Life Cycle Assessment of the Hebb Building

Kristen Ferma

University of British Columbia

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PROVISO

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

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

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[redacted]

Abstract

The life cycle assessment of the University of British Columbia (UBC) Hebb Building, a reinforced concrete structure constructed in 1964 and consisting of a tower and a theatre, was performed as an exploratory study to determine the environmental impact of its design. This LCA of the Hebb Building is also part of a series of twenty-nine others being carried out simultaneously on respective buildings at UBC to establish the possibility of carrying out environmental performance comparisons across UBC buildings over time and between different materials, structural types and building functions.

The Hebb Building was modeled using OnCenter's On-Screen Takeoff and Athena Sustainable Materials Institute's Impact Estimator (IE) to attain the Bill of Materials and Summary Measures. The Bill of Materials obtained shows that the five most significant materials of the Hebb Building are ballast, concrete, extruded polystyrene, Ontario brick, and rebar. The Summary Measures lists the effects of the eight impact categories during the manufacturing and construction phases, and it was observed that the primary energy consumption and weighted resource use of the Hebb Building were most significant, while the ozone depletion and eutrophication potential are quite minimal. Performing sensitivity analyses on five substantial materials present in the building and examining their affects on each of the impact categories relative to the total building impact shows that a 10% increase in the amount of concrete has the most considerable effect on each of the impact categories.

Lastly, through building performance modeling, it was determined that by upgrading the current insulation and window type of 1" extruded polystyrene and standard glazing to 2.5" foam polyisocyanurate and low E silver argon filled glazing, the Hebb Building's energy performance can be significantly improved over its service life. An energy payback period of 0.6 years was found for the improved Hebb Building.

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1.0 Introduction

Figure 1. East Elevation of Hebb Building, UBC Vancouver Campus
Source: http://www.students.ubc.ca/facultystaff/buildings.cfm

The Hebb Building, located at 2045 East Mall, University of British Columbia (UBC) Vancouver Campus, was constructed in 1964 and is named after Dr. Thomas Carlyle Hebb, who was the first Head of the Physics Department and a physics professor at UBC from 1916 to 1938. The architect on the project was *Thompson, Berwick & Pratt* and the cost of construction of the Hebb Building was $1, 398, 503. The building is primarily used by the Departments of Physics and Engineering Physics, and consists of a 5-floor tower adjacent to a lecture theatre (UBC Building Archive). The tower building was originally composed of a tutorial room, four laboratories, five washrooms, five storage rooms, two experimental rooms, a dark room, a fan room, and a penthouse. The theatre building consisted of a lobby, a coatroom, a lecture theatre, a control room, a storage room, a preparation room, a mechanical room, and a fan room. The Hebb Building is a reinforced concrete structure with brick facings and painted concrete (refer to Figure 1). Table 1 below outlines all the major structural and envelope building characteristics of the Hebb Building.

Table 1. Building Characteristics of the Hebb Building

Building System	Specific Characteristics of Hebb Building
Structure	Reinforced concrete columns and beams supporting concrete suspended slabs
Floors	Foundation: Concrete slab on grade Ground, Second, Third, Fourth, Fifth, Penthouse, Theatre: Concrete suspended slabs
Exterior Walls	Concrete cast-in-place walls with Norman glazed brick cladding and concrete cladding, extruded polystyrene, and plaster
Interior Walls	Concrete cast-in-place walls
Windows	Fixed with aluminum framing and standard glazing
Roof	Concrete suspended slab with rigid insulation. 4-ply built-up Asphalt Roof System – inverted with extruded polystyrene and glass felt envelope material

2.0 Goal & Scope

A clearly defined goal and scope of the study of the Hebb Building is essential to allow for suitable analysis and interpretation of the results, as well as appropriate recommendations. The following section will present the goal and scope of this study, in accordance with sections 4.2.2 and 4.2.3 of ISO 14044 (Canadian Standards Association, 2006).

2.1 Goal of Study

This life cycle analysis (LCA) of the Hebb Building at the University of British Columbia was carried out as an exploratory study to determine the environmental impact of its design. This LCA of the Hebb Building is also part of a series of twenty-nine others being carried out simultaneously on respective buildings at UBC with the same goal and scope.

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

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

2.2 Scope of Study

The product system being studied in this LCA are the structure and envelope of the Hebb 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 Hebb 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 Appendices A and B respectively.

Using the formatted takeoff data, version 4.0.64 of the IE software, the only available software capable of meeting the requirements of this study, is used to generate a whole building LCA model for the Hebb Building in the Vancouver region as an Institutional building type. The IE software is designed to aid the building community in making more environmentally conscious material and design choices. The tool achieves this by applying a set of algorithms to the inputted takeoff data in order to complete the takeoff process and generate a bill of materials (BoM). This BoM then utilizes the Athena Life Cycle Inventory (LCI) Database, version 4.6, in order to generate a cradle-to-grave LCI profile for the building. In this study, LCI profile results focus on the manufacturing (inclusive of raw material extraction), transportation of construction materials to site and their installation as structure and envelope assemblies of the Hebb Building. As this study is a cradle-to-gate assessment, the expected service life of the Hebb 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 Hebb 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 Hebb Building. Finally, using the UBC Residential Environmental Assessment Program (REAP) as a guide, this study then estimates the embodied energy involved in upgrading the insulation and window R-values to REAP standards and generates a rough estimate of the energy payback period of investing in a better performing envelope.

The primary sources of data used in modeling the structure and envelope of the Hebb Building are the original architectural and structural drawings from when the building was initially constructed in 1964. The assemblies of the building that are modeled include the foundation, columns and beams, floors, walls and roofs, as well as their associated envelope and/or openings (i.e. doors and windows). The decision to omit other building components, such as flooring, electrical aspects, HVAC system, finishing and detailing, etc., are associated with the limitations of available data and the IE software, as well as to minimize the uncertainty of the model. In the analysis of these assemblies, some of the drawings lack sufficient material details, which necessitate the usage of assumptions to complete the modeling of the building in the IE software. Furthermore, there are inherent assumptions made by the IE software in order to generate the bill of materials and limitations to what it can model, which necessitated further assumptions to be made. These assumptions and limitation will be discussed further as they emerge in the Building Model section of this report and, as previously mentioned, all specific input related assumption are contained in the Input Assumptions document in Appendix B.

3.0 Building Model

For the purposes of this LCA study, takeoffs using OnCenter's OnScreen TakeOff were performed and the Athena Sustainable Materials Institute's Impact Estimator (IE) for buildings was used to attain the Bill of Materials, Summary Measures, and Absolute Impact Values for the Hebb Building. The following sections will describe the takeoff methodology implemented and discuss the major assumptions that arose during modeling, as well as introduce and analyze the Bill of Materials.

3.1 Takeoffs

OnCenter's OnScreen TakeOff software allows for simplified takeoffs to be performed with increased accuracy and convenience. Takeoffs from the structural and architectural drawings of the Hebb Building were executed by creating linear conditions to measure lineal foot objects such as walls, area conditions to measure surface areas such as slabs, and count conditions to count objects such as windows. The main source of information for performing these takeoffs is the original structural and architectural drawings of the Hebb Building created by *Thompson, Berwick & Pratt Architects*, which are outlined in Table 2, as well as frequent site exploration. A logical nomenclature system (refer to Appendix A) was adopted to ensure organization and transparency of all the assembly types (foundations, walls, columns and beams, floors, roofs, extra basic materials). The takeoffs were performed systematically by

Table 2. Structural & Architectural Drawings of Hebb Building used for takeoffs

Drawing No.	Description
656-07-001	Tower basement & foundation details
656-07-002	Tower ground floor plan & details
656-07-003	Tower second & typical floor plans & details
656-07-004	Tower roof & penthouse roof plans & details
656-07-005	Tower wall details
656-07-006	Stairs & bridge plans & details
656-07-007	Theatre lobby, basement & foundations
656-07-008	Theatre house & preparation room floor
656-07-009	Theatre roof
656-06-021	Elevations [west] & window details
656-06-022	East elevations & lecture theatre roof plan
656-06-023	Elevations [north & south] & details
656-06-024	Typical wall sections [& cross-sections]
656-06-025	Elevator sections & details, wall sections
656-06-026	Lecture theatre longitudinal section
656-06-028	Lecture theatre wall sections
656-06-029	Wall-sections elevations & details

assembly type per floor, and are recorded separately into either the tower or theatre portion of the Hebb Building. Takeoffs were performed once on the tower's typical floor plan and then the quantities were tripled for input into the Impact Estimator to represent the third, fourth, and fifth floors of the tower. These takeoff measurements as well as their converted values for input into the EIE software for both the tower and theatre are presented in tabular form as the 'IE Inputs Document' in Appendix A.

Some associated challenges that arose with completing takeoffs were blurry drawings, incomplete information, and limited site investigation. For instance, the partition walls within the laboratories of the tower are not provided in the drawings, and restricted access to these laboratories during site exploration prevented proper observation of the walls; therefore, the tower has been modeled as presented in the structural drawings, without partition walls. These challenges have thus required for assumptions to be made throughout the takeoffs phase. The following sections will discuss how each assembly type is modeled and the general assumptions associated with each. Specific details of the assumptions, justifications, methods, and calculations for each of the assembly types for both the tower and theatre of Hebb Building can be found in tabular form as the 'IE Input Assumptions Document' in Appendix B.

3.1.1 Foundations

The foundation assembly for both the tower and theatre of the Hebb Building is composed of concrete slab-on-grade and concrete footings and takeoffs were carried out on drawings 656-07-001 and 656-07-007. Concrete strength was set to 4000 psi and an average percent content of concrete flyash was assumed. For the 5" slab-on-grade, the areas measured from takeoffs required adjustments to determine the appropriate length and width inputs for IE to accommodate the IE limitation of only 4" or 8" thick slabs. For the footings measured with linear conditions, a number of them required width adjustments to maintain the same volume of footing because the IE limits the footing thickness to be between 7.5" and 19.7". In addition, heights of some footings were determined from dimensioning the structural drawings because only elevations are provided. Lastly, concrete stairs were modeled as footings using a linear condition with an average stair thickness. The north and south stairwells of the tower were modeled to have an average stair thickness of 8" based on the structural drawing 656-07-006 and the theatre stairs were modeled to have an average stair thickness of 24" based on the structural drawing 656-06-026.

3.1.2 Walls

The wall assemblies for both the tower and theatre of the Hebb Building consist of concrete cast-in-place interior and exterior walls. Linear takeoffs were performed on the structural drawings 656-07-001 to 004 for the tower and 656-07-007 and 656-07-008 for the theatre. Concrete strength was set to 4000 psi and an average percent content of concrete flyash was assumed. Many of the walls required length adjustments to accommodate the wall thickness limitation of either 8" or 12" in the Impact Estimator. For the exterior walls of the tower and theatre, the architectural drawings 656-06-024 and 656-06-028 specify that the exterior wall envelope is comprised of plaster, 1" Styrofoam insulation, a vapor barrier, 4.75" Norman glazed brick cladding on 90% of the height of the wall, and 3.75" concrete cladding on the remaining 10% of the height of the wall (refer to Figure 2a & 2b below).

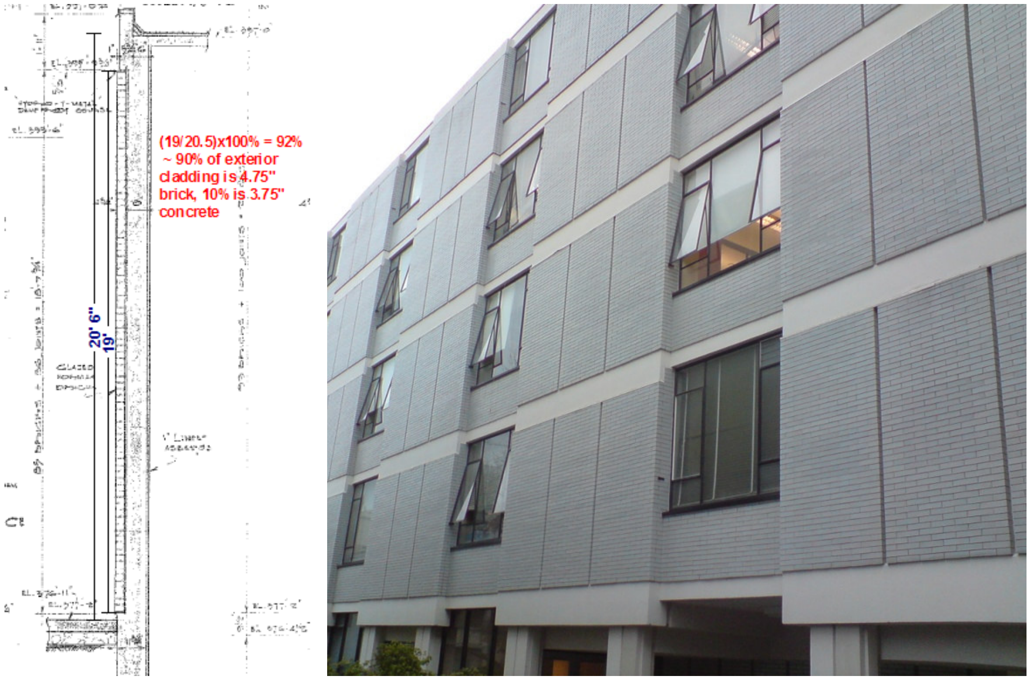

Figure 2a & 2b. Exterior Walls – 90% Norman glazed brick cladding & 10% concrete cladding
Source: Structural Drawing 656-06-028 & Photo taken by Kristen Ferma - March 2, 2010

Due to the Impact Estimator's material limitations, the exterior wall assembly was modeled using surrogate materials most similar to the actual conditions. Regular Gypsum ½" was used as a substitute for plaster, 1" Styrofoam insulation was modeled as 1" extruded polystyrene, the vapor barrier was assumed to be polyethylene 6mil, standard

Ontario brick cladding was used as an alternate for Norman brick, and the exterior paint was assumed to be alkyd solvent based. In addition, the exterior walls were modeled to have the brick cladding on 100% of the height of the wall.

For the theatre of Hebb Building, the wall heights in the lobby were determined from dimensioning of the structural drawing 656-07-007 and from the given elevations. As for the lecture theatre itself, the heights vary throughout the length of the wall; therefore, an average floor to floor height of 26 feet was used throughout the lecture theatre, as determined from dimensioning of the architectural drawing 656-06-026.

For the openings of the tower walls, count and area conditions for the doors and windows were performed on the drawings 656-06-021 to 23 and 656-07-005. The doors are assumed to be of the Impact Estimator's standard size or 32" x 7', where in fact they are actually 36" x 7' in size. Based on site investigation, it has been observed that the doors are solid wood (refer to Figure 3) and that the windows are best estimated as being fixed with standard glazing and aluminum framing. As for the openings of the theatre walls, the type, number, and location of doors were determined from site exploration since they were not specified in the drawings.

From observation, there are no windows located in the theatre and the doors are best modeled as being steel exterior doors.

