Douglas Kenny Building: A Life Cycle Assessment

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PROVISO

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

If further information is required or if you would like to include details from this study in your research please contact rob.sianchuk@gmail.com.

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Abstract

This report outlines the study done on the Douglas Kenny building using Life Cycle Assessment for a cradle to gate analysis. The building structural system is primarily concrete, with steel stud interior walls. It was concluded that the Kenny building has similar environmental impacts to comparable buildings on UBC campus built with similar materials, per square foot of floor area. In comparison however, its impacts are much higher than that of wood frame, and concrete frame with wood studs, with the exception of the ozone depletion potential impact category. The primary energy consumption of the Kenny building for manufacturing and construction is approximately 28,832,000 Mega Joules, seven other summary measures were used to asses impact and are described in the preceding report. A sensitivity analysis was performed on the building with the conclusion that the addition of concrete will add the most environmental impacts, with rebar addition also showing significant impacts, information which may have been useful during construction, or possibly a renovation. An energy model was performed on the Douglas Kenny building using the R value of the exterior wall assemblies, and roofs, to model heat loss. It was found that with the addition of insulation materials the buildings energy consumption over a 50 year life span, including manufacturing and construction, can decrease by one third.

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1 Introduction

The Douglas Kenny Building was designed by Reno Negrin and Associates and built between 1982 and 1984 for a cost of 2.5 million dollars. It is located on the west side of UBC campus on West Mall Road. It is currently in use as the UBC psychology building, with its primary function research labs and offices. The building has 4 floors and a mechanical penthouse containing 110 offices, 183 labs, 21 classrooms, 20 washrooms, and a large centralized atrium which extends 4 floors high to a 1300 square foot skylight. More details outlining the structural systems are described in table 1 below.

Table 1 Douglas Kenny Building System overview

Building System	**Specific Characteristics of Douglas Kenny Building**
Structure	Floors 1-4: Round concrete columns, square concrete beams, concrete walls on exterior surrounding stairwells, some concrete block walls present on second floor. Penthouse: Steel Stud.
Floors	Concrete slab with built in beams spanning larger beams which connect columns.
Exterior Walls	Floors 1-4: Concrete with some brick, followed by steel stud with batt insulation and drywall. Penthouse: Steel studs with vertical metal cladding and extruded batt insulation. Curtain wall surrounding atrium.
Interior Walls	Steel Stud with drywall on both sides, some concrete blocks walls present on second floor.
Windows	Double glazing on exterior windows, single glazing on interior windows. Glazing type not specified.
Roof	Main Roof: Concrete slab with built in beams spanning large beams which connect columns, roof membrane, rigid insulation, gravel . Penthouse: Open web steel joists, metal deck, exterior drywall, roofing membrane, rigid insulation, gravel. Skylight covering atrium.

2 Goal and Scope

2.1 Goal of Study

This life cycle analysis (LCA) of the Douglas Kenny at the University of British Columbia was carried out as an exploratory study to determine the environmental impact of it's design. This LCA of the Kenny building is also part of a series of twenty-nine 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 Kenny building. An exemplary application of these references are in the assessment of potential future performance upgrades to the structure and envelope of the Kenny building. When this study is considered in conjunction with the twenty-nine 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 Kenny building 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.

2.2 Scope of Study

The product system being studied in this LCA are the structure and envelope of the Kenny building on a square foot finished floor area of academic 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 Kenny building, as well as associated transportation effects throughout.

2.3 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 Annexes A and B respectively.

Using the formatted takeoff data, version 4.0.64 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 Kenny building in the Vancouver region as an Institutional 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 (inclusive of raw material extraction), transportation of construction materials to site and their installation as structure and envelope assemblies of the Kenny building. As this study is a cradle-to-gate assessment, the expected service life of the Kenny building 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 Kenny building, 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 Kenny building. 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 generates a rough estimate of the energy payback period of investing in a better performing envelope.

The primary sources of data used in modeling the structure and envelope of the Kenny building are the original architectural drawings from when the was initially constructed from 1982-1984. The assemblies of the building that are modeled include the foundation, columns and beams, floors, walls and roofs, as well as their associated envelope and/or openings (ie. doors and windows). The decision to omit other building components, such as flooring, electrical aspects, HVAC system, finishing and detailing, etc., are associated with the limitations of available data and the IE software, as well as to minimize the uncertainty of the model. 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 bill of materials and limitations to what it can model, which necessitated further assumptions to be made. These assumptions and limitation will be discussed further as they emerge in the Building Model section of this report and, as previously mentioned, all specific input related assumption are contained in the Input Assumptions document in Annex B.

2 Building Model

To properly model the Douglas Kenny Building two different pieces of software were needed. To determine the specific quantity of each assembly group (foundation, walls ect.) a takeoff program was used. These outputs were inputted into an Impact Estimator, which breaks down the assembly groups into individual materials and performs a life cycle assessment on each material. The final output from this program is the core objective of building this model and will yield specific environmental impacts of the building as a whole. The nomenclature used follows a logical order of inputs into the Impact Estimator, with the first word set describing the category of input, the second word set describing the type of input, and the third word describing the location or type. This nomenclature was standardized across all 29 projects used in the larger study for uniformity and simplicity.

2.1 Takeoffs

The program used to perform takeoffs on the Douglas Kenny buildings is called ‘On Screen Takeoff’ and was created by ‘On Center Software Inc’. In this program conditions are created to find specific volumes, areas and measurements to meet the appropriate inputs for the Impact Estimator. The five major categories of inputs in the Impact Estimator are: Foundations, Walls, Columns and Beams, Roofs, Floors, and Extra Basic material. Within each group more specific takeoffs such as the area of walls and the number of windows were done for each floor. The results for the sub-catagories is discussed below. The outputs from the takeoff software, as well as the inputs for the Impact Estimator can be seen in Appendix A, while the assumptions and necessary calculations to accompany these inputs can be found in Appendix B.

2.1.1 Foundation

The foundation of the Douglas Kenny building contains 10 types of rectangular footings and 5 types of strip footings. Sitting approximately 400mm above the top of the footings is a 130mm slab on grade which the first floor sits on. The concrete type used in the Kenny building was specified at 25 MPa, however, the Impact Estimator used does not have this strength of concrete as an input so a strength of 30 MPa, the closest that the software provided, was used. The fly ash concentration for all of the concrete in the building was not specified so an average concentration was assumed. Each of the footings contains unique dimensions and rebar as can be found in appendix A, these dimensions and specifications were found in drawing 732-07-007.

In addition to the foundation, all of the stairs in the building and some of the floors surrounding the stairwell were modeled as one large footing. The dimensions of the concrete footings were calculated so that the volumes of concrete are equal to that found in the takeoff of the stairs and stairwell floors. This assumption was made for the stairs because there is no 'stairs' input in the Impact Estimator and the footings input allows a specification of the rebar size, allowing it to be more accurate. The stairwell floors which are situated at the corners of the buildings and supported by the cast in place walls were not modeled as a flooring system, because they are not supported by the column and beam system, and they have no consistent span. Modeling as a footing likely allows the volume of concrete and rebar to be more accurate than by using a existing flooring system.

2.1.2 Walls

In the Douglas Kenny building there are two primary type of exterior walls and three types of interior walls, as well as a curtain wall and skylight that surround the atrium of the building. The exterior walls for every floor except the penthouse are a 200mm thick concrete walls, steel studs on the inside, and batt insulation in the cavity. The penthouse is primarily for HVAC maintenance and storage and is a steel stud wall with vertical metal cladding on the outside. The interior walls are primarily steel stud walls with drywall on each side, the other interior walls are 200mm thick concrete walls which are present in the stairwells and the atrium, as well as a small portion of concrete block walls present at the south east corner of the building on the second floor. There is no skylight input for the Impact Estimator, as a result the skylight over the atrium of the building was chosen to be modeled as a curtain wall because of the resemblance it has to the curtain wall to which it is connected. The extra structural support given to the skylight is provided by Hollow Structural Steel Sections which is included in the Extra Basic Material input category.

The window inputs in the Impact Estimator require the window area, number of windows, type of glazing and type of framing. The windows and doors are included in the wall category because the program subtracts the amount of wall that will be filled by a window or door from the total wall area. A window area and count function was performed on the exterior walls using the elevation plans. However, for the interior windows the majority of the takeoffs had to be done using the plan view by measuring the window lengths, and a site visit was needed to measure the window heights to determine the area. The doors throughout the building are solid wood doors, with the exception of the doors within concrete block walls on the second floor, which are primarily all hollow steel doors.

2.1.3 Columns and Beams

The Impact Estimator does not treat columns, beams, floors or roofs as a volume of material rather these systems take inputs such as span, width and live load to calculate the appropriate amount of material that would be needed to make the appropriate floor, roof, columns and beams. This is done so that different types of systems, from concrete to steel I beams to light frame construction, can be examined and their impacts weighed without a complex volume calculation occurring for each different material. The Kenny building consists of round concrete columns spaced at 10 meters in both directions, with large square concrete girders spanning the columns in both directions. In addition there are smaller intermediate beams built into the floor system, running in a single direction. These smaller beams were modeled as part of the flooring system in the Impact Estimator as described in detail in section 2.1.5.

2.1.4 Roof

The Douglas Kenny building has two different roofing systems one concrete system for the main roof and one for the steel system in the penthouse. The main roof consist of a similar structural system to that of the floors using a precast double T structure with larger beams spanning columns in both directions. Overlaying the concrete slab is a roof membrane followed by 75mm rigid insulation with a 50mm gravel ballast. The penthouse roof uses open web steel joist as structural support, with a metal roof deck overlaid by a roof membrane followed by 75mm rigid insulation with a 50mm gravel ballast. This roofing system was inputted as individual components into the Impact Estimator for greater precision. The largest assumption made was to use a “Standard Modified Bitumen Membrane 2 Ply” as the roof membrane. A roof membrane type was not specified so this assumption was made because of the wide spread use of the Bitumen membrane and the popularity of this membrane in the 1980’s.

