CIVL 498C - LIFE CYCLE ANALYSIS OF UBC BUILDINGS

THE BUCHANAN BUILDING

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ABSTRACT

The following report is an analysis of the environmental impacts created by the University of British Columbia's Buchanan building. The analysis was done by creating a material model in the Athena Environmental Impact Estimator. Takeoffs for the model were done using OnScreen Takeoff 3.

The Buchanan building's primary energy consumption was found to be 208.21 MJ / ft^2. The weighted resource use was found to be 149.88 kg / ft^2. The global warming potential was found to be 19.46 kg CO_2 eq. / kg / ft^2. The acidification potential was found to be 6.43 moles of H+ eq. / kg / ft^2. The human health respiratory effects potential was found to be 0.06 kg $PM_{2.5}$ eq. / kg / ft^2. The eutrophication potential was found to be 0.00 kg N eq. / kg / ft^2. The ozone depletion potential was found to be 0.00 kg CFC-11 eq. / kg / ft^2. Finally, the smog potential was found to be 0.10 kg NOx eq. / kg / ft^2.

In addition, a series of sensitivity analyses were carried out to discover which materials created the largest impacts. As expected, it was found that concrete had the biggest influence on the buildings emissions. Moreover, it was discovered that rebar had the largest impact on the eutrophication potential of the Buchanan building.

An operating energy analysis was also carried out on the Buchanan building. It was discovered that by increasing the building's insulation to meet the Residential Environmental Assessment Program's insulation requirements 464 520 422 MJ of energy would be saved over an 80 year building lifespan.

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1.0 INTRODUCTION

The Buchanan building is located at 1866 Main Mall on the Vancouver campus of the University of British Columbia (UBC). It is a concrete framed building that is heavily influenced by the modern movement in architecture, specifically Mies Van Der Rohe, Walter Gropius, and the master plan of Illinois Institute of Technology. Original design work was carried out by the architecture firm of Thompson, Berwick & Pratt. Construction of the building began in 1956 and continued steadily through until 1960. The original cost of construction was $2 650 000. The main function of the Buchanan building is to serve as office and teaching space for members of the UBC Arts Department. The Buchanan building consists of five blocks: A, B, C, D and E. These five blocks are arranged in a sideways S-shape as shown in Figure 1 below.

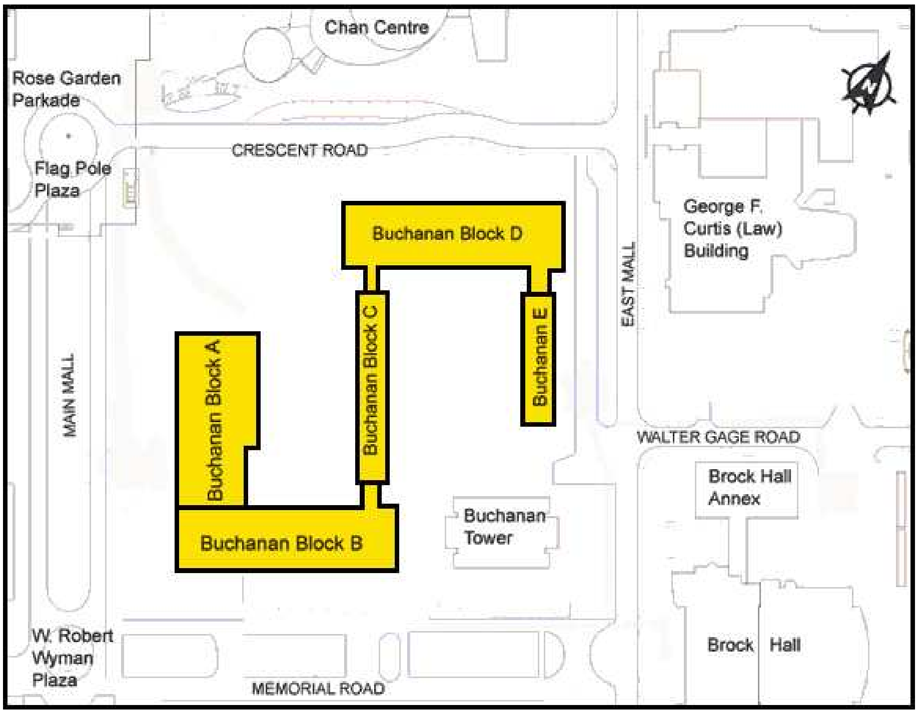

Figure 1. The Buchanan building.

Block A consists of 30 820 ft^2 divided between two floors. Block B consists of 53 820 ft^2 divided between three floors. Block C consists of 31 200 ft^2 divided between four floors. Block D consists of 54 020 ft^2 divided between three floors. Block E consists of 21 280 ft^2 divided between four floors. The Buchanan building has a total area of 190 940 ft^2.

Block A’s main floor consists of three large lecture halls; its second floor consists of four large classrooms, a student lounge and an office for the Dean of the Arts Department. Blocks B and D both consist of approximately thirty classrooms spread out over three floors. Blocks C and E both consist of approximately ninety offices spread out over four floors.

The structural and envelope inputs related to the Buchanan building are detailed in Table 1 below.

Table 1. Buchanan building characteristics.

Building System	**Specific Characteristics of Buchanan**
Structure	**Block A:** Concrete beams and columns supporting concrete suspended slabs **Block B and D:** Concrete beams and columns supporting concrete suspended slabs **Block C and E:** Concrete beams and columns supporting concrete suspended slabs
Floors	**Block A:** Foundation: Concrete slab on grade; Second floor: Suspended slabs **Block B and D:** Foundation: Concrete slab on grade; Second and third floor: Suspended slabs **Block C and E:** Foundation: Concrete slab on grade; Second, third and floor: Suspended slabs
Exterior Walls	**Block A:** Glazing dominated curtain walls and concrete block walls with batt insulation **Block B and D:** Mix of cast-in-place and concrete block walls with batt insulation **Block C and E:** Mix of cast-in-place and concrete block walls with batt insulation
Interior Walls	**Block A:** Gypsum on wood stud walls **Block B and D:** Gypsum on wood stud walls **Block C and E:** Gypsum on wood stud walls
Windows	**Block A:** Standard glazing with aluminum framing **Block B and D:** Standard glazing with aluminum framing **Block C and E:** Standard glazing with aluminum framing
Roof	**Block A:** Suspended slab with 2-ply modified bitumen membrane roofing and rigid insulation **Block B and D:** Suspended slab with 2-ply modified bitumen membrane roofing and rigid insulation **Block C and E:** Suspended slab with 2-ply modified bitumen membrane roofing and rigid insulation
HVAC/heating	**All Blocks:** Steam generated by natural gas

2.0 GOAL AND SCOPE

The following section outlines the goals and scope of this project.

2.1 Goal of Study

This life cycle analysis (LCA) of the Buchanan building at the University of British Columbia was carried out as an exploratory study to determine the environmental impact of it's design. The Buchanan building consists of five blocks named Block A, Block B, Block C, Block D, and Block E. This LCA of the Buchanan building is also part of a series of twelve others being carried out simultaneously on respective buildings at UBC with the same goal and scope.

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

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

2.2 Scope of Study

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

2.3 Tools, Methodology and Data

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

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

Using the formatted takeoff data, version 4.0.51 of the IE software, the only available software capable of meeting the requirements of this study, is used to generate a whole building LCA model for the Buchanan building in the Vancouver region as an Institutional building type. The IE software is designed to aid the building community in making more environmentally conscious material and design choices. The tool achieves this by applying a set of algorithms to the inputted takeoff data in order to complete the takeoff process and generate a bill of materials

(BoM). This BoM then utilizes the Athena Life Cycle Inventory (LCI) Database, version 4.6, in order to generate a cradle-to-grave LCI profile for the building. In this study, LCI profile results focus on the manufacturing and transportation of materials and their installation in to the initial structure and envelope assemblies. As this study is a cradle-to-gate assessment, the expected service life of the Buchanan building is set to 1 year, which results in the maintenance, operating energy and end-of-life stages of the building's life cycle being left outside the scope of assessment.

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

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

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

The primary sources of data for this LCA are the original architectural and structural drawings from when the Buchanan building was initially constructed in between 1956 and 1960.

The assemblies of the building that are modeled include the foundation, columns and beams, floors, walls and roofs, as well as the associated envelope and openings (ie. doors and windows) within each of these assemblies. The decision to omit other building components, such as flooring, electrical aspects, HVAC system, finishing and detailing, etc., are associated with the limitations of available data and the IE software, as well as to minimize the uncertainty of the model. In the analysis of these assemblies, some of the drawings lack sufficient material details, which necessitate the usage of assumptions to complete the modeling of the building in the IE software. Furthermore, there are inherent assumptions made by the IE software in order to generate the 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 energy in the Building Model section and, as previously mentioned, all specific input related assumption are contained in the Input Assumptions document in Annex B.

3.0 BUILDING MODEL

In order to carry out a reasonably accurate LCA, a reasonably accurate building model must first be computed.

3.1 Takeoffs

The first step in creating a reasonable building model is to carry out a takeoff of the materials used. The takeoff for the Buchanan building was based on digital versions of the original building drawing which were provided by the UBC Records Department. Unfortunately, due to the vintage of these drawings, many of them were fairly grainy and hard to read. In addition, the original drawings had been completed by hand, making some of them even harder to decipher. Furthermore, a few details regarding material types were not included in the provided drawing set; thus, reasonable assumptions had to be made where the common materials of the time were assumed to be used. For example, the amount of fly ash used in the cement was never explicitly stated; thus, an average amount of nine percent was assumed.

The takeoffs for the Buchanan building were done using OnCenter's On-Screen Takeoff 3 Software. On-Screen allows for the building drawings to be uploaded onto its interface so that takeoffs could be digitally superimposed over top. There are three basic types of takeoff conditions available in On-Screen: linear, area, and count. The linear condition is used to compute a linear length, such as the length of wall located within the building. The area condition is used to compute a surface area, such as the area of a roof slab. The count condition is used to compute the number of times a certain object is present, such as the number of windows located within a certain wall. Each assembly group in the EIE used a slightly different combination of the above listed conditions, as well as a few reasonable assumptions, to calculate material takeoffs.

A few major assumptions were made to complete this project to simplifying repeated building assemblies and materials with the Buchanan Blocks.

The first major assumption is that the second and third floors of Block B are the same. Thus, only a takeoff of the second floor was completed but each assembly was modeled twice, once for each floor. For example, assemblies B_2nd_Beam&Column and B_3rd_Beam&Column

are identical and both based off on takeoffs related to the Block B second floor. Both floor plans are identical in size and shape; thus, this assumption should not greatly affect the model. This same assumption was used to relate all four floors of Block C which are also identical in size and shape.

The second major assumption is that Blocks C and E have equivalent material usage per square foot. This meant that only Block C takeoffs were required. The Block C takeoffs were then modeled in EIE to produce a Block C Bill of Materials. The Bill of Material amounts were then multiplied by the ratio of Block E square footage to Block C square footage to create an estimated Bill of Materials for Block E which is displayed in the Appendix B. The values in this new Bill of Materials were then entered into the final model through the Extra Basic Materials assembly group. Both Block C and E are office buildings of almost identical layout; thus, this assumption would not greatly affect the model.

The third major assumption is that Blocks B and D are identical buildings. Thus, much like the first major assumption with similar floors, only a takeoff of the Block B was completed but each assembly was modeled twice, once for each Block. Both Blocks B and D are classroom blocks with very similar layouts and have a less than 1% difference in square footage, therefore, this assumption should not greatly affect the model. The one exception was that the main floor of Block D was more similar to the second floor of Block B rather than the main floor of Block B. Because of this, both the main and second floors of Block D were modeled the same as the second floor of Block B.

The modelling techniques and assumptions specifically related to each assembly group are provided in greater detail in the next section.

3.2 Assembly Groups

An overview of the modelling techniques and assumptions related to each assembly group are provided below. Actual calculations related to specific assembly assumptions are listed in the EIE Input Assumptions Document, which is located in Appendix B. The EIE Input Assumptions Document can be directly compared to the EIE Inputs Tables, which are located in Appendix A.

3.2.1 Columns and Beams

The column and beam takeoffs were completed mainly using OnScreen's count condition. For each set, a count condition for the number of beams and a condition for the number of columns were created and the two amounts were computed. The floor-to-floor height and live load were then taken directly from what was stated on the drawings. The supporting span and bay size were then computed by taking the average of each value within the designated assembly type. For example, in the assembly B_2nd_Beam&Column there are bay sizes of both 27'4" and 10'2"; averaging out the two bay sizes results in an average bay size of 21'6" which is the value that was input into the EIE.

3.2.2 Floors

All floors within the Buchanan building are concrete suspended slabs. The surface area of the slabs was computed using the area condition in OnScreen. The computed areas were then converted into rectangular slabs of equivalent surface area with spans between 12' and 30' as those are close to the EIE span limits. The length and span of the idealized rectangular slabs were then inputed into the EIE. For example, the assembly A_2nd_Slab_5"_Concrete comprised of a slab 100' by 122' and another slab 20' by 62' which, combined, results in a total surface area of 13440 ft^2. A rectangular slab 120' by 112' results in an equivalent surface area; thus, the latter values were entered into the EIE. The concrete strength and live load were taken directly from the drawings and then entered into the EIE as the closest possible acceptable value. For example, a live load for classrooms was said to be 60 psf; however, the closest value that the EIE accepts is 75 psf. The flyash percentage was assumed to be average.

3.2.3 Roofs

All roofs in the Buchanan building are concrete suspended slabs. The length, span, concrete strength, live load, and flyash percentage are all calculated in the same manner as the floor suspended slabs. In addition, the Buchanan roofs include vapour barriers, insulation and a bitumen roof envelope. The majority of the inputs associated with these envelope materials were given in the building drawings; however, a few of the values were not given and had to be assumed. These assumptions include: the bitumen was standard modified, the insulation was extruded polystyrene, and the vapour barrier was 3 mil polyethylene.

3.2.4 Foundations

There are two foundation types that were used in this model: concrete footings and slabs on grade.

The concrete footing takeoffs were completed mainly using area conditions in OnScreen. An area condition was created for each assembly name to calculate the surface area of the given footing type. If there were multiple similar footings they were combined to make a single footing equivalent volume. The thickness of each assembly was recorded off of the drawings. If the thickness was not an acceptable sizing according to the EIE it was decreased to the closest acceptable size. At the same time the width of the footing was increased to account for the change in volume. For example, the assembly A_Foundation_Footing_2'4" is actually a combination of four 10’ square footings that are 28 inches thick resulting in a total, combined volume of 933.33 ft^2. A single 20’ by 31’1.3” footing 18 inches thick also has the same volume; thus, those are the values inputed into the EIE. Concrete strength and rebar size were also read off of the drawings. If there were multiple rebar sizes in a footing an average size was assumed. For example, assembly D_Foundation_Footing3' has #5, #6 and #7 sized rebar so #6 was used in the model. If the rebar size is outside the range that the EIE allows, the closest allowable value was assumed. For example, assembly D_Foundation_Footing3'Wall has #8 rebar but #6 was used in the model. The flyash percentage was assumed to be average.

Stairs were also modelled as concrete footings. The stair takeoffs were done using the linear condition in OnScreen and the stair detail drawings. The thickness of the stairs was computed as the average thickness throughout. All other calculations and assumptions were completed using the methodology outlined for regular concrete footings.

