Limitations on maximum footing thickness forced changes in footing dimensions. The volume of concrete within the footing has been kept constant by increasing footing length and reducing footing thickness simultanously. original thickness / = input thickness original length * = input length 60 in. / 4 = 15 in. 44 ft *4 = 176 ft
		18" footing w/ 20M * 2 per building	Since there are two identical footings, the length is muliplied by 2 to find the final input length. length * 2 = final input length 24 ft * 2 = 48 ft
STAIRS	Concrete Footing	Stairs	The total area of stairs was determined and modeled as a single footing for each set. Dimensions were determined as follows using the length to width ratio for a single flight of stairs. Thickness was averaged across the length of the stairs. All other specs are from the structural drawings. sqrt(area *4 / 14) = length length * 4 / 14 = width sqrt (1361*4/14) = 69 ft 69 ft *4 / 14 = 19.7 ft
		Stairs Floors 3-5	The total area of stairs was determined and modeled as a single footing for each set. Dimensions were determined as follows using the length to width ratio for a single flight of stairs. Thickness was averaged across the length of the stairs. All other specs are from the structural drawings. sqrt(area *4 / 14) = length length * 4 / 14 = width sqrt (438*4/14) = 39.2 ft ft *4 / 14 = 11.2 ft Since this represents one of three identical floors length is then multiplied by three. Length = 39.2 * 3 = 117.6 ft
		Stairs floors 8-17	The total area of stairs was determined and modeled as a single footing for each set. Dimensions were determined as follows using the length to width ratio for a single flight of stairs. Thickness was averaged across the length of the stairs. All other specs are from the structural drawings. sqrt(area *4 / 14) = length length * 4 / 14 = width sqrt (170*4/14) = 24.4 ft ft *4 / 14 = 7 ft Since this represents one of ten identical floors length is then multiplied by 10 Length = 24.4 * 10 = 244 ft
		Stairs 18+	The total area of stairs was determined and modeled as a single footing for each set. Dimensions were determined as follows using the length to width ratio for a single flight of stairs. Thickness was averaged across the length of the stairs. All other specs are from the structural drawings. sqrt(area *4 / 14) = length length * 4 / 14 = width sqrt (1361*4/14) = 69 ft 69 ft *4 / 14 = 19.7 ft

Assembly Group	Assembly Type	Assembly Name	Specific Assumptions
BASIC MATERIALS	Concrete Cast In Place	4000 psi Average Flyash Concrete (y	Volume added is the sum of the volumes remainin from the thick concrete walls: 1089 ft^3 + 846 ft^3 +2910 ft^3 + 417 ft^3 = 5262 ft^3 27 ft^3 = 1 yrd^3 5262 ft^3 /27 ft^3/yrd^3 = 194.89 yrd^3

Window Assumptions and Calculations

Window Assemblies	# Windows	Sub-wins/Wins	Total Wins
1	16	2	32
2	42	3	126
3	3	15	45
5	7	9	63
6	14	12	168
6A	3	16	48
7	3	6	18
8	21	6	126
9	3	6	18
4	6	12	72
			716
Floors 8-17			
6	8	12	96
8	4	6	24
2	16	3	48
			168
Floor 18			
6	6	12	72
2	2	3	6
9	2	6	12
8	8	6	48
7	6	6	36
			174
Floors 3-5			
1	12	2	24
2	8	3	24
3	8	15	120
6	4	12	48
7	3	6	18
8	7	6	42
9	2	6	12
			288

Window equivalents in window schedule for unspecified window units:

36 = type 6 ➔ 12 windows total
22 = type 2 ➔ 3 windows total
18 = type 8 ➔ 8 windows total
35 = type 6 ➔ 12 windows total
23 = type 2 ➔ 3 windows total

29 = type 2 ➔ 3 windows total
52 = type 8 ➔ 8 windows total
28 = type 1 ➔ 2 windows total
41 = type 6 ➔ 12 windows total
26 = type 2 ➔ 3 windows total
39 = type 9 ➔ 6 windows total
38 = type 6 ➔ 12 windows total
37 = 3 x type 7 ➔ 6 windows each
19 = type 9 ➔ 6 windows total
20 = type 2 ➔ 3 windows total
45 = type 8 ➔ 8 windows total
46 = type 8 ➔ 8 windows total
48 = type 1 ➔ 2 windows total
21 = type 2 and type 1 ➔ 5 total
32 = type 3 ➔ 15 windows total
43 = type 3 ➔ 15 windows total
33 = type 3 ➔ 15 windows total
23 = type 2 ➔ 3 windows total
25 = type 2 ➔ 3 windows total
28 = type 2 ➔ 3 windows total
31 = type 2 ➔ 3 windows total

Appendix C: Aggregated Summary Measures for Residences at UBC

		Residences						
Impact Category	Units	**Vanier** 1959,1961,1968	**Totem** 1964	**Gage** 1972	**Fariview** 1985	**Thunderbird** 1995	**MarineDrive** 2005	**Averag**
Primary Energy Consumption	MJ	288.43	404.14	328.49	282.91	495.45	924.05	453.9
Weighted Resource Use	kg	116.42	196.50	182.15	99.98	182.69	574.48	225.3
Global Warming Potential	(kg CO2 eq / kg)	20.11	29.56	25.64	16.74	28.40	75.10	32.5
Acidification Potential	(moles of H+ eq / kg)	3.66	10.13	10.65	7.03	6.10	26.26	10.6
HH Respiratory Effects Potential	(kg PM2.5 eq / kg)	0.05	0.08	0.13	0.09	0.07	0.26	0.1
Eutrophication Potential	(kg N eq / kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Ozone Depletion Potential	(kg CFC-11 eq / kg)	1.81E-08	3.27E-08	4.92E-08	1.55E-07	1.58E-07	1.23E-07	8.94E-
Smog Potential	(kg NOx eq / kg)	0.06	0.14	0.18	0.09	0.10	0.41	0.1