2.1.5 Floors

The floor throughout the building is a concrete slab with small intermediate beams built into the floor slab, which is all supported by the column and beam system discussed in section 2.1.3. The assembly chosen to model the floors was the precast double T which was used because of smaller beams built into the floor. The first floor was not included in this assembly because it is included as the Slab on Grade. Also, some of the floors surrounding the stairwells of the building are just floor slabs with no column and beam support so they were included in the footings section. The goal and scope of this project, as previously discussed, does not include the material overlaying the floor such as carpets or tile.

2.1.6 Extra Basic Material

The extra basic material (XBM) is primarily from several architectural features from around the building. The first material input was from the roof parapets, which surround all of the roofs on the main structure. This 30 MPa concrete input required a volume calculation for the parapets which sit 1.2 meters high and are 200mm thick. There were no details of the parapets in the plans, so due to the minimal structural importance of these parapets very little use of rebar is likely so a rebar input was ignored. The extra steel material inputted was a result of several Hollow Steel Sections which are present in the atrium. The diameter of the steel sections were measured by hand on a site visit, and found to be 250mm (10inch), while the wall thickness was assumed to be 12mm (1/2 inch) after researching standard thicknesses for the appropriate diameter.

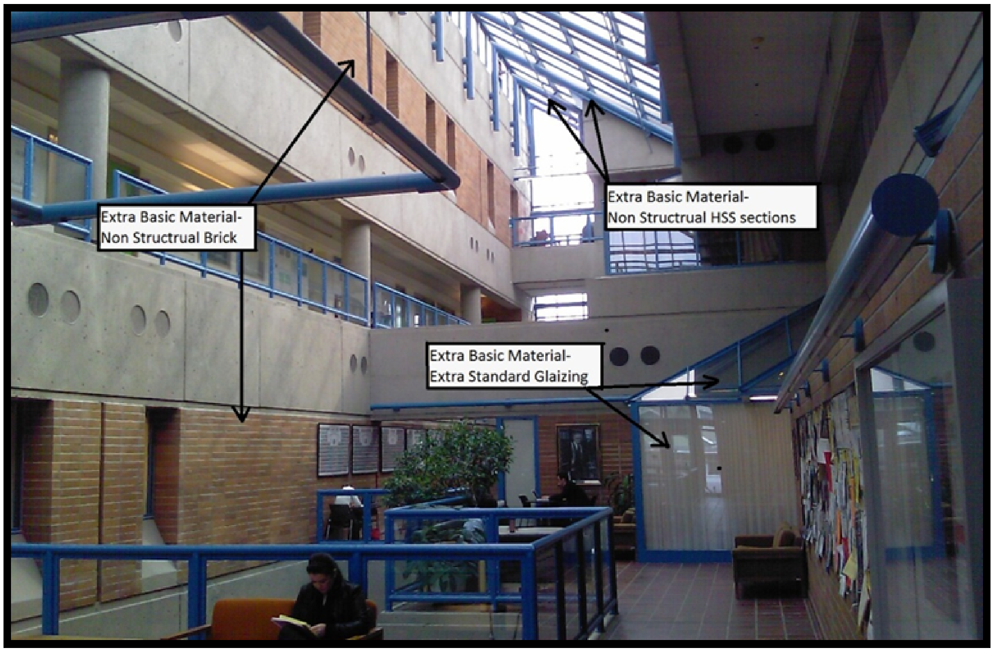


Figure 1. Picture taken during site visit illustrating Extra Basic Materials

In addition to the concrete and steel there was also some brick that was used on the exterior of the building as well as in the atrium, this brick appears to be veneer, however, it is not clear and could carry some structural loads. Due to a lack of structural drawings these sections of wall were included as a typical concrete wall with the additional brick added in as an extra basic material. The area of this additional brick was found using the exterior and cross sectional elevations in the architectural drawings. The final extra basic material is the extra windows that are present in the atrium, they are primarily used as extensions from the solid concrete walls and are more clearly shown Figure 1 below. Since these windows require only a single glazing, and the Impact Estimator only has double glazing inputs, the area was divided by 2 to give a more accurate input.

2.2 Bill of Materials

The Bill of Materials (BoM) is an output from the Impact Estimator and was created by breaking down each of the individual assembly inputs into individual materials so the breakdown of materials in the building can be examined and further analyzed, the BoM output is organized in Table 2.

Table 2. Bill of Materials for Douglas Kenny Building

Material	Quantity	Unit
1/2" Moisture Resistant Gypsum Board	1783.8066	m2
1/2" Regular Gypsum Board	32803.7692	m2
5/8" Moisture Resistant Gypsum Board	437.58	m2
6 mil Polyethylene	4076.479	m2
Aluminum	21.9943	Tonnes
Ballast (aggregate stone)	1785	kg
Batt. Fiberglass	12091.7923	m2 (25mm)
Commercial(26 ga.) Steel Cladding	641.4444	m2
Concrete 20 MPa (flyash av)	609.7778	m3
Concrete 30 MPa (flyash av)	4171.2284	m3
Concrete 60 MPa (flyash av)	788.2341	m3
Concrete Blocks	6459.7553	Blocks
EPDM membrane	1126.9992	kg
Extruded Polystyrene	6446.8781	m2 (25mm)
Galvanized Decking	3.9374	Tonnes
Galvanized Sheet	1.4114	Tonnes
Galvanized Studs	54.0889	Tonnes
Glazing Panel	15.1428	Tonnes
Hollow Structural Steel	10.8575	Tonnes
Joint Compound	34.9557	Tonnes
Modified Bitumen membrane	18539.0977	kg
Mortar	20.5719	m3
Nails	2.7428	Tonnes
Ontario (Standard) Brick	556.7835	m2

Open Web Joists	4.6314	Tonnes
Paper Tape	0.4012	Tonnes
Rebar, Rod, Light Sections	320.869	Tonnes
Screws Nuts & Bolts	2.5304	Tonnes
Small Dimension Softwood Lumber, kiln-dried	45.0619	m3
Solvent Based Alkyd Paint	4.7165	L
Standard Glazing	759.6553	m2
Water Based Latex Paint	453.5904	L
Welded Wire Mesh / Ladder Wire	12.6276	Tonnes

The five largest quantities of material in the Kenny building are Concrete, Drywall, Galvanized Steel Studs, Rebar, and Standard Glazing. The concrete is the main structural component of the Kenny building and there is no surprise that it has several hundred times more material (by weight) than any other material in the building. The majority of the concrete that is in the building is 30MPa because that is what was specified whenever the option was available, the 20 and 60 MPa concrete is a result of the flooring and roofing which are pre-cast systems and do not have inputs for specific concrete strengths. The main proportion of the concrete is a result of the 200mm thick exterior walls, stairwells, concrete foundations and SOG, as well as the concrete flooring and roof system. The biggest assumption which could affect the accuracy of the amount of concrete in the model was to use the precast flooring system, the reasons behind this assumption is discussed in more detail in section 2.1.5.

The large quantity of drywall is due to the number of interior walls in the Kenny building, for example the first floor has over 1 Km of interior walls; this is because of the large number of small offices and labs. Each of these interior walls requires drywall on each side, while the exterior walls only require a single layer of drywall. Another reason for the large amount of drywall is the use of drywall on the exterior walls, particularly around the stairwells. In several other concrete buildings designed at similar times around UBC campus, such as CEME for example, have only a concrete wall with no steel studs, insulation, or drywall on the interior, specifically around the stairwells.

The galvanized studs are the primary product of the steel stud walls and are the secondary structural system, they are present in the large majority of the walls in the building, interior and exterior. One assumption which will affect the amount of galvanized studs in the building is the thickness of the studs used. The Impact Estimator has a minimum stud thickness of 39 x 92mm while the specified stud thickness is 39 x 68 mm. This thickness was likely used because of the large number of small offices and classrooms and the additional stud thickness would have reduced the amount of floor space, the additional thickness was probably not needed for much structural support either because of the concrete frame structure.

The surprising amount of rebar, 320 tonnes or about 6 times the amount of the steel studs, is purely a product of the overwhelming amount of concrete used on this structure. The only location in which rebar was not used for concrete construction was the roof parapets, as they were an extra basic material and it was assumed that they had very little or no rebar because of their lack of structural use. One assumption made which may have affected the amount of rebar used in the building was to model the stairs and stairwell floors as footings. A footing uses about 695 m^3 of concrete per tonne of rebar, while the pre-cast flooring system chosen uses 55 m^3 of concrete per tonne of rebar. This could put our estimation of the rebar used for our stairs off at somewhere in the neighbourhood of 1200% which is obviously very significant.

The fifth largest proportion of material was determined to be the standard glazing, while this choice could have easily been dictated to another material it was chosen because of the large portion of glazing used relative to other concrete buildings. The type of glazing was not specified in the architectural drawings, therefore this quantity is entirely affected by the choice of using standard glazing, however, it is in all likelihood the best choice for this case. One particular area which may effect the quantity of glazing is the glass added as a Extra Basic Material, this glazing was a product of the windows used on the main floor of the atrium (see figure 1) and is only single glazing. Due to this single glazing the standard glazing input was divided by two which may still give a slight over estimate of the amount of window area needed, however, is much closer than if nothing was done to account for the single glazing.

Two other significant outputs from the Bill of Material which use assumptions that could vary their volume is the use of the “Standard Modified Bitumen Membrane 2 Ply” and the use of “Standard Brick”. The reasons for both of these assumptions were discussed in sections 2.1.4 and 2.1.6 respectively. The use of the Standard brick will likely over estimate the amount of Brick used in the building if it is in fact veneer brick. Its classification as an XBM *if it is not a veneer brick* will likely over estimate the amount of concrete used in the building, because instead of using brick in as an alternative for the concrete in the walls it uses is in addition to the concrete. The use of a Standard Modified Bitumen Membrane is drastically better from an environmental perspective than the use of a PVC membrane or EPDM membrane, as shown in Table 3. This assumption could drastically underestimate the impact of the building from this perspective.