Takeoffs for concrete slabs on grade were done using the area condition in OnScreen. Much like the suspended slabs, the computed areas were then converted into rectangular slabs of equivalent surface area and the length and span of the idealized rectangular slabs were then used to create the model. For example, the assembly B_Foundation_Slab4" comprised of a slab 98' by 9'6" and another slab 26' by 2'8" which, combined, results in a total surface area of 1000 ft^2. A rectangular slab 40' by 25' results in an equivalent surface area; thus, the latter values were entered into the EIE. The slab thicknesses were found on the drawings; however, EIE only allows concrete slabs on grade to have thicknesses of 4" or 8". To make the model compatible with the EIE the thicknesses were converted to either 4" or 8" and the slabs length was changed in order to maintain the original slab volume. For example, assembly B_Foundation_Slab6" is actually a 77' by 65' slab that is 6" thick which results in a total volume of 2502.5 ft^3. By changing the thickness to 8" the length would also have to decrease from 77' to 58' to keep the same area. Thus, a 58' by 65' slab with an 8" thickness is what is entered into the model. Furthermore, concrete strength was assumed to be 4000 psi with an average flyash percentage as well as an assumed that there was a 6 mil polyethylene vapour barrier underneath all slabs on grade.

3.2.5 Walls

The wall types used in the Buchanan building are as follows: concrete block, cast-in-place, curtain, and wood stud.

The lengths of the concrete block walls are calculated using the linear condition in OnScreen. Their heights and rebar sizes are found in the building drawing. However, in the case of rebar, if the rebar size listed in the drawing is too big or too small to be input into the EIE, the closest acceptable value was assumed. For example, assembly A_2nd_Brick_In calls for #3 rebar in the drawings. Since #4 is the smallest size that the EIE accepts, #4 rebar is used in the model.

Much like concrete block walls, the lengths of cast-in-place walls are calculated using the linear condition in OnScreen. Heights, thicknesses, concrete strength, and rebar size are taken directly from the drawings. Much like the slabs on grade, the wall thicknesses are converted to either 8” or 12” (in order to be compatible with EIE) and the wall heights are changed in order to maintain the original wall volume. Some of the walls also have #4 rebar which is outside of the range available in EIE; thus, they are modeled with #5 rebar. The flyash percentage is assumed to be the average.

The lengths of all curtain walls were calculated using the linear condition in OnScreen. The thickness of insulation for all curtain walls was assumed to be the same as all other exterior walls in the model. The percent glazing and percent spandrel were calculated using elevation details from the original drawings.

Like all other wall lengths, the lengths of wood stud walls were calculated using linear conditions in OnScreen. The wall type, wall height, stud spacing, stud thickness, and sheathing type were all found on the original drawings. The stud type was assumed to be kiln-dried. For wood studded walls that included gypsum board, regular 1/2” gypsum was assumed.

Windows for all walls were modeled as being fixed aluminum frames even though portions of many of the windows are, in fact, operable. Because only small portions of the windows are operable, assuming the windows are fully fixed is more accurate than assuming the windows are fully operable. The count condition in OnScreen was used to find the number of windows related to a specific wall. The number of windows was then multiplied by the square footage of a single window in order to compute the total window area related to a given wall. For example, assembly D_2nd_Wall_NS_Wood includes 92 separate 9’9” by 7’ windows. Multiplying the three values together yields a total window area of 2965.16 ft^2, the value that is used in the model. Many of the windows travelled through both an exterior concrete block wall and an interior wood stud wall. In these cases the windows were modeled with the interior wood stud wall and empty holes were modeled into the exterior concrete block wall. This is done so that the windows are not modeled twice. For example, the assemblies B_2nd_Wall_NSBlock and B_2nd_Wall_NS_Wood are located back-to-back and, therefore, share the same set of 92 windows and have the same total window area of 2965.16 ft^2. However, assembly B_2nd_Wall_NS_Wood also includes wood window frames and standard glazing where as assembly B_2nd_Wall_NSBlock does not include any framing or glazing; thus, the window materials are only counted once.

Like windows, the number of doors within each respective wall type was calculated using the count condition in OnScreen. Exterior doors were assumed to be aluminum with 80% glazing whereas interior doors were assumed to be hollow wood core.

The drawings specified that many of the wood stud walls included 1” batt insulation but did not specify the specific type. Therefore, it was assumed that rockwool batt insulation was used.

3.2.6 Extra Basic Materials

Other than the materials related to Block E, the only assumption made in extra basic materials was related to the exterior porcelain panels located below the windows on Blocks B, C, D, and E. The takeoffs for the porcelain panels were done using the count condition in OnScreen. Once the number of panels was known it was multiplied by the area in order to create total panel area. This total panel area was then modeled in extra basic materials as standard glazing. This was done because the EIE does not have porcelain in its material database; standard glazing was used because it is the most closely related material in the EIE.

3.3 Bill of Materials

Table 2 below displays the bill of materials for the Buchanan model as computed by the EIE.

Table 2. Bill of materials.

Material	Quantity	Unit
1/2" Gypsum Fibre Gypsum Board	107249.45	sf
3 mil Polyethylene	68438.89	sf
6 mil Polyethylene	39477.50	sf
Aluminium	39.60	Tons
Batt. Fiberglass	518.90	sf (1”)
Batt. Rockwool	33480.50	sf (1”)
Concrete 20 MPa (flyash av)	15.57	yd3
Concrete 30 MPa (flyash av)	12589.95	yd3
Concrete Blocks	48921.00	Blocks
EPDM membrane	5882.29	lb
Extruded Polystyrene	60729.31	sf (1”)
Galvanized Sheet	0.10	Tons
Glazing Panel	10.65	Tons
Joint Compound	8.97	Tons
Modified Bitumen membrane	12306.89	lb
Mortar	207.31	yd3
Nails	16.85	Tons
Paper Tape	0.10	Tons
Rebar, Rod, Light Sections	505.24	Tons
Screws Nuts & Bolts	0.13	Tons
Small Dimension Softwood Lumber, kiln-dried	122.31	bdfm
Softwood Plywood	25.63	msf (3/8”)
Standard Glazing	50330.43	sf
Water Based Latex Paint	73.67	US gallons
Welded Wire Mesh / Ladder Wire	2.84	Tons

It is important to keep in mind that there is some uncertainty related to the accuracy of the Bill of Materials due to the assumptions mentioned in the previous section.

Firstly, because the EIE Bill of Materials accounts for construction wastes, modelling Block E off of the Block C bill of materials will overestimate the amount of materials in Block E by an additional 5%.

Secondly, the live loads allowed for by the EIE were slightly different from the live loads that the Buchanan building was originally designed for. This led to many of the live loads, relating to the columns and beams, and suspended slabs, being overestimated. This, in turn, likely led to a slight over estimation in the amount of 4000 psi concrete and rebar used in construction.

Thirdly, by modelling all the windows as fixed when many are, in fact, partially operable would lead to the amount of framing material (such as aluminum, screws, nuts, and bolts) being underestimated. However, many of the windows in the Buchanan building include coupling mullions. The EIE does not take into account coupling mullions; it assumes all windows have their own independent frame. Thus, the amount of framing materials is also overestimated. Because these two relatively equal uncertainties skew the results in opposite directions they would, hypothetically, cancel each other out.

4.0 SUMMARY MEASURES

The following section describes the potential embodied effects that the different life cycle stages of the Buchanan building have and points to consider regarding their accuracy.

4.1 Embodied Effects

The various embodied effects that were analyzed in this report are: acidification potential, global warming potential, human health respiratory effects, ozone depletion, smog potential, eutrophication potential, weighted resource use, and energy consumption. A more complete explanation of these embodied effects can be found in The Journal of Industrial Ecology located on TRACI's website or in the help menu of the EIE.

Energy consumption refers to the amount of energy consumed to transform and/or transport raw materials into products and buildings. Energy consumption is reported in mega-joules. The average energy consumption for academic buildings on UBC campus was found to be approximately 363.58 MJ.

Acidification potential consists of the processes that increase the acidity of water and soil systems. Acid deposition can corrode buildings and other man-made structures. Acidification is reported as H^+ equivalence effect on a mass basis. The average acidification for academic buildings on UBC campus was found to be approximately 9.96 moles of H+ eq. / kg.

Global warming potential refers to the potential change in the earth's climate caused by the accumulation of greenhouse gas emissions that trap reflected sunlight heat which would have otherwise passed out of the earth's atmosphere. These gases can be absorbed and neutralized by the environment; however, recently the rate of these emissions has exceeded the rate of absorption. Global warming potential is reported as equivalency basis relative to CO_2 – in kg. The average global warming potential for academic buildings on UBC campus was found to be approximately 32.46 kg CO_2 eq. / kg.

Human health respiratory effects refer to the probability of ambient particulate matter negatively effecting human health. Ambient concentrations of particulate matter are strongly associated with rates of mortality and chronic and acute respiratory symptoms. Human health respiratory effects are reported as equivalent $PM_{2.5.}$ The average human health respiratory effect for academic buildings on UBC campus was found to be approximately 0.09 kg $PM_{2.5}$ eq. / kg.

Ozone depletion is the potential reduction of the protective ozone within the stratosphere caused by emissions of ozone-depleting substances. Ozone-depleting substances, such as anthropogenic emissions of chlorofluorocarbons (CFCs) and halons, are believed to be causing an acceleration of destructive chemical reactions. These chemical reactions, in turn, are believed to be causing lower ozone levels and ozone “holes” in certain locations. Ozone depletion is reported as mass of equivalent CFC-11. The average ozone depletion potential for academic buildings on UBC campus was found to be approximately 0.00 kg CFC-11 eq. / kg.

Smog potential refers to the potential formation of reactive oxidant gases (ozone gases) in the troposphere. Having these gases present in the troposphere leads to detrimental impacts on human health and ecosystems. Rates of ozone formation in the troposphere are governed by complex chemical reactions, which are, in turn, influenced by ambient concentrations of nitrogen oxides, volatile organic compounds, temperature, sunlight, and convective flows. Smog potential is reported as mass of equivalent ethylene basis. The average smog potential for academic buildings on UBC campus was found to be approximately 0.15 kg NOx eq. / kg.

Eutrophication potential refers to the potential fertilization of surface waters by previously scarce nutrients. When a previously scarce nutrient is added to surface water it can lead to the proliferation of aquatic photosynthetic plant life. This, in turn, may lead to further consequences, such as: foul odor or taste; death or poisoning of fish or shellfish; reduced biodiversity; or the production of chemical compounds that are toxic to humans, marine mammals, or livestock. Eutrophication is reported as equivalent mass of nitrogen basis. The average eutrophication potential for academic buildings on UBC campus was found to be approximately 0.00 kg N eq. / kg.

Weighted resource use refers to the amount of land, water and fossil fuels that are depleted due to the raw materials extraction, manufacturing, transportation and construction of the building. The methodologies that support the resource depletion categories have the least consensus out of all the emission effect categories. There is still no consensus on the “value” of resources; thus, the ways of calculating this category will likely change over time as research develops. Weighted resource use is reported as mass. The average weighted resource use for academic buildings on UBC campus was found to be approximately 244.44 kg.

4.2 Obtained Values

The following table displays the estimated embodied effects related to the Buchanan building at the manufacturing and construction life cycle stages in addition to the total estimated effects.

Table 3. Embodied effects at different life stages.

Impact Category	Units	Manufacturing		
		Material	Transportation	Total
Primary Energy Consumption	MJ	34389142.41	1139442.491	35528584.91
Weighted Resource Use	kg	28450195.33	34192.10287	28484387.43
Global Warming Potential	(kg CO2 eq / kg)	3600411.836	1999.984821	3602411.821
Acidification Potential	(moles of H+ eq / kg)	1173756.602	680.0883298	1174436.691
HH Respiratory Effects Potential	(kg PM2.5 eq / kg)	11838.89144	0.819842164	11839.71129
Eutrophication Potential	(kg N eq / kg)	103.3115121	0.004880722	103.3163929
Ozone Depletion Potential	(kg CFC-11 eq / kg)	0.008780179	8.23655E-08	0.008780261
Smog Potential	(kg NOx eq / kg)	17840.70498	15.32739835	17856.03238

Impact Category	Units	Construction		
		Material	Transportation	Total
Primary Energy Consumption	MJ	1578262.804	2648809.894	4227072.698
Weighted Resource Use	kg	72479.56054	60281.45049	132761.011
Global Warming Potential	(kg CO2 eq / kg)	107898.3086	4476.192373	112374.501
Acidification Potential	(moles of H+ eq / kg)	51294.9822	1442.856772	52737.83897
HH Respiratory Effects Potential	(kg PM2.5 eq / kg)	57.43534834	1.735593432	59.17094177
Eutrophication Potential	(kg N eq / kg)	0.000329405	0.010899619	0.011229024
Ozone Depletion Potential	(kg CFC-11 eq / kg)	1.00566E-10	1.83384E-07	1.83485E-07
Smog Potential	(kg NOx eq / kg)	1270.723373	32.27660754	1302.99998

Impact Category	Units	Total Effects	
		Overall	Per Square foot
Primary Energy Consumption	MJ	39,755,657.60	208.21
Weighted Resource Use	kg	28,617,148.44	149.88
Global Warming Potential	(kg CO2 eq / kg)	3,714,786.32	19.46
Acidification Potential	(moles of H+ eq / kg)	1,227,174.53	6.43
HH Respiratory Effects Potential	(kg PM2.5 eq / kg)	11,898.88	0.06
Eutrophication Potential	(kg N eq / kg)	103.33	0.00
Ozone Depletion Potential	(kg CFC-11 eq / kg)	0.01	0.00
Smog Potential	(kg NOx eq / kg)	19,159.03	0.10

It is important to note that for every embodied effect analyzed, approximately 98% of the impacts took place during the manufacturing of the materials stage. This is, most likely, because the manufacturing stage includes the raw resource extractions, processes that have very high environmental impacts.

4.3 Uncertainty Related to Values

As stated earlier, the Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI) is what is used by the EIE to compute the embodied effects of a given model. Unfortunately, there is some uncertainty related to calculating these values. It is important to be aware of these uncertainties to fully understand what these values mean.

For instance, one should note that TRACI uses midpoint modelling instead of endpoint modelling. Midpoint modelling refers to the potential impacts created, not the actual impacts. Therefore, it is possible that a predicted impact never actually occurs.

There are also assumptions about the special variability of the impacts. This is important because many of the impact categories, such as acidification and resource use, only affect the regions in which they occur. Although it is possible for TRACI to regionalize its emission effects, the EIE does not do this. Instead it assumes non-regionalized effects. Since emissions do affect different environmental regions differently, uncertainty in the results is created.

Even if regional effects are taken into account, one must also be aware of the fact that not all the emissions occurred in the same location. Raw materials can be mined thousands of kilometres away from where a building is being constructed. Thus, the impacts related to the raw material extraction and the impacts caused by the building assembly can occur in completely different locations. In addition, different emissions have different travel potential. Air emissions, for example, have a far greater travel potential than land and water emissions. This is important because the larger the area in which an emission can reach the greater the potential impact it can have.

TRACI also makes assumptions about the temporal variability of the impacts. Many emissions have “shelf lives;” thus, a past emission usually has a lower impact than a current or future emissions of the same kind because they have, likely, already started being neutralized by the surrounding environment. Moreover, it is possible for two emissions to chemically interact and create a different emission with a different environmental impact. It would be nearly impossible for TRACI to take this into account since one cannot readily predict all present emissions in the area and how they will interact thus resulting in further uncertainty in the model's environmental impact.

TRACI also assumes that ecological processes respond in a linear manner to mediate environmental impacts. Thus, TRACI does not take intervention thresholds into account. This is important because the rate in which environmental impacts are neutralized by the environment changes the likelihood of impacts negatively effecting the surrounding environment.

4.4 Sensitivity Analysis

A sensitivity analysis was carried out on a few of the different construction materials used to create the Buchanan building. Sensitivity analysis is a technique that is used to determine how different values of an independent variable will impact a particular dependent variable under a given set of assumptions. A sensitivity analysis is a very useful tool to carry out with an LCA because it helps breakdown the different embodied effects related to the different building materials. Being aware of what building materials cause the bulk of the impacts can help designers make more informed and, in turn, better decisions. Figure 2 displays the percent change of embodied effects caused by a 10% change in the amount of the following independent variables: 4000 psi concrete; concrete blocks; aluminum; and rebar, rods, and light sections.

