UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Life Cycle Assessment of the George F. Curtis Addition Building

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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.

CIVL 498C: Whole Building Life Cycle Assessment

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Final Report; Submitted for Rob Sianchuk

Amie Dawe
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Abstract

The George F Curtis Addition Building (Curtis Addition) was constructed in 1972 on the University of British Columbia and serves as an academic and office space for the UBC Faculty of Law and its students. A whole building life cycle assessment was conducted on the concrete 75,195 square foot building using structural and architectural drawings. A material quantity takeoff was performed using On Center's OnScreen Takeoff software, and the building was modeled in Athena's Impact Estimator (IE) to generate a bill of materials and summary measures.

The materials contributing most significantly to the building make-up are ballast, roofing asphalt, Type III glass felt, 5/8" gypsum board and #15 organic felt; mostly components of the built-up roof. Concrete and rebar comprise the majority of the structure's volume, and have the largest impact on the building's impact assessment profile, as determined by a sensitivity analysis. The Curtis Addition, when compared to the average UBC academic building, was found to have larger impacts in all category measures except for ozone depletion potential. The less environmentally-friendly building profile is most likely a result of the vast use of concrete and a built-up roof.

Energy models of the existing Curtis Addition building and an 'improved' version, based on REAP's minimum insulation standards, were created. Comparison of the models revealed an energy payback period of 1.5 years.

This life cycle assessment of the manufacturing and construction phases of the Curtis Addition Building enables quantification of its environmental impacts and showcases the broad applications of building LCAs.

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1.0 Introduction

This report presents a whole building life cycle assessment performed on the George F. Curtis Building Addition. The Curtis Addition, also commonly referred to as the Law Building, is located at 1822 East Mall on the University of British Columbia Campus. The original building was named after George F. Curtis, the first Dean and a UBC Law professor since 1945. The concrete addition was designed by architect Fred T. Hollingsworth and construction took place between 1972 and 1974. The structure cost $3,400,000 to erect and was funded with grants from the BC Government.

The Curtis Addition is a two story building with a basement, comprised of a three-floor library, one large lecture theatre, two floors of office-filled corridors, and a student interaction space. It serves as an office space for UBC Law faculty, an academic resource and quiet study area for UBC Law students, and a lecture space for both. The total interior floor space of the Curtis Addition is approximated to be 75,195 square feet.

The building is mostly poured concrete; the exterior components are concrete walls and several skylights. Interior walls are steel stud partitions, and are supported by a framework of concrete columns and beams. The floors and roof are all suspended concrete slabs, with the exception of the theatre, where the roof is a steel joist system. All roof surface area is built up with tar and gravel underlain by insulation. Please refer to Table 1: Curtis Addition Building System Characteristics below for a detailed breakdown of the general building system.

ASSEMBLY	DESCRIPTION
Structure	Concrete columns and beams supporting concrete suspended slabs
Floors	Basement: Concrete slab on grade First and Second Floors: Concrete suspended slabs
Exterior Walls	Basement: Cast in place walls First and Second Floors: Cast in place walls with strips of curtain wall (skylights and window walls with bronze tinted glazing) Note: The spandrel wall surrounding the library is insulated with 2” of fiberglass batt
Interior Walls	Variety of cast in place walls and steel stud walls with 5/8” gypsum board envelope
Windows	All windows and curtain walls are bronze tinted glazed
Roof	All roof area except for theatre: Concrete suspended slab Theatre roof: Steel joist system with 1.5” rigid insulation Entire Roof: Built-up with high degree melt tar and gravel (exception of small area covering two stair wells that is covered with neoprene hypalon)

Table 1: Curtis Addition Building System Characteristics

2.0 Goal and Scope

2.1 Goal of Study

This life cycle analysis (LCA) of the George F. Curtis Building Addition (Curtis Addition) at the University of British Columbia was carried out as an exploratory study to determine the environmental impact of its design. This LCA of the Curtis Addition 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 Curtis Addition. An exemplary application of these references are in the assessment of potential future performance upgrades to the structure and envelope of the Curtis Addition. 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 Curtis Addition 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 systems being studied in this LCA are the structure and envelope of the Curtis Addition 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 Curtis Addition, as well as associated transportation effects throughout.

2.2.1 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 Curtis Addition 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 Curtis Addition. As this study is a cradle-to-gate assessment, the expected service life of the Curtis Addition 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 Curtis Addition, 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 Curtis Addition. 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 Curtis Addition are the original architectural and structural drawings from when the building was initially constructed in 1974. 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 (i.e. doors and windows). The decision to omit other building components, such as flooring, electrical aspects, HVAC system, finishing and detailing, etc., are associated with the limitations of available data and the IE software, as well as to minimize the uncertainty of the model. 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.

3.0 Building Model

The Curtis Addition Building model was constructed using two major software programs; On Center OnScreen Takeoff and Athena's Impact Estimator (IE). The material quaintly takeoff was performed using OnScreen, and the quantities were input into the IE. The IE was then used to generate a bill of materials, summary measures and absolute value measures for the Curtis Addition Building. Challenges were encountered and many assumptions were made during the course of modeling the building, however all were thoroughly documented and are discussed in detail in the following section.

3.1 Takeoff

The material quantity takeoff was performed on the Curtis Addition Building using the OnScreen Takeoff software. The program is a tool that provides an interface for users to conduct and keep track of quantity takeoffs from structural and architectural drawings. It is an efficient and accurate was to perform takeoffs, with digital tools increasing the accuracy of recorded values.

The drawings for the Curtis Addition were imported into OnScreen in a .pdf file format. They were then rotated and scaled as appropriate. Three types of conditions were used to collect quantities; count conditions, linear conditions and area conditions. All quantities were recorded with one or more of the condition types and categorized into one of six assemblies; foundations, walls (including windows and doors), columns and beams, floors, roofs and extra basic materials. Each condition recorded was named using the standard format of *Assembly_Descriptor_Descriptor*. This was a very important step in the takeoff process, as common nomenclature enabled an easy transfer of data into the Impact Estimator. In addition, specific data required for inputs into the IE were recorded in the notes section of the OnScreen conditions.

Most takeoff conditions were separated according to common characteristics. For example, columns and beams were modeled separately for each floor of the building. To further demonstrate, cast in place walls were organized by thickness (8", 10" or 12") and envelope (none, gypsum on one side, gypsum on both sides, etc). This also made double checking the model, isolating errors and making amendments far easier to perform and track.

In general, different assembly takeoffs were documented on different drawings. The foundation assembly, which includes footings, slabs on grade and stairs, was mostly tracked on the *foundation plan*. The wall, window, door, floor and roof assemblies were recorded on the *floor plans* with some additional wall and window conditions accounted for on the *elevations*. The *wall assembly schedule* and *door schedule* both aided in determining detailed characteristics pertaining to the wall envelopes and doors, respectively. Lastly, the columns and beams were documented on the *floor framing plans*.

Although the OnScreen program significantly improved the quality and speed of the quantity takeoff, there were several challenges in using the program. Many of the .pdf files imported for the Curtis Addition Building were of poor quality. Even using the 'enhancing' and 'darkening' features in the software did not fully eliminate all grainy drawing portions or recover poorly scanned information. Much information was spread over numerous drawings, so flipping back and forth between them created room for error and modeling mistakes to be made. The secondary view window provided a way to minimize the probability of these consequences.

3.1.1 Foundations

The foundation assembly of the model consisted of slabs on grade, footings and stairs. All concrete was specified and modeled as 4000 psi strength. No flyash content was defined in the building drawings, so an average content was used.

The slabs on grade were modeled as area conditions and all converted to a thickness of 8" to ensure compatible inputs for the Impact Estimator. The footings were either strip of square footings and were all modeled using linear conditions and count conditions, respectively. In order to facilitate data input into the IE, all footings were converted to an equivalent length of strip footing. This allowed several OnScreen conditions to be aggregated into fewer IE input conditions. The stair takeoffs were an amalgamation of area conditions multiplied by widths and were also modeled as an equivalent strip footing. This enabled the rebar within the stairs to be accounted for in the model. Some rebar specifications for footings and stairs were not available as modeling choices in the IE, and had to be modeled incorrectly.

3.1.2 Walls

The wall assembly consisted of cast in place walls, steel stud walls and curtain walls. All interior walls were modeled as linear conditions, and the exterior walls were modeled as a combination of linear and area conditions (this depended on which drawing the conditions were tracked on). Wall conditions were separated by floor, type and thickness. All cast in place walls were converted to either 8" or 12" thickness to ensure compatible inputs for the Impact Estimator. Again, all concrete was specified and modeled as 4000 psi strength. No flyash content was defined in the building drawings, so an average content was used. Some rebar specifications were not available in the IE, and had to be modeled incorrectly. The steel stud walls were modeled as 1 5/8 x 3 5/8, as stated in a previous report done on the Curtis Addition Building (Aloisio). No sheathing type or stud spacing were specified in the drawings, so a common spacing of 24 inches on center was assumed. A light stud weight of 25 gauge was assumed due to the interior nature of the partition walls.

Wall envelopes either did not exist (many of the poured concrete walls), or were specified as gypsum board. The earlier referenced report on the Curtis Addition Building also specified 5/8" thick gypsum board, so the same assumption was used (Aloisio).

All curtain wall windows and skylights were specified as single pane bronze tinted glazed windows. However, the IE does not provide the option to model that information; the IE curtain wall condition is predefined as a double pane system with standard glazing. The percent viewable glazing on all curtain walls was estimated from the architectural drawings. These are source of inaccuracy in the building model. As with the curtain walls, all windows were noted as bronze tinted glazed, but have been modeled as standard glazing, as bronze tinted glaze in not a provided model choice. Windows were accounted for using a count condition and area condition, ensuring to gather all necessary data for the IE inputs.

Doors were modeled using count conditions and were easy to takeoff due to the detailed door schedule. Some wall conditions inevitably had more than one door type; however, the IE only allows one door type per wall condition. In this case, the most common door within that specific wall type was chosen to represent all of the doors.

3.1.3 Columns and Beams

The columns and beams assembly was very simple to takeoff and enter into the IE. The conditions were separated by floor, and accounted for using count conditions. The area of supported floor was also measured using an area condition. The supported floor area and number of columns was then used to calculate an equivalent supported span and bay size for the IE inputs. Live loads were specified as 75, 100 and 150 psf, but were all modeled as 100 psf due to IE input limitations.

3.1.4 Floors

Floors were documented in the takeoff using area conditions, measured to the inside edge of the walls. All floors were concrete suspended slab and as before, all concrete was specified and modeled as 4000 psi strength. No flyash content was defined in the building drawings, so an average content was used. As with the columns and beams assembly, design live loads were specified as 75, 100 and 150 psf, but were modeled as 100 psf due to IE input limitations. Appropriate floor spans and widths were calculated to ensure the values fit within the ranges specified in the Impact Estimator.

3.1.5 Roofs

Most of the roof was concrete suspended slab, and the same modeling techniques and assumptions were made as with the concrete suspended slab floors. One part of the roof was observed to be a steel joist roofing system, which was modeled with few assumptions and some additional extra basic materials to account for the steel decking and large steel beams. Some of the roof areas were sloped, and calculations were performed to ensure the correct roof area was computed from the areas captured on the bird's eye view plans. Additionally the Curtis Addition boasts a built-up roof assembly; a layering of high-degree-melt tar and gravel atop the concrete slab and steel joist system. This was modeled as an inverted 4-ply asphalt roofing system, as it most closely resembled the actual roofing material. Underlying insulation was also accounted for.

3.1.6 Extra Basic Materials

A few remaining materials that did not fall into the main five assemblies were modeled here. This includes extra concrete topping on concrete floor slabs, steel decking and large steel beams, miscellaneous insulation, and window portions of the trellis feature. The concrete topping, steel decking, insulation and trellis glazing were all recorded using area conditions. They were easily converted into necessary units for the IE inputs. The extra steel beams were modeled using linear conditions, as beam properties per linear foot were used to calculate final values.

All of the quantity takeoff values were formatted and entered into the Impact Estimator. A detailed breakdown of these inputs can be found in Annex A: IE Inputs Document. The actual alterations, calculations and assumptions for each input can be referred to in Annex B: IE Input Assumptions Document.

3.2 Bill of Materials

All of the material quantities measured during the takeoff were then input into the Impact Estimator and a summarized list of materials was generated. This list, or bill of materials, is presented in

Table 2: Bill of Materials for the Curtis Addition Building, below. Note all values expressed are in metric units for project comparison and consistency purposes.