Table 3. Comparing the Impacts of 3 Types of Roofing Membranes

Impact	Modified Bitumen Membrane	EPDM Roofing Membrane	PVC Membrane
Primary Energy Consumption	100.00%	281.16%	164.91%
Weighted Resource Use	100.00%	479.95%	149.16%
Global Warming Potential	100.00%	1090.41%	287.65%
Acidification Potential	100.00%	1401.79%	390.23%
HH Respiratory Effects Potential	100.00%	139269.35%	224.17%
Eutrophication Potential	100.00%	4069192.64%	327.64%
Ozone Depletion Potential	100.00%	34868200020420.00%	195.18%
Smog Potential	100.00%	65798.45%	156.05%

This table illustrates how sensitive the impacts can be to the selection of most correct material for your building. The sensitivity analysis described later in the report will show how sensitive the impacts are to the volume of material inputted.

3 Summary Measures

3.1 Description and Introduction

The Impact Estimator outputs eight environmental impact categories. The first category, Primary Energy Consumption, takes into account all of the direct energy use that is a result of the material production and transportation. This can include things such as the energy needed to refine and mould steel into the desired shape, ship it to the building site, and use it during construction. The second category is called weighted resource use. This takes into account all of the different resources used during manufacturing and construction of the building and a weighting factor is applied to each component to give a general sense of how much environmental impact the materials in the building have caused. For example the aluminum in the building, which is a non-renewable resource, carries a higher weighted resource use than wood, which is a renewable resource.

The third category involves Global Warming Potential, this gives some value in kg of carbon dioxide equivalent caused by the manufacturing and construction of the material in the building. Acidification Potential is the fourth category, this describes the potential effect of acidification of soils and water by the transformation of air pollutants into acid. This is a problem in dense cities where acid rain is common, this number, in Moles of Hydrogen (or pH), gives a sense of the severity of this type of pollution for a given building. The next category, Human Health Respiratory Effects (HHRE), was created to address the emissions of particulate matter, which are causing respiratory problems, particularly for children in many large cities worldwide.

The sixth category of environmental effects addressed in the Impact Estimator is called the Eutrophication Potential and is measured in Kilograms of Nitrogen equivalent. This category deals with the potential of water pollution, all of the effects are converted to Nitrogen equivalent to provide a basis for the water pollution impacts as a whole instead of examining them individually. The next category used by the Impact Estimator is the Ozone Depletion Potential which measures the effect of the building on deteriorating the atmosphere, causing increased harmful UV rays which cause several health risks such as skin cancer and various other less studied effects. The final assessment category is Smog Potential, which is also linked to the emissions of particulate matter and has some ties to Human Health Respiratory Effects however it is not a direct correlation and it is measured in NO_x rather than kg PM 2.5 equivalent in HHRE.

While these results are more useful than examining the absolute values of energy consumption, resource use, and air water land emissions, which can have several hundred types of basic chemical outputs, they are still do not provide an accurate idea of the impact of the building without comparing it to other similar buildings. This step can be done in any number of ways but is done in the Impact Estimator by examining the source of the impact, from manufacturing, construction, and maintenance to end of life impacts, then by comparing the buildings on a square foot basis to similar buildings. Using this method it is easy to assess the difference in potential environmental effects between building types, say concrete or wood frame, and it also makes it easier to compare and adjust the building materials to attain the most efficient and environmentally friendly design.

3.2 Results

For this particular design the focus is primarily on the manufacturing and construction impacts of the building, the summary measures output is shown in Table 4.

Table 4. Summary Measures of the Douglas Kenny Building

Summary Measure	Manufacturing			Construction			Combined Total
	Material	Transportation	Total	Material	Transportation	Total	
Primary Energy Consumption MJ	26055800	775630	26831430	694772	1306392	2001165	28832594
Weighted Resource Use kg	18736348	517	18736865	16081	835	16915	18753780
Global Warming Potential (kg CO2 eq)	2646781	1351	2648132	49253	2328	51581	2699713
Acidification Potential (moles of H+ eq)	1104235	465	1104700	25445	744	26189	1130889
HH Respiratory Effects Potential (kg PM2.5 eq)	8403	1	8403	28	1	29	8432
Eutrophication Potential (kg N eq)	1017.42	0.48	1017.91	24.14	0.77	24.91	1042.82
Ozone Depletion Potential (kg CFC-11 eq)	0.005838	0	0.005839	0	0	0	0.005839
Smog Potential (kg NOx eq)	11913	10	11924	823	17	840	12763

This table tells us how much potential impact the Kenny building has in each of the eight summary measure categories. Table 5 (below) gives us a more realistic idea of how good or bad the Kenny building performs environmentally, all of the values are treated on a percent scale of the Kenny building and are done on a per square basis.

Table 5. Summary Measures per squrare foot of floor area

	Academic Buildings at UBC							
Building Name	**Douglas Kenny**	**Geography**	**Hennings**	**Buchanan**	**HRMacMillan**	**CEME**	**FSC**	**AERL**
Year Built	1982-1984	1925	1945	1958-1960	1967	1976	1998	2004
Building Structure Type	Concrete	Wood	Concrete	Concrete	Concrete	Concrete	Concrete	Concrete
Building Interior Wall Type	Steel	Wood	Wood	Wood	Concrete Block	Concrete/Wood/Steel	Steel	Steel
Primary Energy Consumption	100%	32%	68%	67%	103%	76%	99%	103%
Weighted Resource Use	100%	13%	69%	73%	129%	57%	104%	66%
Global Warming Potential	100%	18%	61%	71%	117%	63%	91%	92%
Acidification Potential	100%	22%	69%	73%	118%	61%	85%	91%
HH Respiratory Effects Potential	100%	26%	78%	78%	113%	58%	88%	109%
Eutrophication Potential	100%	13%	62%	76%	95%	61%	107%	76%
Ozone Depletion Potential	100%	132%	60%	84%	101%	61%	120%	62%
Smog Potential	100%	19%	69%	76%	129%	64%	84%	83%

From this table we can see a much easier way to determine the relative impacts of the building. It is not surprising that the impacts of the Kenny building are very similar to the Forest Science center (FSC) and the Aquatic Ecosystems Research Laboratory (AREL) because of their building similarities. However, it is interesting that the buildings which use at least some type of wood frame construction have significantly lower impacts in almost all categories. The one category which stands out, and has rather large variations from building to building is the Ozone Depletion Potential. This chart can provide a guide when choosing between building systems for a new building, specific assemblies can be chosen based on the desired environmental objectives.

3.3 Uncertainties

Uncertainty in the project can result from any number of areas ranging from the assumptions being made to mistakes in calculations. The uncertainties can be broken up into two main components, uncertainty in the Life Cycle Inventory (LCI) Database, and in the Impact Assessment. There can also be a considerable amount of uncertainty in defining the Goal and Scope, however, the clear definition of our project boundary, functional unit, and IA categories from section 2 removes the need of discussion of these uncertainties from project to project.

3.3.1 LCI Database

The LCI Database used in the Impact Estiamtor compiles as much of the relevant impacts associated with the individual materials as possible, with the end result being a full list of the volumes of compounds emitted which can have some effect on the environment. The first uncertainty involved with is data base it the collection or allocation methods used to find the data, if these methods are not completely consistent from product to product it can create data uncertainty in the database. Another concern is a lack of data about a certain product which nevertheless has to be categorized in the LCI database.

In addition there can be uncertainty in the database created by the size of the project, it is not accurate that the impacts of 1 kg of concrete on a small job are the same as the impacts of 1 kg of concrete on a very large job. This direct, linear scaling is different from project to project and can introduce some uncertainty in the model. Another uncertainty is caused by time which can cause effects such as the reduced efficiency of factories, this will affect the uncertainty of the model in the future. Time can also affect how relevant your data is at current time, which depends on when the data was collected; vintage data, as it is called can cause significant uncertainties in the LCI Database. The database can also have uncertainties when looking at the effects from site to site, transportation distances and manufacturing techniques can vary significantly, even when examining the same product from city to city.

3.3.2 Impact Assessment

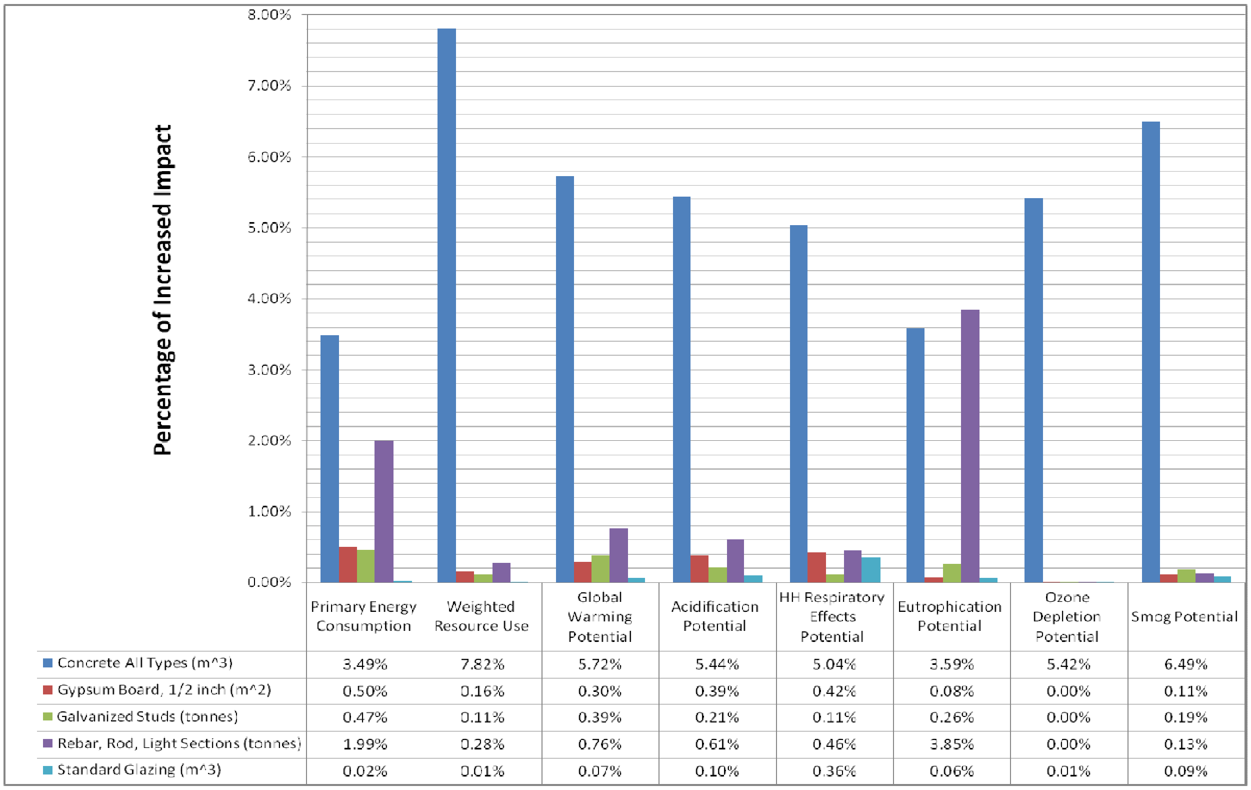
The impact assessment side of the LCA takes the outputs from the LCI database an converts them into relevant, and more easily interpreted data. One area which can cause uncertainty in this data is the lifetimes of the substances, and the distance of travel. For example CO_2 can have a significantly longer lifetime than NO_x and can travel and become much more wide spread, so the effect of a set amount of

CO_2 emitted compared to NO_x can be uncertain. There is also some recognition that we do not know all the factors which affect the Impacts and our simple lack of knowledge causes uncertainty.