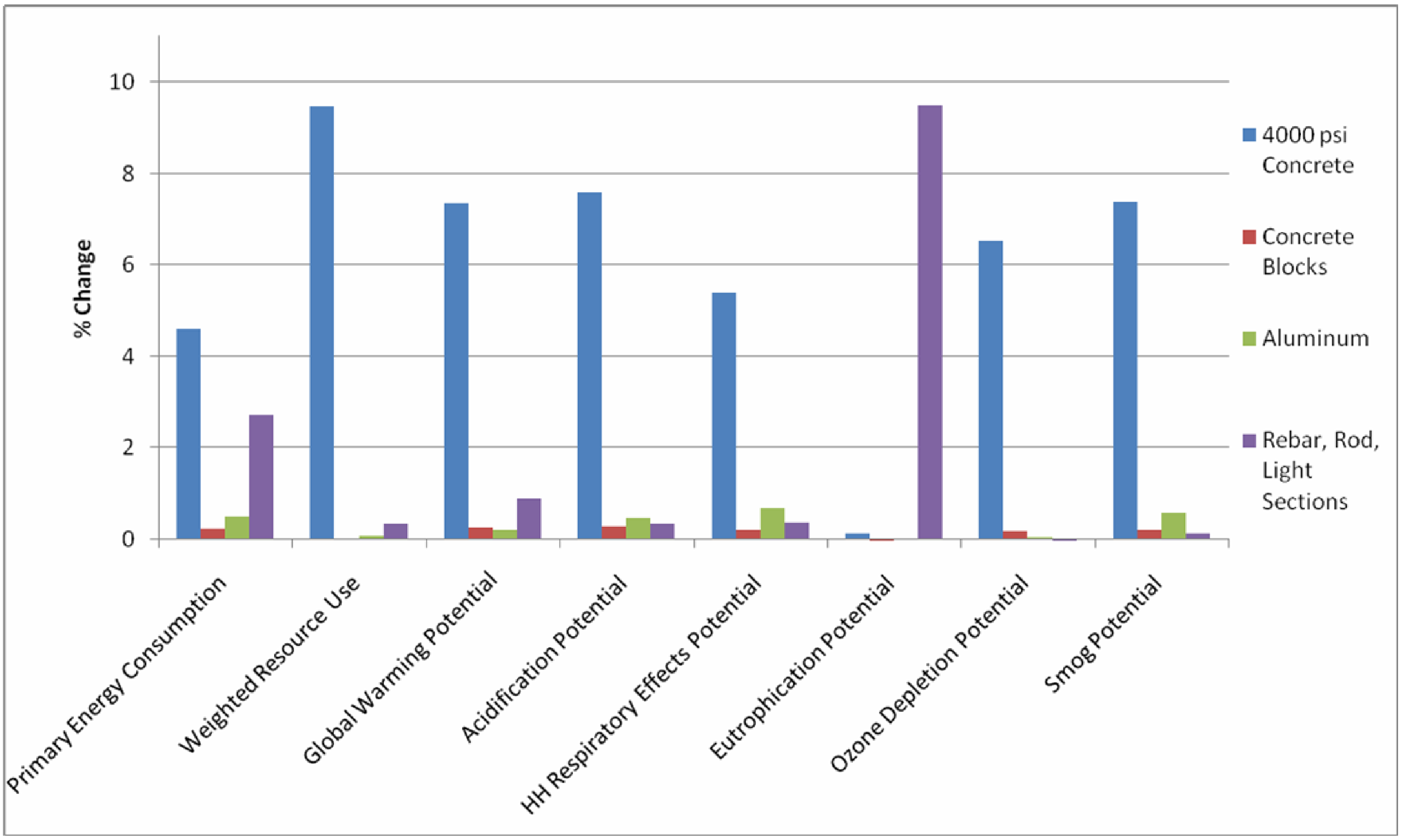

Figure 2. Percent change of overall embodied effects due to a 10% change in given material amount.

It is important to be aware that the majority of the Buchanan building is made of 4000 psi concrete; thus, a 10% change in the amount of 4000 psi concrete has more significance than a 10% change in any of the other materials used. However, it is still important to note just how great an impact the concrete has on the emission effects of the building. If a less impactful process of producing concrete was discovered it's use could greatly decrease the building's overall impact.

It is interesting to see on the graph that the rebar used in the Buchanan building is the driving force behind the buildings eutrophication potential. Therefore, if minimizing eutrophication potential was a specific goal of the design, minimizing the amount of rebar within the structure would probably be the easiest way of achieving this.

It is also interesting to see that the rebar has comparable primary energy consumption to 4000 psi concrete even though there is a far lesser volume of rebar. This is caused because the manufacturing of steel is a far more energy intensive process than the creation of concrete.

A sensitivity analysis was also carried out to discover how greatly the porcelain panels located on the exterior of Blocks B, C, D, and E impact the environment. Please keep in mind that the porcelain panels were modeled as standard glazing in the EIE; thus, there is slightly more uncertainty related to these results. The percentage of the buildings embodied effects caused by the porcelain panels are displayed in Figure 3 below.

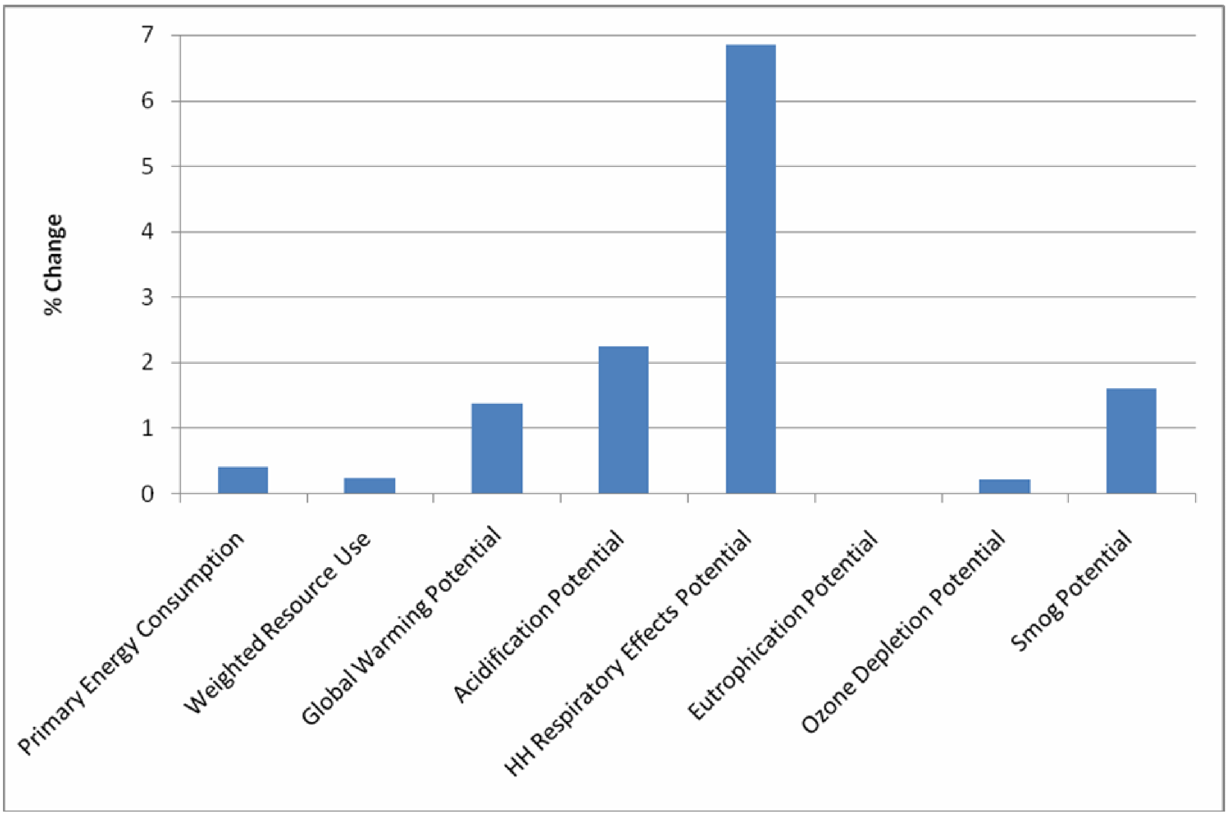

Figure 3. Percentage of embodied effects due to porcelain panels.

It is interesting to note how significantly a small, aesthetic design feature, such as these porcelain panels, can impact the environment. For example, as shown in Figure 3, the porcelain panels were responsible for almost 7% of the potential human health respiratory effects caused by the Buchanan building. This is an excellent example of a situation where carrying out a LCA could help designers make a more informed decision. If the designers of the Buchanan building were aware of the environmental impacts related to the porcelain panels maybe they would have decided to use a lower-impacting material for the panels, or maybe not include the panels at all.

5.0 BUILDING PERFORMANCE

The following section looks into how the current Buchanan building performs from an energy perspective. In addition, an idealized, version of the Buchanan building, with respect to operating energy, is analyzed to roughly investigate how materials can reduce further impacts during the service life of the building.

5.1 Energy Performance Improving Materials

All building materials require energy to be embodied through their extraction, manufacturing, transportation, and assembly into buildings in construction. However, some materials can offset their embodied energy when in service by resisting heat transfer and, thus, allowing the building to operate using a lower amount of operational heating energy. Over the course of a building's lifetime the amount of operating energy that a fairly resistant material can save can become a fairly significant factor in helping to minimize the buildings overall environmental impact.

Insulation materials such as batt rockwool and extruded polystyrene are great examples of materials that, if implemented extensively into a design, can significantly lower the amount of operating energy needed over a building's lifetime. Using low E argon filled windows instead of single pane glazing is another way that energy savings can be achieved.

5.2 Energy Performance Payback Period

Although using strategic materials, like those previously stated, can significantly lower operating energy needs in the long term, they usually require more initial energy to be embodied in their manufacturing when compared to their simpler, less insulating counterparts. Therefore, it is important to calculate the energy payback period of the building. The energy payback period is the amount of time it takes for the operating energy savings to outweigh the extra initial embodied energy. If the building service life is expected to be greater than the payback period, the use of operating energy saving materials would allow the building to have a lower impact than it otherwise would.

5.3 Energy Performance of Buchanan

Calculations were done on the Buchanan building to investigate what type of operating energy saving could be achieved given idealized insulating materials. In order to do this an energy performance analysis was carried out for both the actual building and the idealized version of the building. Only roof and wall insulation, and window materials were considered in this analysis because they account for the vast majority of the building's thermal insulation. The roof insulation was 1" extruded polystyrene, the wall insulation was 1" batt rockwool, and the windows were standard glazing. The first step was to calculate the window, wall and roof surface area of the building and the R-values of the various materials. R-values are used in the construction industry to quantify a material's thermal resistance in (ft^2 F h)/ BTU. The higher the R-value the better insulating the material is. The R-values for the insulating materials used in the Buchanan building are given in Table 4 below.

Table 4. Material R-values.

	R-Value ((ft^2 F h)/ BTU)
Extruded polystyrene	5 per 1"
Batt. Rockwool	3.14 per 1"
Low E silver argon filled glazing	3.75 per total
Standard glazing (single pane)	0.91 per total

Next, the R-values of an idealized building were assumed to be the minimum Residential Environmental Assessment Program's (REAP) insulation requirements. In order to account for the increased thermal resistance requirements, the idealized building model replaced the 1" extruded polystyrene with 8" extruded polystyrene, the 1" batt rockwool with 5.73" batt rockwool, and the standard glazing with Low E silver argon filled glazing.

Using the areas and R-values a weighted average R-value was computed for both the actual and ideal building models, seen in Table 5.

Table 5. Surface areas and R-values.

		R-Value (ft^2 F h/BTU)	
	Area (ft2)	Actual Building	Ideal Building
Exterior Wall	49666.71	3.14	18
Window	30078.69	0.91	3.75
Roof	64242	5	40
Weighted Average	143987.4	3.50	24.84

The next step is to find the heat loss through the building assemblies. The heat loss through an assembly can be calculated via the following equation.

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

Where,

R = Calculated R-Value in ft^2 °F h/BTU

A = Surface area of assembly of interest in ft^2

ΔT =(Inside Temperature – Outside Temperature) in °F

The heat loss values were then extrapolated over an 80 year period. In addition, the actual and idealized buildings were both modelled in the EIE and the initial embodied energy requirements of both were found. The total energy requirements for both the buildings are shown in Figure 4.

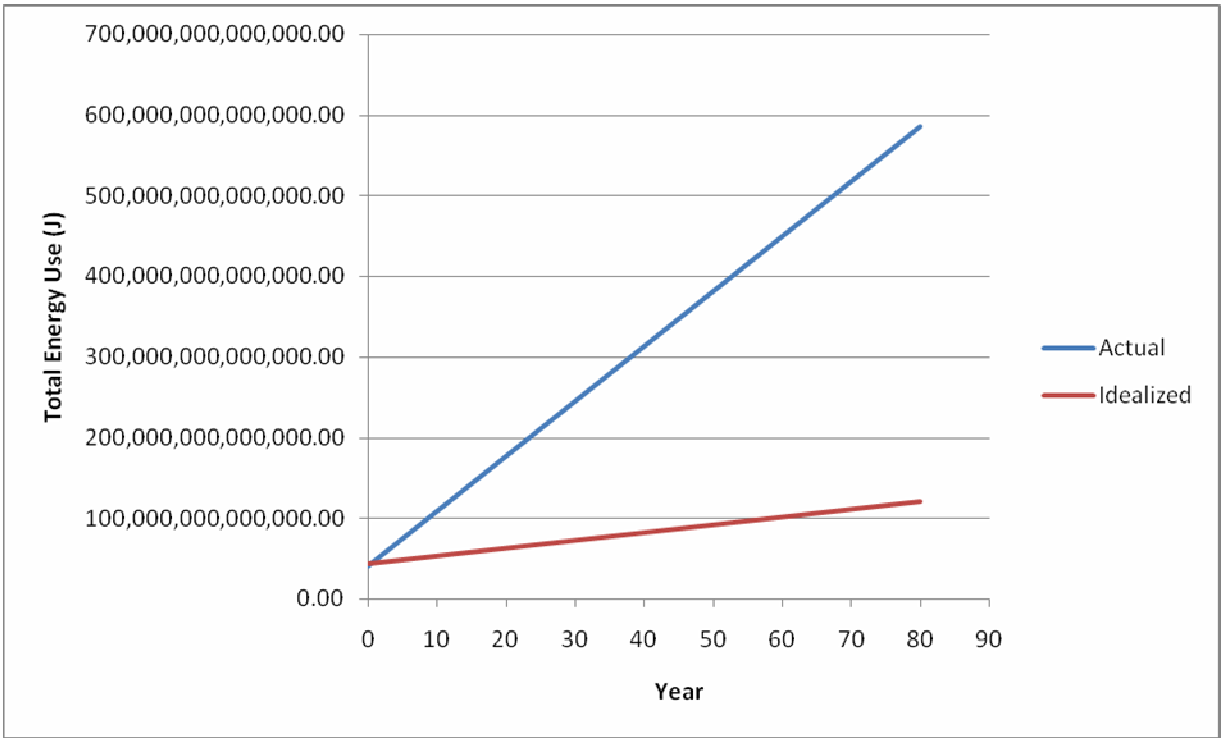

Figure 4. Total energy use by actual and idealized buildings.

As shown in Figure 4, the idealized building is far more energy efficient over its lifetime as it would save 464 520 422 MJ of energy over an 80 year building lifespan. In addition, the energy payback is almost instant. Therefore, it would have an energy efficient idea to construct the original building using the idealized insulation. It may not, however, be environmentally logical to replace the current insulation with the idealized insulation at this time. This is because manufacturing and construction impacts related to the current insulations have already occurred; thus, changing the insulations now would mean that the initial energy usage would become the sum of both the actual and ideal insulation cases. If, sometime in the future, the current insulations have to be replaced for maintenance reasons it would then make sense to replace the current insulations with the idealized insulations.