Material	Quantity	Unit
Ballast (aggregate stone)	61906.502	kg
Roofing Asphalt	39665.348	kg
Type III Glass Felt	13442.883	m2
5/8" Regular Gypsum Board	8937.0811	m2
#15 Organic Felt	6721.4413	m2
Concrete 30 MPa (flyash av)	5210.5714	m3
Extruded Polystyrene	4658.5092	m2 (25mm)
Batt. Fiberglass	1201.998	m2 (25mm)
6 mil Polyethylene	440.5254	m2
Softwood Plywood	419.9221	m2 (9mm)
Rebar, Rod, Light Sections	275.7429	Tonnes
EPDM membrane	163.1503	kg
Wide Flange Sections	141.7024	Tonnes
Galvanized Decking	127.0998	Tonnes
Standard Glazing	86.607	m2
Polyethylene Filter Fabric	54.3288	Tonnes
5/8" Fire-Rated Type X Gypsum Board	42.4443	m2
Water Based Latex Paint	35.7273	L
Glazing Panel	33.0513	Tonnes
Aluminum	12.9882	Tonnes
Galvanized Studs	10.6444	Tonnes
Joint Compound	8.9617	Tonnes
Small Dimension Softwood Lumber, kiln-dried	4.1861	m3
Galvanized Sheet	4.0585	Tonnes
Nails	1.9998	Tonnes
Solvent Based Alkyd Paint	1.4739	L
Welded Wire Mesh / Ladder Wire	1.2044	Tonnes
Screws Nuts & Bolts	0.7045	Tonnes
Paper Tape	0.1029	Tonnes

Table 2: Bill of Materials for the Curtis Addition Building

The bill of materials is sorted by quantity from largest to smallest. It can be seen the five largest materials by sheer value are ballast stone, roofing asphalt, Type III glass felt, 5/8" gypsum board and #15 organic felt. All five materials, with the exception of the gypsum board, are part of the roof assembly; they represent the built up roof covering the Curtis Addition. When input into Athena, an inverted 4-ply built up asphalt roofing system was used. Extruded polystyrene and glass felt were selected to represent the specified 1.5 inches of rigid insulation. The 4-ply asphalt system clearly dictated the output on the bill of materials, but most likely properly accounted for the actual amount of material used in the roof. The gypsum board comes from the interior steel stud walls, most of which had an envelope of 5/8" thick gypsum on one or two sides.

Exploring further down the list, 30MPa concrete, rebar and extruded polystyrene are also demonstrated as large contributors to the building's bill of materials. The extruded polystyrene is again a roofing component, and was entered into the IE as part of the roofing insulation, as mentioned above. The concrete and rebar however, are stand alone. This result is expected, as most of the building structure is comprised of reinforced concrete; slabs on grade, suspended floor and roof slabs, columns and beams and cast in place walls. The slabs and walls were modeled fairly accurately, as the IE allowed the input of specific component dimensions. However, notable uncertainty arises from the columns and beams. In the Impact Estimator, load designations and supported floor spans are input, and the necessary size of beams and columns is computed within the program. If the Curtis Addition maintained any redundant design or purposeful excess column sizing, this would not be captured in the IE model. If any discrepancies exist, the generated bill of materials may present an underestimate of the amount of concrete in the actual building. It should be noted this also applies to the value output for the rebar, rod and light sections. This is because the columns and beams contain rebar and hence represent part of the rebar value in the bill of materials.

4.0 Summary Measures

The most useful outputs from the Curtis Addition IE model for the whole building LCA are the summary measures. The Impact Estimator calculates the building impact in eight different predefined categories: primary energy consumption (in MJ), weighted resource use (in kg), global warming potential (in kg of CO_2 equivalents), acidification potential (in moles of H+ equivalents), human health respiratory effects potential (in kg of PM2.5 equivalents), eutrophication potential (in kg of N equivalents), ozone depletion potential (in kg of CFC-11 equivalents) and smog potential (in kg of NO_x equivalents). The impacts are tabulated for each building life cycle stage. The scope of this project focuses on the raw material extraction, manufacturing and construction phases of the building's life cycle. The table below shows a summary of the Curtis Addition's impact assessment for each category, separated by life cycle stage. The impact per square foot of building floor space has been calculated (using a total area of 75,195 ft^2) and is also displayed.

Curtis Addition	Manufacturing			Construction			Total Effects	Total Effects per sq. ft.
	Material	Transportation	**Total**	Material	Transportation	**Total**		
Primary Energy Consumption MJ	2.69E+07	6.05E+05	**2.75E+07**	8.91E+05	1.87E+06	**2.76E+06**	**3.30E+07**	**439.39**
Weighted Resource Use kg	1.56E+07	4.05E+02	**1.56E+07**	2.06E+04	1.10E+03	**2.17E+04**	**1.56E+07**	**207.89**
Global Warming Potential (kg CO2 eq)	2.41E+06	1.06E+03	**2.42E+06**	6.06E+04	3.01E+03	**6.36E+04**	**2.54E+06**	**33.81**
Acidification Potential (moles of H+ eq)	9.10E+05	3.65E+02	**9.11E+05**	2.98E+04	9.78E+02	**3.07E+04**	**9.72E+05**	**12.93**
HH Respiratory Effects Potential (kg PM2.5 eq)	7.00E+03	4.40E-01	**7.01E+03**	3.34E+01	1.18E+00	**3.45E+01**	**7.07E+03**	**0.09**
Eutrophication Potential (kg N eq)	1.02E+03	3.80E-01	**1.02E+03**	2.94E+01	1.01E+00	**3.04E+01**	**1.08E+03**	**0.01**
Ozone Depletion Potential (kg CFC-11 eq)	3.19E-03	4.37E-08	**3.19E-03**	2.57E-11	1.23E-07	**1.23E-07**	**3.19E-03**	**4.24E-08**
Smog Potential (kg NOx eq)	1.06E+04	8.23E+00	**1.06E+04**	7.30E+02	2.19E+01	**7.52E+02**	**1.21E+04**	**0.16**

Table 3: Impact Assessment Summary for the Curtis Addition Building

Each of the eight impact categories measures a unique and very important effect the building potentially has on the environment. It should be noted from the above table that the manufacturing life cycle stage of the Curtis Addition building contributes significantly more towards each impact category than the construction life cycle stage of the building. This is a logical outcome, as there are typically more processes involved in resource extraction and manufacturing versus construction. Each impact category is outlined in further detail below.

4.1 Primary Energy Consumption

The primary energy consumption is measured in mega joules and refers to the energy used in all processes used to transform or transport raw materials involved in the building's life cycle stages. It essentially represents the embodied energy, accounting for direct and indirect energy embedded within the processes.

4.2 Weighted Resource Use

The weighted resource use refers to the resources used in each life cycle stage and is measured in kilograms. The weighting reflects a valuation of the ecological carrying capacity effects of extracting the necessary resources. The ecological carrying capacity is based on categories such as soil stability and regenerative capacity, ground and surface water quality, resource extraction of biodiversity and wildlife habitat.

4.3 Global Warming Potential

The global warming potential is measured in kg of CO_2 equivalents; it attempts to quantify the amount of global warming that will result from the increased amount of CO_2 released into the atmosphere during the building's life cycle. Converting released emissions to CO_2 equivalents enables the estimation of how much capacity to absorb infrared radiation is lost. This loss of capacity results in a heated atmosphere, hence potentially contributing to global warming.

4.4 Acidification Potential

The acidification potential is computed based on moles of H+ equivalents released through the life cycle of the building. This correlates to the potential acidification effects due to the increased concentration of acidifying H+ ions in the surrounding environment. This potentially increases the acidity of water and soil systems which in turn damages forests, leaches soils, affects fish mortality, etc.

4.5 Human Health Respiratory Effects Potential

The equivalent kilograms of particulate matter sized less than 2.5 microns in diameter are estimated to quantify the potential impact on human health respiratory effects. Particulate matter is proven to be extremely hazardous to the human body, as it can stay in the air for weeks. Surrounding populations breathe it in, and the particulate matter enters the body via the lungs. It proceeds to contribute to, enhance and cause a plethora of health problems.

4.6 Eutrophication Potential

The eutrophication potential is measured by equivalent kilograms of nitrogen. Released nitrogen during the building's life cycle stages can reach aquatic environments and can potentially promote algae growth in nutrient deficient surface waters. The probability of emissions being transported to susceptible aquatic environments is taken into account.

4.7 Ozone Depletion Potential

The ozone depletion potential is quantified by measuring the equivalent kilograms of CFC-11 emissions released through the building's life cycle stages. The CFC-11 pollutants alter the stratospheric ozone column, essentially depleting the ozone layer. The Curtis Addition IE model demonstrates a very minor impact in this category compared to the other seven.

4.8 Photochemical Smog Potential

This impact category evaluates the amount of potential smog forming substances released during the building's life cycle. Equivalent kilograms of NO_x are how the emissions are correlated to the potential amount of ozone formed photochemically. These changes occur and make an impact in the tropospheric ozone concentrations.

These impact categories are an important way to organize the summary measures of the Curtis Addition Building and its life cycle stages. However, the table presented above merely provides values, and no basis for comparison. To enhance the usefulness of the summary measures, the impacts from the Curtis Addition Building have been compared to the average academic building on the UBC campus. Please see below for the associated table and visual representation.

	Average	Curtis Addition	% Difference
Primary Energy Consumption MJ	240.49	439.39	82.7%
Weighted Resource Use kg	145.81	207.89	42.6%
Global Warming Potential (kg CO2 eq)	21.07	33.81	60.5%
Acidification Potential (moles of H+ eq)	8.95	12.93	44.5%
HH Respiratory Effects Potential (kg PM2.5 eq)	0.07	0.09	33.7%
Eutrophication Potential (kg N eq)	0.01	0.01	84.8%
Ozone Depletion Potential (kg CFC-11 eq)	0.00	0.00	-22.9%
Smog Potential (kg NOx eq)	0.10	0.16	58.5%

Table 4: Normalized Impact Category Summary Measures

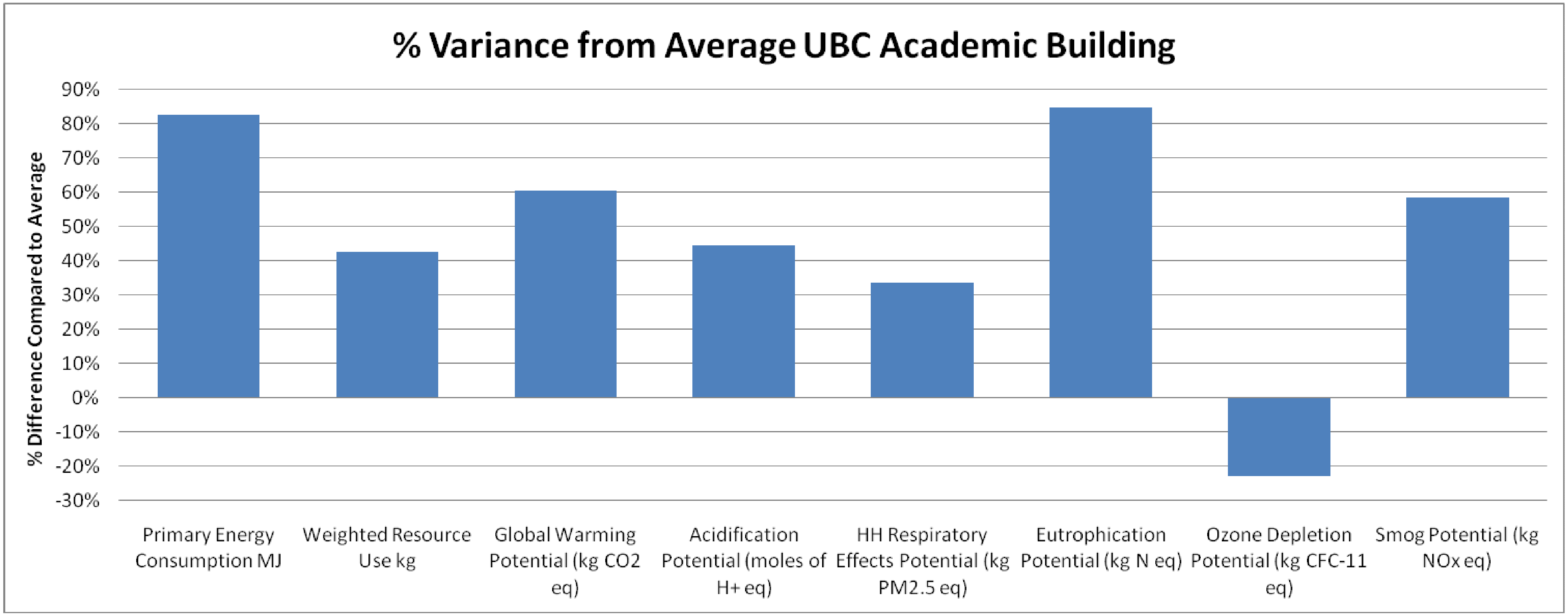

Figure 1: Impacts by Category, Normalized to an Average UBC Academic Building

4.9 Limitations and Uncertainties

Although the IE program utilized is capable of generating convenient summary measures, all results should be applied with caution and doubled with an understanding of their limitations. Uncertainties are present within the life cycle inventory (LCI) databases and in the life cycle impact assessment (LCIA) procedures. Uncertainty is present within the data contained in both the LCI database and the data used in the LCIA. Temporal and spatial variability also give rise to several uncertainties within the LCI data and LCIA processes. Temporal variability refers to the changes that occur over time (affecting LCI data), and how emissions and impacts are measured and interpreted through time and over defined time periods (in LCIA). Spatial variability refers to the difference in data between regions (affecting LCI data) and the difference in environmental sensitivity from region to region (affecting LCIA). How the emissions are assumed to be distributed is also a LCIA spatial uncertainty. Finally, there is variability in production technologies (affecting LCI data) and human exposure patterns (affecting the LCIA process).