Similar to the issue from the LCI database the effect of time introduces uncertainty, however in this case it is the changing of the climate and other environmental factors, rather than an aging factory, which can cause different weights for each criteria. A significant source of uncertainty is the lack of variations of impacts between locations. One glaring example is the lack of importance of the eutrophication potential category if there is no water to pollute, as is often the case for non-coastal cities. This also carries over to the differences caused in exposure to humans or wildlife, the effects are much less significant if there are few or no people being affected by the impact, especially in the categories such as HH Respiratory effects, this can also cause uncertainty.

3.4 Sensitivity Analysis

Sensitivity analysis was conducted on the results from the Douglas Kenny Building LCA. The five largest materials found in the quantity takeoff were chosen to do the analysis on. The materials are Concrete (All types), ½ inch gypsum board, galvanized studs, rebar and standard glazing (glass). The analysis was done by adding ten percent of each material to the model and looking at the total impact it has on the summary measures. The results from the analysis are presented in the graph below.



	Primary Energy Consumption	Weighted Resource Use	Global Warming Potential	Acidification Potential	HH Respiratory Effects Potential	Eutrophication Potential	Ozone Depletion Potential	Smog Potential
🟦 Concrete All Types (m^3)	3.49%	7.82%	5.72%	5.44%	5.04%	3.59%	5.42%	6.49%
🟥 Gypsum Board, 1/2 inch (m^2)	0.50%	0.16%	0.30%	0.39%	0.42%	0.08%	0.00%	0.11%
🟩 Galvanized Studs (tonnes)	0.47%	0.11%	0.39%	0.21%	0.11%	0.26%	0.00%	0.19%
🟪 Rebar, Rod, Light Sections (tonnes)	1.99%	0.28%	0.76%	0.61%	0.46%	3.85%	0.00%	0.13%
🟦 Standard Glazing (m^3)	0.02%	0.01%	0.07%	0.10%	0.36%	0.06%	0.01%	0.09%

Figure 2. Sensitvity Analysis Results

As you can see the majority of the additional impacts are caused by the addition of concrete, primarily due to the overwhelming volume of concrete when compared to the other materials. However, it is interesting that despite adding much less rebar, by volume or weight, there is a significant increase in impacts of the overall building in the categories of primary energy consumption and eutrophication potential. Since the majority of the time the concrete that is being added to the building will contain rebar this large impact of the added rebar is even more significant because it highlights the total increase in impacts. For example if an assembly such as floors or footings were added, which contain rebar, the additional 10% of material would now increase the primary energy consumption by 5.48% and the eutrophication potential by 7.44%, this is a huge jump in impacts. The other materials, however, have relatively low impacts, even gypsum board which has over 8 Km of walls in the building. From these results it is clear that a reduction of concrete, and by association rebar, will significantly decrease the impacts of the building.

Sensitivity analysis can be an important tool during the design, or renovations phase of a building. It can allow the designer to see where improvement in the design can be found. It is common that environmental choices are made, but the impacts of those choices can be insignificant if made in the wrong areas, the use of sensitivity analysis helps minimize the environmental impact of the decisions.

4 Building Performance

Building performance is a measure of the embodied energy and operating energy of the building. This primarily pertains to the buildings' insulation properties and the potential for total reduction of energy of the building with the increase of the buildings ability to hold or keep out heat. While it is also relevant to look at lowering the embodied energy by initial design decisions such as wall types and floor assemblies, this analysis is more useful when examining all of the impacts using the previous tools described, such as sensitivity analysis and comparison of summary measures.

The primary materials that will increase the building performance from a maintenance perspective is the use of insulation to increase the R values of the wall. Insulation can be added in a number of forms with varying impacts, such as adding batt insulation during construction, blown cellulose insulation as a retrofitting solution, or by using a exterior insulation, such as extruded polystyrene, which is common for roof assemblies. Exterior insulation can be especially beneficial because of its ability to prolong the life of roofs by limiting the temperature fluctuation and UV damage of direct sunlight. In general the impact of adding insulation to increase the R value of the walls is significantly lower than trying to increase the R value by adding other materials, such as concrete or drywall. The use of cellulose is especially environmentally low impact, it is made from recycled newspapers and has a very high R value.

To calculate the buildings performance the current building was first tested by determining the R value of each of the exterior walls. For the Kenny building the concrete exterior walls had an R values of

$$\frac{\frac{R = \left(R_{200\ \text{thick conc wall}}\right) + \left(R_{1\ \text{sheet Drywall}}\right) + \left(R_{67.5\ \text{batt insulation}}\right) = 0.26 + 0.06 + 1.539 = 1.913\ ({}^{0}Cm^{2}}{W} = 10.86\ ({}^{\circ}Fft^{2}}{BTU}$$

while the penthouse had an R value of

$$\frac{\frac{R = \left(R_{1\ \text{sheet Drywall}}\right) + \left(R_{150\ \text{extruded Poly}}\right) = 2 * 0.06 + 3.75 = 3.87\ ({}^{0}Cm^{2}}{W} = 21.97\ ({}^{\circ}Fft^{2}}{BTU}$$

. The total wall R value was found by taking a weighted average of the two values based on the amount of wall area, and was found to be $\frac{R = 12.43\ ({}^{\circ}Fft^{2}}{BTU}$. The same procedure was used on the roofs and an R value of $\frac{14.71\ ({}^{\circ}Fft^{2}}{BTU}$ was found. While the windows have a R value of $\frac{1.76\ ({}^{\circ}Fft^{2}}{BTU}$. From these values the annual energy usage was calculated by using the average monthly temperatures for Vancouver and subtracting them from the indoor desired temperature (20°C) and finding the energy loss per month by the equation: $\frac{Energy\ loss}{month} = \frac{Total\ Building\ Exterior\ Area * \Delta T * 24hours * \#days\ in\ month}{R_{whole\ building}}$.

From this value it was concluded that the yearly energy consumption was approximately 1,030,000 MJ. From here we set an objective of our improved building to have an exterior wall R-value of 18, a window R value of 3.75 and a roof R value of 40. Back calculating it was found that that the batt insulation needed to be increased to 131 mm, the windows had to be made silver argon filled low e windows, and the extruded polystyrene on the roof had to be increased to 205 mm. Using these new inputs the new yearly energy consumption was calculated to be 542,000 MJ, or roughly half of what it was previously. However, this added insulation comes with some additional embodied energy cost of 1,130,000 MJ, which was calculated by changing the inputs in the Impact Estimator to the new insulation values and outputting the primary energy consumption. The results are shown below in a graph of the yearly energy expenditure.

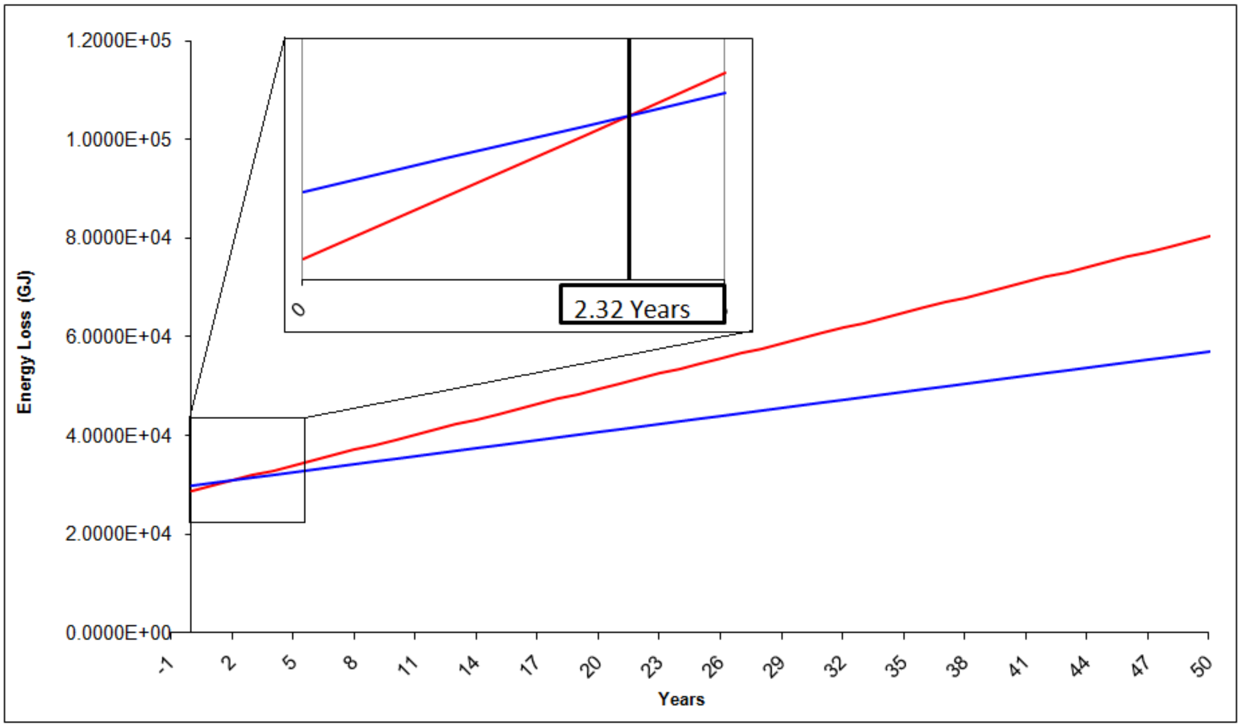


Figure 3. Yearly Energy Consumption of Current Building (Red) and Improved Building (Blue)