Figure 3. Solid wood door in Hebb Tower Source: Photo taken by Kristen Ferma - March 2, 2010

3.1.3 Columns & Beams

The Impact Estimator internally calculates the sizing of the columns and beams based on the following inputs: number of columns, number of beams, bay size, supported span, floor to floor height, and live load. The number of concrete columns and beams on each floor of the tower and theatre were determined using count conditions on the structural drawings 656-07-002, 656-07-003, and 656-07-008. As stated on the structural drawing 656-07-001, the live loads for floors are as follows:

- Labs, classrooms, and theatre have specified live loads of 60psf
- Corridors, entrances, and stairs have specified live loads of 100psf

An average of these values of 75psf was used for the Impact Estimator Input of live load. For the tower specifically, each floor was modeled to have columns along the load bearing wall on line B in the same fashion as the columns along line A, even though they are not shown on the structural drawings (refer to Figure 4). In addition, since the bay size is limited to a maximum of 40 feet in the Impact Estimator, 40 feet is used as the approximate bay size, where in fact the actual bay size in the tower is 41.5 feet.

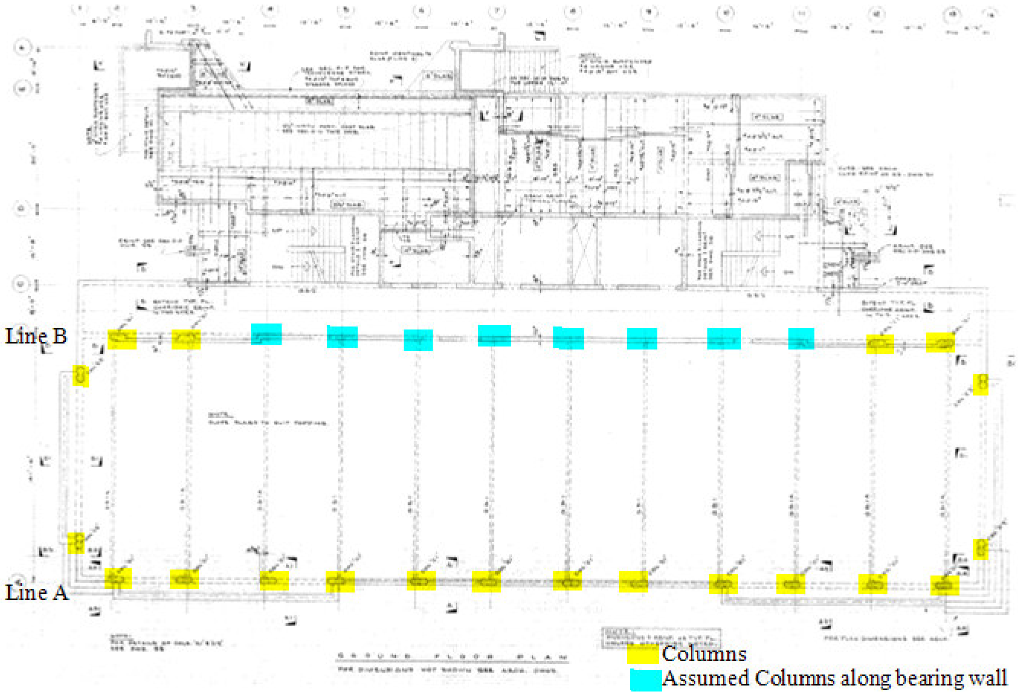

Figure 4. Assumed columns along Line B bearing wall
Source: Structural Drawing 656-07-002 Ground Floor Plan

For the theatre specifically, the walls were all varying in height; therefore, an average floor to floor height of 10.5 feet was used throughout the lobby and 26 feet throughout the theatre, as determined from the architectural drawing 656-06-026.

3.1.4 Floors

Figure 5. Sloping floor of Hebb Theatre
Source: Photo taken by Kristen Ferma - March 2, 2010

The Impact Estimator calculates the thickness of the floors based on the following inputs: floor width, span, concrete strength, concrete flyash content, and live load. Takeoffs using the area condition were performed on the concrete suspended slab floors from the structural drawings 656-07-002, 656-07-003, and 656-07-008, and the floor widths were determined by dividing the measured floor area by the span. The concrete strength was set to 4000 psi since it was not specified in the drawings and an average percent content of concrete flyash was assumed. A live load of 75 psf was inputted in the Impact Estimator, as determined in section 3.1.3. The floor of the theatre was modeled as flat instead of the actual sloped floor (refer to Figure 5), and the flattened area used to determine floor width was measured on the structural drawing 656-07-008. The floor envelopes, such as flooring material, gypsum, insulation, etc., were not accounted for in the model due to limitations and uncertainty, as discussed in further detail in section 2.3.

3.1.5 Roofs

The roof width for both the tower and theatre were determined from takeoff area measurements of the concrete suspended roof (from structural drawings 656-07-004 and 656-07-009) divided by the span. Concrete strength was set to 4000 psi and an average percent content of concrete flyash was assumed. A live load of 45 psf was applied instead of the 27 psf specified on the structural drawing 656-07-001 due to the live load inputs limitation of the Athena Impact Estimator. For both the tower and theatre, all that is

Figure 6. Suspended ceiling of Hebb Theatre
Source: Photo taken by Kristen Ferma - March 2, 2010

specified about the roof envelope from the drawings is that it has 1" rigid insulation. Therefore, for the roof model, the envelope was assumed to be comprised of a 4-ply built-up Asphalt Roof System – inverted with extruded polystyrene and glass felt envelope material. The vapor barrier was assumed to be polyethylene 6mil. Moreover, the suspended ceiling of the theatre was excluded from the model because it is not within the defined scope of the study (refer to Figure 6).

3.1.6 Extra Basic Materials

The window glazing in the lobby on the east elevation of the theatre (refer to Figure 7) was added separately into the Impact Estimator as an extra basic material instead of removing the number of windows and window area from the wall assembly. Window takeoffs were done using the area condition and inputted into the Impact Estimator as an amount standard glazing in square feet.

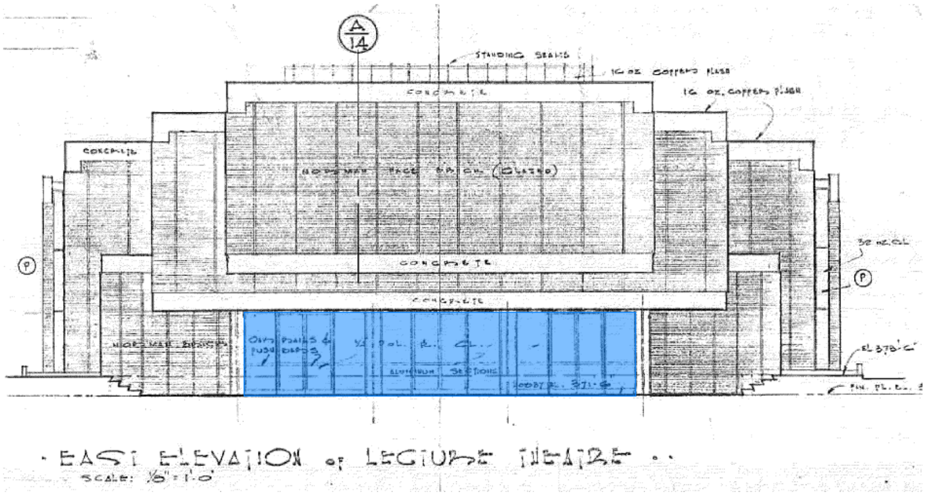

Figure 7. Window Extra Basic Material on East Elevation of Hebb Theatre
Source: Architectural Drawing 656-06-022 East elevations & lecture theatre roof plan

3.2 Bill of Materials

The Bill of Materials shows the total amount of all building materials resulting from the construction of the project in metric units and was generated from the takeoffs. Table 3 below presents material amounts for the tower, theatre, and total Hebb Building. The five most significant materials, according to Table 3, are: ballast (aggregate stone), concrete 30 MPa (flyash av), extruded polystyrene, Ontario (standard) brick, and rebar, rod, light sections. This section will discuss these five materials in terms of the assemblies contributing to the amount showing and how these amounts are affected by the assumptions made during modeling.

Table 3. Bill of Materials for the Hebb Building

Material	Quantity			Unit
	Tower	**Theatre**	**Total (Tower + Theatre)**	
#15 Organic Felt	1781.9173	2867.9018	4649.819	m^2
1/2" Regular Gypsum Board	3795.66	967.9658	4763.6258	m^2
6 mil Polyethylene	4489.4367	1600.6193	6090.056	m^2
Aluminum	7.1822	-	7.1822	Tonnes
Ballast (aggregate stone)	16411.995	39621.36	56033.3556	kg
Cold Rolled Sheet	0.697	0.1778	0.8748	Tonnes
Concrete 30 MPa (flyash av)	2738.0398	1080.8477	3818.8875	m^3
EPDM membrane	473.252	-	473.252	kg
Expanded Polystyrene	-	6.51	6.51	m^2 (25mm)
Extruded Polystyrene	8518.6469	4880.999	13399.6458	m^2 (25mm)
Galvanized Sheet	0.9312	0.8732	1.8044	Tonnes
Joint Compound	3.7881	0.966	4.7542	Tonnes
Mortar	100.4448	25.6153	126.0602	m^3
Nails	1.258	0.0674	1.3253	Tonnes
Ontario (Standard) Brick	3623.13	923.9674	4547.0974	m^2
Paper Tape	0.0435	0.0111	0.0546	Tonnes
Polyethylene Filter Fabric	-	0.0534	0.0534	Tonnes
Rebar, Rod, Light Sections	193.0474	32.3607	225.4081	Tonnes
Roofing Asphalt	10515.656	4657.5932	15173.2496	kg
Small Dimension Softwood Lumber, kiln-dried	8.208	-	8.208	m^3
Solvent Based Alkyd Paint	359.0004	92.1415	451.142	L
Standard Glazing	664.6098	33.4624	698.0722	m^2
Type III Glass Felt	3563.8345	-	3563.8345	m^2
Water Based Latex Paint	70.0536	-	70.0536	L
Welded Wire Mesh / Ladder Wire	1.1224	0.5933	1.7156	Tonnes

The amount of ballast (aggregate stone) shown in the Bill of Materials is mostly from the roofing aggregate, which includes the assemblies 5.1.1 for both the tower and the theatre of Hebb as seen in Appendix A. As previously stated in section 3.1.5, the concrete suspended roof of the Hebb Building was modeled to have a 4-ply built-up Asphalt Roof System – inverted with extruded polystyrene and glass felt envelope material. The roofing envelope required assumptions to be made based on typical roofing systems because all that was known about the roof from the drawings was that it has 1" rigid insulation. Due to the lack of information on the building's roofing system, the amount of ballast as determined from the Impact Estimator is not accurately representative of the actual amount in the building; therefore, it could be an over- or under-estimation.

As this structure is a reinforced concrete building, the amount of 30 MPa concrete containing an average amount of flyash is quite significant, as can be seen in Table 3. The amount of concrete determined by the Impact Estimator is based on the inputs of the foundation assemblies, including the concrete slab-on-grades and concrete footings, cast-in-place wall assemblies, concrete column and beam assemblies, concrete suspended floor assemblies, and concrete suspended roof assemblies for both the tower and the theatre of Hebb Building (refer to Appendix A). For all these concrete assemblies, strength of 4000 psi and average flyash content was assumed during modeling. As stated in the Athena EIE software, average flyash concentration of 9% cement replacement can vary significantly from region to region, due to differing local conditions, availability and design mixes. Since the use of flyash is not actually known for the Hebb Building and an average amount was assumed for modeling, this contributes to the inaccuracy of the results. In addition, many of the assemblies required simplifications and adjustments to meet the input limitations of the Athena EIE software – for instance, adjustments of footing widths to address limitation on footing thickness, approximating stairs as footings, and adjustments of wall lengths to satisfy a wall thickness input of either 8" or 12". All these adjustments could have resulted in an over- or under-estimation of the actual amount of concrete present in the building. Since the Impact Estimator calculates the sizing of the beams and columns and the thickness of floors internally, the values it determines based on the inputs may not truly embody the actual assembly. Another consideration, as discussed in section 3.1.2, would be the fact that the exterior walls were modeled to have brick cladding on 100% of the height of the wall, which disregards the 10% of the height of the wall being covered in 3.75" of concrete cladding in reality. Consequently, this contributes to the under-estimation of the amount of concrete in the Hebb Building.

The amount of extruded polystyrene insulation in the Bill of Materials is from its presence on all the exterior walls of the tower and the theatre, as well as the roofs (refer to Appendix A). 1" extruded polystyrene represents the 1" Styrofoam insulation specified in the building drawings and the amount is dependent on the exterior wall and roof quantities. As previously stated, wall dimension adjustments to account for Athena EIE limitations would be the primary source of error for wall quantities and thus would also affect extruded polystyrene amounts accordingly. The error in dimension approximations of the exterior walls would be minimal; therefore, the amount of extruded polystyrene determined is an acceptable approximation to reality.

The model of the Hebb Building consists of Ontario (standard) brick cladding on all exterior walls of the tower and theatre, which was used as a surrogate for the specified 4.75" Norman brick (refer to exterior brick clad walls in section 2.1 for both the tower and theatre in Appendix A). The amount of brick presented in the Bill of Materials under-estimates the actual conditions by 20%. Although the model assumes Ontario brick cladding upon 100% of the height of the wall compared to the actual wall assembly having brick on only 90% of the height of the wall, the amount of brick determined is still an under-estimation due to the fact that 4.75" thick Norman brick is substituted with only 3.5" thick Ontario brick. Perhaps a more appropriate surrogate for 4.75" Norman brick would have been the metric modular brick available in the Athena EIE software, which has a thickness of 4"; but this would still result in a slight under-estimation of the quantity of brick. This demonstrates that the assumptions necessary to accommodate Athena EIE software limitations can have a significant effect on the accuracy of the building model and in turn the resulting impacts determined for that building.

The amount of rebar, rod, and light sections presented in the Bill of Materials is significant due to the fact that Hebb Building is a reinforced concrete structure which contains rebar in all its assemblies (slab-on-grades, footings, cast-in-place walls, columns and beams, and suspended slabs – refer to Appendix A). Since the Athena EIE software internally calculates the amount of rebar required based on the dimensional inputs and rebar type, error could arise from this if the determined reinforcement does not accurately represent the actual reinforcement layout of the Hebb Building. In addition, #5 rebar was specified for the majority of the reinforcement used in the assemblies, but #4 and #6 bars are also present. This could potentially result in a slight under- or over-estimation of the amount of reinforcement.

4.0 Summary Measures

The Summary Measures as outputted from the Impact Estimator is a detailed list of the impact indicators based on US EPA's Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI). The impact categories supported by the Athena EIE software are based on mid-point impact estimation methods and include the following: primary energy consumption, weighted resource use, global warming potential, acidification potential, human health (HH) respiratory effects potential, eutrophication potential, ozone depletion potential, and smog potential. Tables 4, 5, and 6 display the Summary Measure results by Life Cycle Stage resulting from the Hebb Tower model, Hebb Theatre model, and total Hebb Building model, respectively. They also present the total overall effects and total effects per square foot. Since the scope of this study is cradle-to-gate, the life cycle stages considered were manufacturing, which includes resource extraction and transportation, and construction, which includes transportation of products and on-site construction activities.