6.0 CONCLUSION

Modelling and running an LCA on the Buchanan building allowed for many of the building's embodied effects to be calculated. Because of the many sources of uncertainty, these values should be used with their consideration. However, the results do give an initial estimation of the environmental impacts associated with the cradle-to-gate life cycle of the Buchanan building. Major findings include, the primary energy consumption was found to be 208.21 MJ / ft^2. The weighted resource use was found to be 149.88 kg / ft^2. The global warming potential was found to be 19.46 kg CO_2 eq. / kg / ft^2. The acidification potential was found to be 6.43 moles of H+ eq. / kg / ft^2. The human health respiratory effects potential was found to be 0.06 kg $PM_{2.5}$ eq. / kg / ft^2. The eutrophication potential was found to be 0.00 kg N eq. / kg / ft^2. The ozone depletion potential was found to be 0.00 kg CFC-11 eq. / kg / ft^2. Finally, the smog potential was found to be 0.10 kg NOx eq. / kg / ft^2.

In addition to finding the overall impacts associated with the building, a series of sensitivity analyses were carried out to discover which materials created the largest impacts. As expected, it was found that concrete, the most prevalent material used in the building, had the biggest influence on the building's emissions. However, it was also discovered that rebar, a material that was not used nearly as extensively as concrete, had a far more significant effect on the eutrophication potential of the building than the concrete. Thus, if minimizing eutrophication potential is a design requirement then one should focus on minimizing the amount of rebar used. A separate sensitivity analysis was carried out on the porcelain panels located on the exterior of the building. It was found that the panels were the cause of almost 7% of the human health respiratory effects potential associated with the Buchanan building. Thus, removing these panels, which serve no structural purpose, would noticeably lower the human health respiratory effects.

An operating energy analysis was also carried out on the Buchanan building. It was computed that increasing the building's insulation to meet the REAP's insulation requirements would save 464 520 422 MJ of energy over an 80 year building lifespan. Thus, it would have made sense from an energy conservation standpoint to have increased the amount of insulation to match the REAP's insulation requirements when the building was initially constructed.

APPENDIX A: EIE INPUT TABLES

Assembly Group	Assembly Type	Assembly Name	Input Fields	Ideal Inputs	EIE Input
1 Columns and Beams					
	1.1 Mixed Columns and Beams				
		1.1.1 A_Main_Beam&Column			
			Type	Concrete	Concrete
			Number of Columns	44	44
			Number of Beams	33	33
			Height (ft)	10.25	10.25
			Bay Size (ft)	40	40
			Supported Span (ft)	10	10
			Live Load (psf)	60	75
		1.1.2 A_Main_Beam&Column2			
			Type	Concrete	Concrete
			Number of Columns	24	24
			Number of Beams	18	18
			Height (ft)	10.25	10.25
			Bay Size (ft)	10	10
			Supported Span (ft)	20	20
			Live Load (psf)	60	75
		1.1.3 A_2nd_Beam&Column			
			Type	Concrete	Concrete
			Number of Columns	44	44
			Number of Beams	33	33
			Height (ft)	15.6	15.6
			Bay Size (ft)	10	10
			Supported Span (ft)	40	40
			Live Load (psf)	40	45
		1.1.4 A_2nd_Beam&Column2			
			Type	Concrete	Concrete
			Number of Columns	24	24
			Number of Beams	18	18
			Height (ft)	15.6	15.6
			Bay Size (ft)	10	10
			Supported Span (ft)	20	20
			Live Load (psf)	40	45
		1.1.5 B_Main_Beam&Column_Outside			
			Type	Concrete	Concrete
			Number of Columns	44	44
			Number of Beams	36	36
			Height (ft)	9.75	9.75
			Bay Size (ft)	16.75	16.75
			Supported Span (ft)	20	20
			Live Load (psf)	60	75
		1.1.6 B_Main_Beam&Column_Inside			
			Type	Concrete	Concrete
			Number of Columns	38	38
			Number of Beams	42	42
			Height (ft)	9.75	9.75
			Bay Size (ft)	16.75	16.75

	Supported Span (ft)	8.37	10
	Live Load (psf)	60	75
1.1.7 B_2nd_Beam&Column			
	Type	Concrete	Concrete
	Number of Columns	79	79
	Number of Beams	77	77
	Height (ft)	11	11
	Bay Size (ft)	21.6	21.6
	Supported Span (ft)	13.51	13.51
	Live Load (psf)	60	75
1.1.8 B_3rd_Beam&Column			
	Type	Concrete	Concrete
	Number of Columns	79	79
	Number of Beams	77	77
	Height (ft)	11	11
	Bay Size (ft)	21.6	21.6
	Supported Span (ft)	13.51	13.51
	Live Load (psf)	60	75
1.1.9 C_2nd_column&beam			
	Type	Concrete	Concrete
	Number of Beams	56	56
	Number of Columns	60	60
	Height (ft)	9.08	9.08
	Bay Size (ft)	9.4	10
	Supported Span (ft)	9.5	9.5
	Live Load (psf)	50	75
1.1.10 C_main_column&beam			
	Type	Concrete	Concrete
	Number of Beams	56	56
	Number of Columns	60	60
	Height (ft)	9.08	9.08
	Bay Size (ft)	9.4	10
	Supported Span (ft)	9.5	9.5
	Live Load (psf)	50	75
1.1.11 C_3rd_column&beam			
	Type	Concrete	Concrete
	Number of Beams	56	56
	Number of Columns	60	60
	Height (ft)	9.08	9.08
	Bay Size (ft)	9.4	10
	Supported Span (ft)	9.5	9.5
	Live Load (psf)	50	75
1.1.12 C_4th_column&beam			
	Type	Concrete	Concrete
	Number of Beams	56	56
	Number of Columns	60	60
	Height (ft)	9.08	9.08
	Bay Size (ft)	9.4	10
	Supported Span (ft)	9.5	9.5
	Live Load (psf)	50	75
1.1.13 D_main_Beam&Column			
	Type	Concrete	Concrete
	Number of Columns	79	79
	Number of Beams	77	77

			Height (ft)	11	11
			Bay Size (ft)	21.6	21.6
			Supported Span (ft)	13.51	13.51
			Live Load (psf)	60	75
		1.1.14 D_2nd_Beam&Column			
			Type	Concrete	Concrete
			Number of Columns	79	79
			Number of Beams	77	77
			Height (ft)	11	11
			Bay Size (ft)	21.6	21.6
			Supported Span (ft)	13.51	13.51
			Live Load (psf)	60	75
		1.1.15 D_3rd_Beam&Column			
			Type	Concrete	Concrete
			Number of Columns	79	79
			Number of Beams	77	77
			Height (ft)	11	11
			Bay Size (ft)	21.6	21.6
			Supported Span (ft)	13.51	13.51
			Live Load (psf)	60	75
2 Floors					
	2.1 Concrete Suspended Slabs				
		1.2.1 A_2nd_Slab_5"_Concrete			
			Length (ft)	100 and 20	448
			Span (ft)	122 and 62	30
			Concrete (psi)	4000	4000
			Live Load (psf)	60	75
			Concrete flyash %	-	average
		1.2.2 A_2nd_Slab_6"_Concrete			
			Length (ft)	60 and 20	80
			Span (ft)	11 and 41	18.5
			Concrete (psi)	4000	4000
			Live Load (psf)	60	75
			Concrete flyash %	-	average
		1.2.3 A_MainStairs_Landings			
			Length (ft)	15.5	15.5
			Span (ft)	20	20
			Concrete (psi)	4000	4000
			Live Load (psf)	100	100
			Concrete flyash %	-	average
		1.2.4 B_Main_Slab4.5"			
			Length (ft)	79.5	177.77
			Span (ft)	67	30
			Concrete (psi)	4000	4000
			Live Load (psf)	60	75
			Concrete flyash %	-	average
		1.2.5 B_2nd_Slab4.5"			
			Length (ft)	260	580.33
			Span (ft)	67	30
			Concrete (psi)	4000	4000
			Live Load (psf)	60	75
			Concrete flyash %	-	average
		1.2.6 B_3nd_Slab4.5"			
			Length (ft)	260	580.33

	Span (ft)	67	30
	Concrete (psi)	4000	4000
	Live Load (psf)	60	75
	Concrete flyash %	-	average
1.2.7 B_LinkStairs_Landing			
	Length (ft)	9.21	20.262
	Span (ft)	66	30
	Concrete (psi)	4000	4000
	Live Load (psf)	100	100
	Concrete flyash %	-	average
1.2.8 B_LinkStairs_Entrance			
	Length (ft)	9.21	9.21
	Span (ft)	23	23
	Concrete (psi)	4000	4000
	Live Load (psf)	100	100
	Concrete flyash %	-	average
1.2.9 B_MainStairs_Landings			
	Length (ft)	9.21	27.937
	Span (ft)	91	30
	Concrete (psi)	4000	4000
	Live Load (psf)	100	100
	Concrete flyash %	-	average
1.2.10 C_2nd_slab			
	Length (ft)	141	178.6
	Span (ft)	38	30
	Concrete (psi)	4000	4000
	Live Load (psf)	50	75
	Concrete flyash %	-	average
1.2.11 C_main_slab			
	Length (ft)	141	178.6
	Span (ft)	38	30
	Concrete (psi)	4000	4000
	Live Load (psf)	50	75
	Concrete flyash %	-	average
1.2.12 C_3rd_slab			
	Length (ft)	141	178.6
	Span (ft)	38	30
	Concrete (psi)	4000	4000
	Live Load (psf)	50	75
	Concrete flyash %	-	average
1.2.13 C_4th_slab			
	Length (ft)	141	178.6
	Span (ft)	38	30
	Concrete (psi)	4000	4000
	Live Load (psf)	50	75
	Concrete flyash %	-	average
1.2.14 C_LinkStairs_Landings			
	Length (ft)	32	32
	Span (ft)	15	15
	Concrete (psi)	4000	4000
	Live Load (psf)	100	100
	Concrete flyash %	-	average
1.2.15 C_ExitStairs_Landings			
	Length (ft)	12	9

			Span (ft)	9	12
			Concrete (psi)	4000	4000
			Live Load (psf)	100	100
			Concrete flyash %	-	average
		1.2.16 D_Main_Slab4.5"			
			Length (ft)	79.5	177.77
			Span (ft)	67	30
			Concrete (psi)	4000	4000
			Live Load (psf)	60	75
			Concrete flyash %	-	average
		1.2.17 D_2nd_Slab4.5"			
			Length (ft)	260	580.33
			Span (ft)	67	30
			Concrete (psi)	4000	4000
			Live Load (psf)	60	75
			Concrete flyash %	-	average
		1.2.18 D_3nd_Slab4.5"			
			Length (ft)	260	580.33
			Span (ft)	67	30
			Concrete (psi)	4000	4000
			Live Load (psf)	60	75
			Concrete flyash %	-	average
		1.2.19 D_LinkStairs_Landing			
			Length (ft)	9.21	20.262
			Span (ft)	66	30
			Concrete (psi)	4000	4000
			Live Load (psf)	100	100
			Concrete flyash %	-	average
		1.2.20 D_LinkStairs_Entrance			
			Length (ft)	9.21	9.21
			Span (ft)	23	23
			Concrete (psi)	4000	4000
			Live Load (psf)	100	100
			Concrete flyash %	-	average
		1.2.21 D_MainStairs_Landings			
			Length (ft)	9.21	27.937
			Span (ft)	91	30
			Concrete (psi)	4000	4000
			Live Load (psf)	100	100
			Concrete flyash %	-	average
3 Roofs					
	3.1 Concrete Suspended Slabs				
		3.1.1 A_Roof_Entrance			
			Length (ft)	50	100
			Span (ft)	60	30
			Concrete (psi)	4000	4000
			Live Load (psf)	40	45
			Concrete flyash %	-	average
		Define Envelope	Category	Roof Envelope	Roof Envelope
			Material	Bitumen	Bitumen
			Type	-	Standard Modified
			Thickness	-	-
			Category	Insulation	Insulation

			Material	-	Polystyrene
			Type	-	Extruded
			Thickness (in.)	1	2
			Category	-	Vapour barrier
			Material	-	Polyethylene
			Type	-	3 mil
			Thickness	-	-
		3.1.2 A_Roof_ConcreteSlab			
		Define Envelope	Length (ft)	100	379.17
			Span (ft)	122	30
			Concrete (psi)	4000	4000
			Live Load (psf)	40	45
			Concrete flyash %	-	average
			Category	Roof Envelope	Roof Envelope
			Material	Bitumen	Bitumen
			Type	-	Standard Modified
			Thickness	-	-
			Category	Insulation	Insulation
			Material	-	Polystyrene
			Type	-	Extruded
			Thickness (in.)	1	2
			Category	-	Vapour barrier
			Material	-	Polyethylene
			Type	-	3 mil
			Thickness	-	-
		3.1.3 B_Roof_Slab4.5"			
		Define Envelope	Length (ft)	260	580.67
			Span (ft)	67	30
			Concrete (psi)	4000	4000
			Live Load (psf)	40	45
			Concrete flyash %	-	average
			Category	Roof Envelope	Roof Envelope
			Material	Bitumen	Bitumen
			Type	-	Standard Modified
			Thickness	-	-
			Category	Insulation	Insulation
			Material	-	Polystyrene
			Type	-	Extruded
			Thickness (in.)	1	2
			Category	-	Vapour barrier
			Material	-	Polyethylene
			Type	-	3 mil
			Thickness	-	-
		3.1.4 C_Roof_Slab			
		Define Envelope	Length (ft)	141	178.6
			Span (ft)	38	30
			Concrete (psi)	4000	4000
			Live Load (psf)	40	45
			Concrete flyash %	-	average
			Category	Roof Envelope	Roof Envelope
			Material	Bitumen	Bitumen
			Type	-	Standard Modified

			Thickness	-	-
			Category	Insulation	Insulation
			Material	-	Polystyrene
			Type	-	Extruded
			Thickness (in.)	1	2
			Category	-	Vapour barrier
			Material	-	Polyethylene
			Type	-	3 mil
			Thickness	-	-
		3.1.5 D_Roof_Slab4.5"			
		Define Envelope	Length (ft)	260	580.67
			Span (ft)	67	30
			Concrete (psi)	4000	4000
			Live Load (psf)	40	45
			Concrete flyash %	-	average
			Category	Roof Envelope	Roof Envelope
			Material	Bitumen	Bitumen
			Type	-	Standard Modified
			Thickness	-	-
			Category	Insulation	Insulation
			Material	-	Polystyrene
			Type	-	Extruded
			Thickness (in.)	1	2
			Category	-	Vapour barrier
			Material	-	Polyethylene
			Type	-	3 mil
			Thickness	-	-
4 Foundations					
	4.1 Concrete Footings				
		4.1.1 A_Foundation_Footing_1'6"			
			Length (ft.)	5 @ approx. 5.25	10
			Width (ft.)	5 @ approx. 5.25	13.9
			Thickness (in.)	18	18
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		4.1.2 A_Foundation_Footing_2'			
			Length (ft.)	2 @ 3 and 7.5	8
			Width (ft.)	2 @ 3 and 7.5	12.33
			Thickness (in.)	24	18
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	6 and 7	6
		4.1.3 A_Foundation_Footing_2'4"			
			Length (ft.)	4 @ 10	20
			Width (ft.)	4 @ 10	31.11
			Thickness (in.)	28	18
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	8	6
		4.1.4 A_Foundation_Footing_1'9"			
			Length (ft.)	7	7