The graph shows an energy payback period of 2 years and 4 months to net out even from an energy perspective. Over a 50 year service life the improved building uses its embodied energy once over while the current design uses its embodied energy twice over, a very significant result. While these results provide some idea as to the effect of adding additional insulation, they do not take into account a number of factors which may vary the results. The first is the other potential impacts of increasing the amount of building material, outside of primary energy consumption. Another issue is the heat loss in the building that is unavoidable, such as thermal bridges, and open windows and doors. In addition envelope upgrade in the case of the Kenny building would be quite difficult, because of the need for expansion of the cavities of the exterior walls to fit more insulation. An upgrade would likely require a re-working of all the wall systems and would decrease the amount of floor space available. Further research into the cost and environmental damage of the upgrade would need to be undertaken with the shortened (remaining) building span life considered.

5 Conclusions

The goal of this report is to cover the environmental impacts using life cycle assessment of the Douglas Kenny Building and compare the results to other buildings using the same methods to assess the impacts and examine ways environmental impact improvement. The physical project boundaries set forth in the scope of the project include only components of the buildings' structure and envelope. It does not include interior materials such as carpets, acoustic ceiling board, or anything outside of the building envelope, such as exterior stairs. Takeoffs of the building were done using "On Screen Takeoff" software, and the building was broken into 6 major categories for input into the Impact Estimator: columns and beams, floors, roofs, foundations, walls, and extra materials. Each of these assemblies have sub categories with assumptions made to most accurately model the building in the Impact Estimator. The Impact Estimator outputs the summary measures from eight different categories: primary energy consumption, acidification potential, global warming potential, human health respiratory effects, ozone depletion potential, smog potential, eutrophication potential, and weighted resource use, these findings are summarized in table 4. These impacts are easily compared to the impacts of buildings for which LCA has been completed with the same scope of work, and it was found that the Kenny building has similar environmental impacts, per square foot, to buildings of similar construction materials, however the impacts are generally much higher than compared to buildings which used wood construction.

Using the bill of material as an output from the Impact Estimator a sensitivity analysis was run to determine the potential ways of lowering the buildings impact. The effect of the addition of 10% more concrete and rebar had a significant effect on all summary measures categories, however, the addition of other materials has almost insignificant effects. The final analysis option is to examine the building envelope and the effect of adding more insulation. It was found that the energy payback period of adding additional insulation was about a 2 years and four months, and over the lifetime of the building reduced the total energy usage by about one third. One way to make further improvements to the LCA model of the Kenny building would be to obtain structural drawings of the building and complete more accurate takeoffs of the building, gaining a more comprehensive knowledge of the building, to try and reduce the number of assumptions that were made.

Appendix A: IE Input Document

1 Foundation		Known/Measured	IE Input
1.1 Concrete Footing			
1.1.1 Footing_Column_Type1			
	Length (m)	1.75	21.09
	Width (m)	1.75	1.92
	Thickness (mm)	600.00	500.00
	Concrete (MPa)	25.00	30.00
	Concrete flyash %	-	average
	Rebar	20M	20M
1.1.2 Footing_Column_Type2			
	Length (m)	2.30	26.18
	Width (m)	2.30	2.91
	Thickness (mm)	800.00	500.00
	Concrete (MPa)	25.00	30.00
	Concrete flyash %	-	average
	Rebar	20M	20M
1.1.3 Footing_Column_Type3			
	Length (m)	2.00	7.10
	Width (m)	2.00	2.37
	Thickness (mm)	700.00	500.00
	Concrete (MPa)	25.00	30.00
	Concrete flyash %	-	average
	Rebar	20.00	20.00
1.1.4 Footing_Column_Type4			
	Length (m)	2.80	17.71
	Width (m)	2.80	3.54
	Thickness (mm)	800.00	500.00
	Concrete (MPa)	25.00	30.00
	Concrete flyash %	-	average
	Rebar	25.00	20.00
1.1.5 Footing_Column_Type5			
	Length (m)	3.00	7.10
	Width (m)	3.00	3.55
	Thickness (mm)	700.00	500.00
	Concrete (MPa)	25.00	30.00
	Concrete flyash %	-	average
	Rebar	25.00	20.00
1.1.6 Footing_Column_Type9			
	Length (m)	6.00	13.89
	Width (m)	4.50	5.44
	Thickness (mm)	700.00	500.00
	Concrete (MPa)	25.00	30.00
	Concrete flyash %	-	average
	Rebar	20M	20M
1.1.7 Footing_Column_Type10			
	Length (m)	11.00	16.50
	Width (m)	7.50	13.00
	Thickness (mm)	1300.00	500.00

	Concrete (MPa)	25.00	30.00
	Concrete flyash %	-	average
	Rebar	20M	20M
1.1.8 Footing_Column_Type11			
	Length (m)	8.50	13.17
	Width (m)	8.50	13.17
	Thickness (mm)	1200.00	500.00
	Concrete (MPa)	25.00	30.00
	Concrete flyash %	-	average
	Rebar	20M	20M
1.1.9 Footing_Column_Type13			
	Length (m)	1.20	1.63
	Width (m)	4.00	4.43
	Thickness (mm)	750.00	500.00
	Concrete (MPa)	25.00	30.00
	Concrete flyash %	-	average
	Rebar	20M	20M
1.1.10 Footing_Column_Type14			
	Length (m)	10.00	12.10
	Width (m)	6.50	8.60
	Thickness (mm)	800.00	500.00
	Concrete (MPa)	25.00	30.00
	Concrete flyash %	-	average
	Rebar	20M	20M
1.1.11 Footing_Strip_Type6			
	Length (m)	30.00	30.00
	Width (m)	0.85	0.85
	Thickness (mm)	350.00	350.00
	Concrete (MPa)	25.00	30.00
	Concrete flyash %	-	average
	Rebar	15M	15M
1.1.12 Footing_Strip_Type7			
	Length (m)	189.00	189.00
	Width (m)	0.65	0.65
	Thickness (mm)	250.00	250.00
	Concrete (MPa)	25.00	30.00
	Concrete flyash %	-	average
	Rebar	15.00	15.00
1.1.13 Footing_Strip_Type8			
	Length (m)	56.00	56.00
	Width (m)	0.65	0.65
	Thickness (mm)	250.00	250.00
	Concrete (MPa)	25.00	30.00
	Concrete flyash %	-	average
	Rebar	15M	15M
1.1.14 Footing_Strip_Type12			
	Length (m)	7.00	7.00
	Width (m)	0.75	0.75
	Thickness (mm)	250.00	250.00
	Concrete (MPa)	25.00	30.00

		Concrete flyash %	-	average
		Rebar	15M	15M
1.1.15 Footing_Strip_Type15				
		Length (m)	11.00	11.00
		Width (m)	1.40	1.40
		Thickness (mm)	250.00	250.00
		Concrete (MPa)	25.00	30.00
		Concrete flyash %	-	average
		Rebar	15M	15M
1.1.16 Footing_Stairs				
		Length (m)	-	15.85
		Width (m)	-	15.85
		Thickness (mm)	-	200.00
		Concrete (MPa)	25.00	30.00
		Concrete flyash %	-	average
		Rebar	10M	10M
1.1.17 Footing_StaiwellFloors				
		Length (m)	15.23	15.23
		Width (m)	15.23	15.23
		Thickness (mm)	200.00	200.00
		Concrete (MPa)	25.00	30.00
		Concrete flyash %	-	average
		Rebar	10M	10M
1.2 Concrete Slab-on-Grade				
1.2.1 SOG_100mm				
		Length (m)	51.51	58.73
		Width (m)	51.51	58.73
		Thickness (mm)	130.00	100.00
		Concrete (MPa)	25.00	30.00
		Concrete flyash %	-	average
	Envelope	Category	Vapour Barrier	Vapour Barrier
		Material	Polyethylene 6 mil	Polyethylene 6 mil
		Thickness	6mm	6mm
2 Walls				
2.1 Cast In Placen Concrete				
2.1.1 Wall_Cast-in-Place_AllFloors				
		Length (m)	675.28	675.28
		Height (m)	4.30	4.30
		Thickness (mm)	200.00	200.00
		Concrete (MPa)	25.00	30.00
		Concrete flyash %	average	average
		Rebar	20M	20M