Table 4. Summary Measures by Life Cycle Stage resulting from Hebb Tower

Impact Category	Units	Manufacturing	Construction	Total Tower Effects (Man. + Constr.)	
		Total	Total	Overall	Per Sq. Ft
Primary Energy Consumption	MJ	12,755,626.20	2,058,057.87	14,813,684.07	275.27
Weighted Resource Use	kg	8,431,643.59	13,148.80	8,444,792.39	156.92
Global Warming Potential	(kg CO2 eq / kg)	1,177,309.25	38,033.39	1,215,342.64	22.58
Acidification Potential	(moles of H+ eq / kg)	510,267.64	20,125.70	530,393.35	9.86
HH Respiratory Effects Potential	(kg PM2.5 eq / kg)	3,724.28	22.69	3,746.96	0.07
Eutrophication Potential	(kg N eq / kg)	513.25	20.00	533.25	0.01
Ozone Depletion Potential	(kg CFC-11 eq / kg)	0.00	0.00	0.00	0.00
Smog Potential	(kg NOx eq / kg)	6,055.89	488.41	6,544.30	0.12

Table 5. Summary Measures by Life Cycle Stage resulting from Hebb Theatre

Impact Category	Units	Manufacturing	Construction	Total Theatre Effects (Man. + Constr.)	
		Total	Total	Overall	Per Sq. Ft
Primary Energy Consumption	MJ	3,875,158.99	602,659.89	4,477,818.88	340.49
Weighted Resource Use	kg	3,153,944.88	4,550.65	3,158,495.53	240.17
Global Warming Potential	(kg CO2 eq / kg)	401,288.20	13,193.83	414,482.02	31.52
Acidification Potential	(moles of H+ eq / kg)	167,350.00	6,982.15	174,332.15	13.26
HH Respiratory Effects Potential	(kg PM2.5 eq / kg)	1,120.49	7.64	1,128.13	0.09
Eutrophication Potential	(kg N eq / kg)	126.32	6.74	133.06	0.01
Ozone Depletion Potential	(kg CFC-11 eq / kg)	0.00	0.00	0.00	0.00
Smog Potential	(kg NOx eq / kg)	2,204.85	167.32	2,372.18	0.18

Table 6. Summary Measures by Life Cycle Stage resulting from total Hebb Building (tower + theatre)

Impact Category	Units	Manufacturing	Construction	Total Tower & Theatre Effects (Man. + Constr.)	
		Total	Total	Overall	Per Sq. Ft
Primary Energy Consumption	MJ	16,630,785.18	2,660,717.76	19,291,502.95	288.08
Weighted Resource Use	kg	11,585,588.47	17,699.44	11,603,287.92	173.27
Global Warming Potential	(kg CO2 eq / kg)	1,578,597.45	51,227.22	1,629,824.66	24.34
Acidification Potential	(moles of H+ eq / kg)	677,617.64	27,107.86	704,725.50	10.52
HH Respiratory Effects Potential	(kg PM2.5 eq / kg)	4,844.77	30.33	4,875.09	0.07
Eutrophication Potential	(kg N eq / kg)	639.57	26.74	666.31	0.01
Ozone Depletion Potential	(kg CFC-11 eq / kg)	0.00	0.00	0.00	0.00
Smog Potential	(kg NOx eq / kg)	8,260.74	655.74	8,916.48	0.13

From Table 6, it is evident that during the manufacturing and construction phase of the Hebb Building, primary energy consumption and weighted resource use is very significant. This is because primary energy includes all energy used to transform and transport raw materials into products, as well as the indirect energy required for processing and transporting energy, which is dominant during the manufacturing and construction stages, especially for a concrete structure. Resource use is associated with resource extraction, which is also predominant in the manufacturing stage. As for the HH respiratory effects potential, eutrophication potential, ozone depletion potential, and smog potential categories, the total effects on the Hebb Building are not as extensive during the manufacturing and design phases. Their impacts may become more significant during the operation, maintenance, and demolition stages.

The following sections will briefly describe and interpret each of the Summary Measure impact categories. Sensitivity analyses were also performed for five substantial materials present in the building: 30 MPa concrete with average flyash, extruded polystyrene, Ontario brick, rebar, and roofing asphalt. The affect of a 10% increase of these materials on each of the impact categories, relative to the total building impact, will also be discussed in the subsequent sections. Performing a sensitivity analysis on an LCA study is very beneficial because it can provide the analyzer during the design or renovation phase the opportunity to observe and compare the effects certain materials on the overall performance of a building, thus acting as a decision tool when selecting the most optimal materials for an assembly. In addition, sensitivity analyses can also encourage efficient design and use of materials by showcasing the fact that significant environmental impacts from the project can arise with only a marginal increase in certain materials. Lastly, uncertainties associated with life cycle impact assessments will be discussed.

4.1 Primary Energy Consumption

Primary energy consumption, reported in mega-joules (MJ), is the total energy used to transform and transport raw materials into products during the manufacturing and construction phases. This includes inherent energy contained in raw materials as well as indirect energy use associated with processing, converting, and delivering energy. Figure 8 illustrates the sensitivity of primary energy consumption of the Hebb Building to a 10% increase in five materials, and it is evident that all of the materials have a significant effect on this impact category, ranging from 0.515% to 3.574%. A 10% increase in the amount of concrete yields the highest effect on the primary energy consumption of the Hebb Building, and this is because concrete requires a substantial amount of energy to be processed, manufactured, and constructed. Primary energy consumption is notably sensitive to changes in the amount of all of these materials because all materials involve some form of transformation and processing from its raw source.

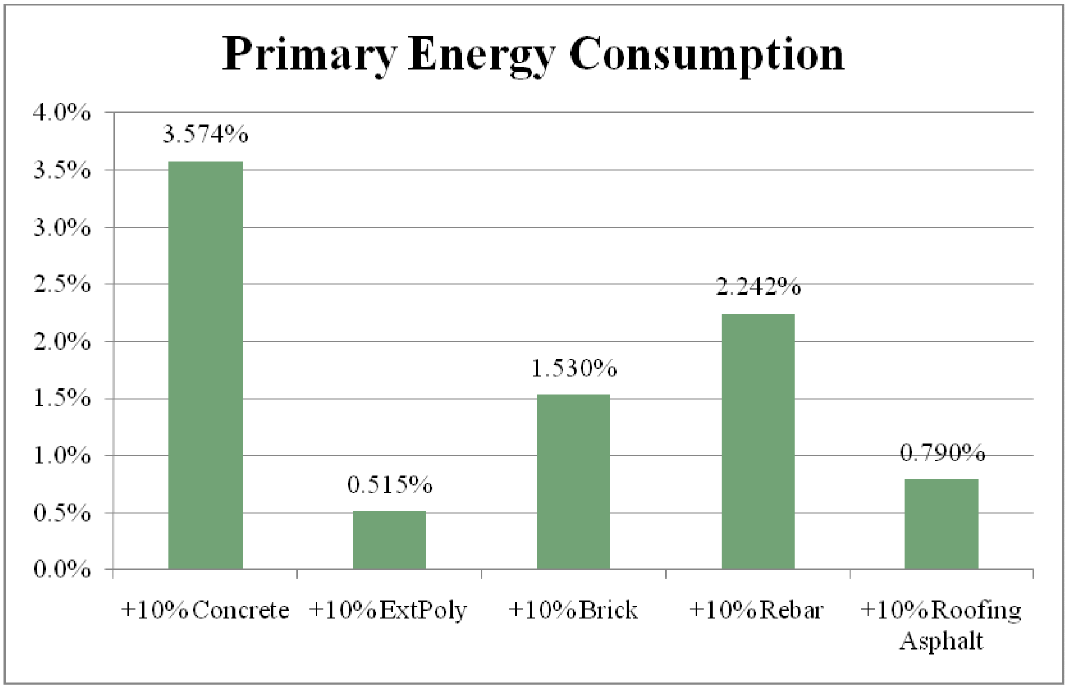

Figure 8. Sensitivity of primary energy consumption to a 10% increase in materials

4.2 Weighted Resource Use

Weighted resource use, reported in kilograms (kg), addresses the resource extraction activities associated with the manufacturing of each building material. As stated in the Athena EIE software, the values reported for this impact category are the sum of the weighted resource requirements for all products used in each of the designs. Figure 9 below illustrates the sensitivity of weighted resource use to a 10% increase in five materials, and it is evident that an increase in the amount of concrete results in the most significant effect on this impact category. This is due to the fact that the manufacturing of concrete involves a large amount of raw resources, such as aggregate, gravel, sand, and cement. A 10% increase in the amount of brick has the second most significant impact on weighted resource use and an increase in rebar has a minimal effect, while an increase in extruded polystyrene and roofing asphalt results in negligible effects.

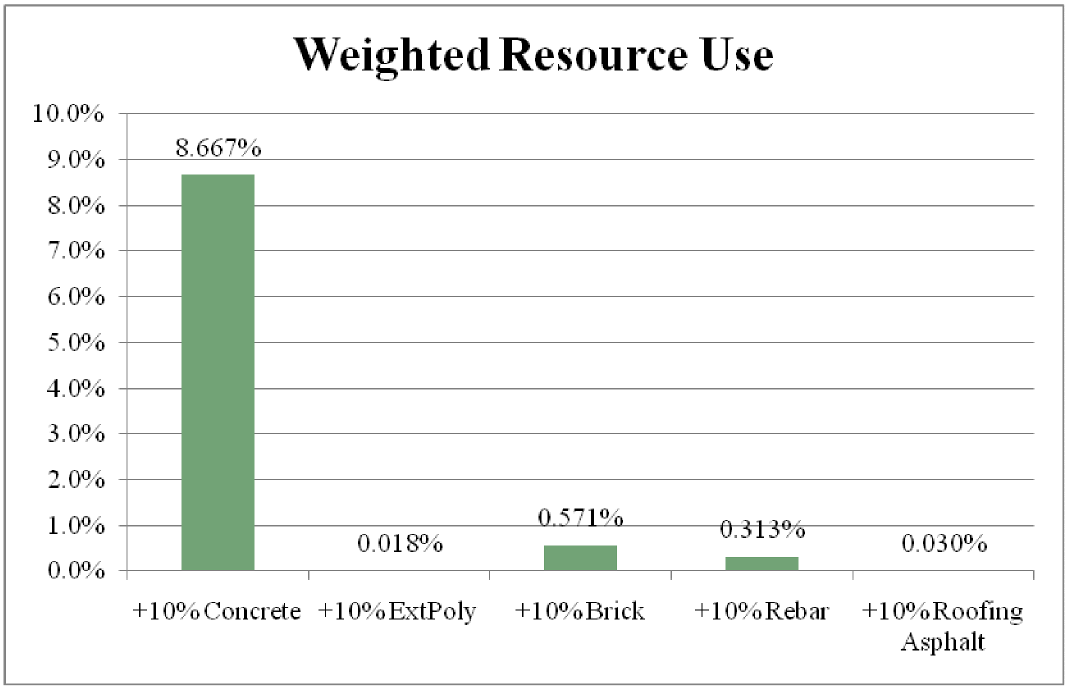

Figure 9. Sensitivity of weighted resource use to a 10% increase in materials

4.3 Global Warming Potential

Global warming potential is a reference measure expressed on an equivalency basis relative to carbon dioxide and is presented in kg CO_2 equivalent. It is a measure of the potential contribution to global warming a given mass of greenhouse gas has. Figure 10 presents the sensitivity of the Hebb Building's global warming potential to five materials. An increase in the amount of concrete yields the most significant effect on the global warming potential, and this is due to the associated discharge of a high volume of carbon dioxide emissions during the production of cement. For one ton of cement manufactured, approximately one ton of carbon dioxide is emitted. The other materials have effects on this impact category ranging from 0.306% to 0.890%, but are quite minimal in comparison to the 6.497% increase in global warming potential caused by a 10% increase in concrete. Greenhouse gas emissions are inherent in all material production, to a certain extent, and this is verified by this sensitivity analysis.

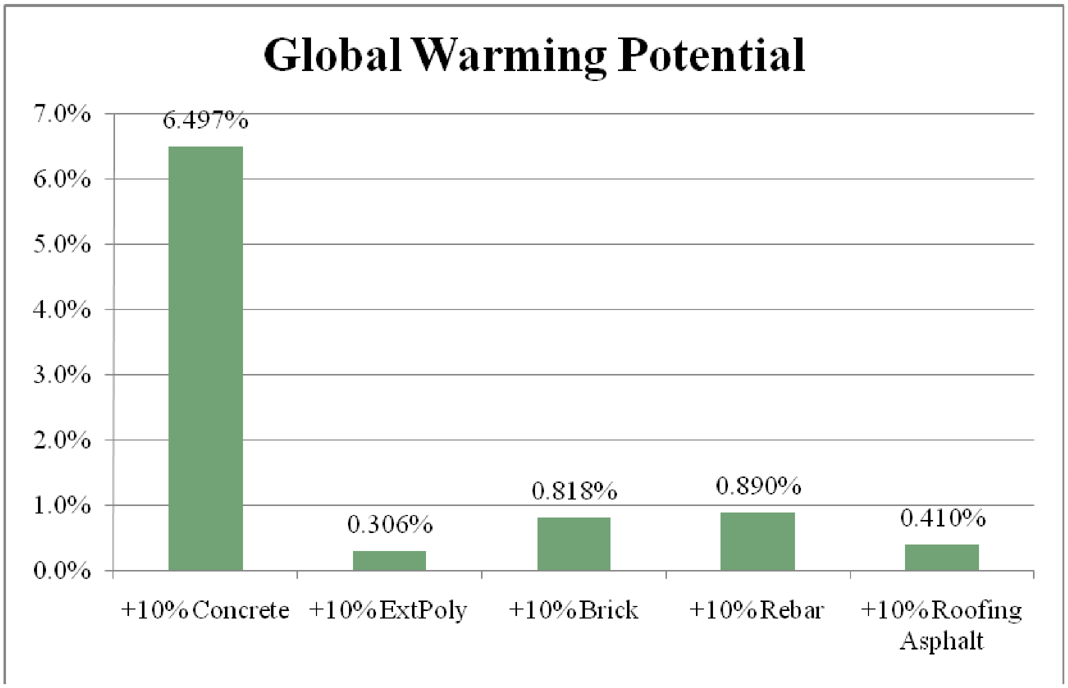

Figure 10. Sensitivity of global warming potential to a 10% increase in materials

4.4 Acidification Potential

This impact category refers to the potential of a body of water or air to experience an increase in acidity due to high concentrations of SO_2 and NO_x. According to the Athena EIE software, the acidification potential is calculated based on the air or water emission's H^+ equivalence effect on a mass basis. As seen in Figure 11, the acidification potential of the Hebb Building is most affected by concrete amount, resulting in a 5.985% increase in this impact. As previously stated, the manufacturing of concrete results in significant chemical emissions, and thus heavily influences acidification potential. An increase in brick has the second most affect on this impact category because it has a somewhat similar manufacturing process as concrete, but it, along with the other materials, are still not as influential as concrete in enhancing the potential of acidification.