4.10 Sensitivity Analysis

The summary measures can also be utilized to conduct a sensitivity analysis. Five materials were chosen from the Curtis Addition bill of materials (Table 2: Bill of Materials for the Curtis Addition Building) and were individually increased by 10% in the IE model. The adjusted models were then compared to the original Curtis Addition model and percentage differences were calculated. These percentages can be applied on a linear basis, i.e. the percentage difference corresponding to a 10% increase is the same absolute value for a 10% decrease. The tabulated results are depicted in the figure on the following page.

It can be observed that altering the volume of concrete in the building had the largest affect on the building's environmental impact assessment profile. The rebar, rod and light sections had the next largest impact, followed by the roofing asphalt. The gypsum board and extruded polystyrene had very minimal impact on the summary measures when compared to the current model. It should also be noted that all impact categories were affected by less than 10% from a 10% change; this is indicative of the magnitude of impact material design decisions would have on the building's environmental impact profile.

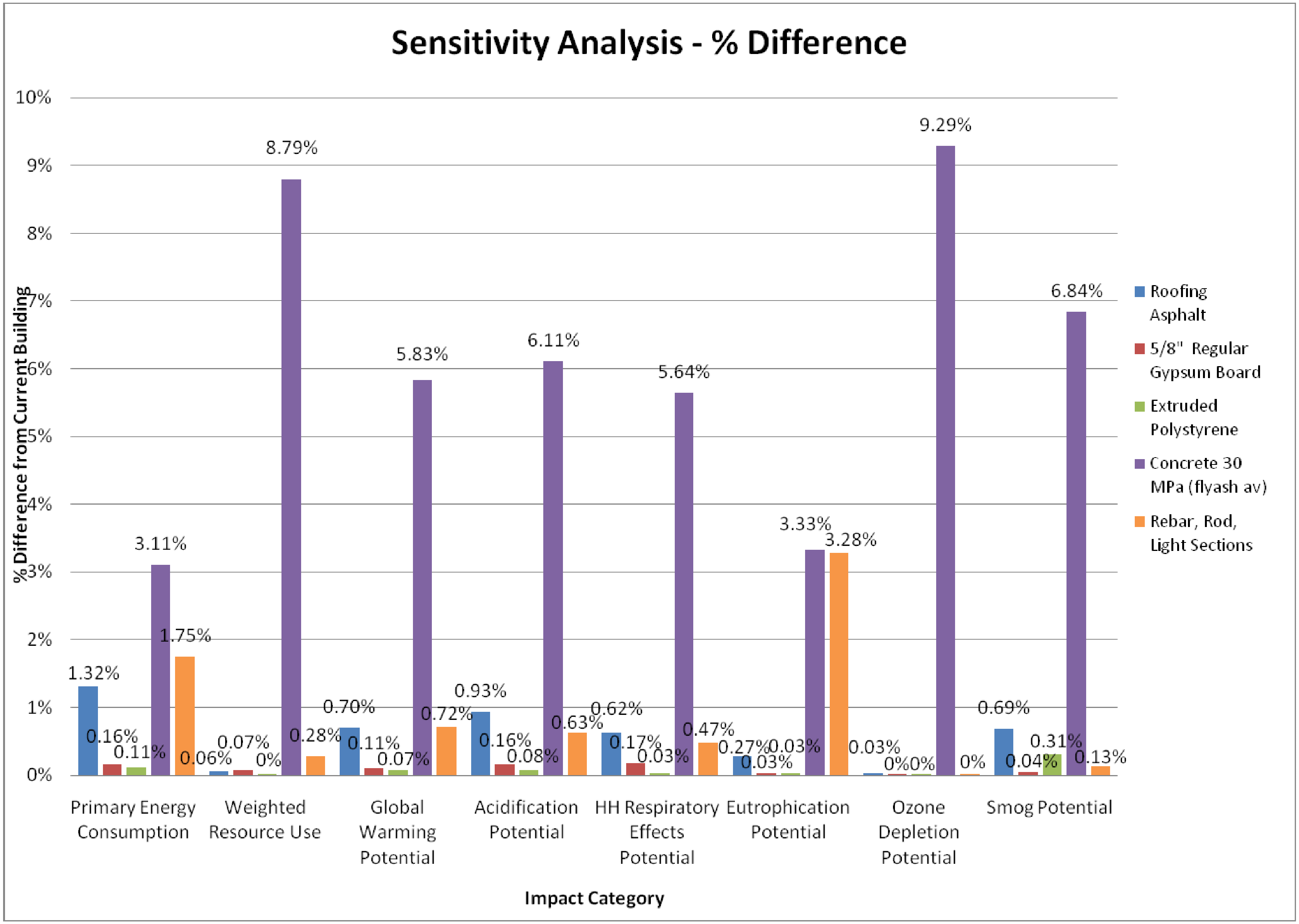

Figure 2: Sensitivity of Select Materials to the Curtis Addition Impact Assessment Profile

As seen here, a sensitivity analysis is useful in determining the affect certain materials will have on the summary measures of a building. Sensitivity analyses can be performed easily during the design phase or major renovation stage of a building, providing appropriate estimates for materials that will heavily weight the building's impact on the environment, and also those that will have little effect on the building's LCIA profile. This can then be applied to decisions surrounding the choice of materials used to construct or renovate the building, resulting in solutions with a lower environmental impact.

5.0 Building Performance

The building performance of the Curtis Addition can be expressed through embodied energy and required operating energy. The embodied energy refers to the energy used in creating the building, and depends on the type and amounts of materials used. The energy necessary to operate the building can be roughly determined by the amount of heat loss experienced over time. This is dictated by the properties of the exterior assemblies; specifically materials of the exterior walls and roof, windows and any insulation currently in place.

The assemblies that contribute to the Curtis Addition's operating energy demand were designed and constructed almost forty years ago, and there are several remediation opportunities to improve the building's performance. The exterior walls of the Curtis Addition building are made of poured concrete, which has little to no thermal retention capacity. Most heat is kept in the building with the use of insulation on the walls; of which very little is present in the current building. Some exterior walls have a 5/8" thick gypsum board envelope on the interior, and the main spandrel wall surrounding the library has 2" of fiberglass batt insulation. Due to the minimal amount of insulation present in the building, a practical solution to improve the amount of energy retained is to add more insulation. Another building component that facilitates heat loss is the windows. Much of the Curtis Addition is windows and skylights; they are all single pane windows with bronze tinted glaze. Double pane windows filled with argon and with silver or tin glazing can significantly improve the insulating properties of windows. The last major building component that contributes to energy loss is the roof. The roof provides a significant portion of the building surface area exposed to the outside air where lower temperatures are present. The Curtis Addition roof is mostly a 3.5" thick concrete suspended slab, with the exception of the steel joist roof system spanning the theatre, which contains ½" thick plywood sheathing. The entire roof is covered by a built-up tar and gravel system, underlain by a 1.5" thick layer of extruded polystyrene or rigid fiberglass. As with the walls, a great way to reduce heat loss through the roof is to add insulation.

5.1 Performance Model Concept and Calculations

The performance of the Curtis Addition has been assessed from an embodied energy and operating energy standpoint. The embodied energy for the current building was obtained from the summary measures output by the Athena model. The primary energy use impact category was selected to represent this value. The operating energy demand was estimated by calculating the approximate heat loss the building experiences on an annual basis.

The heat loss through the exterior assemblies of the building was estimated using the following thermodynamics equation:

$$Q = \frac{1}{R} \cdot A \cdot \Delta T$$ *[Equation 1]*

Where,

R = Calculated R-Value ($ft^2 \cdot °F \cdot hr/BTU$)

A = Assembly of interest (ft^2)

ΔT = Inside Temperature – Outside Temperature (°F)

One R-value for the entire building was calculated using a weighted average of the R-values for each assembly; exterior walls, windows and the roof. The R-value for the exterior walls was also computed using a weighted average. The areas for different wall conditions were extracted from the OnScreen Takeoff model, and assigned appropriately sourced average R-values. All exterior walls in the Curtis Addition are poured concrete, so an R-value of 0.08 multiplied by the thickness of the cast in place wall was used. Any interior 5/8" gypsum board was also accounted for by adding 0.56. The temperature difference between the interior of the building and the outside environment was computed on a monthly basis using historical average temperatures. The heat loss obtained using *Equation 1* was then converted from BTU/hour to Joules/month, and summed to find the annual heat loss experienced by the building.

An 'improved' building was then modeled in the IE using the above mentioned remediation techniques. Extra insulation was added on the walls and roof and windows were replaced with more energy savvy materials. The amount of insulation added was determined by using the minimum insulation requirements outlined by the Residential Environmental Assessment Program (REAP). Using the determined target R-values, a thickness of insulation was back calculated using the goal seek analysis function in Microsoft Excel. Below is a table summarizing the assembly areas and corresponding R-values used in *Equation 1* calculations:

Building Assembly	Total Area (ft^2)	R-Value (ft^2·°F·hr/BTU)		
		'Current' Building	Target	'Improved' Building
Exterior Wall	46090.33	1.39	18	19.05
Window	215	0.91	3.2	3.75
Roof	33376.75	8.97	40	41.72
Weighted Average	79682.08	4.56	27.18	28.51

Table 5: Summary Areas and R-Values for Curtis Addition Building Performance Model

To meet REAP's minimum insulation standards, the following alterations were made to the model; 3.5" of extruded polystyrene insulation was added to exterior walls, 6.5" of extruded polystyrene insulation was added to the roof, and all windows were replaced with low E silver glazed argon filled double panes. The following table summarizes the embodied energy obtained from the Athena model (primary energy use measured in manufacturing and construction life cycle stages) and the calculated operating energy for both building models:

	'Current' Building	'Improved' Building
Embodied Energy (MJ)	30281736.37	33964448.91
Operating Energy (MJ/year)	2,898,096.93	464,014.69

Table 6: Total Energy for Current and Improved Curtis Addition Building Performance Models

5.2 Performance Model Results and Interpretation

The model results presented in Table 6: Total Energy for Current and Improved Curtis Addition Building Performance Models were then extrapolated over several years to determine the energy payback period. The following graph compares the energy use, or heat loss, of both building models over 80 years. The embodied energy is taken into account at Year 0.

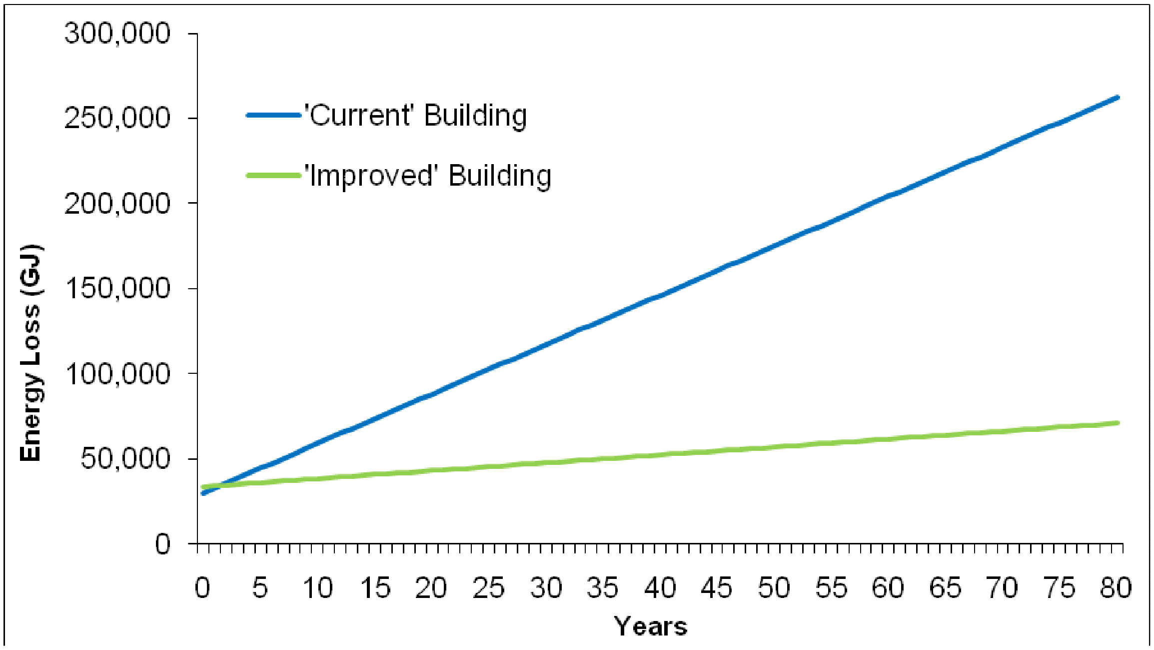

Figure 3: Energy Usages for 'Current' and 'Improved' Curtis Addition Building Models