	Window Opening	Number of Windows	58.00	58.00
		Total Window Area (m2)	61.55	61.55
		Fixed/Operable	Fixed	Fixed
		Frame Type	Aluminum	Aluminum
		Glazing Type	Standard Glazing	Standard Glazing
	Door Opening	Number of Doors	47.00	47.00
		Door Type	Solid Wood Door	Solid Wood Door
2.1.2 Wall_Cast-in-Place_SteelStud_AllFloors				
		Length (m)	907.62	907.62
		Height (m)	4.24	4.24
	Concrete	Thickness	200.00	200.00
		Reinforcement	20M	20M
		Concrete (MPa)	25.00	30.00
		Concrete flyash %	-	average
	Steel Stud	Sheathing Type	none	none
		Stud Spacing	400.00	400.00
		Stud Weight	Light Weight	Light Weight
		Stud thickness	39 x 92	39 x 92
	Window Opening	Number of Windows	497.00	497.00
		Total Window Area (m2)	557.39	557.39
		Fixed/Operable	Fixed	Fixed
		Frame Type	Aluminum	Aluminum
		Glazing Type	Standard Glazing	Standard Glazing
	Door Opening	Number of Doors	18.00	18.00
		Door Type	Solid Wood Door	Solid Wood Door
	Envelope	Category	Insulation	Insulation
		Material	Fiberglass Batt	Fiberglass Batt
		Thickness (mm)	68.50	68,5
		Category	Vapour Barrier	Vapour Barrier
		Material	Polyethylene 6 mil	Polyethylene 6 mil
		Category	Gypsum board	Gypsum board
		Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
		Thickness	-	-
2.2 Steel Stud				
2.2.1 Wall_SteelStud_Ground Floor				
		Length (m)	1029.81	1029.81
		Height (m)	4.30	4.30
		Sheathing Type	none	none
		Stud Spacing	400.00	400.00
		Stud Weight	Light Weight	Light Weight
		Stud thickness	39 x 92	39 x 92
	Window Opening	Number of Windows	35.00	35.00
		Total Window Area (m2)	55.71	55.71
		Fixed/Operable	Fixed	Fixed
		Frame Type	Aluminum	Aluminum

	Glazing Type	Standard Glazing	Standard Glazing
Door Opening	Number of Doors	133.00	133.00
	Door Type	Solid Wood	Solid Wood Door
Envelope	Category	Gypsum board	Gypsum board
	Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
	Thickness	-	-
Envelope	Category	Gypsum board	Gypsum board
	Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
	Thickness	-	-
2.2.2 Wall_SteelStud_Floor2			
	Length (m)	565.89	565.89
	Height (m)	4.30	4.30
	Wall Type	interior	interior
	Sheathing Type	none	none
	Stud Spacing	400.00	400.00
	Stud Weight	Light Weight	Light Weight
	Stud thickness	39 x 92	39 x 92
Window Opening	Number of Windows	6.00	6.00
	Total Window Area (m2)	8.85	8.85
	Fixed/Operable	Fixed	Fixed
	Frame Type	Aluminum	Aluminum
	Glazing Type	Standard Glazing	Standard Glazing
Door Opening	Number of Doors	85.00	85.00
	Door Type	Solid Wood	Solid Wood Door
Envelope	Category	Gypsum board	Gypsum board
	Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
	Thickness	-	-
	Category	Gypsum board	Gypsum board
	Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
	Thickness	-	-
2.2.3 Wall_SteelStud_Floor3			
	Length (m)	814.01	814.01
	Height (m)	4.30	4.30
	Wall Type	interior	interior
	Sheathing Type	none	none
	Stud Spacing	400.00	400.00
	Stud Weight	Light Weight	Light Weight
	Stud thickness	39 x 92	39 x 92
Window Opening	Number of Windows	14.00	14.00
	Total Window Area (m2)	17.80	17.80
	Fixed/Operable	Fixed	Fixed
	Frame Type	Aluminum	Aluminum
	Glazing Type	Standard Glazing	Standard Glazing
Door Opening	Number of Doors	115.00	115.00

	Door Type	Solid Wood	Solid Wood Door
Envelope	Category	Gypsum board	Gypsum board
	Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
	Thickness	-	-
	Category	Gypsum board	Gypsum board
	Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
	Thickness	-	-
2.2.4 Wall_SteelStud_Floor4			
	Length (m)	691.41	691.41
	Height (m)	4.30	4.30
	Wall Type	interior	interior
	Sheathing Type	none	none
	Stud Spacing	400.00	400.00
	Stud Weight	Light Weight	Light Weight
	Stud thickness	39 x 92	39 x 92
Window Opening	Number of Windows	3.00	3.00
	Total Window Area (m2)	2.90	2.90
	Fixed/Operable	Fixed	Fixed
	Frame Type	Aluminum	Aluminum
	Glazing Type	Standard Glazing	Standard Glazing
Door Opening	Number of Doors	117.00	117.00
	Door Type	Solid Wood	Solid Wood Door
Envelope	Category	Gypsum board	Gypsum board
	Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
	Thickness	-	-
	Category	Gypsum board	Gypsum board
	Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
	Thickness	-	-
2.2.5 Wall_SteelStud_Penthouse			
	Length (m)	10.77	10.77
	Height (m)	3.60	3.60
	Wall Type	interior	interior
	Sheathing Type	none	none
	Stud Spacing	400.00	400.00
	Stud Weight	Light Weight	Light Weight
	Stud thickness	39 x 92	39 x 92
Window Opening	Number of Windows	none	none
Envelope	Category	Gypsum board	Gypsum board
	Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
	Thickness	-	-
	Category	Gypsum board	Gypsum board
	Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
	Thickness	-	-
2.2.6 Wall_SteelStud_Washrooms			

			Length (m)	252.00	252.00
			Height (m)	4.30	4.30
			Wall Type	interior	interior
			Sheathing Type	none	none
			Stud Spacing	400.00	400.00
			Stud Weight	Light Weight	Light Weight
			Stud thickness	39 x 92	39 x 92
		Door Opening	Number of Doors	26.00	26.00
			Door Type	Solid Wood	Solid Wood Door
		Envelope	Category	Gypsum board	Gypsum board
			Material	15.9 Exterior Drywall	Gypsum Moisture Resistant 5/8"
			Thickness		-
			Category	Gypsum board	Gypsum board
			Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
			Thickness	-	-
	2.2.7 Wall_SteelStud_Penthouse_Exterior				
			Length (m)	88.84	88.84
			Height (m)	6.72	6.72
		Steel Stud	Wall Type	Exterior	Exterior
			Sheathing Type	none	none
			Stud Spacing	400.00	400.00
			Stud Weight	Light Weight	Light Weight
			Stud thickness	39 x 152	39 x 152
		Window Opening	Number of Windows	none	none
		Door Opening	Number of Doors	8.00	8.00
			Door Type	Solid Wood	Solid Wood Door
		Envelope	Category	Cladding	Cladding
			Material	Metal Cladding	Steel Cladding- Comercial (26 ga.)
			Thickness	-	-
			Category	Insulation	Insulation
			Material	Fiberglass Batt	Fiberglass Batt
			Thickness	150.00	150.00
			Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Category	Gypsum board	Gypsum board
			Material	15.9 Exterior Drywall	Gypsum Moisture Resistant 5/8"
			Thickness		-
			Category	Gypsum board	Gypsum board
			Material	15.9 Exterior Drywall	Gypsum Moisture Resistant 5/8"
			Thickness		-
2.3 Concrete Block Wall					
	2.3.1 Wall_ConcreteBlock_SteelStud_AllFloors				
			Length (m)	124.50	124.50

			Height (m)	4.30	4.30
			Rebar	-	10M
		Steel Stud	Wall Type	interior	interior
			Sheathing Type	none	none
			Stud Spacing	400.00	400.00
			Stud Weight	Light Weight	Light Weight
			Stud thickness	39 x 92	39 x 92
		Door Opening	Number of Doors	16.00	16.00
			Door Type	Steel Interior Door	Steel Interior Door
		Envelope	Category	Gypsum board	Gypsum board
			Material	Gypsum Regular 1/2"	Gypsum Regular 1/2"
			Thickness		-
	2.4 Curtian Wall				
		2.4.1 Wall_Curtain_AllFloors			
			Length (m)	3.22	3.22
			Height (m)	147.69	147.69
			Percent Viewable Glazing	86.88	86.88
			Percent Spandrel Panel	13.12	13.12
			Thickness of Insulation	none	0.00
			Type	Metal Spandrel Panel	Metal Spandrel Panel
3 Columns and Beams					
	3.1 Concrete Column				
		3.1.1 - Column_Concrete_Beam_GroundFloor			
			Number of Columns	35.00	35.00
			Number of Beams	-	
			Floor to Floor Height (m)	0.40	0.40
			Bay Sizes (m)	10000.00	10000.00
			Supported Span	10000.00	10000.00
			Live Load (kPa)	3.60	3.60
		3.1.2 - Column_Concrete_Beam_Floor2			
			Number of Columns	35.00	35.00
			Number of Beams	56.00	56.00
			Floor to Floor Height (m)	4.30	4.30
			Bay Sizes (m)	10.00	10.00
			Supported Span	10.00	10.00
			Live Load (kPa)	3.60	3.60
		3.1.3 - Column_Concrete_Beam_Floor3			
			Number of Columns	34.00	34.00
			Number of Beams	52.00	52.00
			Floor to Floor Height (m)	4.30	4.30
			Bay Sizes (m)	10000.00	10000.00
			Supported Span	10000.00	10000.00

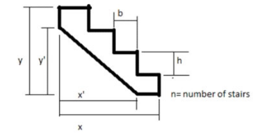
		Live Load (kPa)	3.60	3.60
	3.1.4 - Column_Concrete_Beam_Floor4			
		Number of Columns	31.00	31.00
		Number of Beams	42.00	42.00
		Floor to Floor Height (m)	4.30	4.30
		Bay Sizes (m)	10000.00	10000.00
		Supported Span	10000.00	10000.00
		Live Load (kPa)	3.60	3.60
	3.1.5 - Column_Concrete_Beam_Penthouse			
		Number of Columns	20.00	20.00
		Number of Beams	33.00	33.00
		Floor to Floor Height (m)	4.30	4.30
		Bay Sizes (m)	10000.00	10000.00
		Supported Span	10000.00	10000.00
		Live Load (kPa)	3.60	3.60
4 Floors				
4.1 Concrete Pre Cast Double T				
	4.1.1 - Floor_PrecastDoubleT			
		Number of Bays	57.09	57.00
		Bay Sizes (m)	10.00	10.00
		Span (m)	10.00	10.00
		Live Load (kPa)	3.60	3.60
		With or without concrete topping	Topping Included	Topping Included
5 Roof				
5.1 Concrete Precast Double T				
	5.1.1 - Roof_ConcretePrecastDoubleT_Main			
	Envelope	Number of Bays	16.58	17.00
		Bay Sizes (m)	10.00	10.00
		Span (m)	10.00	10.00
		With or without concrete topping	Topping Included	Topping Included
		Live Load (kPa)	3.60	3.60
		Category	Roof Envelopes	Roof Envelopes
		Material	Roof Membrane	Standard Modified Bitumen Membrane 2 Ply
		Thickness (mm)	-	-
		Category	Insulation	Insulation
		Material	Rigid Insulation	Polystyrene Extruded
		Thickness (mm)	75.00	75.00
		Category	Roof Envelopes	Roof Envelopes
		Material	Gravel Ballast	Ballast (agggeragate Stones)
		Thickness (mm)	50.00	-
5.2 Open Web Steel Joist				
	5.2.1 - Roof_OpenWebSteelJoists_Penthouse			