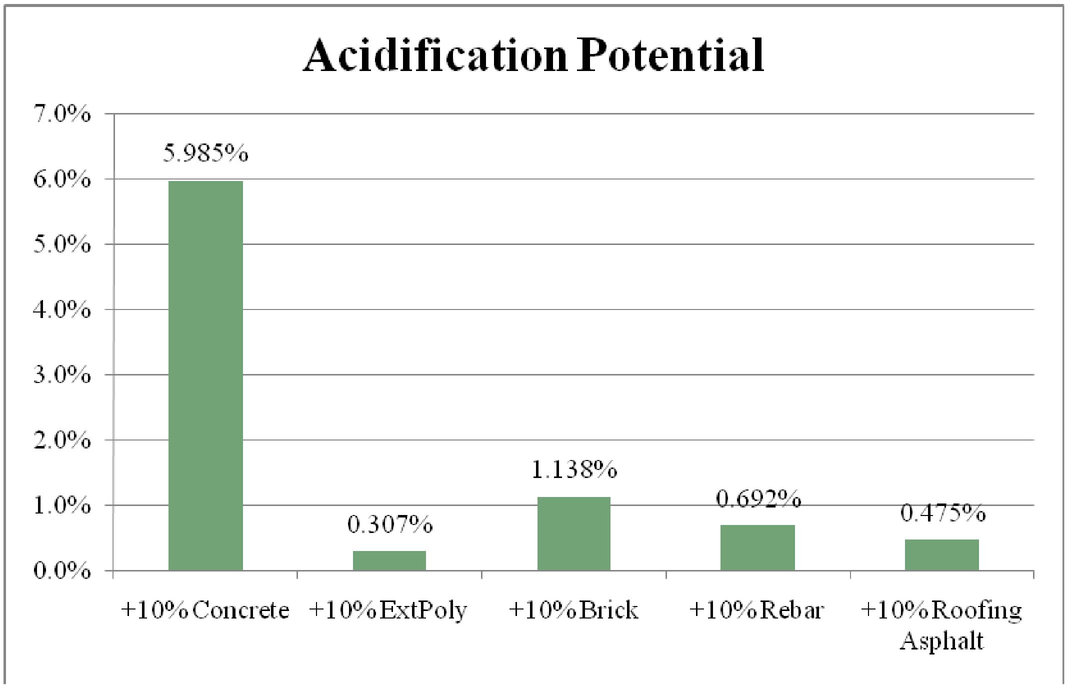

Figure 11. Sensitivity of acidification potential to a 10% increase in materials

4.5 HH Respiratory Effects Potential

This impact category refers to the potential effects of particulate matter on human health, specifically on the respiratory system. Emitted particulates from the production of certain materials can cause many health issues, such as asthma and bronchitis. As stated in the Athena EIE software, TRACI's "Human Health Particulates from Mobile Sources" characterization factor is used on an equivalent particulate matter size ($PM_{2.5}$) basis. According to Figure 12, an increase in the amount of concrete by 10% results in the most significant change in this impact category. In contrast to the 5.974% increase in the HH respiratory effects potential due to the addition of 10% concrete to the Hebb Building, the effects that the other materials are quite diminutive. This is due to the particulate emissions associated with concrete production, but this much greater affect concrete has on this category can also be based on the fact that the Hebb Building is composed of mostly concrete.

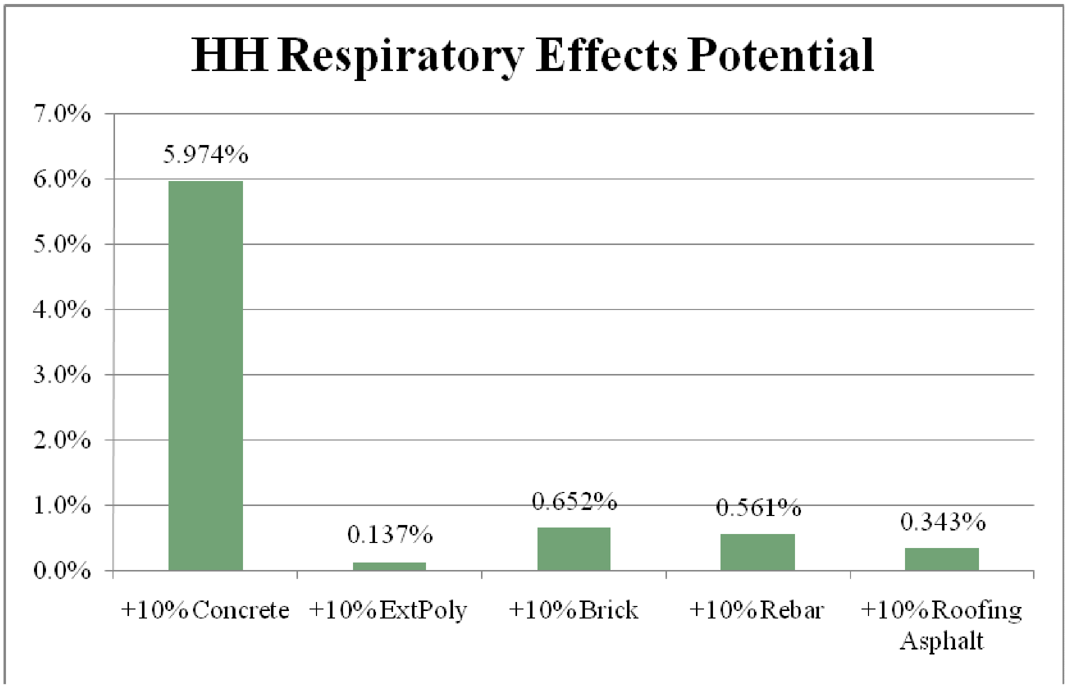

Figure 12. Sensitivity of HH respiratory effects potential to a 10% increase in materials

4.6 Eutrophication Potential

Eutrophication occurs when a body of water receives an excess of nutrients that leads to a surplus of plant growth, which in turn reduces the dissolved oxygen concentration in the water causing negative consequences, from odor to death of organisms and fish (USGS, 2008). Eutrophication is very hazardous to the health of an ecosystem and can exponentially become more severe. The potential of this impact category is expressed on an equivalent mass of nitrogen basis. Referring to Figure 13, it can be seen that an increase in the amount of rebar influences the eutrophication potential the most, resulting in an effect of 4.234%, closely followed by an increase in the amount of concrete. Eutrophication potential is quite insensitive to the amount of brick, roofing asphalt, and extruded polystyrene, with the potential effect of this impact increasing by 0.173%, 0.165%, and 0.149%, respectively.

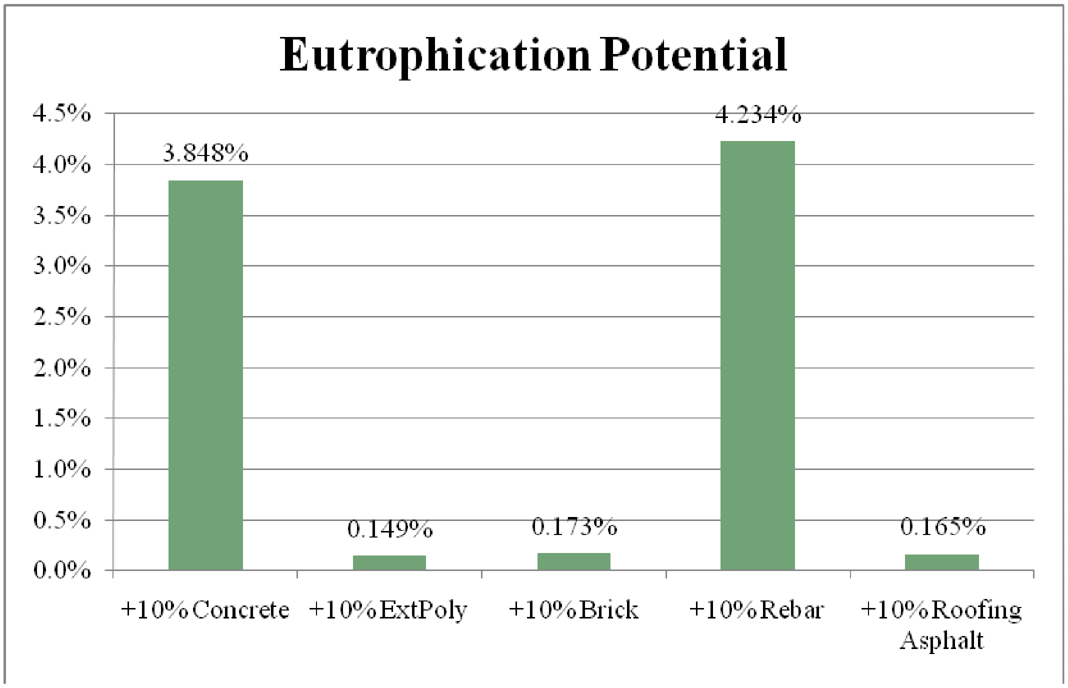

Figure 13. Sensitivity of eutrophication potential to a 10% increase in materials

4.7 Ozone Depletion Potential

According to the Impact Estimator, the ozone depletion potential accounts for impacts related to the reduction of the ozone layer caused by emissions, such as chlorofluorocarbons (CFCs) and halons. The ozone depletion potential is expressed in terms of mass equivalence of CFC-11. It is evident from Figure 14 that this impact category is highly sensitive to concrete, having an increase in its potential of 8.792% in response to a 10% increase in concrete amount. In contrast, the ozone depletion potential is quite indifferent to addition of extruded polystyrene, brick, rebar, and roofing asphalt, which all have an effect of less than 0.02% on the impact category.

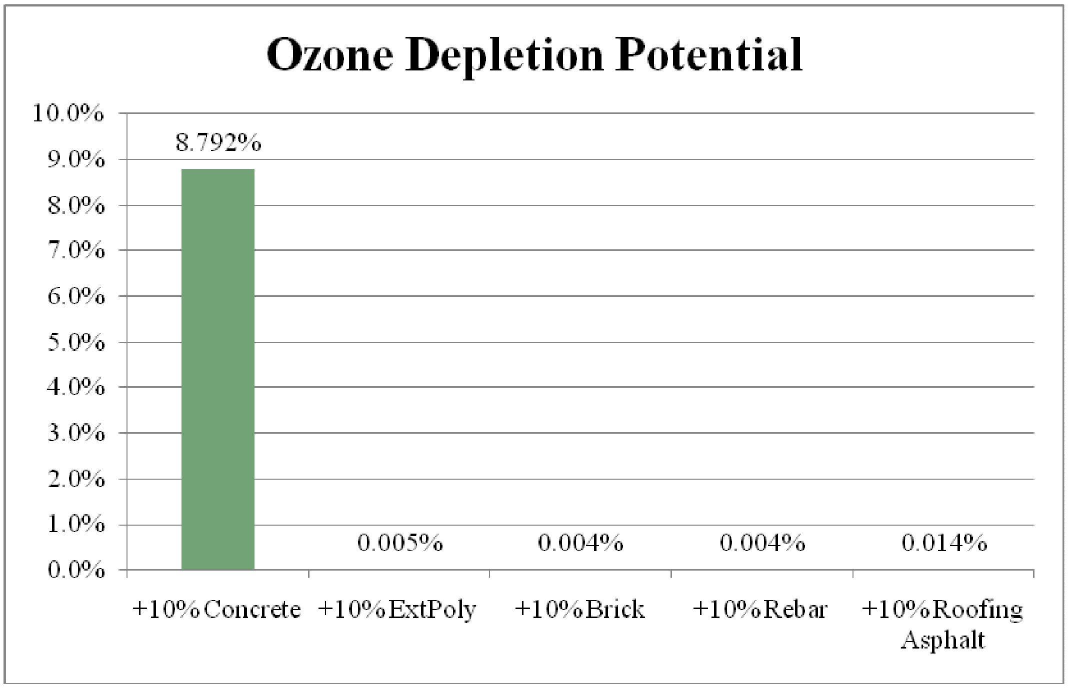

Figure 14. Sensitivity of ozone depletion potential to a 10% increase in materials

4.8 Smog Potential

The smog potential is expressed on a mass of equivalent NO_X basis and represents air emissions from industry and transportation that are trapped at ground level. According to Figure 15, this impact category is very sensitive to adding 10% more concrete, with a 6.370% increase in its potential. The second most influential material is extruded polystyrene, which exhibits a 1.128% increase in smog potential. The effects of adding more brick, rebar, and roofing asphalt are quite minimal, within the range of 0.136% to 0.334%.

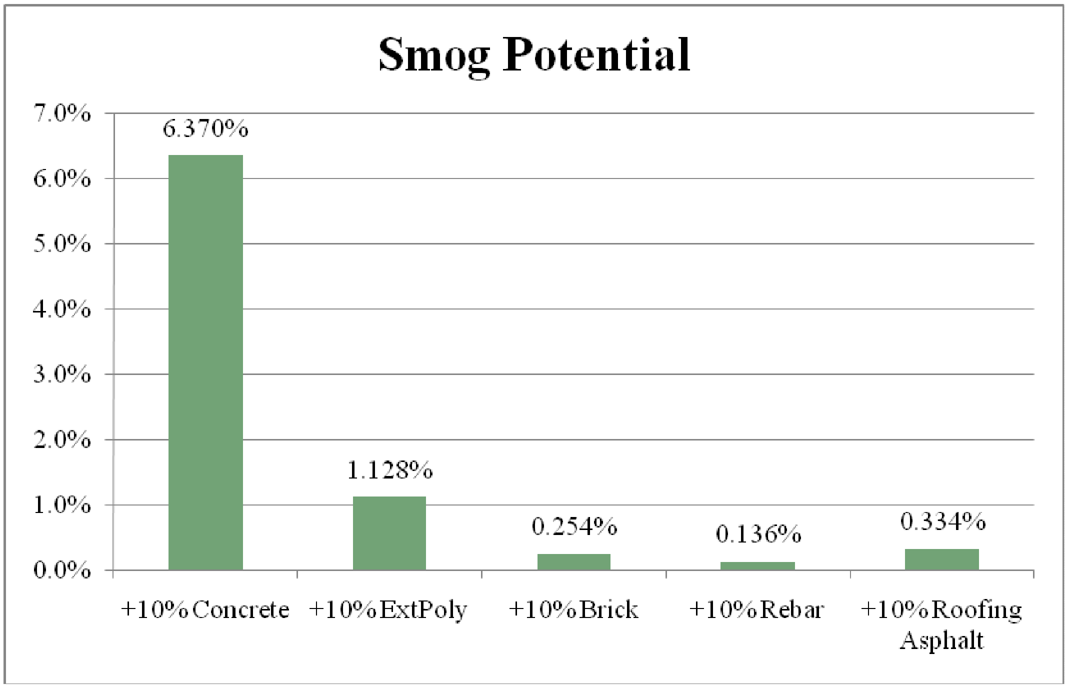

Figure 15. Sensitivity of smog potential to a 10% increase in materials

4.9 Uncertainties associated with Impact Assessment

Due to the inherent complexity of the impact assessment stage of an LCA study, uncertainties and assumptions are inevitable in order to remain accessible to its intended users. The uncertainty associated with this LCA study affects the results and in turn how they are interpreted. During the impact assessment phase, uncertainty can arise as a consequence of data uncertainty, model uncertainty, temporal variability and spatial variability.

Data uncertainty within the impact assessment phase arises from the characterization of emissions, due to the dynamic nature of the various impacts. The impact categories can be heavily influenced by different factors such as unknown lifetimes of substances, time of year, location, temperature, industrial activity, etc. In addition, the travel potential of various emissions is not accounted for during the assessment, and could possibly have a significant affect on the results.

The fact that characterization factors are not known and assessment of all the potential impacts is limited contributes to the model uncertainty. According to ISO 14040, the impact assessment phase of LCA addresses only the environmental issues specified in the goal and scope and thus is not a complete assessment of all potential issues (Canadian Standards Association, 2006). Variations in social values systems amongst countries is not addressed, which could be a significant factor in determining the extent of the impacts being studied. In addition, evaluating the effects of qualitative factors such as aesthetics, politics, and economics is very difficult and thus not accounted for (World Energy Council, 1994).

Temporal variability contributes to the uncertainty because impacts are highly variable as time progresses. The impact assessment performed on this study is not interpreted over time, nor does it account for the effects of varying climate and temperature. These temporal factors could be highly influential on the different impact categories. As for spatial variability, the sensitivity to certain impact categories will differ from region to region. Some of the impact categories, such as global warming and ozone layer depletion, are considered to be global impacts, whereas smog formation and eutrophication are regionalized impacts that vary from location to location. Since this LCA study was performed under a non-regionalized methodology, the impact assessment phase does not account for varying environmental conditions. In addition, regional differences in environmental sensitivity can result from the disregard of external influences on emissions, such as chemical reactions within emissions in the environment, varying rate of decomposition of chemicals, and varying concentration of chemicals during the lifetime of the building.