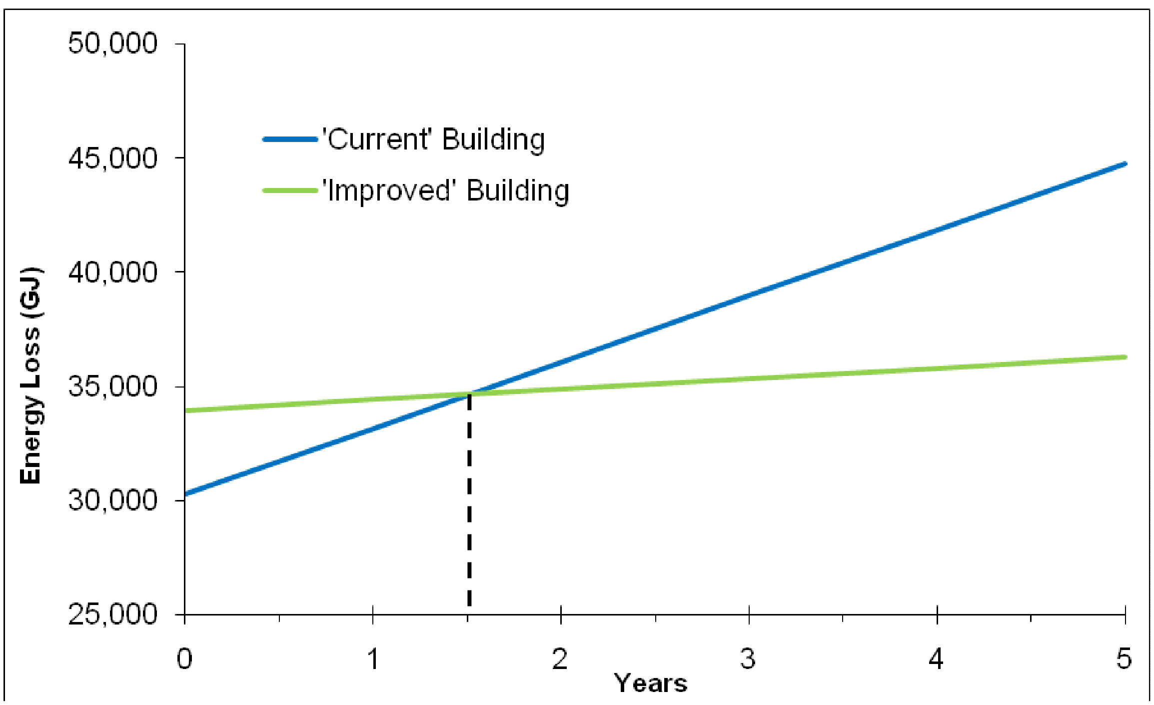

Figure 4: Energy Payback Period for 'Improved' Curtis Addition Building

It can be observed from Figure 4: Energy Payback Period for 'Improved' Curtis Addition Building that it would take approximately one and a half years for energy savings from heat loss remediation to outweigh the initial additional embodied energy of the building due to the extra renovation materials and processes themselves.

The models provide a very rough but useful estimate for assessing the practicality of going forward with renovations to improve building performance. However, there are notable inaccuracies within the model. The major flaw stems from the window assembly; the majority of windows and skylights in the Curtis Addition were modeled as curtain walls in the IE. The Impact Estimator assumes all curtain walls to be double glazed unit with two 6mm panes, though the actual windows in the Curtis Addition are single pane. Therefore, the 'Current' Building Model overestimates the embodied energy (accounts for more glass than is actually present) and the 'Improved' Building Model potentially underestimates the embodied energy (low E silver glaze and argon filling are not able to be specified). This would increase the payback period, as the embodied energies for the building models would be farther apart on the graph from Year 0, taking longer to intersect. Another uncertainty is that variability in occupant behavior; building users leaving windows open or cranking up the thermostat will affect the annual operating energy demand.

However, understanding the application of these results is key to fully utilizing the analysis. Different insulation materials could be explored, and the logistics of implementing each into the existing building must be considered. For example, to add extruded polystyrene onto the walls would require removing and/or replacing gypsum envelopes to cover the insulation. Upgrading the windows would require replacement, which is associated with larger environmental impacts than depicted in this model. As a final note, although the energy payback period demonstrates a means to improve building performance, the financial payback period may not. Implementing new materials to improve building performance measures may not be feasible.

6.0 Conclusions

The building life cycle assessment conducted on the Curtis Addition Building has thoroughly integrated a real building example with the LCA process to demonstrate the applicability and usefulness of life cycle analysis.

A quantity takeoff of the Curtis Addition Building was performed using OnScreen Takeoff software, and a bill of materials was generated using Athena's Impact Estimator. The five materials of greatest quantity were found to be ballast aggregate stone, roofing asphalt, Type III glass felt, 5/8" gypsum board and #15 organic felt. All materials, excluding the gypsum board, are components of the built-up roof assembly. Concrete and rebar were also found to comprise a majority of the material in the building, which is logical considering the building is a concrete structure. Uncertainty in the bill of materials generated from the IE can be attributed to most assumptions made during the modeling process; however, enough data about the building was available through the drawings to avoid any assumptions that would significantly skew the results.

Modeling the building in the IE also allowed summary measures to be generated. Compared to an average UBC academic building, the manufacturing and construction of the Curtis Addition had a notably larger impact on the environment in the following categories; primary energy consumption, weighted resource use, global warming potential, acidification potential, human health respiratory effects potential, eutrophication potential and smog potential. The only impact category where the Curtis Addition demonstrated a lower value than the average UBC academic building was in the ozone depletion potential category. Uncertainty in the impact assessment profile of the Curtis Addition building should also be recognized. Most sources are due to the temporal and spatial variabilities in the LCI databases and LCIA process. A sensitivity analysis was also performed with five different materials. The effect of increasing roofing asphalt, 5/8" gypsum board, extruded polystyrene, 30 MPa concrete and rebar, rods and light sections individually by 10% were all compared. The amount of concrete had the greatest affect on the building's overall environmental impact profile.

An approximate energy model of the Curtis Addition was also computed. Embodied energy was represented as the primary energy use, and the annual operational energy demand was approximated as the annual heat loss experienced by the building. An 'improved' building model was also generated, and heat loss remediation renovations were applied to meet REAP's minimum insulation standards. Extruded polystyrene insulation was added to the exterior walls and roof areas and all existing windows were replaced with silver glazed argon filled windows. Comparing the two energy models, an energy payback period of 1.5 years was calculated. This is an non-conservative result, as the actual energy payback period is likely longer. No financial, social or economical implications were considered; a decision regarding renovations would be dependent on further exploration of these variables. However, the applicability of LCA to a straight forward energy model showcased the usefulness of the process.

Now that the manufacturing and construction life cycle stages of the Curtis Addition Building have been thoroughly explored, it would be beneficial to expand the scope of this study to encompass the operation and maintenance phases. Operational energy data could be collected and even be used to increase the accuracy of the current energy model. More research and a cost-benefit analysis of potential renovations could also be explored. A unique circumstance regarding the Curtis Addition building could also be capitalized on; the actual structure is currently being demolished and rebuilt, and it would be of interest to model the decommissioning and end-of-life building phases. This data would be ideal for comparison purposes, and provide much insight into to uncertainties of the building LCA process.

7.0 References

Athena Sustainable Materials Institute. Overview of the Impact Estimator for Buildings. Website updated February 18th 2010. http://www.athenasmi.org/tools/impactEstimator/index.html

Aloisio, Allison. “Renewing” UBC Renew: Building Full Cost Assessment into Renovate vs. Rebuild Decisions at UBC. October 16th, 2006. UBC School of Community and Regional Planning.

Aloisio, Allison. Renovating the G.F Curtis Building: A Triple Bottom Line Assessment. March 13th, 2006. UBC School of Community and Regional Planning.

Colorado Emery. R-Value Table. Website updated July 29th, 2008. http://www.coloradoenergy.org/procorner/stuff/r-values.htm

Thompson, Berwick, Pratt. *UBC Reports* vol.19, No.10.

8.0 Annex A: IE Input Document

Assembly Group	Assembly Type	Assembly Name	Input Fields	Input Values	
				Known/Measured	EIE Inputs
1 Foundation					
	1.1 Concrete Slab-on-Grade				
		1.1.1 SOG_5"			
			Length (ft)	various	90.405
			Width (ft)	various	90.405
			Thickness (in)	5	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
		1.1.2 SOG_6"			
			Length (ft)	various	49.553
			Width (ft)	various	49.553
			Thickness (in)	6	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
		1.1.3 SOG_Theatre			
			Length (ft)	various	60.369
			Width (ft)	various	60.369
			Thickness (in)	various	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
		1.1.4 SOG_10"			
			Length (ft)	various	8.588
			Width (ft)	various	8.588
			Thickness (in)	10	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
	1.2 Concrete Footings				
		1.2.1 Footing_Strip_16"x10"			
			Length (ft)	502.00	502.00
			Width (ft)	1.333	1.333
			Thickness (in)	0.833	10
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.2 Footing_Strip_16"x16"			
			Length (ft)	6.00	6.00
			Width (ft)	1.333	1.333
			Thickness (in)	1.333	16
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.3 Footing_Strip_18"x10"			

		Length (ft)	275.00	275.00
		Width (ft)	1.500	1.500
		Thickness (in)	0.833	10
		Concrete (psi)	4000	4000
		Concrete flyash %	-	average
		Rebar	#4	#4
		1.2.4 Footing_Strip_20"x10"		
		Length (ft)	498.00	498.00
		Width (ft)	1.667	1.667
		Thickness (in)	0.833	10
		Concrete (psi)	4000	4000
		Concrete flyash %	-	average
		Rebar	#4	#4
		1.2.5 Footing_Strip_24"x10"		
		Length (ft)	10.00	10.00
		Width (ft)	2.000	2.000
		Thickness (in)	0.833	10
		Concrete (psi)	4000	4000
		Concrete flyash %	-	average
		Rebar	#4	#4
		1.2.6 Footing_Strip_24"x16"		
		Length (ft)	53.00	53.00
		Width (ft)	2.000	2.000
		Thickness (in)	1.333	16
		Concrete (psi)	4000	4000
		Concrete flyash %	-	average
		Rebar	#4	#4
		1.2.7 Footing_Strip_30"x10"		
		Length (ft)	34.00	34.00
		Width (ft)	2.500	2.500
		Thickness (in)	0.833	10
		Concrete (psi)	4000	4000
		Concrete flyash %	-	average
		Rebar	#4	#4
		1.2.8 Footing_Strip_32"x10"		
		Length (ft)	16.00	16.00
		Width (ft)	2.667	2.667
		Thickness (in)	0.833	10
		Concrete (psi)	4000	4000
		Concrete flyash %	-	average
		Rebar	#4	#4
		1.2.9 Footing_Strip_3'0"x16"		
		Length (ft)	22.00	22.00
		Width (ft)	3.000	3.000
		Thickness (in)	1.333	16
		Concrete (psi)	4000	4000
		Concrete flyash %	-	average
		Rebar	#4 & #5	#5

1.2.10 Footing_Strip_3'6"x16"			
	Length (ft)	150.00	150.00
	Width (ft)	3.500	3.500
	Thickness (in)	1.333	16
	Concrete (psi)	4000	4000
	Concrete flyash %	-	average
	Rebar	#4 & #5	#5
1.2.11 Footing_Strip_4'0"x16"			
	Length (ft)	160.00	160.00
	Width (ft)	4.000	4.000
	Thickness (in)	1.333	16
	Concrete (psi)	4000	4000
	Concrete flyash %	-	average
	Rebar	#4 & #5	#5
1.2.12 Footing_Strip_7'0"x16"			
	Length (ft)	48.00	48.00
	Width (ft)	7.000	7.000
	Thickness (in)	1.333	16
	Concrete (psi)	4000	4000
	Concrete flyash %	-	average
	Rebar	#7 & #9	#6
1.2.13 Footing_Square_3'0"x10"			
	Length (ft)	various	2185.47
	Width (ft)	various	3.000
	Thickness (in)	various	10
	Concrete (psi)	4000	4000
	Concrete flyash %	-	average
	Rebar	#8	#6
1.2.14 Footing_Square_4'0"x15"			
	Length (ft)	52.00	52.00
	Width (ft)	4.000	4.000
	Thickness (in)	1.250	15
	Concrete (psi)	4000	4000
	Concrete flyash %	-	average
	Rebar	#5	#5
1.2.15 Footing_Square_4'0"x16"			
	Length (ft)	4.00	4.00
	Width (ft)	4.000	4.000
	Thickness (in)	1.333	16
	Concrete (psi)	4000	4000
	Concrete flyash %	-	average
	Rebar	#5	#5
1.2.16 Footing_Square_3'6"x15"			
	Length (ft)	42.00	42.00
	Width (ft)	3.500	3.500
	Thickness (in)	1.250	15
	Concrete (psi)	4000	4000

			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.17 Footing_Square_3'9"x15"			
			Length (ft)	11.25	11.25
			Width (ft)	3.750	3.750
			Thickness (in)	1.250	15
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.18 Footing_Square_4'9"x18"			
			Length (ft)	4.75	4.75
			Width (ft)	4.750	4.750
			Thickness (in)	1.500	18
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#6	#6
		1.2.19 Footing_Square_3'0"x15"			
			Length (ft)	6.00	6.00
			Width (ft)	3.000	3.000
			Thickness (in)	1.250	15
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.20 Footing_Square_2'6"x15"			
			Length (ft)	15.00	15.00
			Width (ft)	2.500	2.500
			Thickness (in)	1.250	15
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.21 Footing_Square_2'6"x12"			
			Length (ft)	12.50	12.50
			Width (ft)	2.500	2.500
			Thickness (in)	1.000	12
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#4 & #8	#6
		1.2.22 Footing_Square_2'0"x15"			
			Length (ft)	2.00	2.00
			Width (ft)	2.000	2.000
			Thickness (in)	1.250	15
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.23 Footing_Square_2'3"x15"			
			Length (ft)	2.25	2.25