			Width (ft.)	7	8.17
			Thickness (in.)	21	18
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	6	6
		4.1.5 A_Foundation_Footing_2'6"x1'6"			
			Length (ft.)	84	84
			Width (ft.)	2.5	2.5
			Thickness (in.)	18	18
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	4
		4.1.6 A_Foundation_Footing_3'x1'6"			
			Length (ft.)	15	15
			Width (ft.)	3	3
			Thickness (in.)	18	18
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	4
		4.1.7 A_Foundation_Footing_1'6"x2'			
			Length (ft.)	298	298
			Width (ft.)	1.5	2
			Thickness (in.)	24	18
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	4
		4.1.8 A_Foundation_Footing_3'6"x2'			
			Length (ft.)	125	125
			Width (ft.)	3.5	4.67
			Thickness (in.)	24	18
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	4
		4.1.9 B_Foundation_Footing16"			
			Length (ft.)	4@5.33 and 8@5.83	20
			Width (ft.)	4@5.33 and 8@5.84	19.3
			Thickness (in.)	16	16
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		4.1.10 B_Foundation_Footing3'			
			Length (ft.)	12 between 20-25	40
			Width (ft.)	12 between 6-6.33	70
			Thickness (in.)	36	18
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5, 6 and 7	6
		4.1.11 B_Foundation_Footing1'			
			Length (ft.)	6 @ 3.25	8
			Width (ft.)	6 @ 3.25	8
			Thickness (in.)	12	2
			Concrete (psf)	4000	4000

	Concrete flyash %	-	average
	Rebar #	4	4
4.1.12 B_Foundation_Footing2'Wall			
	Length (ft.)	96	96
	Width (ft.)	2	2
	Thickness (in.)	18	18
	Concrete (psf)	4000	4000
	Concrete flyash %	-	average
	Rebar #	4	4
4.1.13 B_Foundation_Footing10"Wall			
	Length (ft.)	122	122
	Width (ft.)	0.83	0.83
	Thickness (in.)	12	12
	Concrete (psf)	4000	4000
	Concrete flyash %	-	average
	Rebar #	4	4
4.1.14 B_Foundation_Footing3'Wall			
	Length (ft.)	224	224
	Width (ft.)	3	3
	Thickness (in.)	18	18
	Concrete (psf)	4000	4000
	Concrete flyash %	-	average
	Rebar #	8	6
4.1.15 B_Foundation_Footing2'Wall2			
	Length (ft.)	71	71
	Width (ft.)	2	2
	Thickness (in.)	10	10
	Concrete (psf)	4000	4000
	Concrete flyash %	-	average
	Rebar #	6	6
4.1.16 B_Foundation_Footing3'Wall2			
	Length (ft.)	121	121
	Width (ft.)	3	3
	Thickness (in.)	12	12
	Concrete (psf)	4000	4000
	Concrete flyash %	-	average
	Rebar #	8	6
4.1.17 B_Foundation_Footing2'6"Wall			
	Length (ft.)	167	167
	Width (ft.)	2.5	2.5
	Thickness (in.)	18	18
	Concrete (psf)	4000	4000
	Concrete flyash %	-	average
	Rebar #	5	5
4.1.18 B_Foundation_Footing12"Wall			
	Length (ft.)	32	32
	Width (ft.)	1	1
	Thickness (in.)	10	10
	Concrete (psf)	4000	4000
	Concrete flyash %	-	average
	Rebar #	4	4
4.1.19 B_Foundation_Footing16"Wall			
	Length (ft.)	60	60
	Width (ft.)	1.33	1.33

			Thickness (in.)	10	10
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	4
		4.1.20 C_Foundation_Footing_1'6"x2'Wall			
			Length (ft.)	628	628
			Width (ft.)	2	2
			Thickness (in.)	18	18
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		4.1.21 C_Foundation_Footing_1'x8"Wall			
			Length (ft.)	350	350
			Width (ft.)	1	1
			Thickness (in.)	8	8
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		4.1.22 D_Foundation_Footing16"			
			Length (ft.)	4@5.33 and 8@5.83	20
			Width (ft.)	4@5.33 and 8@5.84	19.3
			Thickness (in.)	16	16
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		4.1.23 D_Foundation_Footing3'			
			Length (ft.)	12 between 20-25	40
			Width (ft.)	12 between 6-6.33	70
			Thickness (in.)	36	18
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5, 6 and 7	6
		4.1.24 D_Foundation_Footing1'			
			Length (ft.)	6 @ 3.25	8
			Width (ft.)	6 @ 3.25	8
			Thickness (in.)	12	2
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	4
		4.1.25 D_Foundation_Footing2'Wall			
			Length (ft.)	96	96
			Width (ft.)	2	2
			Thickness (in.)	18	18
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	4
		4.1.26 D_Foundation_Footing10"Wall			
			Length (ft.)	122	122
			Width (ft.)	0.83	0.83
			Thickness (in.)	12	12
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average

	Rebar #	4	4
4.1.27 D_Foundation_Footing3'Wall			
	Length (ft.)	224	224
	Width (ft.)	3	3
	Thickness (in.)	18	18
	Concrete (psf)	4000	4000
	Concrete flyash %	-	average
	Rebar #	8	6
4.1.28 D_Foundation_Footing2'Wall2			
	Length (ft.)	71	71
	Width (ft.)	2	2
	Thickness (in.)	10	10
	Concrete (psf)	4000	4000
	Concrete flyash %	-	average
	Rebar #	6	6
4.1.29 D_Foundation_Footing3'Wall2			
	Length (ft.)	121	121
	Width (ft.)	3	3
	Thickness (in.)	12	12
	Concrete (psf)	4000	4000
	Concrete flyash %	-	average
	Rebar #	8	6
4.1.30 D_Foundation_Footing2'6"Wall			
	Length (ft.)	167	167
	Width (ft.)	2.5	2.5
	Thickness (in.)	18	18
	Concrete (psf)	4000	4000
	Concrete flyash %	-	average
	Rebar #	5	5
4.1.31 D_Foundation_Footing12"Wall			
	Length (ft.)	32	32
	Width (ft.)	1	1
	Thickness (in.)	10	10
	Concrete (psf)	4000	4000
	Concrete flyash %	-	average
	Rebar #	4	4
4.1.32 D_Foundation_Footing16"Wall			
	Length (ft.)	60	60
	Width (ft.)	1.33	1.33
	Thickness (in.)	10	10
	Concrete (psf)	4000	4000
	Concrete flyash %	-	average
	Rebar #	4	4
4.1.33 A_MainStairs_Stairs			
	Length (ft.)	70	70
	Width (ft.)	7	7
	Thickness (in.)	7	7.5
	Concrete (psf)	4000	4000
	Concrete flyash %	-	average
	Rebar #	5	5
4.1.34 B_LinkStairs_Stairs			
	Length (ft.)	9.21	9.21
	Width (ft.)	49	49
	Thickness (in.)	8	8

			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		4.1.35 B_MainStairs_Stairs			
			Length (ft.)	9.54	9.54
			Width (ft.)	66	66
			Thickness (in.)	8	8
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		4.1.36 C_LinkStairs_Stairs			
			Length (ft.)	65	65
			Width (ft.)	7	7
			Thickness (in.)	10	10
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		4.1.37 C_ExitStairs_Stairs			
			Length (ft.)	32	32
			Width (ft.)	15	15
			Thickness (in.)	8	8
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		4.1.38 D_LinkStairs_Stairs			
			Length (ft.)	9.21	9.21
			Width (ft.)	49	49
			Thickness (in.)	8	8
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		4.1.39 D_MainStairs_Stairs			
			Length (ft.)	9.54	9.54
			Width (ft.)	66	66
			Thickness (in.)	8	8
			Concrete (psf)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
	4.2 Concrete Slab On Grade				
		4.2.1 A_Main_Slab_6"			
		Define Envelope	Length (ft)	105 and 62	100
			Width (ft)	180 and 18.5	198
			Thickness (in.)	6	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Category	-	Vapour barrier
			Material	-	Polyethylene
			Type	-	6mil
			Thickness	-	-
		4.2.2 B_Foundation_Slab6"			
			Length (ft)	77	58
			Width (ft)	65	65
			Thickness (in.)	6	8
			Concrete (psi)	4000	4000

		Define Envelope	Concrete flyash %	-	average
			Category	-	Vapour barrier
			Material	-	Polyethylene
			Type	-	6mil
			Thickness	-	-
		4.2.3 B_Foundation_Slab4"			
		Define Envelope	Length (ft)	98 and 26	40
			Width (ft)	9.5 and 2.67	25
			Thickness (in.)	4	4
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Category	-	Vapour barrier
			Material	-	Polyethylene
			Type	-	6mil
			Thickness	-	-
		4.2.4 B_Main _Slab4"			
		Define Envelope	Length (ft)	40	40
			Width (ft)	73	73
			Thickness (in.)	4	4
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Category	-	Vapour barrier
			Material	-	Polyethylene
			Type	-	6mil
			Thickness	-	-
		4.2.5 C_Foundation_Slab4"			
		Define Envelope	Length (ft)	1200 sqft	30
			Width (ft)	1201 sqft	40
			Thickness (in.)	4	4
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Category	-	Vapour barrier
			Material	-	Polyethylene
			Type	-	6mil
			Thickness	-	-
		4.2.6 D_Foundation_Slab6"			
		Define Envelope	Length (ft)	77	58
			Width (ft)	65	65
			Thickness (in.)	6	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Category	-	Vapour barrier
			Material	-	Polyethylene
			Type	-	6mil
			Thickness	-	-
		4.2.7 D_Foundation_Slab4"			
		Define	Length (ft)	98 and 26	40
			Width (ft)	9.5 and 2.67	25
			Thickness (in.)	4	4
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Category	-	Vapour barrier

		Envelope			
			Material	-	Polyethylene
			Type	-	6mil
			Thickness	-	-
		4.2.8 D_Main _Slab4"			
		Define Envelope	Length (ft)	40	40
			Width (ft)	73	73
			Thickness (in.)	4	4
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Category	-	Vapour barrier
			Material	-	Polyethylene
			Type	-	6mil
			Thickness	-	-
5 Walls					
	5.1 Concrete Block				
		5.1.1 A_2nd_Brick_In			
			Length (ft)	176	176
			Height (ft)	15.5	15.5
			Rebar #	3	4
		5.1.2 A_2nd_Wall_10"Brick			
			Length (ft)	401	401
			Height (ft)	15.5	15.5
			Rebar #	4	4
		5.1.3 B_2nd_Wall_EW			
			Length (ft)	128	128
			Height (ft)	11	11
			Rebar #	4	4
		5.1.4 B_2nd_Wall_NSBlock			
		Opening	Length (ft)	467	467
			Height (ft)	11	11
			Rebar #	5	5
			Total Opening Area (ft2)	2965.16	2965.16
			Number of Windows	92	92
			Frame Material	-	-
			Frame Type	-	-
			Glazing Type	-	-
		5.1.5 B_3nd_Wall_NSBlock			
		Opening	Length (ft)	467	467
			Height (ft)	11	11
			Rebar #	5	5
			Total Opening Area (ft2)	3223	3223
			Number of Windows	100	100
			Frame Material	-	-
			Frame Type	-	-
			Glazing Type	-	-
		5.1.6 B_3nd_Wall_EW			
			Length (ft)	128	128
			Height (ft)	11	11
			Rebar #	4	4
		5.1.7 B_All_StairsWall			
			Length (ft)	126	126
			Height (ft)	35	35
			Rebar #	5	5

		Opening	Total Opening Area (ft2)	630	630
			Number of Windows	2	2
			Frame Material	Aluminum	Aluminum
			Frame Type	Fixed	Fixed
			Glazing Type	Standard	Standard
		5.1.8 C_2nd_Wall_Outside			
		Opening	Length (ft)	323	323
			Height (ft)	9.08	9.08
			Rebar #	5	5
			Total Opening Area (ft2)	1841.6	1841.6
			Number of Windows	80	80
			Frame Material	-	-
			Frame Type	-	-
			Glazing Type	-	-
		5.1.9 C_Main_Wall_Outside			
		Opening	Length (ft)	323	323
			Height (ft)	9.08	9.08
			Rebar #	5	5
			Total Opening Area (ft2)	1841.6	1841.6
			Number of Windows	80	80
			Frame Material	-	-
			Frame Type	-	-
			Glazing Type	-	-
		5.1.10 C_3rd_Wall_Outside			
		Opening	Length (ft)	323	323
			Height (ft)	9.08	9.08
			Rebar #	5	5
			Total Opening Area (ft2)	1841.6	1841.6
			Number of Windows	80	80
			Frame Material	-	-
			Frame Type	-	-
			Glazing Type	-	-
		5.1.11 C_4th_Wall_Outside			
		Opening	Length (ft)	323	323
			Height (ft)	9.08	9.08
			Rebar #	5	5
			Total Opening Area (ft2)	1841.6	1841.6
			Number of Windows	80	80
			Frame Material	-	-
			Frame Type	-	-
			Glazing Type	-	-
		5.1.12 D_Main_Wall_EW			
			Length (ft)	128	128
			Height (ft)	11	11
			Rebar #	4	4
		5.1.13 D_Main_Wall_NSBlock			
		Opening	Length (ft)	467	467
			Height (ft)	11	11
			Rebar #	5	5
			Total Opening Area (ft2)	2965.16	2965.16
			Number of Windows	92	92
			Frame Material	-	-
			Frame Type	-	-
			Glazing Type	-	-
		5.1.14 D_2nd_Wall_EW			

			Length (ft)	128	128
			Height (ft)	11	11
			Rebar #	4	4
		5.1.15 D_2nd_Wall_NSBlock			
		Opening	Length (ft)	467	467
			Height (ft)	11	11
			Rebar #	5	5
			Total Opening Area (ft2)	2965.16	2965.16
			Number of Windows	92	92
			Frame Material	-	-
			Frame Type	-	-
			Glazing Type	-	-
		5.1.16 D_3nd_Wall_NSBlock			
		Opening	Length (ft)	467	467
			Height (ft)	11	11
			Rebar #	5	5
			Total Opening Area (ft2)	3223	3223
			Number of Windows	100	100
			Frame Material	-	-
			Frame Type	-	-
			Glazing Type	-	-
		5.1.17 D_3nd_Wall_EW			
			Length (ft)	128	128
			Height (ft)	11	11
			Rebar #	4	4
		5.1.18 D_All_StairsWall			
		Opening	Length (ft)	126	126
			Height (ft)	35	35
			Rebar #	5	5
			Total Opening Area (ft2)	630	630
			Number of Windows	2	2
			Frame Material	Aluminum	Aluminum
			Frame Type	Fixed	Fixed
			Glazing Type	Standard	Standard
	5.2 Cast In Place				
		5.2.1 A_Foundation_TieBeam_12x12			
			Length (ft)	154	154
			Width (ft)	1	1
			Thickness (in.)	12	12
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5
		5.2.2 A_Foundation_TieBeam_16x16			
			Length (ft)	275	275
			Width (ft)	1.33	1.78
			Thickness (in.)	16	12
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5
		5.2.3 A_Foundation_Wall_10"			
			Length (ft)	636	636
			Width (ft)	17.5	14.58
			Thickness (in.)	10	12
			Concrete (psi)	4000	4000

			Concrete flyash %	-	average
			Rebar #	4	5
		5.2.4 A_2nd_8"			
			Length (ft)	57	57
			Width (ft)	9.5	9.5
			Thickness (in.)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5
		5.2.6 B_Foundation_TieBeam			
			Length (ft)	344	344
			Width (ft)	1	1
			Thickness (in.)	12	12
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		5.2.7 B_Foundation_Wall8"			
			Length (ft)	414	414
			Width (ft)	8.33	8.33
			Thickness (in.)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		5.2.8 B_Foundation_Wall8"2			
			Length (ft)	401	401
			Width (ft)	6.17	6.17
			Thickness (in.)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5
		5.2.9 B_Foundation_Wall8"3			
			Length (ft)	116	116
			Width (ft)	11.17	11.17
			Thickness (in.)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5
		5.2.10 B_Foundation_Wall10"			
			Length (ft)	243	243
			Width (ft)	11.17	9.31
			Thickness (in.)	10	12
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5
		5.2.11 B_Foundation_Wall6"			
			Length (ft)	10	10
			Width (ft)	4.5	3.38
			Thickness (in.)	6	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5
		5.2.12 B_Foundation_ShortWall			
			Length (ft)	53	53
			Width (ft)	2.75	2.29