Uncertainty in the impact assessment phase can also transpire due to differences in human exposure patterns. Whether emissions are being emitted within the structure or exiting the structure alters the extent of various impacts. This could potentially result in an over- or under-estimation of certain environmental impacts.

5.0 Building Performance

The building performance in terms of energy consumption of the current Hebb Building was determined from total areas and heat flow resistances (R-values) of the exterior walls, windows, and roof areas, as well as the initial embodied energy of the building. The performance of the current building was then compared to an improved Hebb Building, where the R-values of the windows, wall insulation, and roof insulation were increased to the minimum Residential Environmental Assessment Program's (REAP's) insulation requirements. The following sections will discuss the current and improved building components, the calculations and methodology associated with the building performance model, the comparison of the improved building to the current building in terms of energy consumption over the building's service life, and further considerations.

5.1 Current Building

The current Hebb Building consists of concrete cast-in-place exterior walls with brick cladding, 6mil polyethylene, 1" extruded polystyrene, and plaster. The windows are fixed with standard glazing and aluminum framing. The concrete suspended roof consisted of a 4-ply built-up Asphalt Roof System inverted with extruded polystyrene and glass felt envelope material. For the purposes of this building performance estimation, focus was only put on the insulation and window types; the assigned R-values for the wall and roof insulation of 1" extruded polystyrene, and standard glazed windows of the current building are presented in Table 7 below (Colorado Energy, 2008).

Table 7. Assigned R-Values to Measured Areas of Assemblies for Current Building

	Total Area (ft2)	R-Value (ft2.degF.h/BTU)
Exterior Wall	45531.59	5.00
Window	7082.97	0.19
Roof	15183.98	5.00
Weighted Average	67798.54	4.50

5.2 Improved Building

The improved Hebb Building was created by altering the current wall insulation, roof insulation, and window type to increase the R-values to the minimum REAP's insulation requirements:

- EA 1.1; Roof – minimum R-40
- EA 1.2; Exterior Wall Insulation – minimum R-18
- EA 1.3; Energy Star Windows – minimum R-3.2

In order to achieve a minimum R-value of 18 for the exterior wall insulation, the 1” extruded polystyrene of the current building was replaced with 2.5” of foam polyisocyanurate insulation, which has an R-value of 7.2 per inch. Instead of standard glazed windows of the current building, the improved building had low E silver argon filled glazing, which has an R-value of 3.75 per type. To achieve an R-value of 40 for the roof insulation, 7” of extruded polystyrene was added to the current building’s 1” of insulation. These R-values for the improved building are summarized in Table 8 below:

Table 8. Assigned R-Values to Measured Areas of Assemblies for Improved Building

	Total Area (ft2)	R-Value (ft2.degF.h/BTU)
Exterior Wall	45531.59	18.00
Window	7082.97	3.75
Roof	15183.98	40.00
Weighted Average	67798.54	21.44

This improved building was then modeled in the Impact Estimator to determine its primary energy consumption to allow for comparison with the current building. Section 5.3 will go on to discuss the details of methodology behind the model used to estimate and compare the building performances of the current and improved building.

5.3 Building Performance Model Methodology

In order to determine the heat loss through the current and improved building over the service life, the weighted average of R-values based on the percentage of total exterior building surface area was used in conjunction with the following heat loss equation:

$$Q = \left(\frac{1}{R}\right) A \Delta T$$

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

A = Assembly of interest ft^2

ΔT = Inside Temperature – Outside Temperature in °F

The heat loss as determined by this equation was converted into heat loss in BTU for each month, which was then used to calculate the annual energy usage in joules for both the current and improved building. The graph of the cumulative heat losses, also accounting for the initial embodied energy as determined from the Impact Estimator, for the current and improved building is presented and discussed in the following section.

5.4 Energy Performance Results

Figure 16 is a graph of the cumulative heat losses over an assumed service life of 80 years, also taking into account the initially invested embodied energy into materials for each of the current and improved buildings at year zero.

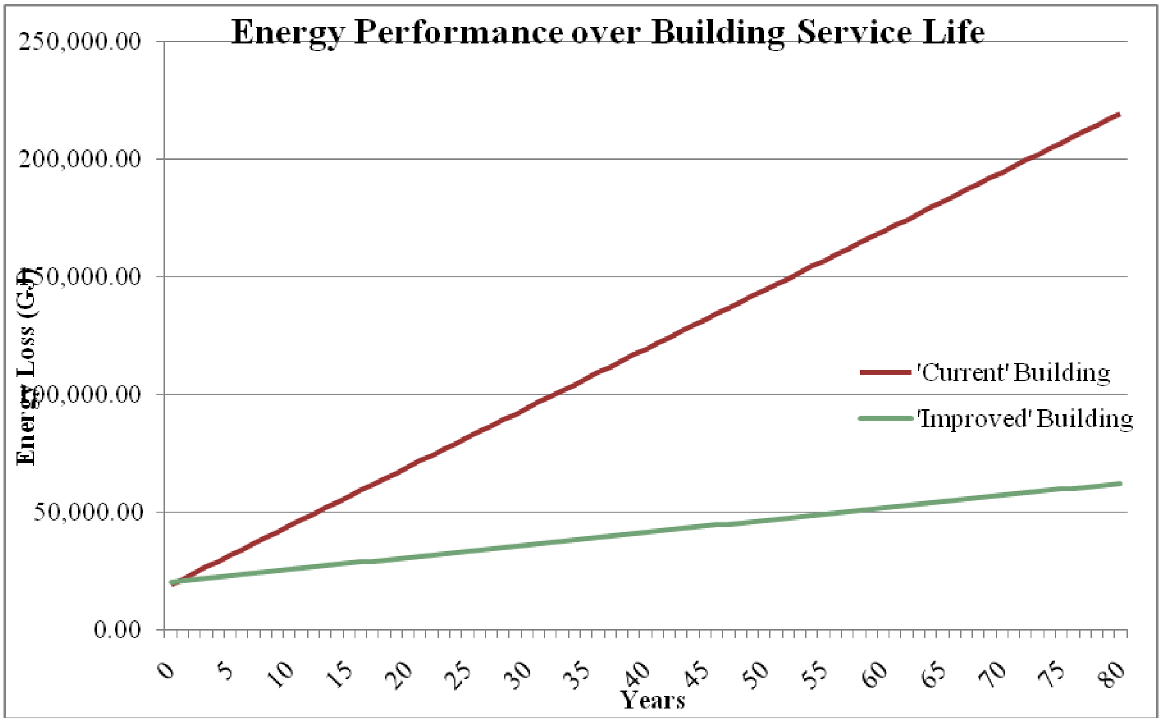

Figure 16. Energy Loss versus Time for the Current and Improved Hebb Building over the Service Life

From Figure 16, it is evident that the improved building has a much better energy performance than the current building over the service life, with total energy savings of approximately 160,000GJ. This holds true even though, from observing the first five years of the building's life in Figure 17, the initial energy loss of the improved building is greater than the current building. This model demonstrates that investing in materials – such as foam polyisocyanurate insulation and low E silver argon filled glazed windows – that are more energy efficient, can save further impacts during the service life of the building.

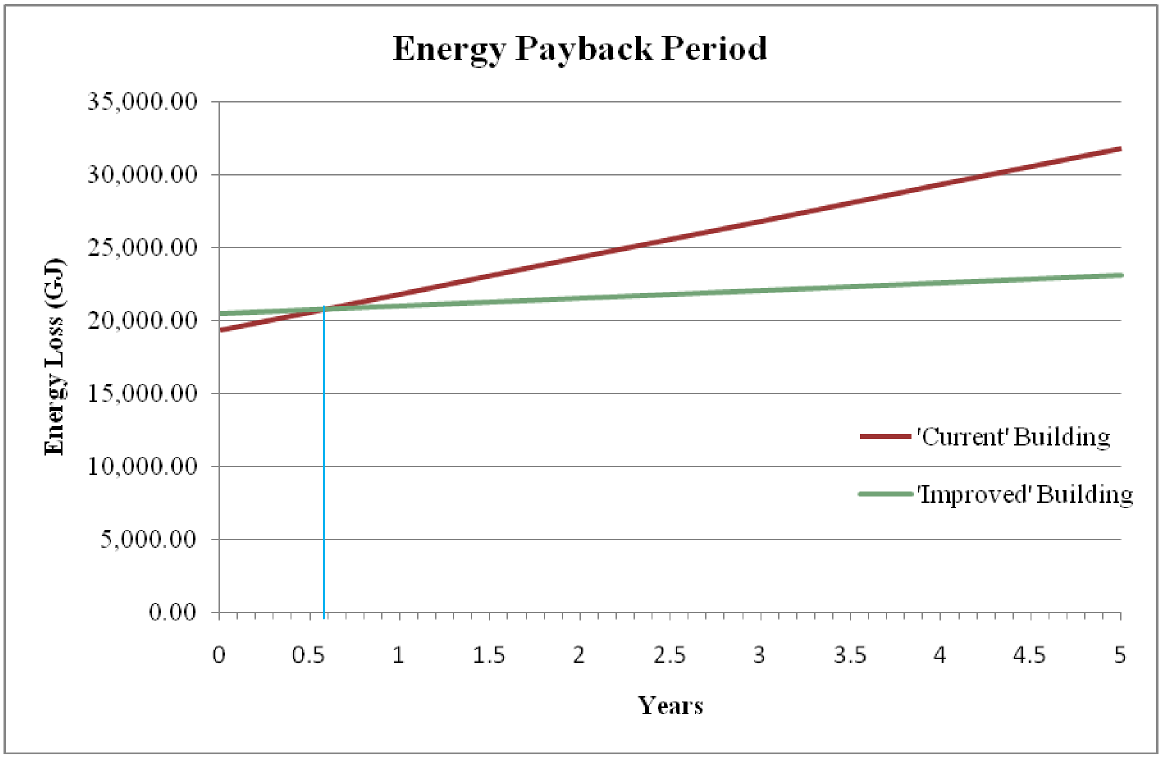

Figure 17. Energy Loss versus Time for the Current and Improved Hebb Building for the first 5 years

The decision to invest in better performing materials to reduce the impact during the service life of Hebb Building is also justified by the fact that the model presents an energy payback period of 0.6 years, or approximately seven months (refer to Figure 17 above). In other words, it would take only seven months to save the energy that was invested into reducing Hebb Building's heat loss, which was achieved by incorporating the proposed insulation and window type upgrades.

5.5 Further Considerations

The building performance model presented in this section is very approximate and is intended to provide a simple and general 'big picture' of the potential effects investing in energy efficient materials can have on the overall performance of a building. While it is acceptable to conclude that initially investing on more energy efficient materials may improve the energy performance of a building in the long run, other factors, such as logistics, economics, and environmental concerns, must be considered. If the opportunity to improve the Hebb Building was available, the actual payback period would be longer than seven months because the wall and roof assemblies would require removal and replacement to allow for the installation of the more efficient insulation. In addition, economically investing in the more expensive foam polyisocyanurate and low E silver argon filled windows may not be feasible due to project budget constraints. Upgrading the Hebb Building through renovations and installation of new materials may also introduce other environmental impacts, and if these impacts outweigh the targeted energy savings, then it would not be reasonable to undergo these improvements. This demonstrates the importance and applicability of executing LCA studies on buildings in order to determine the most appropriate assembly to provide optimal performance. Preferably, carrying out an LCA study during the design phase is most desired as it allows for many different materials to be compared before selection, and their interactions within the assemblies can be analyzed in terms of overall performance.

6.0 Conclusion

The life cycle assessment of the reinforced concrete structure of the Hebb Building within the defined goal and scope of the study has been carried out by performing takeoffs and modeling the building in the Impact Estimator. Assumptions and adjustments were required to model the assembly types within the Hebb Building, and they are taken into account during the analysis of the results. The Bill of Materials produced shows that the five most significant materials of the Hebb Building are ballast, concrete, extruded polystyrene, Ontario brick, and rebar.

The Summary Measures determined from the Impact Estimator lists the effects of the eight impact categories during the manufacturing and construction phases. It was observed that the primary energy consumption and weighted resource use were most significant, while the ozone depletion and eutrophication potential are quite negligible in terms of the whole Hebb Building effects. From performing sensitivity analyses on five substantial materials present in the building and examining their affects on each of the impact categories relative to the total building impact, it is evident that a 10% increase in the amount of concrete has the most considerable effect on each of the impact categories, in comparison to increases in the other four materials.

Lastly, through building performance calculations and modeling, it was determined that by upgrading the current insulation and window type of 1" extruded polystyrene and standard glazing to 2.5" foam polyisocyanurate and low E silver argon filled glazing, the minimum REAP's insulation requirements can be met and Hebb Building's energy performance can be drastically improved over its service life. This improved building would have an energy payback period of 0.6 years, or approximately seven months.

This LCA study of the Hebb Building can be further developed and improved by expanding the scope from cradle-to-gate to cradle-to-grave. Incorporating operational and demolition impacts would provide a more holistic view of the environmental effects the Hebb Building is capable of. Performing more detailed takeoffs that include assemblies such as mechanical, HVAC, flooring, finishes, and desks would also result in a more representative model of the building. The simplifications employed during modeling could also be refined to provide more accurate findings. As for impact assessment, using a more thorough and extensive LCA software that can model more complex scenarios in a transparent way, such as SimaPro, can yield more reliable results.