			Width (ft)	2.250	2.250
			Thickness (in)	1.250	15
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.24 Footing_Square_3'3"x15"			
			Length (ft)	3.25	3.25
			Width (ft)	3.250	3.250
			Thickness (in)	1.250	15
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.25 Footing_Trellis_8"thick			
			Length (ft)	32.39	349.67
			Width (ft)	32.388	3.000
			Thickness (in)	0.667	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#4 & #6	#6
		1.2.26 Footing_Stairs_TotalLength			
			Length (ft)	various	493.98
			Width (ft)	various	5.000
			Thickness (in)	0.417	10
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#3 & #4	#4
2 Walls					
	2.1 Cast In Place				
		2.1.1 Wall_Cast-in-Place_4.5"_noEnvelope			
			Length (ft)	61	13.725
			Height (ft)	4	10
			Thickness (in)	4.5	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		2.1.2 Wall_Cast-in-Place_6"_G1			
			Length (ft)	various	28.294
			Height (ft)	various	10
			Thickness (in)	6	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular	Gypsum Regular 5/8"

				5/8"	
		Door Opening	Number of Doors	2	2
			Door Type	Solid Wood Door	Solid Wood Door
		2.1.3 Wall_Cast-in-Place_8"_noEnvelope			
			Length (ft)	various	2324.950
			Height (ft)	various	10
			Thickness (in)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Door Opening	Number of Doors	20	20
			Door Type	various	Solid Wood Door
		Window Opening	Number of Windows	5	5
			Total Window Area (ft2)	97	97
			Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
			Glazing Type	Bronze Tinted Glazing	Standard Glazing
		2.1.4 Wall_Cast-in-Place_8"_G1			
			Length (ft)	various	1458.750
			Height (ft)	varrious	10
			Thickness (in)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
		Door Opening	Number of Doors	26	26
			Door Type	various	Solid Wood Door
		Window Opening	Number of Windows	2	2
			Total Window Area (ft2)	28	28
			Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
			Glazing Type	Bronze Tinted Glazing	Standard Glazing
		2.1.5 Wall_Cast-in-Place_8"_G1+Ins			
			Length (ft)	239	358.500
			Height (ft)	15	10
			Thickness (in)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Envelope	Category	Insulation	Insulation
			Material	Fiberglass Batt	Fiberglass Batt
			Thickness (in)	2	2
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"

2.1.6 Wall_Cast-in-Place_8"_G2			
	Length (ft)	various	555.288
	Height (ft)	various	10
	Thickness (in)	8	8
	Concrete (psi)	4000	4000
	Concrete flyash %	-	average
	Rebar	#4	#5
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
Door Opening	Number of Doors	3	3
	Door Type	various	Aluminium Exterior Door, 80% Glazing
2.1.7 Wall_Cast-in-Place_10"_noEnvelope			
	Length (ft)	various	1136.979
	Height (ft)	various	10
	Thickness (in)	10	8
	Concrete (psi)	4000	4000
	Concrete flyash %	-	average
	Rebar	#4	#5
Door Opening	Number of Doors	5	5
	Door Type	various	Steel Interior Door
2.1.8 Wall_Cast-in-Place_10"_G1			
	Length (ft)	various	23.500
	Height (ft)	various	10
	Thickness (in)	10	8
	Concrete (psi)	4000	4000
	Concrete flyash %	-	average
	Rebar	#4	#5
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
Door Opening	Number of Doors	1	1
	Door Type	Solid Wood Door	Solid Wood Door
2.1.9 Wall_Cast-in-Place_10"_G2			
	Length (ft)	5	8.750
	Height (ft)	14	10
	Thickness (in)	10	8
	Concrete (psi)	4000	4000
	Concrete flyash %	-	average
	Rebar	#4	#5
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"

2.1.10 Wall_Cast-in-Place_12"_noEnvelope			
	Length (ft)	various	699.850
	Height (ft)	various	10
	Thickness (in)	12	8
	Concrete (psi)	4000	4000
	Concrete flyash %	-	average
	Rebar	#4	#5
Window Opening	Number of Windows	12	12
	Total Window Area (ft2)	90	90
	Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
	Glazing Type	Bronze Tinted Glazing	Standard Glazing
2.1.11 Wall_Cast-in-Place_12"_G1			
	Length (ft)	various	71.150
	Height (ft)	various	10
	Thickness (in)	12	8
	Concrete (psi)	4000	4000
	Concrete flyash %	-	average
	Rebar	#4	#5
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
2.1.12 Wall_Cast-in-Place_12"_G1+WP			
	Length (ft)	298	447.000
	Height (ft)	14	10
	Thickness (in)	12	8
	Concrete (psi)	4000	4000
	Concrete flyash %	-	average
	Rebar	#4	#5
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
Envelope	Category	Insulation	Insulation
	Material	Insulation	Polystyrene Extruded
	Thickness (in)	1	1
Envelope	Category	Vapour Barier	Vapour Barier
	Material	Water Proofing	Polyethylene 6 mil
2.1.13 Wall_Cast-in-Place_12"_G2			
	Length (ft)	various	65.575
	Height (ft)	various	10
	Thickness (in)	12	8
	Concrete (psi)	4000	4000
	Concrete flyash %	-	average
	Rebar	#4	#5
Envelope	Category	Gypsum Board	Gypsum Board
	Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
Envelope	Category	Gypsum Board	Gypsum Board

		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Door Opening	Number of Doors	4	4
		Door Type	various	Aluminium Exterior Door, 80% Glazing
2.2 Steel Stud Walls				
	2.2.1 Wall_SteelStud_G1			
		Length (ft)	various	406.008
		Height (ft)	various	10
		Sheathing Type	-	None
		Stud Spacing	-	24oc
		Stud Weight	-	Light (25Ga)
		Stud Thickness	-	1 5/8 x 3 5/8
	Envelope	Category	Gypsum Board	Gypsum Board
		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Door Opening	Number of Doors	1	1
		Door Type	Solid Wood Door	Solid Wood Door
	2.2.2 Wall_SteelStud_G2			
		Length (ft)	various	2515.838
		Height (ft)	various	10
		Sheathing Type	-	None
		Stud Spacing	-	24oc
		Stud Weight	-	Light (25Ga)
		Stud Thickness	-	1 5/8 x 3 5/8
	Envelope	Category	Gypsum Board	Gypsum Board
		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Envelope	Category	Gypsum Board	Gypsum Board
		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Door Opening	Number of Doors	90	90
		Door Type	various	Aluminium Exterior Door, 80% Glazing
	2.2.3 Wall_SteelStud_G2+F			
		Length (ft)	31.000	43.400
		Height (ft)	14	10
		Sheathing Type	-	None
		Stud Spacing	-	24oc
		Stud Weight	-	Light (25Ga)
		Stud Thickness	-	1 5/8 x 3 5/8
	Envelope	Category	Gypsum Board	Gypsum Board
		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
	Envelope	Category	Gypsum Board	Gypsum Board
		Material	Fire Rated Gypsum 5/8"	Gypsum Fire Rated Type X 5/8"
	Door Opening	Number of Doors	1	1
		Door Type	Solid Wood Door	Solid Wood Door
2.3 Curtain Wall				
	2.31. Wall_Curtain_98%Glazing_noEnvelope			
		Length (ft)	various	674.200

			Height (ft)	various	10
			Percent Viewable Glazing	98	98
			Percent Spandrel Panel	2	2
			Thickness of Insulation (in)	0.188	0.188
			Spandrel Type (Metal/Glass)	Metal	Metal
		2.3.2 Wall_Curtain_90%Glazing_noEnvelope			
			Length (ft)	various	148.350
			Height (ft)	various	10
			Percent Viewable Glazing	90	90
			Percent Spandrel Panel	10	10
			Thickness of Insulation (in)	0.250	0.250
			Spandrel Type (Metal/Glass)	Metal	Metal
		Door Opening	Number of Doors	12	12
			Door Type	Aluminium Glazed Door	Aluminium Exterior Door, 80% Glazing
		2.3.3 Wall_Curtain_70%Glazing_noEnvelope			
			Length (ft)	15.000	2.125
			Height (ft)	1.417	10
			Percent Viewable Glazing	70	70
			Percent Spandrel Panel	30	30
			Thickness of Insulation (in)	0.250	0.250
			Spandrel Type (Metal/Glass)	Metal	Metal
		2.3.4 Wall_Curtain_90%Glazing_G1			
			Length (ft)	20.000	21.750
			Height (ft)	10.875	10
			Percent Viewable Glazing	90	90
			Percent Spandrel Panel	10	10
			Thickness of Insulation (in)	0.188	0.188
			Spandrel Type (Metal/Glass)	Metal	Metal
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
		Door Opening	Number of Doors	1	1
			Door Type	Aluminium Glazed Door	Aluminium Exterior Door, 80% Glazing
		2.3.5 Wall_Curtain_70%Glazing_G1			
			Length (ft)	23.000	20.700
			Height (ft)	9	10
			Percent Viewable Glazing	70	70
			Percent Spandrel	30	30

			Panel		
			Thickness of Insulation (in)	0.250	0.250
			Spandrel Type (Metal/Glass)	Metal	Metal
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
3 Columns and Beams					
	3.1 Concrete Columns and Beams				
		3.1.1 Column_Concrete_Beam_Concrete_MainFloor_Library			
			Number of Beams	20	20
			Number of Columns	18	18
			Floor to floor height (ft)	14.000	14.000
			Bay sizes (ft)	25.999	25.999
			Supported span (ft)	25.999	25.999
			Live load (psf)	75, 100 & 150	100
		3.1.2 Column_Concrete_Beam_Concrete_MainFloor_Offices			
			Number of Beams	42	42
			Number of Columns	47	47
			Floor to floor height (ft)	11.000	11.000
			Bay sizes (ft)	17.465	17.465
			Supported span (ft)	17.465	17.465
			Live load (psf)	75, 100 & 150	100
		3.1.3 Column_Concrete_Beam_Concrete_SecondFloor_Library			
			Number of Beams	20	20
			Number of Columns	18	18
			Floor to floor height (ft)	14.000	14.000
			Bay sizes (ft)	27.007	27.007
			Supported span (ft)	27.007	27.007
			Live load (psf)	75, 100 & 150	100
		3.1.4 Column_Concrete_Beam_Concrete_SecondFloor_Offices			
			Number of Beams	42	42
			Number of Columns	41	41
			Floor to floor height (ft)	11.000	11.000
			Bay sizes (ft)	18.207	18.207
			Supported span (ft)	18.207	18.207
			Live load (psf)	75, 100 & 150	100
		3.1.5 Column_Concrete_Beam_Concrete_Roof_Library			
			Number of Beams	20	20

			Number of Columns	16	16
			Floor to floor height (ft)	13.875	13.875
			Bay sizes (ft)	28.300	28.300
			Supported span (ft)	28.300	28.300
			Live load (psf)	75, 100 & 150	100
		3.1.6 Column_Concrete_Beam_Concrete_Roof_Offices			
			Number of Beams	28	28
			Number of Columns	32	32
			Floor to floor height (ft)	10.875	10.875
			Bay sizes (ft)	19.329	19.329
			Supported span (ft)	19.329	19.329
			Live load (psf)	75, 100 & 150	100
4 Floors					
	4.1 Concrete Suspended Slabs				
		4.1.1 Floor_ConcreteSuspendedSlab_MainFloor			
			Floor Width (ft)	887.016	887.016
			Span (ft)	30.000	30.000
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Life load (psf)	75, 100 & 150	100
		4.1.2 Floor_ConcreteSuspendedSlab_SecondFloor			
			Floor Width (ft)	487.034	487.034
			Span (ft)	30.000	30.000
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Life load (psf)	75, 100 & 150	100
5 Roof					
	5.1 Concrete Suspended Slab				
		5.1.1 Roof_ConcreteSuspendedSlab_BuiltUp			
			Roof Width (ft)	944.105	944.105
			Span (ft)	30.000	30.000
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Life load (psf)	40	45
		Envelope	Category	Built Up Roof	4-Ply Built-up Asphalt Roof System - Inverted
			Material	Tar and gravel on rigid insulation	Extruded Polystyrene, Glass Felt
			Thickness (in)	1.5	1.5
		5.1.2 Roof_ConcreteSuspendedSlab_NeopreneHypalon			
			Roof Width (ft)	19.30	19.30

			Span (ft)	30	30
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Life load (psf)	40	45
		Envelope	Category	Roof Envelopes	Roof Envelopes
			Material	Neoprene Hypalon	Polyethylene Filter Fabric
			Thickness (in)	-	-
	5.2 Steel Joist Roof				
		5.2.1 Roof_SteelJoists_BuiltUp			
			Roof Width (ft)	189.333	189.333
			Roof Length (ft)	18.000	18.000
			Decking Type	2x2 fir strips 24" o.c.	Plywood
			Decking Thickness (in)	-	1/2"
			Steel Gauge	20	18
			Joist Type	1' 5/8 x 12	1' 5/8 x 12
			Joist Spacing	bolts 24" o.c.	24"
		Envelope	Category	Built Up Roof	4-Ply Built-up Asphalt Roof System - Inverted
			Material	Tar and gravel on rigid fiberglass	Fiberglass, Glass Felt
			Thickness (in)	1.5	1.5
6 Extra Basic Materials					
	6.1 Concrete				
		6.1.1 XBM_ConcreteTopping	Concrete (m3)	-	124.817
	6.2 Steel				
		6.2.1 XBM_GalvanizedDecking	Galvanized Steel Decking (tons)	-	138.738
		6.2.2 XBM_WideFlangeSections	Wide Flange Sections (tons)	-	154.678
	6.3 Insulation				
		6.3.1 XBM_Insulation	Extruded Polystyrene (sf(1"))	-	808
	6.4 Standard Glazing				
		6.4.1 XBM_StandardGlazing	Standard Glazing (sf)	-	708