			Thickness (in.)	10	12
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		5.2.13 B_Main_Wall12"			
			Length (ft)	54	54
			Width (ft)	9.75	9.75
			Thickness (in.)	12	12
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		5.2.14 B_Main_Wall8"			
			Length (ft)	152	152
			Width (ft)	9.75	9.75
			Thickness (in.)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5
		Opening	Number of Doors	1	1
			Door Material	Aluminum	Aluminum
			Door Type	Exterior	Exterior, 80% Glazing
		5.2.15 B_Main_Wall10"			
			Length (ft)	126	126
			Width (ft)	9.75	8.13
			Thickness (in.)	10	12
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		Opening	Total Opening Area (ft2)	190.84	190.84
			Number of Windows	24	24
			Frame Material	Aluminum	Aluminum
			Frame Type	Fixed	Fixed
			Glazing Type	Standard	Standard
		5.2.16 C_Foundation_CenterWall			
			Length (ft)	278	278
			Width (ft)	5.5	5.5
			Thickness (in.)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5
		5.2.17 C_Foundation_ExteriorWall			
			Length (ft)	354	354
			Width (ft)	6	6
			Thickness (in.)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5
		5.2.18 C_Foundation_InsideWall			
			Length (ft)	328	328
			Width (ft)	4.625	4.625
			Thickness (in.)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5

		5.2.19 D_Foundation_TieBeam			
			Length (ft)	344	344
			Width (ft)	1	1
			Thickness (in.)	12	12
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		5.2.20 D_Foundation_Wall8"			
			Length (ft)	414	414
			Width (ft)	8.33	8.33
			Thickness (in.)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
		5.2.21 D_Foundation_Wall8"2			
			Length (ft)	401	401
			Width (ft)	6.17	6.17
			Thickness (in.)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5
		5.2.22 D_Foundation_Wall8"3			
			Length (ft)	116	116
			Width (ft)	11.17	11.17
			Thickness (in.)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5
		5.2.23 D_Foundation_Wall10"			
			Length (ft)	243	243
			Width (ft)	11.17	9.31
			Thickness (in.)	10	12
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5
		5.2.24 D_Foundation_Wall6"			
			Length (ft)	10	10
			Width (ft)	4.5	3.38
			Thickness (in.)	6	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	4	5
		5.2.25 D_Foundation_ShortWall			
			Length (ft)	53	53
			Width (ft)	2.75	2.29
			Thickness (in.)	10	12
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar #	5	5
	5.3 Curtain				
		5.3.1 A_Roof_Skylight			
			Length (ft)	75	75
			Width (ft)	11	11
			Percent Viewable Glazing (%)	100	95

			Percent Spandrel Panel (%)	0	5
			Thickness of Insulation (in)	-	1
		5.3.2 A_2nd_PlateGlass			
			Length (ft)	115	115
			Width (ft)	9.5	9.5
			Percent Viewable Glazing (%)	-	95
			Percent Spandrel Panel (%)	-	5
			Thickness of Insulation (in)	-	1
		Opening	Number of Doors	2	2
			Door Material	-	Aluminum
			Door Type	Exterior	Exterior, 80% Glazing
		5.3.3 A_Main_PlateGlass			
			Length (ft)	181	181
			Width (ft)	9.5	9.5
			Percent Viewable Glazing (%)	-	95
			Percent Spandrel Panel (%)	-	5
			Thickness of Insulation (in)	-	1
		Opening	Number of Doors	4	4
			Door Material	-	Aluminum
			Door Type	Exterior	Exterior, 80% Glazing
	5.4 Wood Stud				
		5.4.1 A_2nd_Wall_In			
			Length (ft)	349	349
			Height (ft)	9.5	9.5
			Wall Type	Interior	Interior
			Sheathing Type	None	None
			Stud Spacing (in)	16	16
			Stud Type	-	Kiln-dried
			Stud Thickness	2x4	2x4
		Opening	Number of Doors	26	26
			Door Material	Wood	Wood
			Door Type	Interior	Hollow Core Interior
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	-	Regular
			Thickness (in)	-	0.5
		5.4.2 B_2nd_Wall_EW_Wood			
			Length (ft)	128	128
			Height (ft)	11	11
			Wall Type	Interior	Interior
			Sheathing Type	None	None
			Stud Spacing (in)	16	16
			Stud Type	-	Kiln-dried
			Stud Thickness	2x4	2x4
		Envelope	Category	Insulation	Insulation
			Material	Batt	Rockwool Batt
			Thickness (in)	2	2
		5.4.3 B_2nd_Wall_NS_Wood			
			Length (ft)	467	467
			Height (ft)	11	11
			Wall Type	Interior	Interior
			Sheathing Type	Plywood	Plywood
			Stud Spacing (in)	24	24
			Stud Type	-	Kiln-dried

			Stud Thickness	2x6	2x6
		Opening	Total Opening Area (ft2)	2965.16	2965.16
			Number of Windows	92	92
			Frame Material	Aluminum	Aluminum
			Frame Type	Fixed	Fixed
			Glazing Type	Standard	Standard
		Envelope	Category	Insulation	Insulation
			Material	Batt	Rockwool Batt
			Thickness (in)	1	1
		5.4.4 B_3nd_Wall_EW_Wood			
			Length (ft)	128	128
			Height (ft)	11	11
			Wall Type	Interior	Interior
			Sheathing Type	None	None
			Stud Spacing (in)	16	16
			Stud Type	-	Kiln-dried
			Stud Thickness	2x4	2x4
		Envelope	Category	Insulation	Insulation
			Material	Batt	Rockwool Batt
			Thickness (in)	2	2
		5.4.5 B_3nd_Wall_NS_Wood			
			Length (ft)	467	467
			Height (ft)	11	11
			Wall Type	Interior	Interior
			Sheathing Type	Plywood	Plywood
			Stud Spacing (in)	24	24
			Stud Type	-	Kiln-dried
			Stud Thickness	2x6	2x6
		Opening	Total Opening Area (ft2)	2965.16	2965.16
			Number of Windows	92	92
			Frame Material	Aluminum	Aluminum
			Frame Type	Fixed	Fixed
			Glazing Type	Standard	Standard
		Envelope	Category	Insulation	Insulation
			Material	Batt	Rockwool Batt
			Thickness (in)	1	1
		5.4.6 B_2nd_InteriorWall			
			Length (ft)	953	953
			Height (ft)	11	11
			Wall Type	Interior	Interior
			Sheathing Type	Plywood	Plywood
			Stud Spacing (in)	-	16
			Stud Type	-	Kiln-dried
			Stud Thickness	-	2x4
		Opening	Number of Doors	31	31
			Door Material	Wood	Wood
			Door Type	Interior	Hollow Core Interior
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	-	Regular
			Thickness (in)	-	0.5
		5.4.7 B_3nd_InteriorWall			
			Length (ft)	953	953
			Height (ft)	11	11
			Wall Type	Interior	Interior

			Sheathing Type	Plywood	Plywood
			Stud Spacing (in)	-	16
			Stud Type	-	Kiln-dried
			Stud Thickness	-	2x4
		Opening	Number of Doors	31	31
			Door Material	Wood	Wood
			Door Type	Interior	Hollow Core Interior
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	-	Regular
			Thickness (in)	-	0.5
		5.4.8 C_2nd_Wall_Outside_Wood			
			Length (ft)	323	323
			Height (ft)	9.08	9.08
			Wall Type	Interior	Interior
			Sheathing Type	Plywood	Plywood
			Stud Spacing (in)	24	24
			Stud Type	-	Kiln-dried
			Stud Thickness	2x6	2x6
			Total Opening Area (ft2)	1841.6	1841.6
			Number of Windows	80	80
		Opening	Frame Material	Aluminum	Aluminum
			Frame Type	Fixed	Fixed
			Glazing Type	Standard	Standard
		Envelope	Category	Insulation	Insulation
			Material	Batt	Rockwool Batt
			Thickness (in)	1	1
		5.4.9 C_Main_Wall_Outside_Wood			
			Length (ft)	323	323
			Height (ft)	9.08	9.08
			Wall Type	Interior	Interior
			Sheathing Type	Plywood	Plywood
			Stud Spacing (in)	24	24
			Stud Type	-	Kiln-dried
			Stud Thickness	2x6	2x6
			Total Opening Area (ft2)	1841.6	1841.6
			Number of Windows	80	80
		Opening	Frame Material	Aluminum	Aluminum
			Frame Type	Fixed	Fixed
			Glazing Type	Standard	Standard
		Envelope	Category	Insulation	Insulation
			Material	Batt	Rockwool Batt
			Thickness (in)	1	1
		5.4.10 C_3rd_Wall_Outside_Wood			
			Length (ft)	323	323
			Height (ft)	9.08	9.08
			Wall Type	Interior	Interior
			Sheathing Type	Plywood	Plywood
			Stud Spacing (in)	24	24
			Stud Type	-	Kiln-dried
			Stud Thickness	2x6	2x6
			Total Opening Area (ft2)	1841.6	1841.6
			Number of Windows	80	80
		Opening	Frame Material	Aluminum	Aluminum
			Frame Type	Fixed	Fixed

			Glazing Type	Standard	Standard
		Envelope	Category	Insulation	Insulation
			Material	Batt	Rockwool Batt
			Thickness (in)	1	1
		5.4.11 C_4th_Wall_Outside_Wood			
			Length (ft)	323	323
			Height (ft)	9.08	9.08
			Wall Type	Interior	Interior
			Sheathing Type	Plywood	Plywood
			Stud Spacing (in)	24	24
			Stud Type	-	Kiln-dried
			Stud Thickness	2x6	2x6
			Total Opening Area (ft2)	1841.6	1841.6
			Number of Windows	80	80
		Opening	Frame Material	Aluminum	Aluminum
			Frame Type	Fixed	Fixed
			Glazing Type	Standard	Standard
		Envelope	Category	Insulation	Insulation
			Material	Batt	Rockwool Batt
			Thickness (in)	1	1
		5.4.12 C_2nd_inside_wall			
			Length (ft)	776	776
			Height (ft)	9.08	9.08
			Wall Type	Interior	Interior
			Sheathing Type	None	None
			Stud Spacing (in)	-	16
			Stud Type	-	Kiln-dried
			Stud Thickness	2x4	2x4
		Opening	Number of Doors	32	32
			Door Material	Wood	Wood Hollow Core
			Door Type	Interior	Interior
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	-	Regular
			Thickness (in)	-	0.5
		5.4.13 C_Main_inside_wall			
			Length (ft)	776	776
			Height (ft)	9.08	9.08
			Wall Type	Interior	Interior
			Sheathing Type	None	None
			Stud Spacing (in)	-	16
			Stud Type	-	Kiln-dried
			Stud Thickness	2x4	2x4
		Opening	Number of Doors	32	32
			Door Material	Wood	Wood Hollow Core
			Door Type	Interior	Interior
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	-	Regular
			Thickness (in)	-	0.5
		5.4.14 C_3rd_inside_wall			
			Length (ft)	776	776
			Height (ft)	9.08	9.08
			Wall Type	Interior	Interior
			Sheathing Type	None	None

			Stud Spacing (in)	-	16
			Stud Type	-	Kiln-dried
			Stud Thickness	2x4	2x4
		Opening	Number of Doors	32	32
			Door Material	Wood	Wood
			Door Type	Interior	Hollow Core Interior
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	-	Regular
			Thickness (in)	-	0.5
		5.4.15 C_4th_inside_wall			
			Length (ft)	776	776
			Height (ft)	9.08	9.08
			Wall Type	Interior	Interior
			Sheathing Type	None	None
			Stud Spacing (in)	-	16
			Stud Type	-	Kiln-dried
			Stud Thickness	2x4	2x4
		Opening	Number of Doors	32	32
			Door Material	Wood	Wood
			Door Type	Interior	Hollow Core Interior
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	-	Regular
			Thickness (in)	-	0.5
		5.4.16 D_2nd_Wall_EW_Wood			
			Length (ft)	128	128
			Height (ft)	11	11
			Wall Type	Interior	Interior
			Sheathing Type	None	None
			Stud Spacing (in)	16	16
			Stud Type	-	Kiln-dried
			Stud Thickness	2x4	2x4
		Envelope	Category	Insulation	Insulation
			Material	Batt	Rockwool Batt
			Thickness (in)	2	2
		5.4.17 D_2nd_Wall_NS_Wood			
			Length (ft)	467	467
			Height (ft)	11	11
			Wall Type	Interior	Interior
			Sheathing Type	Plywood	Plywood
			Stud Spacing (in)	24	24
			Stud Type	-	Kiln-dried
			Stud Thickness	2x6	2x6
			Total Opening Area (ft^2)	2965.16	2965.16
			Number of Windows	92	92
		Opening	Frame Material	Aluminum	Aluminum
			Frame Type	Fixed	Fixed
			Glazing Type	Standard	Standard
		Envelope	Category	Insulation	Insulation
			Material	Batt	Rockwool Batt
			Thickness (in)	1	1
		5.4.18 D_main_Wall_EW_Wood			
			Length (ft)	128	128
			Height (ft)	11	11
			Wall Type	Interior	Interior

			Sheathing Type	None	None
			Stud Spacing (in)	16	16
			Stud Type	-	Kiln-dried
			Stud Thickness	2x4	2x4
		Envelope	Category	Insulation	Insulation
			Material	Batt	Rockwool Batt
			Thickness (in)	2	2
		5.4.19 D_main_Wall_NS_Wood			
			Length (ft)	467	467
			Height (ft)	11	11
			Wall Type	Interior	Interior
			Sheathing Type	Plywood	Plywood
			Stud Spacing (in)	24	24
			Stud Type	-	Kiln-dried
			Stud Thickness	2x6	2x6
		Opening	Total Opening Area (ft^2)	2965.16	2965.16
			Number of Windows	92	92
			Frame Material	Aluminum	Aluminum
			Frame Type	Fixed	Fixed
			Glazing Type	Standard	Standard
		Envelope	Category	Insulation	Insulation
			Material	Batt	Rockwool Batt
			Thickness (in)	1	1
		5.4.20 D_3nd_Wall_EW_Wood			
			Length (ft)	128	128
			Height (ft)	11	11
			Wall Type	Interior	Interior
			Sheathing Type	None	None
			Stud Spacing (in)	16	16
			Stud Type	-	Kiln-dried
			Stud Thickness	2x4	2x4
		Envelope	Category	Insulation	Insulation
			Material	Batt	Rockwool Batt
			Thickness (in)	2	2
		5.4.21 D_3nd_Wall_NS_Wood			
			Length (ft)	467	467
			Height (ft)	11	11
			Wall Type	Interior	Interior
			Sheathing Type	Plywood	Plywood
			Stud Spacing (in)	24	24
			Stud Type	-	Kiln-dried
			Stud Thickness	2x6	2x6
		Opening	Total Opening Area (ft^2)	2965.16	2965.16
			Number of Windows	92	92
			Frame Material	Aluminum	Aluminum
			Frame Type	Fixed	Fixed
			Glazing Type	Standard	Standard
		Envelope	Category	Insulation	Insulation
			Material	Batt	Rockwool Batt
			Thickness (in)	1	1
		5.4.22 D_2nd_InteriorWall			
			Length (ft)	953	953
			Height (ft)	11	11
			Wall Type	Interior	Interior
			Sheathing Type	Plywood	Plywood