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Appendix A

Contents:

IE Inputs Document for Hebb Tower

IE Inputs Document for Hebb Theatre

IE Inputs Document - HEBB Tower

Assembly Group	Assembly Type	Assembly Name	Input Fields	Input Values	
				Known/Measured	EIE Inputs
1 Foundation					
	1.1 Concrete Slab-on-Grade				
		1.1.1 SOG_5"_Tower			
			Length (ft)	115.62	115.62
			Width (ft)	115.62	115.62
			Thickness (in)	5	4
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
	1.2 Concrete Footing				
		1.2.1 Footing_F1a_Basement			
			Length (ft)	4.25	4.25
			Width (ft)	2	8.42
			Thickness (in)	80	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.2 Footing_F1b_Basement			
			Length (ft)	0.92	0.92
			Width (ft)	0.83	0.83
			Thickness (in)	12	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.3. Footing_F2a_Basement			
			Length (ft)	5.17	5.17
			Width (ft)	2.5	10.53
			Thickness (in)	80	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.4 Footing_F2b_Basement			
			Length (ft)	3.92	3.92
			Width (ft)	1.125	1.125
			Thickness (in)	12	12
			Concrete (psi)	-	4000

			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.5 Footing_FA_Basement			
			Length (ft)	152.5	152.5
			Width (ft)	3.5	3.50
			Thickness (in)	15	15
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.6 Footing_FB_Basement			
			Length (ft)	280.29	280.29
			Width (ft)	2	2.00
			Thickness (in)	12	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.7 Footing_FC_Basement			
			Length (ft)	148.5	148.5
			Width (ft)	4	4
			Thickness (in)	15	15
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.8 Footing_FD_Basement			
			Length (ft)	34	34
			Width (ft)	2	2.00
			Thickness (in)	12	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.9 Footing_FE_Basement			
			Length (ft)	56.83	56.83
			Width (ft)	2.5	2.50
			Thickness (in)	12	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.10 Footing_FF_Basement			
			Length (ft)	22.42	22.42
			Width (ft)	2	2
			Thickness (in)	12	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.11 Footing_FG_Basement			

			Length (ft)	48.06	48.06
			Width (ft)	1.8	7.58
			Thickness (in)	80	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.12 Footing_FH_Basement			
			Length (ft)	25.08	25.08
			Width (ft)	1.5	6.32
			Thickness (in)	80	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.13 Footing_FJ_Basement			
			Length (ft)	30.50	30.50
			Width (ft)	2.75	2.75
			Thickness (in)	12.00	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.14 Footing_FK_Basement			
			Length (ft)	24.33	24.33
			Width (ft)	3.00	3.00
			Thickness (in)	12.00	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.15 Footing_FL_Basement			
			Length (ft)	38.83	38.83
			Width (ft)	1.5	1.5
			Thickness (in)	12	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.16 Footing_FM_Basement			
			Length (ft)	29.67	29.67
			Width (ft)	2	2.00
			Thickness (in)	12	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.17 Footing_FN_Basement			
			Length (ft)	16.42	16.42
			Width (ft)	1.50	1.50
			Thickness (in)	12	12
			Concrete (psi)	-	4000

			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.18 Stairs_South/North_Platform			
			Length (ft)	141.74	141.74
			Width (ft)	5.33	4.26
			Thickness (in)	6	7.5
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.19 Stairs_South/North_Steps			
			Length (ft)	182.83	182.83
			Width (ft)	5.33	5.33
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
2 Walls					
	2.1 Cast In Place				
		2.1.1 Wall_Cast-In-Place_W1_Ext_BrickClad_Basement_10"			
		Envelope	Length (ft)	453.73	567.16
			Height (ft)	12	12
			Thickness (in)	10	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
			Category	Plaster	Gypsum Board
			Material	Plaster	Gypsum Regular
			Thickness (in)	-	0.5
			Category	Insulation	Insulation
			Material	Styrofoam	Polystyrene Extruded
			Thickness (in)	1	1
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness (in)	-	-
			Category	Cladding	Cladding
			Material	Norman Glazed Brick	Brick - Ontario (standard)
			Thickness (in)	4.75	-
			Category	Paint	Paint
			Material	-	Alkyd Solvent Based
			Thickness (in)	-	-
		2.1.2 Wall_Cast-In-Place_W1_Ext_BrickClad_Basement_11.75"			
			Length (ft)	29	28.40
			Height (ft)	12	12
			Thickness (in)	11.75	12
			Concrete (psi)	-	4000
			Concrete flyash	-	average

			%		
			Rebar	#5	#5
		Envelope	Category	Plaster	Gypsum Board
			Material	Plaster	Gypsum Regular
			Thickness (in)	-	0.5
			Category	Insulation	Insulation
			Material	Styrofoam	Polystyrene Extruded
			Thickness (in)	1	1
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness (in)	-	-
			Category	Cladding	Cladding
			Material	Norman Glazed Brick	Brick - Ontario (standard)
			Thickness (in)	4.75	-
			Category	Paint	Paint
			Material	-	Alkyd Solvent Based
			Thickness (in)	-	-
		2.1.3 Wall_Cast-In-Place_W1_Int_Basement_10"			
			Length (ft)	157.75	197.19
			Height (ft)	12	12
			Thickness (in)	10	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Door Opening	Number of Doors	4	4
			Door Type	Solid Wood Door	Solid Wood Door
		2.1.4 Wall_Cast-In-Place_W1_Int_Basement_8"			
			Length (ft)	301.07	301.07
			Height (ft)	12	12
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Door Opening	Number of Doors	7	7
			Door Type	Solid Wood Door	Solid Wood Door
		2.1.5 Wall_Cast-In-Place_W2_Ext_BrickClad_GrndFlr_10"			
			Length (ft)	336.67	420.84
			Height (ft)	12	12
			Thickness (in)	10	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Window Opening	Number of Windows	9	9
			Total Window Area (ft2)	501.99	501.99
			Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame

			Glazing Type	-	Standard Glazing
		Envelope	Category	Plaster	Gypsum Board
			Material	Plaster	Gypsum Regular
			Thickness (in)	-	0.5
			Category	Insulation	Insulation
			Material	Styrofoam	Polystyrene Extruded
			Thickness (in)	1	1
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness (in)	-	-
			Category	Cladding	Cladding
			Material	Norman Glazed Brick	Brick - Ontario (standard)
			Thickness (in)	4.75	-
			Category	Paint	Paint
			Material	-	Alkyd Solvent Based
			Thickness (in)	-	-
		2.1.6 Wall_Cast-In-Place_W2_Ext_BrickClad_GrndFlr_11.75"			
			Length (ft)	38.13	37.34
			Height (ft)	12	12
			Thickness (in)	11.75	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Envelope	Category	Plaster	Gypsum Board
			Material	Plaster	Gypsum Regular
			Thickness (in)	-	0.5
			Category	Insulation	Insulation
			Material	Styrofoam	Polystyrene Extruded
			Thickness (in)	1	1
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness (in)	-	-
			Category	Cladding	Cladding
			Material	Norman Glazed Brick	Brick - Ontario (standard)
			Thickness (in)	4.75	-
			Category	Paint	Paint
			Material	-	Alkyd Solvent Based
			Thickness (in)	-	-
		2.1.7 Wall_Cast-In-Place_W2_Ext_GrndFlr_8"			
			Length (ft)	156.97	156.97
			Height (ft)	12	12
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Window Opening	Number of Windows	7	7

			Total Window Area (ft2)	440.72	440.72
			Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
			Glazing Type	-	Standard Glazing
		Envelope	Category	Plaster	Gypsum Board
			Material	Plaster	Gypsum Regular
			Thickness (in)	-	0.5
			Category	Insulation	Insulation
			Material	Styrofoam	Polystyrene Extruded
			Thickness (in)	1	1
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness (in)	-	-
		2.1.8 Wall_Cast-In-Place_W2_Ext_GrndFlr_AdditionalWall			
			Length (ft)	175.81	175.81
			Height (ft)	4	4
			Thickness (in)	12	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.9 Wall_Cast-In-Place_W2_Int_GrndFlr_10"			
			Length (ft)	91.67	114.59
			Height (ft)	12	12
			Thickness (in)	10	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Door Opening	Number of Doors	4	4
			Door Type	Solid Wood Door	Solid Wood Door
		2.1.10 Wall_Cast-In-Place_W2_Int_GrndFlr_6"			
			Length (ft)	73.22	54.92
			Height (ft)	12	12
			Thickness (in)	6	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.11 Wall_Cast-In-Place_W2_Int_GrndFlr_7.5"			
			Length (ft)	28.08	26.33
			Height (ft)	12	12
			Thickness (in)	7.5	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.12 Wall_Cast-In-Place_W2_Int_GrndFlr_8"			
			Length (ft)	260.48	260.48
			Height (ft)	12	12

			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Door Opening	Number of Doors	7	7
			Door Type	Solid Wood Door	Solid Wood Door
		2.1.13 Wall_Cast-In-Place_W3_Ext_BrickClad_TypFlr_10"			
			Length (ft)	281.83	1,056.87
			Height (ft)	12	12
			Thickness (in)	10	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Window Opening	Number of Windows	13	39
			Total Window Area (ft2)	570.2	1710.6
			Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
			Glazing Type	-	Standard Glazing
		Envelope	Category	Plaster	Gypsum Board
			Material	Plaster	Gypsum Regular
			Thickness (in)	-	0.5
			Category	Insulation	Insulation
			Material	Styrofoam	Polystyrene Extruded
			Thickness (in)	1	1
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness (in)	-	-
			Category	Cladding	Cladding
			Material	Norman Glazed Brick	Brick - Ontario (standard)
			Thickness (in)	4.75	-
			Category	Paint	Paint
			Material	-	Alkyd Solvent Based
			Thickness (in)	-	-
		2.1.14 Wall_Cast-In-Place_W3_Ext_BrickClad_TypFlr_7.5"			
			Length (ft)	32.92	92.58
			Height (ft)	12	12
			Thickness (in)	7.5	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Envelope	Category	Plaster	Gypsum Board
			Material	Plaster	Gypsum Regular
			Thickness (in)	-	0.5
			Category	Insulation	Insulation
			Material	Styrofoam	Polystyrene Extruded

			Thickness (in)	1	1
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness (in)	-	-
			Category	Cladding	Cladding
			Material	Norman Glazed Brick	Brick - Ontario (standard)
			Thickness (in)	4.75	-
			Category	Paint	Paint
			Material	-	Alkyd Solvent Based
			Thickness (in)	-	-
		2.1.15 Wall_Cast-In-Place_W3_Ext_BrickClad_TypFlr_8"			
			Length (ft)	93.48	280.44
			Height (ft)	12	12
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Window Opening	Number of Windows	6	18
			Total Window Area (ft2)	341	1023
			Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
			Glazing Type	-	Standard Glazing
		Envelope	Category	Plaster	Gypsum Board
			Material	Plaster	Gypsum Regular
			Thickness (in)	-	0.5
			Category	Insulation	Insulation
			Material	Styrofoam	Polystyrene Extruded
			Thickness (in)	1	1
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness (in)	-	-
			Category	Cladding	Cladding
			Material	Norman Glazed Brick	Brick - Ontario (standard)
			Thickness (in)	4.75	-
			Category	Paint	Paint
			Material	-	Alkyd Solvent Based
			Thickness (in)	-	-
		2.1.16 Wall_Cast-In-Place_W3_Int_TypFlr_10"			
			Length (ft)	101.47	380.52
			Height (ft)	12	12
			Thickness (in)	10	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Door Opening	Number of Doors	14	42
			Door Type	Solid Wood Door	Solid Wood Door
		2.1.17 Wall_Cast-In-Place_W3_Int_TypFlr_5.75"			

			Length (ft)	54.26	117
			Height (ft)	12	12
			Thickness (in)	5.75	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Window Opening	Number of Windows	6	18
			Total Window Area (ft2)	373.08	1119.24
			Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
			Glazing Type	-	Standard Glazing
		2.1.18 Wall_Cast-In-Place_W3_Int_TypFlr_8"			
			Length (ft)	89.83	269.49
			Height (ft)	12	12
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Door Opening	Number of Doors	7	21
			Door Type	Solid Wood Door	Solid Wood Door
		2.1.19 Wall_Cast-In-Place_W4_Ext_BrickClad_SecondFlr_10"			
			Length (ft)	280.08	350.10
			Height (ft)	12	12
			Thickness (in)	10	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Window Opening	Number of Windows	13	13
			Total Window Area (ft2)	570.2	570.2
			Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
			Glazing Type	-	Standard Glazing
		Envelope	Category	Plaster	Gypsum Board
			Material	Plaster	Gypsum Regular
			Thickness (in)	-	0.5
			Category	Insulation	Insulation
			Material	Styrofoam	Polystyrene Extruded
			Thickness (in)	1	1
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness (in)	-	-
			Category	Cladding	Cladding
			Material	Norman Glazed Brick	Brick - Ontario (standard)
			Thickness (in)	4.75	-
			Category	Paint	Paint
			Material	-	Alkyd Solvent Based

			Thickness (in)	-	-
		2.1.20 Wall_Cast-In-Place_W4_Ext_BrickClad_SecondFlr_7.5"			
			Length (ft)	194.53	182.37
			Height (ft)	12	12
			Thickness (in)	7.5	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Window Opening	Number of Windows	6	6
			Total Window Area (ft2)	373.08	373.08
			Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
			Glazing Type	-	Standard Glazing
		Envelope	Category	Plaster	Gypsum Board
			Material	Plaster	Gypsum Regular
			Thickness (in)	-	0.5
			Category	Insulation	Insulation
			Material	Styrofoam	Polystyrene Extruded
			Thickness (in)	1	1
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness (in)	-	-
			Category	Cladding	Cladding
			Material	Norman Glazed Brick	Brick - Ontario (standard)
			Thickness (in)	4.75	-
			Category	Paint	Paint
			Material	-	Alkyd Solvent Based
			Thickness (in)	-	-
		2.1.21 Wall_Cast-In-Place_W4_Ext_BrickClad_SecondFlr_8"			
			Length (ft)	93.5	93.50
			Height (ft)	12	12
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Window Opening	Number of Windows	6	6
			Total Window Area (ft2)	341	341
			Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
			Glazing Type	-	Standard Glazing
		Envelope	Category	Plaster	Gypsum Board
			Material	Plaster	Gypsum Regular
			Thickness (in)	-	0.5
			Category	Insulation	Insulation
			Material	Styrofoam	Polystyrene Extruded
			Thickness (in)	1	1

			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness (in)	-	-
			Category	Cladding	Cladding
			Material	Norman Glazed Brick	Brick - Ontario (standard)
			Thickness (in)	4.75	-
			Category	Paint	Paint
			Material	-	Alkyd Solvent Based
			Thickness (in)	-	-
		2.1.22 Wall_Cast-In-Place_W4_Int_SecondFlr_10"			
			Length (ft)	101.08	126.35
			Height (ft)	12	12
			Thickness (in)	10	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Door Opening	Number of Doors	8	8
			Door Type	Solid Wood Door	Solid Wood Door
		2.1.23 Wall_Cast-In-Place_W4_Int_SecondFlr_8"			
			Length (ft)	88.08	88.08
			Height (ft)	12	12
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Door Opening	Number of Doors	7	7
			Door Type	Solid Wood Door	Solid Wood Door
		2.1.24 Wall_Cast-In-Place_W5_Ext_BrickClad_Penthouse_7.5"			
			Length (ft)	33.17	31.10
			Height (ft)	12	12
			Thickness (in)	7.5	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Envelope	Category	Plaster	Gypsum Board
			Material	Plaster	Gypsum Regular
			Thickness (in)	-	0.5
			Category	Insulation	Insulation
			Material	Styrofoam	Polystyrene Extruded
			Thickness (in)	1	1
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness (in)	-	-
			Category	Cladding	Cladding
			Material	Norman Glazed Brick	Brick - Ontario (standard)
			Thickness (in)	4.75	-

			Category	Paint	Paint
			Material	-	Alkyd Solvent Based
			Thickness (in)	-	-
		2.1.25 Wall_Cast-In-Place_W5_Ext_BrickClad_Penthouse_8"			
			Length (ft)	294.44	294.44
			Height (ft)	12	12
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Window Opening	Number of Windows	18	18
			Total Window Area (ft2)	1003.14	1003.14
			Frame Type	Fixed, Aluminum Frame	Fixed, Aluminum Frame
			Glazing Type	-	Standard Glazing
		Envelope	Category	Plaster	Gypsum Board
			Material	Plaster	Gypsum Regular
			Thickness (in)	-	0.5
			Category	Insulation	Insulation
			Material	Styrofoam	Polystyrene Extruded
			Thickness (in)	1	1
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness (in)	-	-
			Category	Cladding	Cladding
			Material	Norman Glazed Brick	Brick - Ontario (standard)
			Thickness (in)	4.75	-
			Category	Paint	Paint
			Material	-	Alkyd Solvent Based
			Thickness (in)	-	-
3 Columns and Beams					
	3.1 Concrete Column & Beam				
		3.1.1 Column_Beam_Concrete_Basement			
			Number of Columns	25	25
			Number of Beams	5	5
			Bay sizes (ft)	41.5	40
			Supported span (ft)	12.5	12.5
			Floor to floor height (ft)	12	12
			Live load (psf)	60, 100	75
		3.1.2 Column_Beam_Concrete_GrndFlr			
			Number of Columns	28	28
			Number of Beams	12	12
			Bay sizes (ft)	41.5	40