9.0 Annex B: IE Assumptions Document

Assembly Group	Assembly Type	Assembly Name	Specific Assumptions
1 Foundation	In the Impact Estimator, SOG inputs are limited to either a 4” or 8” thickness. Since the actual SOG thicknesses for the Curtis Addition were not 4” or 8” thick, the areas measured in OnScreen required calculations to adjust the areas to accommodate this limitation. Also, all SOG rebar was specified as #3, however this is not a choice in Ahtena. All rebar were modelled as #4. The Impact Estimator limits the thickness of footings to be between 7.5” and 19.7” thick. As there are a number of cases where footing thicknesses exceed 19.7”, their widths were increased accordingly to maintain the same volume of footing while accommodating this limitation. Again, rebar modelling choices were limited and hence adjusted from observed specifications. Lastly, the concrete stairs were modelled as footings (ie. Footing_Stairs_TotalLength). Also, all stair rebar was specified as #3 and #4, however #3 is not a choice in Ahtena. All rebar was modelled as #4.		
	1.1 Concrete Slab-on-Grade		
		1.1.1 SOG_5"	The following OnScreen conditions with similar characteristics were aggregarted to create this condition: #40: SOG_5"_NW(Tunnel) #41: SOG_5"_Library Their slab areas had to be adjusted to fit into the 8" thickness specified in the Impact Estimator. The following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[SUM(Measured Slab Areas) x (Actual Slab Thickness) / (8”/12)] = sqrt[(385 ft2 + 12,692 ft2) x (5"/12)) / (8”/12)] = 90.41 feet
		1.1.2 SOG_6"	The following OnScreen conditions with similar characteristics were aggregarted to create this condition: #42: SOG_6"_SW #43: SOG_6"_Mid Their slab areas had to be adjusted to fit into the 8" thickness specified in the Impact Estimator. The following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[SUM(Measured Slab Areas) x (Actual Slab Thickness) / (8”/12)] = sqrt[(1,323 ft2 + 1,951 ft2) x (6"/12)) / (8”/12)] = 49.55 feet

		1.1.3 SOG_Theatre	The following OnScreen condition was used to create this condition: #44: SOG_6"_Theatre The slab area had to be adjusted to fit into the 8" thickness specified in the Impact Estimator. The slab consists of varrying thickness and the following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[SUM((Measured Step Length) x (Actual Step Thicknesss)) x (Slab Width) / (8”/12)] = sqrt[(((6x14"/12) x (19"/12)) + ((4x10"/12) x (11.5"/12)) + ((74-6-4) x (6"/12))) x (3885 ft2 / 74ft) = 60.37 feet
		1.1.4 SOG_10"	The following OnScreen condition was used to create this condition: #45: SOG_10"_Theatre The slab area had to be adjusted to fit into the 8" thickness specified in the Impact Estimator. The following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[(Measured Slab Areas) x (Actual Slab Thickness) / (8”/12)] = sqrt[(59 ft2) x (10"/12)) / (8”/12)] = 8.59 feet
	1.2 Concrete Footing		
		1.2.9 Footing_Strip_3'6"x16"	The following OnScreen conditions with similar characteristics were aggregarted to create this condition: #10: Footing_Strip (3'6x16")_8"RcWall_SE #11: Footing_Strip (3'6x16")_10"RcWall_SouthStair #12: Footing_Strip (3'6x16")_12"RcWall_SouthStair The total length of footing input into Athena was the sum of the conditions: = SUM (linear feet of strip footing) = SUM (41ft + 52ft + 57ft) = 150 feet

		1.2.10 Footing_Strip_4'0"x16"	The following OnScreen conditions with similar characteristics were aggregarted to create this condition: #13: Footing_Strip (4'0x16")_8"RcWall_General #14: Footing_Strip (4'0x16")_10"RcWall_SE #15: Footing_Strip (4'0x16")_12"RcWall_Mid The total length of footing input into Athena was the sum of the conditions: = SUM (linear feet of strip footing) = SUM (80ft + 9ft + 71ft) = 160 feet
		1.2.13 Footing_Square_3'0"x10"	The following OnScreen conditions with similar characteristics were aggregarted to create this condition: #17: Footing_Square (7'2x7'2)_South #57: Footing_Square (7'0x7'0)_Mid #18: Footing_Square (8'0x8'0)_South #19: Footing_Square (11'9x11'9)_South-SE-mid The dimensions of these footing were adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7” and converted to one equivalent length of strip footing. The thickness was set to 10” and the width to 3'. The equivalent length in feet was then computed as follows; = SUM[(Footing Count) x (Actual Footing Area) x (Actual Footing Thickness)] / [(3ft) x (10"/12)] = [Total Footing Volume] / [(3ft) x (10"/12)] = SUM[(2 x 7'2" x 7'2" x 27"/12) + (1 x 7' x 7' x 27"/12) + (5 x 8' x 8' x 29"/12) + (9 x 11'9" x 11'9" x 42"/12)] / (3' x 10"/12) = 2185.47 feet
		1.2.14 Footing_Square_4'0"x15"	The following OnScreen conditions with similar characteristics were aggregarted to create this condition: #20: Footing_Square (4'0x4'0)_West #21: Footing_Square (4'0x4'0)_West #22: Footing_Square (4'0x4'0)_West #23: Footing_Square (4'0x4'0)_NW The footing was converted into a 4'0" wide strip footing for input into Athena. The equivalent length was calculated as follows: = SUM (footing counts) x 4' = SUM (6 + 3 + 3 + 1) x 4' = 52 feet

		1.2.16 Footing_Square_3'6" x15"	The following OnScreen conditions with similar characteristics were aggregarted to create this condition: #25: Footing_Square (3'6"x3'6")_NMid #26: Footing_Square (3'6"x3'6")_North #27: Footing_Square (3'6"x3'6")_NW #28: Footing_Square (3'6"x3'6")_NW The footing was converted into a 3'6" wide strip footing for input into Athena. The equivalent length was calculated as follows: = SUM (footing counts) x 3'6" = SUM (3 + 6 + 1 + 2) x 3'6" = 42 feet
		1.2.17 Footing_Square_3'9" x15"	The following OnScreen condition was used to create this condition: #29: Footing_Square (3'9"x3'9")_NMid The footing was converted into a 3'9" wide strip footing for input into Athena. The equivalent length was calculated as follows: = (Footing Count) x 3'9" = 3 x 3'9" = 11.25 feet
		1.2.19 Footing_Square_3'0" x15"	The following OnScreen conditions with similar characteristics were aggregarted to create this condition: #31: Footing_Square (3'0"x3'0")_North #32: Footing_Square (3'0"x3'0")_North The footing was converted into a 3'0" wide strip footing for input into Athena. The equivalent length was calculated as follows: = SUM (footing counts) x 3'0" = SUM (1 + 1) x 3'0" = 6 feet
		1.2.20 Footing_Square_2'6" x15"	The following OnScreen conditions with similar characteristics were aggregarted to create this condition: #33: Footing_Square (2'6"x2'6")_North #36: Footing_Square (2'6"x5'3")_NW #38: Footing_Square (2'6"x3'6")_NW The footing was converted into a 2'6" wide strip footing for input into Athena. The equivalent length was calculated as follows: = SUM (footing counts) x 2'6" = SUM (4 + 1 + 1) x 2'6" = 15 feet

		1.2.21 Footing_Square_2'6" x12"	The following OnScreen condition was used to create this condition: #34: Footing_Square (2'6"x2'6")_NW The footing was converted into a 2'6" wide strip footing for input into Athena. The equivalent length was calculated as follows: = (Footing Count) x 2'6" = 5 x 2'6" = 12.5 feet
		1.2.25 Footing_Trellis_8"thick	The following OnScreen condition was used to create this condition: #300: Footing_TrellisArea The trellis was modelled as a footing to attempt to account for the concrete and rebar. All glazing is modelled in Extra Basic Materials. The trellis is roughly 3' wide, so it was modelled as a 3' wide strip footing in Athena. The equivalent length was calculated as follows: = (Measured Trellis Surface Area) / 3'0" = 1.049 ft2 / 3 ft = 349.67 feet

		1.2.26 Footing_Stairs_Total Length	Several OnScreen conditions were aggregated to model the stairs. The total volume of concrete comprising all stair structures was calculated (see table below). A strip footing of assumed 5' width and 10" thickness was then used to compute the equivalent length of footing.

OnScreen Conditions and Output			Width (ft)	Thickness (ft)	Volume (ft3)
#	Name	Qty. (ft2)			
47	Stairs_5"_S1_Landing	17	9		153
48	Stairs_5"_S1_Stairs	41	4.167		170.83
51	Stairs_5"_S2_Stairs	5	8		40
52	Stairs_5"_S2_Stairs	28	3.5		98
53	Stairs_5"_S2_Stairs	6	5.333		32
55	Stairs_5"_S3_Landing	26	11.667		303.33
56	Stairs_5"_S3_Stairs	33	5.5		181.5
60	Stairs_5"_S4_Stairs	31	5.667		175.67
64	Stairs_5"_S5_Stairs	36	3.667		132
67	Stairs_5"_S6_Stairs	19	3.667		69.67
70	Stairs_5"_S7_Stairs	31	5		155
50	Stairs_5"_S2_Landing	352		0.4167	146.67
58	Stairs_5"_S4_marker	182		0.4167	75.83
59	Stairs_5"_S4_Landing	120		0.4167	50
62	Stairs_5"_S5_marker	140		0.4167	58.33
63	Stairs_5"_S5_Landing	185		0.4167	77.08
66	Stairs_5"_S6_Landing	142		0.4167	59.17
69	Stairs_5"_S7_Landing	171		0.4167	71.25
61	Stairs_5"_S4_Stairs	47			8.93
				SUM	2058.26

= (Total Volume of Concrete Stair Structure) / (5') / (10"/12)

= (2050.26 ft3) / (5 ft) / (10"/12) = 493.98 feet

2 Walls	The length of the concrete cast-in-place walls needed adjusting to accommodate the wall thickness limitation (8" or 12") in the Impact Estimator. All wall conditions were formatted to be a standard height of 10'. For the steel stud walls, no sheathing was specified, so none was modelled. The stud spacing was assumed to be 24 o.c. as for buildings typically constructed during the time. It was assumed that steel stud walls were light gauge (25Ga), as they are all interior walls. Finally, stud thickness was modelled as 1 5/8 x 3 5/8 as per a previous report on the Curtis Building. All curtain walls were modelled with an approximate percentage of viewable glazing. The percentage for each wall type was derived from the structural drawings. All windows were observed as bronze tinted glazing, however this is not a choice in Athena. Therefore all windows were modelled as standard glazing.
	2.1 Cast In Place

		2.1.1 Wall_Cast-in-Place_4.5"_noEnvelope	This wall was reduced by a factor in order to fit the 8" thickness limitation of the Impact Estimator. It was also scaled to be 10' high. This was done as follows; = [(Measured Length) x (Measured Height) x (Measured thickness)] / [(10') x (8"/12)] = [(61') x (4') x (4.5"/12)] / [(10') x (8"/12)] = 13.725 feet
		2.1.2 Wall_Cast-in-Place_6"_G1	Several OnScreen conditions were aggregated to create this condition. The volume of the existing wall was computed then converted to an equivalent length of concrete wall of 8" thickness and 10' in height, as shown here:

OnScreen Conditions and Outputs				Existing Wall		
#	Name	Qty. (ft)		Height (ft)	Area (ft2)	Volume (ft3)
163	Wall_Cast-in-place_6"_14'_G1_MainFloor	21	LF	14	294	147.00
182	Wall_Cast-in-place_6"_13'10.5"_G1_MainFloor	6	LF	13.875	83	41.63
					SUM	188.63

= [Wall Volume] / [(10') x (8"/12)]

= 188.63 ft3 / [(10') x (8"/12)] = 28.29 feet

2.1.3 Wall_Cast-in-Place_8"_noEnvelope

Several OnScreen conditions were aggregated to create this condition. The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here:= [Wall Area] / [10'] = 23250 ft2 / [10'] = 2324.95 feetIn addition, there were several door types counted in this wall assembly. Only one door type per wall may be modelled in Athena; the majoirty of the doors in this assembly are solid wood, so it was modelled as such.