		Envelope	Roof Width (m)	39.78	39.78
			Span (m)	10.00	10.00
			Live load (kPa)	3.60	3.60
			Steel Joists	Open Web	Open Web
			Decking Type	Steel	Steel
			Category	Gypsum Board	Gypsum Board
			Material	Exterior Drywall	Gypsum Moisture Resistant
			Thickness (mm)	15.90	5/8"
			Category	Roof Envelopes	Roof Envelopes
			Material	Roof Membrane	Standard Modified Bitumen Membrane 2 Ply
			Thickness (mm)	-	-
			Category	Insulation	Insulation
			Material	Rigid Insulation	Polystyrene Extruded
			Thickness (mm)	75.00	75.00
			Category	Roof Envelopes	Roof Envelopes
			Material	Gravel Ballast	Ballast (agggeragate Stones)
			Thickness (mm)	50.00	-
6 Extra Basic Material					
	6.1 Concrete				
		6.1.1 ExtraBasicMaterial_Concrete			
			30 MPa Average Flyash (m^3)	88.62	88.62
	6.2 Steel				
		6.2.1 ExtraBasicMaterial_Steel			
			Hollow Structrual Steel (tonnes)	10.75	10.75
	6.3 Extra Cladding Material				
		6.2.1 ExtraBasicMaterial_ExtraCladdingMaterial			
			Ontario (Standard) Brick (m^2)	530.27	530.27
	6.3 Extra Envelope Material				
		6.3.1 ExtraBasicMaterial_ExtraEnvelopeMaterial			
			Standard Glazing (m^2)	95.86	47.93

Appendix B: IE Input Assumptions Document

Assembly Group	Assembly Type	Assembly Name	Specific Assumptions
1 Foundation			
	Concrete Strength of 25 Mpa was used, In Athena 30 Mpa was the closest input. No Fly ash concentration was specified, so average was used. Athena limits thickness to 500mm, to account for this limitation extra length and width is added to keep the footing volume the same, by the equation: (Extra length/ width) = [-(lenght+width)+sqrt((length+width)^2 + 4*(length*width*(thickness-500)/500))]/2 In addition there is a number of each footing, as a result the number of footings was multiplied by the length to yield the correct volume. Extra Length = (old length + Extra Length/Width)* Number of Footings The footings from 1.1.12 and below are strip footings		
	1.1 Concrete Footing		
		1.1.1 Footing_Column_Type1	The slab thickness is limited to 500mm in the impact estimator. The following calculation was done in order to determine the extra length and width needed. (Extra length/ Width) = = (-(1.75+1.75) + SQRT((1.75+1.75)^2 + (4*1.75*1.75*(600-500)/500)))/2 = 0.167 m In addition there is a number of each footing, as a result the number of footings was multiplied by the length to yield the correct volume. New Length = (1.75 + 0.167) * (11 columns) = 21.09 m
		1.1.2 Footing_Column_Type2	The slab thickness is limited to 500mm in the impact estimator. The following calculation was done in order to determine the extra length and width needed. (Extra length/ Width) = = (-(2.30+2.30) + SQRT((2.30+2.30)^2 + (4*2.30*2.30*(800-500)/500)))/2 = 0.609 m In addition there is a number of each footing, as a result the number of footings was multiplied by the length to yield the correct volume. New Length = (2.30 + 0.609) * (9 columns) = 26.18 m
		1.1.3 Footing_Column_Type3	The slab thickness is limited to 500mm in the impact estimator. The following calculation was done in order to determine the extra length and width needed. (Extra length/ Width) = = (-(2.00+2.00) + SQRT((2.00+2.00)^2 + (4*2.00*2.00*(700-500)/500)))/2 = 0.366 m In addition there is a number of each footing, as a result the number of footings was multiplied by the length to yield the correct volume. New Length = (2.30 + 0.366) * (3 columns) = 7.1 m
		1.1.4 Footing_Column_Type4	The slab thickness is limited to 500mm in the impact estimator. The following calculation was done in order to determine the extra length and width needed. (Extra length/ Width) = = (-(2.80+2.80) + SQRT((2.80+2.80)^2 + (4*2.80*2.80*(800-500)/500)))/2 = 0.742 m In addition there is a number of each footing, as a result the number of footings was multiplied by the length to yield the correct volume. New Length = (2.30 + 0.742) * (5 columns) = 17.71 m
		1.1.5 Footing_Column_Type5	The slab thickness is limited to 500mm in the impact estimator. The following calculation was done in order to determine the extra length and width needed. (Extra length/ Width) = = (-(3.0+3.0) + SQRT((3.00+3.00)^2 + (4*3.00*3.00*(700-500)/500)))/2 = 0.550 m In addition there is a number of each footing, as a result the number of footings was multiplied by the length to yield the correct volume. New Length = (3.00 + 0.550) * (2 columns) = 17.71 m

1.1.6 Footing_Column_Type9	The slab thickness is limited to 500mm in the impact estimator. The following calculation was done in order to determine the extra length and width needed. (Extra length/ Width) = = (-(6.0+4.5) + SQRT((6.00+4.50)^2 + (4*6.00*4.50*(700-500)/500)))/2 = 0.944 m In addition there is a number of each footing, as a result the number of footings was multiplied by the length to yield the correct volume. New Length = (6.00 + 0.944) * (2 columns) = 13.89 m
1.1.7 Footing_Column_Type10	The slab thickness is limited to 500mm in the impact estimator. The following calculation was done in order to determine the extra length and width needed. (Extra length/ Width) = = (-(11.0+16.5) + SQRT((11.00+16.50)^2 + (4*11.00*16.50*(1300-500)/500)))/2 = 5.50 m In addition there is a number of each footing, as a result the number of footings was multiplied by the length to yield the correct volume. New Length = (11.00 + 5.50) * (1 columns) = 16.50 m
1.1.8 Footing_Column_Type11	The slab thickness is limited to 500mm in the impact estimator. The following calculation was done in order to determine the extra length and width needed. (Extra length/ Width) = = (-(8.50+8.50) + SQRT((8.50+ 8.50)^2 + (4*8.5*8.5*(1200-500)/500)))/2 = 4.67 m In addition there is a number of each footing, as a result the number of footings was multiplied by the length to yield the correct volume. New Length = (8.5 + 4.67) * (1 columns) = 13.17 m
1.1.9 Footing_Column_Type13	The slab thickness is limited to 500mm in the impact estimator. The following calculation was done in order to determine the extra length and width needed. (Extra length/ Width) = = (-(1.20+4.00) + SQRT((1.20+ 4.00)^2 + (4*1.20*4.00*(1200-500)/500)))/2 = 0.427 m In addition there is a number of each footing, as a result the number of footings was multiplied by the length to yield the correct volume. New Length = (1.20 + 0.427) * (1 columns) = 1.63 m
1.1.10 Footing_Column_Type14	The slab thickness is limited to 500mm in the impact estimator. The following calculation was done in order to determine the extra length and width needed. (Extra length/ Width) = = (-(10.0+6.50) + SQRT((10.0+ 6.50)^2 + (4*10.0*6.50*(800-500)/500)))/2 = 2.097 m In addition there is a number of each footing, as a result the number of footings was multiplied by the length to yield the correct volume. New Length = (12.10 + 2.10) * (1 columns) = 12.10 m
1.1.11 Footing_Strip_Type6	
1.1.12 Footing_Strip_Type7	
1.1.13 Footing_Strip_Type8	
1.1.14 Footing_Strip_Type12	
1.1.15 Footing_Strip_Type15	

		1.1.16 Footing_Stairs	The stairs were modeled as footing because of the ability to specify the rebar used. All the stairwells are measured to find the volume and this volume is converted to an equivalent area for a 200mm thickness. The first volume calculation that was performed was to account for the lower stairwell in the atrium it was done by taking the top area and multiplying it by the height: Lower Atrium Stairs Volume = (Above projected Area)*Height = 10.85*0.487 = 5.28 m^3 The next portion of the atrium stairway volume is calculated by taking the side area and multiplying it by the width: Middle Atrium Stair Volume = (Side projected area)*Width = 6.04*2.17 = 13.12 m^3 Upper Atrium Stair Volume = (Side projected area)*Width = 2.07*2.85 = 5.90 m^3 The remainder of the stairwells in the building are located at the corners of the building. The individual stairwell volumes are calculated by using the equation below:  Volume = (x*y/2 - x'*y'/2 - b*h*n/2)*Width = (2.825*2.296/2 - 1.7*1.354/2 - 2.35*1.42*12/2) *1.07 Volume = 0.693 m^3 Each of the individual stairwells are the same volume so a single volume was calculated then the number of stairwells counted and multiplied by the single stairwell volume. This volume is then added to the volume from the stairs in the atrium and the total volume is calculated. Total Stairwell Volume = 28 stairwells*0.693 + 5.28 + 13.12 + 5.90 = 50.26 m^3
		1.1.17 Footing_StaiwellFloors	This floor is primarily located on surrounding the stairwells and the cast in place walls at the corners of the building. Also these floors extend in a few walkways over top of the atrium. They were modeled as a footing because they are not supported by the column and beam system, and they have no consistent span. Modeling as a footing allows the volume of concrete and rebar will likely be more accurate than by using a existing flooring system.
	1.2 Concrete Slab-on-Grade		
		1.2.1 SOG_100mm	The slab on grade thickness is only available in 100mm and 200mm slabs in the impact estimators. The following calculation was done in order to determine the extra length and width needed to account for proper slab thickness. Because the actual slab is 130mm the 100 mm slab was used with the extra length and width added on to keep the volumes the same. (Extra length/ Width) = = (-(51.51+51.51) + SQRT((51.51+51.51)^2 + (4*51.51*51.51*(130-100)/100)))/2 = 7,22 m
2 Walls			
	Concrete Strength of 25 Mpa was used, In Athena 30 Mpa was the closest input. No Fly ash concentration was specified, so average was used. The Stud Spacing is 400 mm on center, the stud thickness is 67.5 mm however the minimum specified thickness available in the impact estimator is 92 mm. The stud weight is also not specified, however, the light weight stud was used in order to maintain as much accuracy as possible to try and a reduce the error of the larger stud weight that is used. The type of window in the building was not specified in the drawings, so standard glazing was used. The takeoffs of the exterior windows were done from the outside elevations of the building, with a count and area measurement. While the limited number of interior windows were measured using plan view in linear meters and the height of the windows measured during a site visit to determine the proper window area, a count was also completed in the plan view.		
	2.1 Cast In Place Concrete		
		2.1.1 Wall_Cast-in-Place_AllFloors	The majority of these walls are present inside the stairwell towers and in the atrium, they are 200mm concrete walls with no insulation or steel studs on either side of the walls.
		2.3.1 Wall_Cast-in-Place_SteelStud_AllFloors	These walls are exclusively exterior walls. There is a 200mm thick cast in place concrete wall on the exterior followed by 89mm steel studs filled with batt insulation a sheet of poly and 15.9mm drywall. This wall type from all floors have been combined into this one category. The top floor is 3.4m and the other floors are 4.3m, to account for this with using a single input into the Impact Estimator, a weighted average to determine the floor height that should be used for the input. The Calculation is shown below: Total Height = [(linear meters of 3.4m wall)*3.4m + (linear meters of 4.3m wall)*4.3]/ (total linear meters) Total Height = (61.42*3.4 + 846.2*4.3) / (907.62) = 4.24 m