			Supported span (ft)	12.5	12.5
			Floor to floor height (ft)	12	12
			Live load (psf)	60, 100	75
		3.1.3 Column_Beam_Concrete_SecondFlr			
			Number of Columns	28	28
			Number of Beams	12	12
			Bay sizes (ft)	41.5	40
			Supported span (ft)	12.5	12.5
			Floor to floor height (ft)	12	12
			Live load (psf)	60, 100	75
		3.1.4 Column_Beam_Concrete_TypFlr			
			Number of Columns	28	84
			Number of Beams	12	36
			Bay sizes (ft)	41.5	40
			Supported span (ft)	12.5	12.5
			Floor to floor height (ft)	12	12
			Live load (psf)	60, 100	75
4 Floors					
	4.1 Concrete Suspended Slab				
		4.1.1 Floor_ConcreteSuspendedSlab_GrndFlr			
			Floor Width (ft)	797.08	797.08
			Span (ft)	12.5	12.5
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Life load (psf)	60, 100	75
		4.1.2 Floor_ConcreteSuspendedSlab_SecondFlr			
			Floor Width (ft)	681.41	681.41
			Span (ft)	12.5	12.5
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Life load (psf)	60, 100	75
		4.1.3 Floor_ConcreteSuspendedSlab_TypFlr			
			Floor Width (ft)	595.39	1786.16
			Span (ft)	12.5	12.5
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Life load (psf)	60, 100	75
		4.1.4 Floor_ConcreteSuspendedSlab_Penthouse			
			Floor Width (ft)	192.67	192.67
			Span (ft)	12	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average

			Life load (psf)	60, 100	75
5 Roof					
	5.1 Concrete Suspended Slab				
		5.1.1 Roof_ConcreteSuspendedSlab_Tower			
		Envelope	Roof Width (ft)	672.98	672.98
			Span (ft)	12.5	12.5
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Life load (psf)	27	45
			Category	-	4-Ply Built-up Asphalt Roof System - Inverted
			Material	Rigid Insulation	Extruded Polystyrene, Glass Felt
			Thickness (in)	1	6
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness	-	-

IE Inputs Document - HEBB Theatre

Assembly Group	Assembly Type	Assembly Name	Input Fields	Input Values	
				Known/Measured	EIE Inputs
1 Foundation					
	1.1 Concrete Slab-on-Grade				
		1.1.1 SOG_5"_Lobby			
			Length (ft)	84.06	84.06
			Width (ft)	84.06	84.06
			Thickness (in)	5	4
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
	1.2 Concrete Footing				
		1.2.1 Footing_L01&02_Lobby			
			Length (ft)	47.83	47.83
			Width (ft)	2	2.58
			Thickness (in)	24.5	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.2 Footing_L03a&05a_Lobby			
			Length (ft)	58	58
			Width (ft)	5	5
			Thickness (in)	18	18
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.3 Footing_L03b_Lobby			
			Length (ft)	21.17	21.17
			Width (ft)	2	2.00
			Thickness (in)	18	18
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.4 Footing_L04_Lobby			
			Length (ft)	77.75	77.75
			Width (ft)	2	6.32
			Thickness (in)	60	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average

			Rebar	#5	#5
		1.2.5 Footing_L05b&14_Lobby			
			Length (ft)	52.75	52.75
			Width (ft)	2	2
			Thickness (in)	12	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.6 Footing_L06a_Lobby			
			Length (ft)	20	20
			Width (ft)	3	3.00
			Thickness (in)	12	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.7 Footing_L06b_Lobby			
			Length (ft)	18.25	18.25
			Width (ft)	5	5.00
			Thickness (in)	18	18
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.8 Footing_L08_Lobby_1'x1'6"			
			Length (ft)	247.48	247.48
			Width (ft)	1.5	1.5
			Thickness (in)	12	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.9 Footing_L12_Lobby			
			Length (ft)	32.08	32.08
			Width (ft)	7.83	6.26
			Thickness (in)	6	7.5
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.10 Footing_LA_Lobby			
			Length (ft)	10.92	10.92
			Width (ft)	5.5	5.5
			Thickness (in)	18	18
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.11 Footing_LB_Lobby			
			Length (ft)	7.92	7.92
			Width (ft)	4.00	4.00
			Thickness (in)	18.00	18
			Concrete (psi)	-	4000

			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.12 Footing_LC_Lobby			
			Length (ft)	6.67	6.67
			Width (ft)	3.25	3.25
			Thickness (in)	18.00	18
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.13 Footing_LD_Lobby			
			Length (ft)	4	4
			Width (ft)	2	2
			Thickness (in)	12	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.14 Stairs_Theatre			
			Length (ft)	65.42	65.42
			Width (ft)	65.5	82.74
			Thickness (in)	24	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
2 Walls					
	2.1 Cast In Place				
		2.1.1 Wall_Cast-In-Place_L01_Lobby_8"			
			Length (ft)	34.54	34.54
			Height (ft)	17.3125	17.3125
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.2 Wall_Cast-In-Place_L02_Lobby_8"			
			Length (ft)	14.17	14.17
			Height (ft)	14.635	14.635
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.3 Wall_Cast-In-Place_L03a_Lobby_8"			
			Length (ft)	39.58	39.58
			Height (ft)	25.5	25.5
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.4 Wall_Cast-In-Place_L03b_Lobby_8"			
			Length (ft)	5.92	5.92

			Height (ft)	25.5	25.5
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.5 Wall_Cast-In-Place_L04_Lobby_8"			
			Length (ft)	81.4	81.40
			Height (ft)	16.5	16.5
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.6 Wall_Cast-In-Place_L05_Lobby_1'8"			
			Length (ft)	4.75	7.92
			Height (ft)	10.3	10.3
			Thickness (in)	20	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.7 Wall_Cast-In-Place_L06_Lobby_1'8"			
			Length (ft)	6.58	11.00
			Height (ft)	10.3	10.3
			Thickness (in)	20	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.8 Wall_Cast-In-Place_L07_Lobby_8"			
			Length (ft)	42.72	42.72
			Height (ft)	18.3	18.3
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.9 Wall_Cast-In-Place_L08_Lobby_6"			
			Length (ft)	24.81	18.61
			Height (ft)	12.0	12.0
			Thickness (in)	6	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.10 Wall_Cast-In-Place_L09-10_Lobby_8"			
			Length (ft)	113.12	113.12
			Height (ft)	12.0	12.0
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.11 Wall_Cast-In-Place_L11_Lobby_10"			

			Length (ft)	42.32	52.90
			Height (ft)	12.0	12.0
			Thickness (in)	10	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.12 Wall_Cast-In-Place_L12a_Lobby_8"			
			Length (ft)	38	38.00
			Height (ft)	3.0	3.0
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.13 Wall_Cast-In-Place_L12b_Lobby_8"			
			Length (ft)	31.92	31.92
			Height (ft)	4.5	4.5
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.14 Wall_Cast-In-Place_L13_Lobby_10"			
			Length (ft)	27.5	34.38
			Height (ft)	10.3	10.3
			Thickness (in)	10	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.15 Wall_Cast-In-Place_L14_Lobby_11.75"			
			Length (ft)	89.57	87.70
			Height (ft)	10.3	10.3
			Thickness (in)	11.75	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.16 Wall_Cast-In-Place_W6_Ext_BrickClad_Theatre_8"			
			Length (ft)	365.74	365.74
			Height (ft)	26	26
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		Door Opening	Number of Doors	2	2
			Door Type	Steel Exterior Door	Steel Exterior Door
		Envelope	Category	Plaster	Gypsum Board
			Material	Plaster	Gypsum Regular
			Thickness (in)	-	0.5
			Category	Insulation	Insulation
			Material	Styrofoam	Polystyrene Extruded

			Thickness (in)	1	1
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness (in)	-	-
			Category	Cladding	Cladding
			Material	Norman Glazed Brick	Brick - Ontario (standard)
			Thickness (in)	4.75	-
			Category	Paint	Paint
			Material	-	Alkyd Solvent Based
			Thickness (in)	-	-
		2.1.17 Wall_Cast-In-Place_W6_Int_Theatre_6"			
			Length (ft)	51.75	38.81
			Height (ft)	26.0	26.0
			Thickness (in)	6	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		2.1.18 Wall_Cast-In-Place_W6_Int_Theatre_8"			
			Length (ft)	74.92	74.92
			Height (ft)	26.0	26.0
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
3 Columns and Beams					
	3.1 Concrete Column & Beam				
		3.1.1 Column_Beam_Concrete_Lobby			
			Number of Columns	10	10
			Number of Beams	10	10
			Bay sizes (ft)	20.83	20.83
			Supported span (ft)	14.25	14.25
			Floor to floor height (ft)	10.5	10.5
			Live load (psf)	60, 100	75
		3.1.2 Column_Beam_Concrete_Theatre			
			Number of Columns	12	12
			Number of Beams	32	32
			Bay sizes (ft)	21.00	21
			Supported span (ft)	9.5	9.5
			Floor to floor height (ft)	26	26
			Live load (psf)	60, 100	75
4 Floors					
	4.1 Concrete Suspended Slab				
		4.1.1 Floor_ConcreteSuspendedSlab_Theatre			
			Floor Width (ft)	789.23	789.23
			Span (ft)	9.5	9.5
			Concrete (psi)	-	4000

			Concrete flyash %	-	average
			Life load (psf)	60, 100	75
5 Roof					
	5.1 Concrete Suspended Slab				
		5.1.1 Roof_ConcreteSuspendedSlab_Theatre			
		Envelope	Roof Width (ft)	497.76	497.76
			Span (ft)	13.60	13.60
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Life load (psf)	27	45
			Category	-	4-Ply Built-up Asphalt Roof System - Inverted
			Material	Rigid Insulation	Extruded Polystyrene, Glass Felt
			Thickness (in)	1	6
			Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness	-	-
6 Extra Basic Materials					
	6.1 Window Glazing				
		6.1.1 XBM_StandardGlazing_Lobby			
			Standard Glazing (sf)	356.62	356.62

Appendix B

Contents:

IE Input Assumptions Document for Hebb Tower

IE Input Assumptions Document for Hebb Theatre

IE Input Assumptions Document - HEBB Tower

Assembly Group	Assembly Type	Assembly Name	Specific Assumptions
1 Foundation	The Impact Estimator, SOG inputs are limited to being either a 4” or 8” thickness. Since the actual SOG thicknesses for the HEBB building were not exactly 4” or 8” thick, the areas measured in OnScreen required calculations to adjust the areas to accommodate this limitation. The Impact Estimator limits the thickness of footings to be between 7.5” and 19.7” thick. As there are a number of cases where footing thicknesses are not within these limitations, their widths were adjusted accordingly to maintain the same volume of footing. Concrete strength was set to 4000psi and an average % of concrete flyash was assumed. Lastly, the North and South concrete staircases were modelled as footings.		
	1.1 Concrete Slab-on-Grade		
		1.1.1 SOG_5"_Tower	The area of this slab had to be adjusted so that the thickness fit into the 4" thickness specified in the Impact Estimator. The following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Slab Area) x (Actual Slab Thickness))/(4”/12)] = sqrt[(10,695.07 x (5”/12))/(4”/12)] = 115.62 feet
	1.2 Concrete Footing		
		1.2.1 Footing_F1a_Basement	The width of this slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. The measured length was maintained, thicknesses were set at 19” and the widths were increased using the following calculations; = [(Cited Width) x (Cited Thickness)] / (19”/12) = [(2’) x (80”/12)] / (19”/12) = 8.42 feet The height from the bottom of the footing to the top of the footing, at an elevation of 365'3", is taken to be 6'8", as determined from measuring the structural drawings.
		Footing_F1b_Basement / Footing_F2b_Basement	The depth of this deep mass concrete footing was taken to be 1'0".

		1.2.3. Footing_F2a_Basement	The width of this slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. The measured length was maintained, thicknesses were set at 19” and the widths were increased using the following calculations; = [(Cited Width) x (Cited Thickness)] / (19”/12) = [(2.5’) x (80”/12)] / (19”/12) = 10.53 feet The height from the bottom of the footing to the top of the footing, at an elevation of 365'3", is taken to be 6'8", as determined from measuring the structural drawings.
		1.2.11 Footing_FG_Basement	Dimensions of the L-shaped footing determined from having a cross-sectional footing area of 12sf, setting thickness to 6'8", and from this calculating width to be 1.8' (from structural drawing). The width of this slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. The measured length was maintained, thicknesses were set at 19” and the widths were increased using the following calculations; = [(Cited Width) x (Cited Thickness)] / (19”/12) = [(1.8’) x (80”/12)] / (19”/12) = 7.58 feet
		1.2.12 Footing_FH_Basement	Dimensions of the L-shaped footing determined from having a cross-sectional footing area of 10sf, setting thickness to 6'8", and from this calculating width to be 1.5' (from structural drawing). The width of this slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. The measured length was maintained, thicknesses were set at 19” and the widths were increased using the following calculations; = [(Cited Width) x (Cited Thickness)] / (19”/12) = [(1.5’) x (80”/12)] / (19”/12) = 6.32 feet

		1.2.18 Stairs_South/North_Platform	The width of this slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be greater than 7.5”. The measured length was maintained, thickness was set to 7.5” and the width was decreased using the following calculation; = [(Cited Width) x (Cited Thickness)] / (7.5”/12) = [(5.33’) x (6”/12)] / (7.5”/12) = 4.26 feet
		1.2.19 Stairs_South/North_Steps	The thickness of the stairs was estimateded to be 8 inches based on the cross-section structural drawings
2 Walls	The length of the concrete cast-in-place walls needed adjusting to accommodate the wall thickness limitation in the Impact Estimator (8" or 12"). Concrete strength was set to 4000psi and an average % of concrete flyash was assumed. The wall envelopes consisting of plaster are modelled as consisting of Regular Gypsum 1/2" due to the unavailability of plaster as a material in Athena EIE. The vapour barrier is assumed to be Polyethylene 6 mil. For the external walls of the tower, the exterior envelope consists of 4.75" Norman Glazed Brick on 90% of the height of the wall, and 3.75" concrete cladding on 10% of the height of the wall. For the model to be inputted into Athena EIE, it is assumed that the exterior envelope consists of Standard Ontario Brick on 100% of the height of the wall. The glazing on the Norman Brick is modeled as Alkyd Solvent Based Paint in Athena EIE. Doors have an actual size of 36"x7', but are modeled assuming they are of standard size in Athena EIE of 32"x7'. Windows are modeled as standard glazing with fixed aluminum framing, which is the closest estimation to the observed windows. Typical Floor (TypFlr) values for measured wall length, number of windows, window area, and number of doors, were multiplied by 3 for EIE inputs to represent all typical floors (typical floor = 3rd, 4th, and 5th floors).		
	2.1 Cast In Place		
		2.1.1 Wall_Cast-In-Place_W1_Ext_BrickClad_Basement_10"	This wall was increased by a factor in order to fit the 8” thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8”] = (453.73’) * [(10”)/8”] = 567.16 feet
		2.1.2 Wall_Cast-In-Place_W1_Ext_BrickClad_Basement_11.75"	This wall was reduced by a factor in order to fit the 12” thickness limitation of the Impact Estimator. This was done by reducing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/12”] = (29’) * [(11.75”)/12”] = 28.40 feet