OnScreen Conditions and Outputs				Existing Wall	
#	Name	Qty. (ft)		Height (ft)	Area (ft2)
164	Wall_Cast-in-place_8"_11'_noEnvelope_MainFloor	139	LF	11	1529
167	Wall_Cast-in-place_8"_14'_noEnvelope_MainFloor	186	LF	12	2232
134	Wall_Cast-in-place_8"_5'_noEnvelope_Basement	37	LF	6	222
135	Wall_Cast-in-place_8"_7'_noEnvelope_Basement	96	LF	8	768
136	Wall_Cast-in-place_8"_8'_noEnvelope_Basement	15	LF	9	135
137	Wall_Cast-in-place_8"_11'_noEnvelope_Basement	133	LF	12	1596
138	Wall_Cast-in-place_8"_14'_noEnvelope_Basement	5	LF	15	75
199	Wall_Cast-in-place_8"_2.5'_noEnvelope_Stair7	19	LF	2.5	48
200	Wall_Cast-in-place_8"_3'_noEnvelope_OfficeSkylightSupport	131	LF	3	393
201	Wall_Cast-in-place_8"_4'_noEnvelope_MainFloor	286	LF	4	1144
202	Wall_Cast-in-place_8"_4'_noEnvelope_SecondFlr_Offices	443	LF	4	1772
204	Wall_Cast-in-place_8"_5'3"_noEnvelope_MainFlr_CondenserPit	89	LF	5.25	467
206	Wall_Cast-in-place_8"_6'_noEnvelope_TheatreProjectionRm	15	LF	6	90
207	Wall_Cast-in-place_8"_7'_noEnvelope_stair1_SecondFloor	11	LF	7	77
208	Wall_Cast-in-place_8"_7.5'_noEnvelope_stair7_SecondFloor	15	LF	7.5	113
211	Wall_Cast-in-place_8"_9'_noEnvelope	40	LF	9	360
212	Wall_Cast-in-place_8"_14'_noEnvelope_stair2	5	LF	14	70
214	Wall_Cast-in-place_8"_15'_noEnvelope	45	LF	15	675
215	Wall_Cast-in-place_8"_18'_noEnvelope_stair1,2&7	67	LF	18	1206
216	Wall_Cast-in-place_8"_22.5'_noEnvelope	71	LF	22.5	1598
217	Wall_Cast-in-place_8"_25'_noEnvelope_stair 1	19	LF	25	475
218	Wall_Cast-in-place_8"_27'_noEnvelope_stair 1	16	LF	27	432
219	Wall_Cast-in-place_8"_30'_noEnvelope_stair 1	8	LF	30	240
118	Wall_Cast-in-place_8"_11'_noEnvelope_Basement	75	LF	12	900
119	Wall_Cast-in-place_8"_14'_noEnvelope_Basement	158	LF	15	2370
183	Wall_Cast-in-place_8"_54"_noEnvelope_SecondFloor	27	LF	4.5	122
186	Wall_Cast-in-place_8"_13'10.5"_noEnvelope_SecondFloor	166	LF	13.875	2303
114	Wall_Cast-in-place_8"_10'_noEnvelope_Theatre	52	LF	10	520
115	Wall_Cast-in-place_8"_11'_noEnvelope_Theatre	27	LF	11	297
116	Wall_Cast-in-place_8"_14'_noEnvelope_Theatre	73	LF	14	1022
				SUM	23250

	2.1.4 Wall_Cast-in-Place_8"_G1	Several OnScreen conditions were aggregated to create this condition. The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here:

	OnScreen Conditions and Outputs			Existing Wall	
#	Name	Qty. (ft)		Height (ft)	Area (ft2)
165	Wall_Cast-in-place_8"_11'_G1_MainFloor	91	LF	11	1001
168	Wall_Cast-in-place_8"_14'_G1_MainFloor	59	LF	14	826
197	Wall_Cast-in-place_8"_2'_G1	54	LF	2	108
198	Wall_Cast-in-place_8"_2.5'_G1_SecondFloorLibrary	23	LF	2.5	58
203	Wall_Cast-in-place_8"_4'_G1_Library	541	LF	4	2164
205	Wall_Cast-in-place_8"_5'3"_G1_SecondFloorLibrary	12	LF	5.25	63
209	Wall_Cast-in-place_8"_7.5'_G1_MainFloor	148	LF	7.5	1110
210	Wall_Cast-in-place_8"_8'_G1_SpandrelOffices	351	LF	8	2808
120	Wall_Cast-in-place_8"_14'_G1_Basement	119	LF	15	1785
184	Wall_Cast-in-place_8"_10'10.5"_G1_SecondFloor	147	LF	10.875	1599
187	Wall_Cast-in-place_8"_13'10.5"_G1_SecondFloor	221	LF	13.875	3066
				SUM	14588

= [Wall Area] / [10']

= 14588 ft2 / [10'] = 1458.75 feet

In addition, there were several door types counted in this wall assembly. Only one door type per wall may be modelled in Athena; the majoirty of the doors in this assembly are wood glazed (roughly 80% glazing). The closest door type in Athena is the Exterior Alum Glazed Door (80% glazed), so it was modelled as such.

	2.1.5 Wall_Cast-in-Place_8"_G1+Ins	The following OnScreen condition was used to create this condition: #213: Wall_Cast-in-Place_15'_G1_SpandrelLibrary The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here: = [Wall Area] / [10'] = 3585 ft2 / [10'] = 358.5 feet In addition, the Curtis Addition wall schedule specified 'plaster on insulation', so a 5/8" gypsum board over 2" of fiberglass batt envelope was assumed. The 2' of fiberglass batt was measured from drawing in the takeoff.

2.1.6 Wall_Cast-in-Place_8"_G2

Several OnScreen conditions were aggregated to create this condition. The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here:

OnScreen Conditions and Outputs				Existing Wall	
#	Name	Qty. (ft)		Height (ft)	Area (ft2)
169	Wall_Cast-in-place_8"_14'_G2_MainFloor	117	LF	14	1638
166	Wall_Cast-in-place_8"_11'_G2_MainFloor	53	LF	11	583
121	Wall_Cast-in-place_8"_14'_G2_Basement	26	LF	15	390
185	Wall_Cast-in-place_8"_10'10.5"_G2_SecondFloor	97	LF	10.875	1055
188	Wall_Cast-in-place_8"_13'10.5"_G2_SecondFloor	136	LF	13.875	1887
				SUM	5553

= [Wall Area] / [10']

= 5553 ft2 / [10'] = 555.29 feet

In addition, there were several door types counted in this wall assembly. Only one door type per wall may be modelled in Athena; the majoirty of the doors in this assembly are wood glazed (roughly 80% glazing). The closest door type in Athena is the Exterior Alum Glazed Door (80% glazed), so it was modelled as such.

2.1.7 Wall_Cast-in-Place_10"_noEnvelope

Several OnScreen conditions were aggregated to create this condition. The volume of the existing wall was computed then converted to an equivalent length of concrete wall of 8" thickness and 10' in height, as shown here:

OnScreen Conditions and Outputs				Existing Wall		
#	Name	Qty. (ft)		Height (ft)	Area (ft2)	Volume (ft3)
141	Wall_Cast-in-place_10"_5'_noEnvelope_Basement	50	LF	6	300	250.00
143	Wall_Cast-in-place_10"_8'_noEnvelope_Basement	18	LF	9	162	135.00
144	Wall_Cast-in-place_10"_11'_noEnvelope_Basement	93	LF	12	1116	930.00
122	Wall_Cast-in-place_10"_7.5'_noEnvelope_Theatre	33	LF	7.5	248	206.25
123	Wall_Cast-in-place_10"_8.5'_noEnvelope_Theatre	28	LF	8.5	238	198.33
124	Wall_Cast-in-place_10"_9.5'_noEnvelope_Theatre	30	LF	9.5	285	237.50
125	Wall_Cast-in-place_10"_12'_noEnvelope_Theatre	13	LF	12	156	130.00
250	Wall_Cast-in-place_10"_15'9"_noEnvelope_Theatre	30	LF	15.75	473	393.75
251	Wall_Cast-in-place_10"_19'3'_noEnvelope_Theatre	28	LF	19.25	539	449.17
252	Wall_Cast-in-place_10"_23'8"_noEnvelope_Theatre	44	LF	23.67	1041	867.78
253	Wall_Cast-in-place_10"_30.5'_noEnvelope_Theatre	26	LF	30.5	793	660.83
220	Wall_Cast-in-place_10"_18'_noEnvelope_MainFlrCorridor	76	LF	18	1368	1140.00
126	Wall_Cast-in-place_10"_7.5'_noEnvelope_Basement	9	LF	7.5	68	56.25
127	Wall_Cast-in-place_10"_14'_noEnvelope_Basement	112	LF	15	1680	1400.00
170	Wall_Cast-in-place_10"_14'_noEnvelope_MainFloor	45	LF	14	630	525.00
					SUM	7579.86

= [Wall Volume] / [(10') x (8”/12)]

= 7579.86 ft3 / [(10') x (8”/12)] = 1137 feet

In addition, there were several door types counted in this wall assembly. Only one door type per wall may be modelled in Athena; the majoirty of the doors in this assembly are hollow metal, so it was modelled as such.

2.1.8 Wall_Cast-in-Place_10"_G1

Several OnScreen conditions were aggregated to create this condition. The volume of the existing wall was computed then converted to an equivalent length of concrete wall of 8" thickness and 10' in height, as shown here:

OnScreen Conditions and Outputs				Existing Wall		
#	Name	Qty. (ft)		Height (ft)	Area (ft2)	Volume (ft3)
128	Wall_Cast-in-place_10"_14'_G1_Basement	6	LF	15	90	75.00
171	Wall_Cast-in-place_10"_14'_G1_MainFloor	7	LF	14	98	81.67
					SUM	156.67

= [Wall Volume] / [(10') x (8”/12)]

= 156.67 ft3 / [(10') x (8”/12)] = 23.5 feet

2.1.9 Wall_Cast-in-Place_10"_G2

The following OnScreen condition was used to create this condition:

#172: Wall_Cast-in-Place_10"_14'_G2_MainFloor

The volume of the existing wall was computed then converted to an equivalent length of concrete wall of 8" thickness and 10' in height, as shown here:

= [Wall Volume] / [(10') x (8”/12)]

= 58.33 ft3 / [(10') x (8”/12)] = 8.75 feet

2.1.10 Wall_Cast-in-Place_12"_noEnvelope

Several OnScreen conditions were aggregated to create this condition. The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here:

OnScreen Conditions and Outputs				Existing Wall	
#	Name	Qty. (ft)		Height (ft)	Area (ft2)
148	Wall_Cast-in-place_12"_11'_noEnvelope_Basement	102	LF	12	1224
149	Wall_Cast-in-place_12"_14'_noEnvelope_Basement	181	LF	15	2715
247	Wall_Cast-in-place_12"_7.5'_noEnvelope_Theatre	1	LF	7.5	8
248	Wall_Cast-in-place_12"_8.5'_noEnvelope_Theatre	3	LF	8.5	26
249	Wall_Cast-in-place_12"_9.5'_noEnvelope_Theatre	55	LF	9.5	523
254	Wall_Cast-in-place_12"_1'_noEnvelope_Theatre	128	LF	1	128
255	Wall_Cast-in-place_12"_10'5"_noEnvelope_Theatre	30	LF	10.5	315
256	Wall_Cast-in-place_12"_13.5'_noEnvelope_Theatre	22	LF	13.5	297
130	Wall_Cast-in-place_12"_11'_noEnvelope_Basement	7	LF	12	84
131	Wall_Cast-in-place_12"_14'_noEnvelope_Basement	112	LF	15	1680
				SUM	6999

= [Wall Area] / [10']

= 6999 ft2 / [10'] = 699.85 feet

2.1.11 Wall_Cast-in-Place_12"_G1	Several OnScreen conditions were aggregated to create this condition. The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here:

OnScreen Conditions and Outputs				Existing Wall	
#	Name	Qty. (ft)		Height (ft)	Area (ft2)
132	Wall_Cast-in-place_12"_14'_G1_Basement	13	LF	15	195
174	Wall_Cast-in-place_12"_14'_G1_MainFloor	25	LF	14	350
190	Wall_Cast-in-place_12"_13'10.5"_G1_SecondFloor	12	LF	13.875	167
				SUM	712

= [Wall Area] / [10']

= 712 ft2 / [10'] = 71.15 feet

2.1.12 Wall_Cast-in-Place_12"_G1+WP	The following OnScreen condition was used to create this condition: #150: Wall_Cast-in-Place_12"_14'_G1+WP_Basement The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here: = [Wall Area] / [10'] = 4470 ft2 / [10'] = 447 feet Also, the Curtis Addition drawings specify 1" insulation and waterproofing on the exterior of the walls. The insulation was assumed to be extruded polystyrene and the waterproffing was chosen as a standard 6mm polyethylene

2.1.13 Wall_Cast-in-Place_12"_G2

Several OnScreen conditions were aggregated to create this condition. The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here:

OnScreen Conditions and Outputs				Existing Wall	
#	Name	Qty. (ft)		Height (ft)	Area (ft2)
133	Wall_Cast-in-place_12"_14'_G2_Basement	12	LF	15	180
173	Wall_Cast-in-place_12"_11'_G2_MainFloor	14	LF	11	154
189	Wall_Cast-in-place_12"_10'10.5"_G2_SecondFloor	13	LF	10.875	141
191	Wall_Cast-in-place_12"_13'10.5"_G2_SecondFloor	13	LF	13.875	180
				SUM	656

= [Wall Area] / [10']

= 656 ft2 / [10'] = 65.575 feet

In addition, there were several door types counted in this wall assembly. Only one door type per wall may be modeled in Athena; the majoirty of the doors in this assembly are wood glazed (roughly 80% glazing). The closest door type in Athena is the Exterior Alum Glazed Door (80% glazed), so it was modelled as such.