			Stud Spacing (in)	-	16
			Stud Type	-	Kiln-dried
			Stud Thickness	-	2x4
		Opening	Number of Doors	31	31
			Door Material	Wood	Wood
			Door Type	Interior	Hollow Core Interior
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	-	Regular
			Thickness (in)	-	0.5
		5.4.23 D_main_InteriorWall			
			Length (ft)	953	953
			Height (ft)	11	11
			Wall Type	Interior	Interior
			Sheathing Type	Plywood	Plywood
			Stud Spacing (in)	-	16
			Stud Type	-	Kiln-dried
			Stud Thickness	-	2x4
		Opening	Number of Doors	31	31
			Door Material	Wood	Wood
			Door Type	Interior	Hollow Core Interior
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	-	Regular
			Thickness (in)	-	0.5
		5.4.24 D_3nd_InteriorWall			
			Length (ft)	953	953
			Height (ft)	11	11
			Wall Type	Interior	Interior
			Sheathing Type	Plywood	Plywood
			Stud Spacing (in)	-	16
			Stud Type	-	Kiln-dried
			Stud Thickness	-	2x4
		Opening	Number of Doors	31	31
			Door Material	Wood	Wood
			Door Type	Interior	Hollow Core Interior
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	-	Regular
			Thickness (in)	-	0.5
6 Extra Basic Materials					
	6.1 Gypsum Board				
		6.1.1 E_totalGypsum			
			1/2" Gypsum Fiber Board (ft^2)	19352.8	19352.8
		6.1.2 E_totalJoint			
			Joint Compound (Tons)	1.79	1.79
		6.1.3 E_totalPaperTape			
			Paper Tape (Tons)	0.021	0.021
	6.2 Other Materials				
		6.2.1 E_totalAluminum			
			Aluminum (Tons)	7.02041	7.02041
		6.2.2 All_StandardGlazing			
			B Exterior Panels (ft^2)	3482.88	3482.88
			C Exterior Panels (ft^2)	8377.92	8377.92
			D Exterior Panels (ft^2)	3482.88	3482.88
			E Total Glazing (ft^2)	10845.79	10845.79

			Total (ft^2)	26189.47	26189.47
		6.2.3 E_totalPaint			
			Water Based Latex Paint (gal)	16.158	16.158
	6.3 Concrete				
		6.3.1 E_total3000psi			
			3000 psi, Average Flyash (yd^3)	6.188963	6.188963
		6.3.2 E_total4000psi			
			4000 psi, Average Flyash (yd^3)	967.03	967.03
		6.3.3 E_totalBlocks			
			Concrete Blocks (#)	3519.8	3519.8
		6.3.4 E_totalMortar			
			Mortar (yd^3)	15.10537	15.10537
	6.4 Insulation				
		6.4.1 E_totalBattRock			
			Batt. Rockwool (ft^2 (1"))	3073.53	3073.53
		6.4.2 E_totalExtPoly			
			Extruded Polystyrene (ft^2 (1"))	3803.44	3803.44
	6.5 Roofing				
		6.5.1 E_total3Poly			
			3 mil Polyethylene (ft^2)	3876.61	3876.61
		6.5.2 E_total6Poly			
			6 mil Polyethylene (ft^2)	868.223	868.223
		6.5.3 E_totalEPDM			
			EPDM Membrane (lb)	1124.38	1124.38
		6.5.4 E_totalBitumen			
			Modified Bitumen Membrane (lb)	770.939	770.939
	6.6 Steel				
		6.6.1 E_totalNails			
			Nails (Tons)	0.81633	0.81633
		6.6.2 E_totalRebar			
			Rebar, Rod, Light Sections (Tons)	0.06349	0.06349
		6.6.3 E_totalWire			
			Welded Wire Mesh / Ladder Wire (Tons)	29.4966	29.4966
	6.7 Wood				
		6.7.1 E_totalSLumber			
			Small DimensionSoftwood Lumber (kiln-dried) (Mbfm)	21.79871	21.79871
		6.7.2 E_totalPlywood			
			Softwood Plywood (msf)	4.15757	4.15757

APPENDIX B: EIE INPUT ASSUMPTIONS TABLE

Assembly Group	Assembly Type	Assembly Name	Input Fields	Ideal Inputs	EIE Input
1 Columns and Beams					
	1.1 Mixed Columns and Beams				
The column and beam takeoffs were completed mainly using OnScreen's count condition. For each set, a count condition for the number of beams and a condition for the number of columns were created and the two amounts were computed. The floor-to-floor height and live load were then taken directly from what was stated on the drawings. The supporting span and bay size were then computed by taking the average of each value within the designated assembly type. For example, in the assembly B_2nd_Beam&Column there are bay sizes of both 27'4" and 10'2"; averaging out the two bay sizes results in an average bay size of 21'6" which is the value that was input into the EIE.					
		1.1.5 B_Main_Beam&Column_Outside			
			Because of the variability of span sizes, they were calculated using the following calculation; = SUM(column span * number of columns with span) / total number of columns in row =(28'4" * 2 + 11'4" * 1) / 3 = 16.75 feet		
		1.1.6 B_Main_Beam&Column_Inside			
			Because of the variability of span sizes, they were calculated using the following calculation; = SUM(column span * number of columns with span) / total number of columns in row =(28'4" * 2 + 11'4" * 1) / 3 = 16.75 feet		
			Because of the variability of bay sizes, they were calculated using the following calculation; = total bay length / total number of columns = 322 feet / 42 = 8.73 feet (round up to 10 feet for EIE)		
		1.1.7 B_2nd_Beam&Column			
			Because of the variability of span sizes, they were calculated using the following calculation; = SUM(column spans) / total number of columns =(1067 feet) / 79 = 13.51 feet		

			Because of the variability of bay sizes, they were calculated using the following calculation; = total bay length / total number of columns = 64'9" / 3 = 21.6 feet
		1.1.8 B_3rd_Beam&Column	
			assumed same as B_2nd_Beam&Column
		1.1.9 C_2nd_column&beam	
			Because of the variability of span sizes, they were calculated using the following calculation; = SUM(column spans) / total number of columns =(12 feet * 2 + 4.5 feet) / 3 = 9.5 feet (round up to 10 feet for the EIE) round bay size up to 10 feet for the EIE
		1.1.10 C_main_column&beam	
			assumed same as C_2nd_column&beam
		1.1.11 C_3rd_column&beam	
			assumed same as C_2nd_column&beam
		1.1.12 C_4th_column&beam	
			assumed same as C_2nd_column&beam
		1.1.13 D_main_Beam&Column	
			assumed same as B_2nd_Beam&Column
		1.1.14 D_2nd_Beam&Column	
			assumed same as B_2nd_Beam&Column
		1.1.15 D_3rd_Beam&Column	
			assumed same as B_2nd_Beam&Column

2 Floors

All floors within the Buchanan building are concrete suspended slabs. The surface area of the slabs was computed using the area condition in OnScreen. The computed areas were then converted into rectangular slabs of equivalent surface area with spans between 12’ and 30’ as those are close to the EIE span limits. The length and span of the idealized rectangular slabs were then inputed into the EIE. For example, the assembly A_2nd_Slab_5"_Concrete comprised of a slab 100’ by 122’ and another slab 20’ by 62’ which, combined, results in a total surface area of 13440 ft2. A rectangular slab 120’ by 112’ results in an equivalent surface area; thus, the latter values were entered into the EIE. The concrete strength and live load were taken directly from the drawings and then entered into the EIE as the closest possible acceptable value. For example, a live load for classrooms was said to be 60 psf; however, the closest value that the EIE accepts is 75 psf. The flyash percentage was assumed to be average.

Stair landings were computed using the linear condition in OnScreen and the stair detail drawings. The linear condition used, computes the span of all the similar stair landings combined to create a single large slab of equivalent volume.

	2.1 Concrete Suspended Slabs		
		1.2.1 A_2nd_Slab_5"_Concrete	
			The area of this slab had to be adjusted to be rectangular using the following calcualtion to find the new span. = SUM(Slab Areas) / new slab length = (100 ft * 122 ft + 20 ft * 62 ft) / 224 ft = 30 feet
		1.2.2 A_2nd_Slab_6"_Concrete	
			The area of this slab had to be adjusted to be rectangular using the following calcualtion to find the new span. = SUM(Slab Areas) / new slab length = (60 ft * 11 ft + 20 ft * 41 ft) / 80 ft = 18.5 feet
		1.2.3 A_MainStairs_Landings	
			All landings combined into single slab using OnScreen
		1.2.4 B_Main_Slab4.5"	
			The length of this slab had to be adjusted to have a span of 30 feet but keeping the same area. This was done using the following calcualtion. = SUM(Slab Areas) / 30 feet = (79.5 ft * 67 ft) / 30 ft = 177.77 feet
		1.2.5 B_2nd_Slab4.5"	
			The length of this slab had to be adjusted to have a span of 30 feet but keeping the same area. This was done using the following calcualtion. = SUM(Slab Areas) / 30 feet = (260 ft * 67 ft) / 30 ft = 580.33 feet
		1.2.6 B_3nd_Slab4.5"	
			Assumed to be same as B_2nd_Slab4.5"
		1.2.7 B_LinkStairs_Landing	
			All landings were combined into a single slab using OnScreen. The length of this slab had to be adjusted to have a span of 30 feet but keeping the same area. This was done using the following

			calcualtion. = SUM(Slab Areas) / 30 feet = (9.21 ft * 66 ft) / 30 ft = 20.262 feet
		1.2.9 B_MainStairs_Landings	
			All landings were combined into a single slab using OnScreen. The length of this slab had to be adjusted to have a span of 30 feet but keeping the same area. This was done using the following calcualtion. = SUM(Slab Areas) / 30 feet = (9.21 ft * 91 ft) / 30 ft = 27.937 feet
		1.2.10 C_2nd_slab	
			The length of this slab had to be adjusted to have a span of 30 feet but keeping the same area. This was done using the following calcualtion. = SUM(Slab Areas) / 30 feet = (141 ft * 38 ft) / 30 ft = 178.6 feet
		1.2.11 C_main_slab	
			Assumed to be same as C_2nd_slab
		1.2.12 C_3rd_slab	
			Assumed to be same as C_2nd_slab
		1.2.13 C_4th_slab	
			Assumed to be same as C_2nd_slab
		1.2.14 C_LinkStairs_Landings	
			All landings combined into single slab using OnScreen
		1.2.15 C_ExitStairs_Landings	
			All landings combined into single slab using OnScreen. Lenght and Span flipped to be within acceptable span range on EIE
		1.2.16 D_Main_Slab4.5"	
			Assumed to be same as B_Main_Slab4.5"
		1.2.17 D_2nd_Slab4.5"	
			Assumed to be same as B_2nd_Slab4.5"
		1.2.18 D_3nd_Slab4.5"	
			Assumed to be same as B_3rd_Slab4.5"
		1.2.19 D_LinkStairs_Landing	
			Assumed to be same as B_LinkStairs_Landing
		1.2.20 D_LinkStairs_Entrance	
			Assumed to be same as B_LinkStairs_Enterance

1.2.21 D_MainStairs_Landings

Assumed to be same as B_MainStairs_Landings

3 Roofs

All roofs in the Buchanan building are concrete suspended slabs. The length, span, concrete strength, live load, and flyash percentage are all calculated in the same manner as the floor suspended slabs. In addition, the Buchanan roofs include vapour barriers, insulation and a bitumen roof envelope. The majority of the inputs associated with these envelope materials were given in the building drawings; however, a few of the values were not given and had to be assumed. These assumptions include: the bitumen was standard modified, the insulation was extruded polystyrene, and the vapour barrier was 3 mil polyethylene.

3.1 Concrete Suspended Slabs

3.1.1 A_Roof_Entrance

The length of this slab had to be adjusted to have a span of 30 feet but keeping the same area. This was done using the following calcualtion.

= (Slab Area) / 30 feet

= (50 ft * 60 ft) / 30 ft

= 100 feet

3.1.2 A_Roof_ConcreteSlab

The area of the slab had to be adjusted to not include the skylight areaThe length of this slab had to be adjusted to have a span of 30 feet but keeping the same area. This was done using the following calcualtion.

= (Slab Area - skylight) / 30 feet

= (100 ft * 122 ft - 825 ft2) / 30 ft

= 379.17 feet

3.1.3 B_Roof_Slab4.5"

The length of this slab had to be adjusted to have a span of 30 feet but keeping the same area. This was done using the following calcualtion.

= (Slab Area) / 30 feet

= (260 ft * 67 ft) / 30 ft

= 580.67 feet

3.1.4 C_Roof_Slab

The length of this slab had to be adjusted to have a span of 30 feet but keeping the same area. This was done using the following calcualtion.

= (Slab Area) / 30 feet

= (141 ft * 38 ft) / 30 ft

= 178.6 feet

3.1.5 D_Roof_Slab4.5"

Assumed to be same as B_Roof_Slab4.5"

4 Foundations

4.1 Concrete Footings

The concrete footing takeoffs were completed mainly using the area condition in OnScreen. An area condition was created for each assembly name to calculate the surface area of the given footing type. If there were multiple similar footings they were combined to make a single footing equivalent volume. The thickness of each assembly was recorded off of the drawings. If the thickness was not an acceptable sizing according to the EIE it was decreased to the closest acceptable size. At the same time the width of the footing was increased to account for the change in volume. For example, the assembly A_Foundation_Footing_2'4" is actually a combination of four 10’ square footings that are 28 inches thick resulting in a total, combined volume of 933.33 ft2. A single 20’ by 31’1.3” footing 18 inches thick also has the same volume; thus, those are the values inputed into the EIE. Concrete strength and rebar size were also read off of the drawings. If there were multiple rebar sizes in a footing an average size was assumed. For example, assembly D_Foundation_Footing3' has #5, #6 and #7 sized rebar so #6 was used in the model. If the rebar size is outside the range that the EIE allows, the closest allowable value was assumed. For example, assembly D_Foundation_Footing3'Wall has #8 rebar but #6 was used in the model. The flyash percentage was assumed to be average.

Stairs were also modelled as concrete footings. The stair takeoffs were done using the linear condition in OnScreen and the stair detail drawings. The thickness of the stairs was computed as the average thickness throughout. All other calculations and assumptions were completed using the methodology outlined for regular concrete footings.

4.1.1 A_Foundation_Footing_1'6"

Combine footings into single footing of equal area. This was done using the following calcualtion.

= (Footing Area * Number of Footings) / New Footing Length

= (5.25 ft * 5.25 ft * 5) / 10 ft

= 13.9 feet

4.1.2 A_Foundation_Footing_2'

Combine footings into single footing of equal area. In addition to account for the EIEs thickness allowances the thickness had to be changed while keeping the same overall volume. This was done using the following calcualtion.