		2.1.3 Wall_Cast-In-Place_W1_Int_Basement_10"	This wall was increased by a factor in order to fit the 8" thickness limitation of the Impact Estimator. This was done by increaseing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8"] = (157.75') * [(10")/8"] = 197.19 feet
		2.1.5 Wall_Cast-In-Place_W2_Ext_BrickClad_GrndFlr_10"	This wall was increased by a factor in order to fit the 8" thickness limitation of the Impact Estimator. This was done by increaseing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8"] = (336.67') * [(10")/8"] = 420.84 feet
		2.1.6 Wall_Cast-In-Place_W2_Ext_BrickClad_GrndFlr_11.75"	This wall was reduced by a factor in order to fit the 12" thickness limitation of the Impact Estimator. This was done by reducing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/12"] = (38.13') * [(11.75")/12"] = 37.34 feet
		2.1.8 Wall_Cast-In-Place_W2_Ext_GrndFlr_AdditionalWall	Additional wall section A1, B1 that is modeled as 4' high, 1' thick
		2.1.9 Wall_Cast-In-Place_W2_Int_GrndFlr_10"	This wall was increased by a factor in order to fit the 8" thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8"] = (91.67') * [(10")/8"] = 114.59 feet
		2.1.10 Wall_Cast-In-Place_W2_Int_GrndFlr_6"	This wall was reduced by a factor in order to fit the 8" thickness limitation of the Impact Estimator. This was done by reducing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8"] = (73.22') * [(6")/8"] = 54.92 feet

		2.1.11 Wall_Cast-In-Place_W2_Int_GrndFlr_7.5"	This wall was reduced by a factor in order to fit the 8” thickness limitation of the Impact Estimator. This was done by reducing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8”] = (28.08') * [(7.5”)/8”] = 26.33 feet
		2.1.13 Wall_Cast-In-Place_W3_Ext_BrickClad_TypFlr_10"	This wall was increased by a factor in order to fit the 8” thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8”] = (281.83') * [(10”)/8”] = 352.29 feet Multiply by 3 (typical floor = floors 3,4,5); = 352.39' * 3 = 1056.87 feet
		2.1.14 Wall_Cast-In-Place_W3_Ext_BrickClad_TypFlr_7.5"	This wall was reduced by a factor in order to fit the 8” thickness limitation of the Impact Estimator. This was done by reducing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8”] = (32.92') * [(7.5”)/8”] = 30.86 feet Multiply by 3 (typical floor = floors 3,4,5); = 30.86' * 3 = 92.58 feet

		2.1.16 Wall_Cast-In-Place_W3_Int_TypFlr_10"	This wall was increased by a factor in order to fit the 8" thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8"] = (101.47') * [(10")/8"] = 126.84 feet Multiply by 3 (typical floor = floors 3,4,5); = 126.84' * 3 = 380.52 feet
		2.1.17 Wall_Cast-In-Place_W3_Int_TypFlr_5.75"	This wall was reduced by a factor in order to fit the 8" thickness limitation of the Impact Estimator. This was done by reducing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8"] = (54.26') * [(5.75")/8"] = 39.00 feet Multiply by 3 (typical floor = floors 3,4,5); = 39.00' * 3 = 117.00 feet
		2.1.19 Wall_Cast-In-Place_W4_Ext_BrickClad_SecondFlr_10"	This wall was increased by a factor in order to fit the 8" thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8"] = (280.08') * [(10")/8"] = 350.10 feet
		2.1.20 Wall_Cast-In-Place_W4_Ext_BrickClad_SecondFlr_7.5"	This wall was reduced by a factor in order to fit the 8" thickness limitation of the Impact Estimator. This was done by reducing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8"] = (194.53') * [(7.5")/8"] = 182.37 feet

		2.1.22 Wall_Cast-In-Place_W4_Int_SecondFlr_10"	This wall was increased by a factor in order to fit the 8” thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8”] = (101.08') * [(10”)/8”] = 126.35 feet
		2.1.24 Wall_Cast-In-Place_W5_Ext_BrickClad_Penthouse_7.5"	This wall was reduced by a factor in order to fit the 8” thickness limitation of the Impact Estimator. This was done by reducing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8”] = (33.17') * [(7.5”)/8”] = 31.10 feet
3 Columns and Beams	The method used to measure column sizing was completely depended upon the metrics built into the Impact Estimator. That is, the Impact Estimator calculates the sizing of beams and columns based on the following inputs; number of beams, number of columns, floor to floor height, bay size, supported span and live load. As stated on the structural drawings, the live loads for floors are as follows: labs, classrooms, and theatre have specified live loads of 60psf; corridors, entrances, and stairs have specified live loads of 100psf. An average of these values of 75psf is used for EIE Inputs.		
	3.1 Concrete Columns & Beams		
		3.1.1 Column_Beam_Concrete_Basement	It is modeled as if there are columns located along the load bearing wall along line B in the same fashion as the columns along line A (refer to structural drawings), even though they are not shown on the structural drawings. Since the bay size is limited to a maximum of 40 feet in the Impact Estimator, 40 feet is used as the approximate bay size, whereas the actual bay size is 41.5 feet.
		3.1.2 Column_Beam_Concrete_GrndFlr	It is modeled as if there are columns located along the load bearing wall along line B in the same fashion as the columns along line A (refer to structural drawings), even though they are not shown on the structural drawings. Since the bay size is limited to a maximum of 40 feet in the Impact Estimator, 40 feet is used as the approximate bay size, whereas the actual bay size is 41.5 feet.
		3.1.3 Column_Beam_Concrete_SecondFlr	It is modeled as if there are columns located along the load bearing wall along line B in the same fashion as the columns along line A (refer to structural drawings), even though they are not shown on the structural drawings. Since the bay size is limited to a maximum of 40 feet in the Impact Estimator, 40 feet is used as the approximate bay size, whereas the actual bay size is 41.5 feet.

		3.1.4 Column_Beam_Concrete_TypFlr	It is modeled as if there are columns located along the load bearing wall along line B in the same fashion as the columns along line A (refer to structural drawings), even though they are not shown on the structural drawings. Since the bay size is limited to a maximum of 40 feet in the Impact Estimator, 40 feet is used as the approximate bay size, whereas the actual bay size is 41.5 feet. Typical Floor (TypFlr) values for number of columns and beams, were multiplied by 3 for EIE inputs to represent all typical floors (typical floor = 3rd, 4th, and 5th floors).
4 Floors	The Impact Estimator calculated the thickness of the material based on floor width, span, concrete strength, concrete flyash content and live load. Concrete strength was set to 4000psi and an average % of concrete flyash was assumed. As stated on the structural drawings, the live loads for floors are as follows: labs, classrooms, and theatre have specified live loads of 60psf; corridors, entrances, and stairs have specified live loads of 100psf. An average of these values of 75psf is used for EIE Inputs. Typical Floor (TypFlr) value for floor width was multiplied by 3 for EIE input to represent all typical floors (typical floor = 3rd, 4th, and 5th floors). All stated about roof envelope from architectural drawings is that it is comprised of 1" rigid insulation. For EIE Model, it is assumed to have a 4-Ply Built-up Asphalt Roof System - Inverted with Extruded Polystyrene, Glass Felt envelope material. Vapour barrier assumed to be polyethylene 6mil.		
5 Roof	The live load was assumed to be 45 psf instead of the specified 27 psf and the concrete strength was set to 4,000psi with average flyash content. All stated about roof envelope from architectural drawings is that it is comprised of 1" rigid insulation. For EIE Model, it is assumed to have a 4-Ply Built-up Asphalt Roof System - Inverted with Extruded Polystyrene, Glass Felt envelope material. Vapour barrier assumed to be polyethylene 6mil.		

IE Input Assumptions Document - HEBB Theatre

Assembly Group	Assembly Type	Assembly Name	Specific Assumptions
1 Foundation	The Impact Estimator, SOG inputs are limited to being either a 4” or 8” thickness. Since the actual SOG thicknesses for the HEBB theatre were not exactly 4” or 8” thick, the areas measured in OnScreen required calculations to adjust the areas to accommodate this limitation. The Impact Estimator limits the thickness of footings to be between 7.5” and 19.7” thick. As there are a number of cases where footing thicknesses are not within these limitations, their widths were adjusted accordingly to maintain the same volume of footing. Concrete strength was set to 4000psi and an average % of concrete flyash was assumed. Lastly, the concrete stairs were modelled as footings.		
	1.1 Concrete Slab-on-Grade		
		1.1.1 SOG_5"_Lobby	The area of this slab had to be adjusted so that the thickness fit into the 8" thickness specified in the Impact Estimator. The following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Slab Area) x (Actual Slab Thickness))/(4”/12)] = sqrt[(5,653.31 x (5”/12))/(4”/12)] = 84.06 feet
	1.2 Concrete Footing		
		1.2.1 Footing_L01&02_Lobby	The width of this slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. The measured length was maintain, thicknesses were set at 19” and the widths were increased using the following calculations; = [(Cited Width) x (Cited Thickness)] / (19”/12) = [(2’) x (24.5”/12)] / (19”/12) = 2.58 feet

		1.2.4 Footing_L04_Lobby	The width of this slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. The measured length was maintain, thicknesses were set at 19” and the widths were increased using the following calculations; = [(Cited Width) x (Cited Thickness)] / (19”/12) = [(2’) x (60”/12)] / (19”/12) = 6.32 feet
		1.2.9 Footing_L12_Lobby	The width of this slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be greater than 7.5”. The measured length was maintain, thicknesses were set at 7.5” and the widths were decreased using the following calculations; = [(Cited Width) x (Cited Thickness)] / (7.5”/12) = [(7.83’) x (6”/12)] / (7.5”/12) = 6.26 feet
		1.2.14 Stairs_Theatre	The thickness of the stairs was estimateded to be 24 inches based on the cross-section architectural drawings. The width of this slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. The measured length was maintain, thicknesses were set at 19” and the widths were increased using the following calculations; = [(Cited Width) x (Cited Thickness)] / (19”/12) = [(65.5’) x (24”/12)] / (19”/12) = 82.74 feet
2 Walls	The length of the concrete cast-in-place walls needed adjusting to accommodate the wall thickness limitation in the Impact Estimator (8" or 12"). Concrete strength was set to 4000psi and an average % of concrete flyash was assumed. The wall envelopes consisting of plaster are modelled as consisting of Regular Gypsum 1/2" due to the unavailability of plaster as a material in Athena EIE. The vapour barrier is assumed to be Polyethylene 6 mil. For the external wall of the theatre, the exterior envelope consists of 4.75" Norman Glazed Brick on 90% of the height of the wall, and 3.75" concrete cladding on 10% of the height of the wall. For the model to be inputted into Athena EIE, it is assumed that the exterior envelope consists of Standard Ontario Brick on 100% of the height of the wall. The glazing on the Norman Brick is modeled as Alkyd Solvent Based Paint in Athena EIE. Doors are modeled as steel exterior doors, which is the closest estimation to the observed doors. The number and location of doors are as determined from site exploration. Wall heights for the lobby determined from dimensioning of structural drawings and given elevations.		
	2.1 Cast In Place		

		2.1.6 Wall_Cast-In-Place_L05_Lobby_1'8"	This wall was increased by a factor in order to fit the 12” thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/12”] = (4.75’) * [(20”)/12”] = 7.92 feet
		2.1.7 Wall_Cast-In-Place_L06_Lobby_1'8"	This wall was increased by a factor in order to fit the 12” thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/12”] = (6.58’) * [(20”)/12”] = 11.00 feet
		2.1.9 Wall_Cast-In-Place_L08_Lobby_6"	The height of this wall varies along its length; therefore, the average height of 12' is used. This wall was reduced by a factor in order to fit the 8” thickness limitation of the Impact Estimator. This was done by reducing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8”] = (24.81') * [(6”)/8”] = 18.61 feet
		2.1.10 Wall_Cast-In-Place_L09-10_Lobby_8"	The height of this wall varies along its length; therefore, the average height of 12' is used.
		2.1.11 Wall_Cast-In-Place_L11_Lobby_10"	The height of this wall varies along its length; therefore, the average height of 12' is used. This wall was increased by a factor in order to fit the 8” thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8”] = (42.32') * [(10”)/8”] = 52.90 feet

		2.1.14 Wall_Cast-In-Place_L13_Lobby_10"	This wall was increased by a factor in order to fit the 8" thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8"] = (27.50') * [(10")/8"] = 34.38 feet
		2.1.15 Wall_Cast-In-Place_L14_Lobby_11.75"	This wall was reduced by a factor in order to fit the 12" thickness limitation of the Impact Estimator. This was done by reducing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/12"] = (89.57) * [(11.75")/12"] = 87.70 feet
		2.1.16 Wall_Cast-In-Place_W6_Ext_BrickClad_Theatre_8"	An average floor to floor height of 26' was used throughout theatre, as determined from architectural drawings; = (19'+32.5'+36'+33'+30'+26'+21'+15'+19.5')/9 = 26'
		2.1.17 Wall_Cast-In-Place_W6_Int_Theatre_6"	An average floor to floor height of 26' was used throughout theatre, as determined from architectural drawings; = (19'+32.5'+36'+33'+30'+26'+21'+15'+19.5')/9 = 26' This wall was increased by a factor in order to fit the 8" thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/8"] = (51.75') * [(6")/8"] = 38.81 feet
		2.1.18 Wall_Cast-In-Place_W6_Int_Theatre_8"	An average floor to floor height of 26' was used throughout theatre, as determined from architectural drawings; = (19'+32.5'+36'+33'+30'+26'+21'+15'+19.5')/9 = 26'
3 Columns and Beams	The method used to measure column sizing was completely depended upon the metrics built into the Impact Estimator. That is, the Impact Estimator calculates the sizing of beams and columns based on the following inputs; number of beams, number of columns, floor to floor height, bay size, supported span and live load. As stated on the structural drawings, the live loads for floors are as follows: labs, classrooms, and theatre have specified live loads of 60psf; corridors, entrances, and stairs have specified live loads of 100psf. An average of these values of 75psf is used for EIE Inputs.		
	3.1 Concrete Columns & Beams		

		3.1.1 Column_Beam_Concrete_Lobby	An average floor to floor height of 10.5' was used throughout lobby, as determined from architectural drawings; = (8.5+9.5+7+9+12+17)/6 = 10.5'
		3.1.2 Column_Beam_Concrete_Theatre	An average floor to floor height of 26' was used throughout theatre, as determined from architectural drawings; = (19'+32.5'+36'+33'+30'+26'+21'+15'+19.5')/9 = 26'
4 Floors	The Impact Estimator calculated the thickness of the material based on floor width, span, concrete strength, concrete flyash content and live load. Concrete strength was set to 4000psi and an average % of concrete flyash was assumed. As stated on the structural drawings, the live loads for floors are as follows: labs, classrooms, and theatre have specified live loads of 60psf; corridors, entrances, and stairs have specified live loads of 100psf. An average of these values of 75psf is used for EIE Inputs.		
5 Roof	The live load was assumed to be 45 psf instead of the specified 27 psf and the concrete strength was set to 4,000psi with average flyash content. All stated about roof envelope from architectural drawings is that it is comprised of 1" rigid insulation. For EIE Model, it is assumed to have a 4-Ply Built-up Asphalt Roof System - Inverted with Extruded Polystyrene, Glass Felt envelope material. Vapour barrier assumed to be polyethylene 6mil.		
6 Extra Basic Materials	Glazing in lobby in East Elevation of Theatre added separately instead of removed from wall assembly.		