2.2 Steel Stud

2.2.1 Wall_SteelStud_G1

Several OnScreen conditions were aggregated to create this condition. The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here:

OnScreen Conditions and Outputs				Existing Wall	
#	Name	Qty. (ft)		Height (ft)	Area (ft2)
176	Wall_SteelStud_3'8"_G1_MainFloor	233	LF	3.667	854.33
177	Wall_SteelStud_11'_G1_MainFloor	16	LF	11	176
179	Wall_SteelStud_14'_G1_MainFloor	40	LF	14	560
152	Wall_SteelStud_14'_G1_Basement	27	LF	14	378
192	Wall_SteelStud_10'10.5"_G1_SecondFloor	15	LF	10.875	163.125
194	Wall_SteelStud_13'10.5"_G1_SecondFloor	139	LF	13.875	1928.625
				SUM	4060.083

= [Wall Area] / [10']

= 4060 ft2 / [10'] = 406 feet

2.2.2 Wall_SteelStud_G2

Several OnScreen conditions were aggregated to create this condition. The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here:

OnScreen Conditions and Outputs				Existing Wall	
#	Name	Qty. (ft)		Height (ft)	Area (ft2)
178	Wall_SteelStud_11'_G2_MainFloor	618	LF	11	6798
181	Wall_SteelStud_14'_G2_MainFloor	329	LF	14	4606
153	Wall_SteelStud_14'_G2_Basement	227	LF	14	3178
193	Wall_SteelStud_10'10.5"_G2_SecondFloor	700	LF	10.875	7612.5
195	Wall_SteelStud_13'10.5"_G2_SecondFloor	193	LF	13.875	2677.875
196	Wall_SteelStud_11'_G2_Theatre	26	LF	11	286
				SUM	25158.38

= [Wall Area] / [10']

= 25158.38 ft2 / [10'] = 2515.84 feet

In addition, there were several door types counted in this wall assembly. Only one door type per wall may be modelled in Athena; the majoirty of the doors in this assembly are wood glazed (roughly 80% glazing). The closest door type in Athena is the Exterior Alum Glazed Door (80% glazed), so it was modelled as such.

2.2.3 Wall_SteelStud_G2+F

The following OnScreen condition was used to create this condition:

#180: Wall_SteelStud_14'_G2+F_MainFloor

The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here:

= [Wall Area] / [10']

= 434 ft2 / [10'] = 43.4 feet

2.3 Curtain Wall

2.31. Wall_Curtain_98%Glazing_noEnvelope

Several OnScreen conditions were aggregated to create this condition. The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here:

OnScreen Conditions and Outputs				Existing Wall	
#	Name	Qty. (ft)		Height (ft)	Area (ft2)
221	Wall_Curtain_OfficeWindows	780	LF	2.67	2080
273	Wall_Curtain_Skylight	777	LF	6	4662
				SUM	6742

= [Wall Area] / [10']

= 6742 ft2 / [10'] = 674.2 feet

		2.3.2 Wall_Curtain_90%Glazing_noEnvelope	Several OnScreen conditions were aggregated to create this condition. The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here:

OnScreen Conditions and Outputs				Existing Wall	
#	Name	Qty. (ft)		Height (ft)	Area (ft2)
234	Wall_Curtain_OfficeEntrances_MainFloor	40	LF	11	440
239	Wall_Curtain_MainEntrance_MainFloor	31	LF	8	248
243	Wall_Curtain_CourtYardEntrance_MainFloor	65	LF	7.5	487.5
274	Wall_Curtain_14'_MainFloor	22	LF	14	308
				SUM	1483.5

= [Wall Area] / [10']

= 1483.5 ft2 / [10'] = 148.35 feet

2.3.3 Wall_Curtain_70%Glazing_noEnvelope	The following OnScreen condition was used to create this condition: #244: Wall_Curtain_noEnvelope_MainEntrance_SecondFloor The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here: = [Wall Area] / [10'] = 21.25 ft2 / [10'] = 2.125 feet
2.3.4 Wall_Curtain_90%Glazing_G1	The following OnScreen condition was used to create this condition: #296: Wall_Curtain_10'10.5"_G1_SecondFloor The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here: = [Wall Area] / [10'] = 217.5 ft2 / [10'] = 21.75 feet
2.3.5 Wall_Curtain_70%Glazing_G1	The following OnScreen condition was used to create this condition: #245: Wall_Curtain_G1_SecondFloor The area of the existing wall was computed then converted to an equivalent length of concrete wall of 10' in height, as shown here: = [Wall Area] / [10'] = 207 ft2 / [10'] = 20.7 feet

3 Columns and Beams	The method used to measure column sizing was completely depended upon the metrics built into the Impact Estimator. That is, the Impact Estimator calculates the sizing of beams and columns based on the following inputs; number of beams, number of columns, floor to floor height, bay size, supported span and live load. This being the case, in OnScreen, concrete columns and beams were accounted for on each floor, while each floor's area was measured. The number of beams supporting each floor were assigned an average bay and span size in order to cover the measured area, as seen assumption details below for each input. The live loading ranged from 75 psf to 150 psf. As 150 psf cannot be modelled in Athena, a standard live load of 100 psf was applied to all column and beam assemblies in an attempt to even out the design live loads adn more accurately represent the Curtis Building.		
	3.1 Concrete Column		
		3.1.1 Column_Concrete_Beam_Concrete_MainFloor_Library	Because of the variability of bay and span sizes, they were calculated using the following calculation; = sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)] = sqrt[(12,167 ft2) / (18)] = 30 feet
		3.1.2 Column_Concrete_Beam_Concrete_MainFloor_Offices	Because of the variability of bay and span sizes, they were calculated using the following calculation; = sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)] = sqrt[(14,337 ft2) / (47)] = 17.47 feet
		3.1.3 Column_Concrete_Beam_Concrete_SecondFloor_Library	Because of the variability of bay and span sizes, they were calculated using the following calculation; = sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)] = sqrt[(13,129 ft2) / (18)] = 27 feet
		3.1.4 Column_Concrete_Beam_Concrete_SecondFloor_Offices	Because of the variability of bay and span sizes, they were calculated using the following calculation; = sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)] = sqrt[(13,592 ft2) / (41)] = 18.21 feet

		3.1.5 Column_Concrete_Beam_Concrete_Roof_Library	Because of the variability of bay and span sizes, they were calculated using the following calculation; = sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)] = sqrt[(12.814 ft2) / (16)] = 28.3 feet
		3.1.6 Column_Concrete_Beam_Concrete_Roof_Offices	Because of the variability of bay and span sizes, they were calculated using the following calculation; = sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)] = sqrt[(11,956 ft2) / (32)] = 19.33 feet
4 Floors	The Impact Estimator calculated the thickness of the material based on floor width, span, concrete strength, concrete flyash content and live load. Athena has a maximum floor span of 9.75m for concrete suspended slabs, so all floors were set to have a span of 30ft. The floor area was then used to calculate the floor width. The live loading ranged from 75 psf to 150 psf. As 150 psf cannot be modelled in Athena, a standard live load of 100 psf was applied to all column and beam assemblies in an attempt to even out the design live loads adn more accurately represent the Curtis Building.		
	4.1 Concrete Suspended Slabs		
		4.1.1 Floor_ConcreteSuspendedSlab_MainFloor	Because of the limitation on concrete suspended slab floor span, the floor widths were calculated using the following calculation; = (Measured Floor Area) / (30 ft) = (26,600 ft) / (30 ft) = 887.016 feet
		4.1.2 Floor_ConcreteSuspendedSlab_SecondFloor	Because of the limitation on concrete suspended slab floor span, the floor widths were calculated using the following calculation; = (Measured Floor Area) / (30 ft) = (25,236 ft) / (30 ft) = 487.034 feet
5 Roof	The Impact Estimator calculated the thickness of the material based on roof width, span, concrete strength, concrete flyash content and live load. Athena has a maximum roof span of 9.75m for concrete suspended slabs and 5.5m for steel joist roof systems, so all concrete suspended slabs were set to have a span of 30ft and all steel joist roof systems were set to have a span of 18ft. The roof area was then used to calculate the roof width.The live loading was specified as 40 psf, which cannot be modelled in Athena. Therefore all roof conditions were modelled with a live load of 45 psf.		
	5.1 Concrete Suspended Slabs		

		5.1.1 Roof_ConcreteSuspendedSlab_BuiltUp	Because of the limitation on concrete suspended slab roof span, the roof widths were calculated using the following calculation; = (Measured Roof Area) / (30 ft) = (28,312 ft) / (30 ft) = 94.105 feet In addition, the engineering drawings specified a built-up roof of tar and gravel, underlain by 1.5" thick rigid insulation. This was modelled as an inverted 4-ply asphalt roofing system, with 1.5" of extruded polystyrene.
		5.1.2 Roof_ConcreteSuspendedSlab_NeopreneHypalon	The roof areas in the condition were all on a 45 degree slope. The correct amount of measured roof area was computed as follows; = (Measured Roof Area) / cos(45) = 304 ft2 / cos(45) = 578.69 ft2 Because of the limitation on concrete suspended slab roof span, the roof widths were calculated using the following calculation; = (Measured Roof Area) / (30 ft) = (578.69 ft) / (30 ft) = 19.3 feet In addition, a neoprene hypalon cover over the concrete suspended slab was specified. Research showed the closest material in the Impact Estimator to neoprene hypalon is polyethylene filter fabric, so it was modelled as such.
	5.2 Steel Joist Roof		

		5.2.1 Roof_SteelJoist_Penthouse	The roof areas in the condition were all on a 15 degree slope. The correct amount of measured rof area was computed as follows; = (Measured Roof Area) / cos(15) = 3,408 ft2 / cos(15) = 4486.05 ft2 Because of the limitation on concrete suspended slab roof span, the roof widths were calculated using the following calculation; = (Measured Roof Area) / (18.04 ft) = (4486.05 ft) / (18.04 ft) = 189.33 feet The steel joist roof system specified 2x2 fir strips of sheathing and steel decking. The sheathing was modelled as 1/2" plywood decking, and the steel decking was modelled in Extra Basic Materials. The steel was specified as 20 gauge, but this is not an option in the Impact Estimator, so the next highest value of 18 gauge steel was used. In addition, the engineering drawings specified a built-up roof of tar and gravel, underlain by 1.5" thick rigid fiberglass. This was modelled as an inverted 4-ply asphalt roofing system, with 1.5" of fiberglass and glass felt.
6 Extra Basic Materials			
	6.1 Concrete		
		6.1.1 XBM_ConcreteTopping	The concrete in this section represents the slab topping in the second floor hallway and theatre. The volume of concrete was calculated as follows; = SUM[(Concrete Topping Thickness) x (Topping Area)] / (35.31 ft3/m3) = [((3"/12) x (1,654 ft2)) + ((1.5"/12) x (31,955 ft2))] / (35.31 ft3/m3) = 124.817 m3 NB: More specific figures were used and carried in conversion calculations.
	6.2 Steel		

		6.2.1 XBM_GalvanizedDecking	The steel in this section represents the steel decking in the second floor of the theatre and the theatre roof system. The weight of steel was calculated as follows (an average density of 7.85 tonnes/m3 was used for steel); = SUM(Decking Area) x (Steel Decking Thickness) / (35.31 ft3/m3) / (0.13 m3 steel/ton steel) = (1,633 ft2 + 3,462 ft2) x (1.5"/12) / (35.31 ft3/m3) / (0.13 m3 steel/ton steel) = 138.738 tons NB: More specific figures were used and carried in conversion calculations.
		6.2.2 XBM_WideFlangeSections	The wide flange sections are present in the theatre balcony flooring system and the theatre roofing system. Steel beam dimensions were recorded and the total weight of steel was then calculated. Please see the following table;

OnScreen Conditions and Outputs			Beam Properties		Calculations	
#	Name	Qty. (ft)	Descriptor	lbs/ft	lbs	Tons
106	XBM_SteelBeams_Theatre2ndFlr_B1	89	angle 5"x3"x3/8"	9.8	872.2	0.4361
107	XBM_SteelBeams_Theatre2ndFlr_B2	75	L 3"x3"x1/4"	4.9	367.5	0.18375
108	XBM_SteelBeams_Theatre2ndFlr_B3	12	W 10x25	25	300	0.15
109	XBM_SteelBeams_Theatre2ndFlr_B4	97	28.5" WWF	120	11640	5.82
302	XBM_SteelBeams_TheatreRoof_B5	591	36" deep joists	500	295500	147.75
303	XBM_SteelBeams_TheatreRoof_B2	71	L 3"x3"x1/4"	4.9	347.9	0.17395
304	XBM_SteelBeams_TheatreRoof_B3	205	L 1'1/4"x1'1/4"x1/8"	1.6	328	0.164
					SUM	154.68

= 154.678 tons

NB: Beam properties sourced from http://www.structural-drafting-net-expert.com/steel-beam.html

	6.3 Insulation		
		6.3.1 XBM_Insulation	This represents the syrofoam insulation specified on stairwell 1. It was modelled as extruded polystyrene in the Impact Estimator.
	6.4 Standard Glazing		
		6.4.1 XBM_StandardGlazing	This represents the trellis windows. They are specified as bronze tinted glazed, but this is not an option in the Impact Estimator. They were therefore modelled as standard glazing.