	2.2 Steel Stud		
		2.2.1 Wall_SteelStud_Ground Floor	The Steel Stud wall is an interior wall with 89mm studs and drywall on each side. No insulation was used. The window area was calculated by measuring the length from the plan view and multiplying by a hand measured window height during a site visit, the calculation is below: Window Area = Total Length * Measured Height = 52.22m * 1.07m = 55.71 m2
		2.2.2 Wall_SteelStud_Floor2	The Steel Stud wall is an interior wall with 89mm studs and drywall on each side. No insulation was used. The window area was calculated by measuring the length from the plan view and multiplying by a hand measured window height during a site visit, the calculation is below: Window Area = Total Length * Measured Height = 8.30m * 1.07m = 8.85 m2
		2.2.3 Wall_SteelStud_Floor3	The Steel Stud wall is an interior wall with 89mm studs and drywall on each side. No insulation was used. The window area was calculated by measuring the length from the plan view and multiplying by a hand measured window height during a site visit, the calculation is below: Window Area = Total Length * Measured Height = 16.69m * 1.07m = 17.80 m2
		2.2.4 Wall_SteelStud_Floor4	The Steel Stud wall is an interior wall with 89mm studs and drywall on each side. No insulation was used. The window area was calculated by measuring the length from the plan view and multiplying by a hand measured window height during a site visit, the calculation is below: Window Area = Total Length * Measured Height = 2.72m * 1.07m = 2.90 m2
		2.2.4 Wall_SteelStud_Penthouse	The Steel Stud wall is an interior wall with 89mm studs and drywall on each side. No insulation was used.
		2.3.2 Wall_SteelStud_Penthouse_Exterior	This steel stud wall has vertical metal cladding on horizontal grits. In addition there is two layers of exterior drywall with batt insulation in between. The height of this was taken as the floor to floor height plus the parapet in order to account for the additional wall above the roof.
	2.3 Concrete Block Wall		
		2.3.1 Wall_ConcBlock_SteelStud_ AllFloors	The Lock Block wall is located on the second floor at the east end of the building. No rebar was specified so 10M will be used for input into the impact estimator.
	2.4 Curtain Wall		
		2.4.1 Wall_Curtain_AllFloors	There is a curtain wall that is present in the atrium and extends up to the ceiling and connects into the skylight. The Skylight above the atrium was also modeled as a curtain wall, it is on an angle. The area of the curtain wall was measured from above, therefore the angle needed to be taken into account and the proper skylight area calculated as shown below. Skylight Area = sqrt((Projected Area)^2 + (Height)^2) = sqrt (299.64^2+4.117^2) = 299.67 m^2 The height and length are calculated by using the actual width of the curtain wall as the width, and the height is calculated accordingly as shown below. Width = 3.22 m Height = (Total Area)/(width) = (299.67 + 175.89)/(3.22) = 147.69
3 Columns and Beams			
	Concrete Strength of 25 Mpa was used, In Athena 30 Mpa was the closest input. No Fly ash concentration was specified, so average was used. The larger concrete beams are running in both directions between the columns, there are smaller concrete beams built into the floor slab spanning the larger beams. The beams were counted on each floor spanning the columns, the columns are spaced at 10m on center in both directions so each of the span and bay are measured at 10m. Note That all the columns are used for one floor below for accuracy, for this reason the first floor height is the height from the footing to the SOG and there are no columns needed for the penthouse walls. The live load was taken to be the standard for this type of building as 3.6 KPa, it was not specified in the building drawings.		
	3.1 Concrete Column and Beam		
		3.1.1 - Column_Concrete_Beam _GroundFloor	There are no beams on the first floor a 130mm SOG was used. The first floor of concrete columns and beams come directly up from the footings as a result they are shorter than the other floors. To find the height from the footing to the first floor a weighted average was used. There are no beams on the first floor a 130mm SOG was used. The calculations is shown below: First Floor Height = ∑[(First Floor Height* # of columns for this height)/(# of columns)] First Floor Height = 450*11/31 + 450*9/31 + 300*3/31 + 300*5/31 + 300*2/31 + 300*1/31 First Floor Height = 396.77 mm = 0.397 m

		3.1.1 - Column_Concrete_Beam_Floor2	The larger concrete beams are running in both directions between the columns, there are smaller concrete beams built into the floor slab spanning the larger beams. The beams were counted on each floor spanning the columns, the columns are spaced at 10m on center in both directions so each of the span and bay are measured at 10m.
		3.1.3 - Column_Concrete_Beam_Floor3	The larger concrete beams are running in both directions between the columns, there are smaller concrete beams built into the floor slab spanning the larger beams. The beams were counted on each floor spanning the columns, the columns are spaced at 10m on center in both directions so each of the span and bay are measured at 10m.
		3.1.1 - Column_Concrete_Beam_Floor4	The larger concrete beams are running in both directions between the columns, there are smaller concrete beams built into the floor slab spanning the larger beams. The beams were counted on each floor spanning the columns, the columns are spaced at 10m on center in both directions so each of the span and bay are measured at 10m.
		3.1.1 - Column_Concrete_Beam_Penthouse	The larger concrete beams are running in both directions between the columns, there are smaller concrete beams built into the floor slab spanning the larger beams. The beams were counted on each floor spanning the columns, the columns are spaced at 10m on center in both directions so each of the span and bay are measured at 10m.
4 Floors			
	4.1 Concrete Precast Double T		
		4.1.1 - Floor_PrecastDoubleT	The actual floor is constructed using larger beams running in both directions along the columns and smaller intermediate girders running between the beams. All of these beams are built into the floor slab. For this reason the Precast Double T floor slab was chosen to model the smaller beams between the larger beams running in both directions.
5 Roof			
	5.1 Concrete Precast Double T		
		5.1.1 - Roof_ConcretePrecastDoubleT_Main	The roof is built using the same construction as the floors, however, it has different overlay materials and rigid insulation. The actual roof is constructed using larger beams running in both directions along the columns and smaller intermediate girders running between the beams. All of these beams are built into the floor slab. For this reason the Precast Double T floor slab was chosen to model the smaller beams between the larger beams running in both directions.
	5.2 Open Web Steel Joist		
		5.2.1 - Roof_OpenWebSteelJoists_Penthouse	The roof was constructed using an open web steel joist which is the exact type of roofing structure that is used in the impact estimator.
6 Extra Basic Material			
	6.1 Concrete		
		6.1.1 ExtraBasicMaterial_Concrete	This concrete is a result of the roof parapet that surrounds all of the roofs of the buildings other than the penthouse. The volume calculation is shown below: Volume (m^3) = Length*Height*Thickness = 369.24 * 1.2 * 0.2 = 88.6176 m^3
	6.2 Steel		
		6.2.1 ExtraBasicMaterial_Steel	The Steel is a result of HSS Steel Sections which are seen in the atrium of the building holding up the skylight and also around the curtain wall for decoration. The diameter of the steel sections were measured by hand on a site visit, and found to be 250mm (10inch), while the wall thickness was assumed to be 12mm (1/2 inch) after researching standard thicknesses for a non structural HSS of the appropriate diameter. The weight calculation is below: Weight = Length*(X-section Area)*Density = 277.31 m * 0.00494 m^2 * 7.85 Tonnes/m^3 Weight = 110.75 tonnes
	6.3 Extra Cladding Material		
		6.2.1 ExtraBasicMaterial_ ExtraCladdingMaterial	The brick in the building is located primarily on the outside of the building however there is some located inside the building in the atrium. It is unclear if the brick is veneer, however there is no input for veneer brick in the impact estimator so normal "standard" brick is used.
	6.3 Extra Envelope Material		
		6.2.1 ExtraBasicMaterial_ExtraEnvelopeMaterial	The extra glass used is due to large single pane windows in the atrium. Because not all the sections were available to do takeoffs some additional amount of window area needed to be added. In addition only double pane windows are available, as a result the amount of window area for this calculation is divided by two to get a more accurate window area. The calculation is shown below: Total EBM window = Takeoff Area + Measured Area = 88.5m^2 + 7.36m^2 = 95.86 m^2 Total Standard Glazing used = 95.86 / 2 = 47.93 m^2