= (Footing Area * Number of Footings * Thickness) / New Footing Length / New Thickness

= (2ft * 2 ft + 7.5ft * 7.5 ft * 24") / 8 ft / 18"

= 12.33 feet

4.1.3 A_Foundation_Footing_2'4"

			Combine footings into single footing of equal area. In addition to account for the EIEs thickness allowances the thickness had to be changed while keeping the same overall volume. This was done using the following calcualtion. = (Footing Area * Number of Footings * Thickness) / New Footing Length / New Thickness = (10 ft * 10 ft * 4 * 28") / 20 ft / 18" = 31.11 feet
		4.1.4 A_Foundation_Footing_1'9"	
			To account for the EIEs thickness allowances the thickness had to be changed while keeping the same overall volume. This was done using the following calcualtion. = (Footing Width * Footing Thickness) / New Thickness = (7 ft * 21") / 18" = 8.17 feet
		4.1.7 A_Foundation_Footing_1'6"x2'	
			To account for the EIEs thickness allowances the thickness had to be changed while keeping the same overall volume. This was done using the following calcualtion. = (Footing Width * Footing Thickness) / New Thickness = (1.5 ft * 24") / 18" = 2 feet
		4.1.8 A_Foundation_Footing_3'6"x2'	
			To account for the EIEs thickness allowances the thickness had to be changed while keeping the same overall volume. This was done using the following calcualtion. = (Footing Width * Footing Thickness) / New Thickness = (3.5 ft * 24") / 18" = 4.67 feet
		4.1.9 B_Foundation_Footing16"	
			Combine footings into single footing of equal area. This was done using the following calcualtion. = (Footing Area * Number of Footings) / New Footing Length = (5.33 ft * 5.33 ft * 4 + 5.83 ft * 5.84 ft * 8) / 20 ft = 19.3 feet
		4.1.10 B_Foundation_Footing3'	
			Combine footings into single footing of equal

			area. In addition to account for the EIEs thickness allowances the thickness had to be changed while keeping the same overall volume. This was done using the following calcualtion. = (Footing Area * Number of Footings * Thickness) / New Footing Length / New Thickness = (233.3 ft2 * 4 * 36') / 40 ft / 18" = 70 feet	
		4.1.11 B_Foundation_Footing1'		
			Combine footings into single footing of equal area. This was done using the following calcualtion. = (Footing Area * Number of Footings) / New Footing Length = (3.25 ft * 3.25 ft * 6) / 8 ft = 8 feet	
		4.1.22 D_Foundation_Footing16"		
			Assumed to be same as B_Foundation_Footing16"	
		4.1.23 D_Foundation_Footing3'		
			Assumed to be same as B_Foundation_Footing3'	
		4.1.24 D_Foundation_Footing1'		
			Assumed to be same as B_Foundation_Footing1'	
		4.1.25 D_Foundation_Footing2'Wall		
			Assumed to be same as B_Foundation_Footing2'Wall	
		4.1.26 D_Foundation_Footing10"Wall		
			Assumed to be same as B_Foundation_Footing10"Wall	
		4.1.27 D_Foundation_Footing3'Wall		
			Assumed to be same as B_Foundation_Footing2'Wall2	
		4.1.28 D_Foundation_Footing2'Wall2		
			Assumed to be same as B_Foundation_Footing3'Wall2	
		4.1.29 D_Foundation_Footing3'Wall2		
			Assumed to be same as B_Foundation_Footing3'Wall2	
		4.1.30 D_Foundation_Footing2'6"Wall		
			Assumed to be same as B_Foundation_Footing2'6"Wall	
		4.1.31 D_Foundation_Footing12"Wall		
			Assumed to be same as B_Foundation_Footing12"Wall	
		4.1.32 D_Foundation_Footing16"Wall		
			Assumed to be same as B_Foundation_Footing16"Wall	
		4.1.33 A_MainStairs_Stairs		
			Done on OnScreen	

4.1.34 B_LinkStairs_Stairs	Done on OnScreen
4.1.35 B_MainStairs_Stairs	Done on OnScreen
4.1.36 C_LinkStairs_Stairs	Done on OnScreen
4.1.37 C_ExitStairs_Stairs	Done on OnScreen
4.1.38 D_LinkStairs_Stairs	Assumed to be same as B_LinkStairs_Stairs
4.1.39 D_MainStairs_Stairs	Assumed to be same as B_MainStairs_Stairs

4.2 Concrete Slab On Grade

Takeoffs for concrete slabs on grade were done using the area condition in OnScreen. Much like the suspended slabs, the computed areas were then converted into rectangular slabs of equivalent surface area and the length and span of the idealized rectangular slabs were then used to create the model. For example, the assembly B_Foundation_Slab4" comprised of a slab 98’ by 9’6” and another slab 26’ by 2’8” which, combined, results in a total surface area of 1000 ft2. A rectangular slab 40’ by 25’ results in an equivalent surface area; thus, the latter values were entered into the EIE. The slab thicknesses were found on the drawings; however, EIE only allows concrete slabs on grade to have thicknesses of 4” or 8”. To make the model compatible with the EIE the thicknesses were converted to either 4” or 8” and the slabs length was changed in order to maintain the original slab volume. For example, assembly B_Foundation_Slab6" is actually a 77’ by 65’ slab that is 6” thick which results in a total volume of 2502.5 ft3. By changing the thickness to 8” the length would also have to decrease from 77’ to 58’ to keep the same area. Thus, a 58’ by 65’ slab with an 8” thickness is what is entered into the model. The concrete strength was taken as 4000 psi and the flyash percentage was assumed to be average. In addition, it was assumed that there was a 6 mil polyethylene vapour barrier underneath all slabs on grade.

4.2.1 A_Main_Slab_6"	The length of this slab had to be adjusted to be rectangular but keeping the same area. In addition, the thickness needs to be adjusted to 8" to be an acceptable EIE input. This was done using the following calcualtion. = (Slab Area * Thickness) / New Length = (105 ft * 180 ft + 62 ft * 18.5 ft) * 6" / 100 ft / 8" = 198 feet
4.2.2 B_Foundation_Slab6"	The thickness needs to be adjusted to 8" to be an acceptable EIE input while keeping the same area. This was done using the following calcualtion. = (Slab Length * Thickness) / 8" = (770 ft * 6") / 8"

			= 58 feet
		4.2.3 B_Foundation_Slab4"	
			The length of this slab had to be adjusted to be rectangular but keeping the same area. This was done using the following calcualtion. = (Slab Area) / New Length = (98 ft * 9.5 ft + 26 ft * 2.67 ft) / 40 ft = 25 feet
		4.2.5 C_Foundation_Slab4"	
			The length of this slab had to be adjusted to be rectangular but keeping the same area. This was done using the following calcualtion. = (Slab Area) / New Length = (1200 ft2) / 30 ft = 40 feet
		4.2.6 D_Foundation_Slab6"	
			Assumed to be same as B_Foundation_Slab6"
		4.2.7 D_Foundation_Slab4"	
			Assumed to be same as B_Foundation_Slab6"
		4.2.8 D_Main _Slab4"	
			Assumed to be same as B_Foundation_Slab6"

5 Walls

The wall types used in the Buchanan building are as follows: concrete block, cast-in-place, curtain, and wood stud. Windows for all walls were modeled as being fixed aluminum frames even though portions of many of the windows are, in fact, operable. Because only small portions of the windows are operable, assuming the windows are fully fixed is more accurate than assuming the windows are fully operable. The count condition in OnScreen was used to find the number of windows related to a specific wall. The number of windows was then multiplied by the square footage of a single window in order to compute the total window area related to a given wall. For example, assembly D_2nd_Wall_NS_Wood includes 92 separate 9'9" by 7' windows. Multiplying the three values together yields a total window area of 2965.16 ft2, the value that is used in the model. Many of the windows travelled through both an exterior concrete block wall and an interior wood stud wall. In these cases the windows were modeled with the interior wood stud wall and empty holes were modeled into the exterior concrete block wall. This is done so that the windows are not modeled twice. For example, the assemblies B_2nd_Wall_NSBlock and B_2nd_Wall_NS_Wood are located back-to-back and, therefore, share the same set of 92 windows and have the same total window area of 2965.16 ft2. However, assembly B_2nd_Wall_NS_Wood also includes wood window frames and standard glazing where as assembly B_2nd_Wall_NSBlock does not include any framing or glazing; thus, the window materials are only counted once.

Like windows, the number of doors within a certain wall type was calculated using the count condition in OnScreen. Exterior doors were assumed to be aluminum with 80% glazing where as interior doors

were assumed to be hollow wood core.
The drawings specified that many of the wood stud walls included 1” batt insulation but did not specify the specific type. Therefore, it was assumed that rockwool batt insulation was used.

5.1 Concrete Block

The lengths of the concrete block walls are calculated using the linear condition in OnScreen and the heights are found in the original drawings. Rebar sizes are also found on the drawing; however, if the rebar size listed in the drawing is too big or too small to be input into the EIE, the closest acceptable value was assumed. For example, assembly A_2nd_Brick_In calls for #3 rebar in the drawings. Since #4 is the smallest size that the EIE accepts, #4 rebar is used in the model.

5.1.12 D_Main_Wall_EW

Assumed to be same as B_Main_Wall_EW

5.1.13 D_Main_Wall_NSBlock

Assumed to be same as B_Main_Wall_NSBlock

5.1.14 D_2nd_Wall_EW

Assumed to be same as B_2nd_Wall_EW

5.1.15 D_2nd_Wall_NSBlock

Assumed to be same as B_2nd_Wall_NSBlock

5.1.16 D_3nd_Wall_NSBlock

Assumed to be same as B_3rd_Wall_NSBlock

5.1.17 D_3nd_Wall_EW

Assumed to be same as B_3nd_Wall_EW

5.1.18 D_All_StairsWall

Assumed to be same as B_All_StairsWall

5.2 Cast In Place

Much like concrete block walls, the lengths of cast-in-place walls are calculated using the linear condition in OnScreen. Heights, thicknesses, concrete strength, and rebar size are taken directly from the drawings. Much like the slabs on grade, the wall thicknesses are converted to either 8” or 12” (in order to be compatible with EIE) and the wall heights are changed in order to maintain the original wall volume. Some of the walls also have #4 rebar which is outside of the range available in EIE; thus, they are modeled with #5 rebar. The flyash percentage is assumed to be the average.

5.2.2 A_Foundation_TieBeam_16x16

The thickness needs to be adjusted to 8" or 12" to be an acceptable EIE input while keeping the same area. This was done using the following calcualtion.

= (Width * Thickness) / 12"

= (1.33 ft * 16") / 12"

= 1.78 feet

5.2.3 A_Foundation_Wall_10"

The thickness needs to be adjusted to 8" or 12" to be an acceptable EIE input while keeping the same area. This was done using the following

	calcualtion. = (Width * Thickness) / 12" = (17.5 ft * 10") / 12" = 14.58 feet
5.2.10 B_Foundation_Wall10"	
	The thickness needs to be adjusted to 8" or 12" to be an acceptable EIE input while keeping the same area. This was done using the following calcualtion. = (Width * Thickness) / 12" = (11.17 ft * 10") / 12" = 9.31 feet
5.2.11 B_Foundation_Wall6"	
	The thickness needs to be adjusted to 8" or 12" to be an acceptable EIE input while keeping the same area. This was done using the following calcualtion. = (Width * Thickness) / 8" = (4.5 ft * 6") / 8" = 3.38 feet
5.2.12 B_Foundation_ShortWall	
	The thickness needs to be adjusted to 8" or 12" to be an acceptable EIE input while keeping the same area. This was done using the following calcualtion. = (Width * Thickness) / 12" = (2.75 ft * 10") / 12" = 2.29 feet
5.2.15 B_Main_Wall10"	
	The thickness needs to be adjusted to 8" or 12" to be an acceptable EIE input while keeping the same area. This was done using the following calcualtion. = (Width * Thickness) / 12" = (9.75 ft * 10") / 12" = 8.13 feet
5.2.19 D_Foundation_TieBeam	
	Assumed to be same as B_Foundation_TieBeam
5.2.20 D_Foundation_Wall8"	
	Assumed to be same as B_Foundation_Wall8"
5.2.21 D_Foundation_Wall8"2	

Assumed to be same as B_Foundation_Wall8"2

5.2.22 D_Foundation_Wall8"3

Assumed to be same as B_Foundation_Wall8"3

5.2.23 D_Foundation_Wall10"

Assumed to be same as B_Foundation_Wall10"

5.2.24 D_Foundation_Wall6"

Assumed to be same as B_Foundation_Wall6"

5.2.25 D_Foundation_ShortWall

Assumed to be same as B_Foundation_ShortWall

5.3 Curtain

The lengths of all curtain walls were calculated using the linear condition in OnScreen. The thickness of insulation for all curtain walls was assumed to be the same as all other exterior walls in the model. The percent glazing and percent spandrel were calculated with the help of details on the original drawings.

5.4 Wood Stud

Like all other wall lengths, the lengths of wood stud walls were calculated using the linear condition in OnScreen. The wall type, wall height, stud spacing, stud thickness, and sheathing type were all found on the original drawings. The stud type was assumed to be kiln-dried since it was the most common stud type used during the time that the building was constructed. For wood studded walls that included gypsum board, regular 1/2” gypsum was assumed because it is so commonly used.

5.4.4 B_3nd_Wall_EW_Wood

Assumed to be same as B_2nd_Wall_EW_Wood

5.4.5 B_3nd_Wall_NS_Wood

Assumed to be same as B_2nd_Wall_NS_Wood

5.4.7 B_3nd_InteriorWall

Assumed to be same as B_2nd_InteriorWall

5.4.9 C_Main_Wall_Outside_Wood

Assumed to be same as C_2nd_Outside_Wood

5.4.10 C_3rd_Wall_Outside_Wood

Assumed to be same as C_2nd_Outside_Wood

5.4.11 C_4th_Wall_Outside_Wood

Assumed to be same as C_2nd_Outside_Wood

5.4.13 C_Main_inside_wall

Assumed to be same as C_2nd_inside_wall

5.4.14 C_3rd_inside_wall

Assumed to be same as C_2nd_inside_wall

5.4.15 C_4th_inside_wall

Assumed to be same as C_2nd_inside_wall

5.4.16 D_2nd_Wall_EW_Wood

Assumed to be same as B_2nd_Wall_EW_Wood

5.4.17 D_2nd_Wall_NS_Wood

Assumed to be same as B_2nd_Wall_NS_Wood

		5.4.18 D_main_Wall_EW_Wood		
			Assumed to be same as B_main_Wall_EW_Wood	
		5.4.19 D_main_Wall_NS_Wood		
			Assumed to be same as B_main_Wall_NS_Wood	
		5.4.20 D_3nd_Wall_EW_Wood		
			Assumed to be same as B_3rd_Wall_EW_Wood	
		5.4.21 D_3nd_Wall_NS_Wood		
			Assumed to be same as B_3nd_Wall_NS_Wood	
		5.4.22 D_2nd_InteriorWall		
			Assumed to be same as B_2nd_InteriorWall	
		5.4.23 D_main_InteriorWall		
			Assumed to be same as B_main_InteriorWall	
		5.4.24 D_3nd_InteriorWall		
			Assumed to be same as B_3nd_InteriorWall	

6 Extra Basic Materials

It was assumed that Blocks C and E have equivalent material usage per square foot. This meant that only Block C takeoffs were required. The Block C takeoffs were then modeled in EIE to produce a Block C Bill of Materials. The Bill of Material amounts were then multiplied by the ratio of Block E square footage to Block C square footage to create an estimated Bill of Materials for Block E which is displayed in Appendix B. The values in this new Bill of Materials were then entered into the final model through extra basic materials assembly group. Both Block C and E are office building of almost identical layout; thus, this assumption should not greatly affect the model. Other than the materials related to Block E, the only assumption made in extra basic materials was related to the exterior porcelain panels located below the windows on Blocks B, C, D, and E. The takeoffs for the porcelain panels were done using the count condition in OnScreen. Once the number of panels was known it was multiplied by the area in order to create total panel area. This total panel area was then modeled in extra basic materials as standard glazing. This was done because the EIE does not have porcelain in its material database; standard glazing was used because it is the most closely related material in the EIE.

Material	Block C Quantity	Block E Quantity	Unit
1/2" Gypsum Fibre Gypsum Board	2636.0718	1797.933	m2
3 mil Polyethylene	528.0392	360.149	m2
6 mil Polyethylene	118.2619	80.661	m2
Aluminium	11.3482	7.740	Tonnes
Batt. Rockwool	418.6497	285.540	m2 (25mm)
Concrete 20 MPa (flyash av)	6.9376	4.732	m3
Concrete 30 MPa (flyash av)	1084.0144	739.352	m3
Concrete Blocks	5160.6148	3519.797	Blocks
EPDM membrane	747.7605	510.010	Kg
Extruded Polystyrene	518.0724	353.351	m2 (25mm)
Joint Compound	2.6308	1.794	Tonnes

Modified Bitumen membrane	512.7077	349.692	Kg
Mortar	16.9326	11.549	m3
Nails	1.2962	0.884	Tonnes
Paper Tape	0.0302	0.021	Tonnes
Rebar, Rod, Light Sections	47.6812	32.521	Tonnes
Small Dimension Softwood Lumber, kiln-dried	52.2232	35.619	m3
Softwood Plywood	566.3051	386.248	m2 (9mm)
Standard Glazing	1477.3212	1007.607	m2
Water Based Latex Paint	89.6686	61.158	L
Welded Wire Mesh / Ladder Wire	0.1008	0.069	Tonnes