Life Cycle Assessment of Chemistry Building South wing

Wendi Zhang

University of British Columbia

CIVL 498C

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PROVISIO

This study has been completed by undergraduate students as part of their coursework at the University of British Columbia (UBC) and is also a contribution to a larger effort – the UBC LCA Project – which aims to support the development of the field of life cycle assessment (LCA).

The information and findings contained in this report have not been through a full critical review and should be considered preliminary.

If further information is required, please contact the course instructor Rob Sianchuk at rob.sianchuk@gmail.com

UNIVERSITY OF BRITISH COLUMBIA

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Executive Summary

This report is the Life Cycle Assessment associated focus on the building's materials in production stage and construction stage for Chemistry building South wing in The University of British Columbia. The Chemistry building South wing located in 2036 Main Mall, Vancouver, British Columbia, Canada, designed and built in 1958 to 63, cost around $1,659,665.

All of the data collected was taken from structural and architectural drawings. Data adjustments and development are done by using programs called On-Screen Takeoff Pro and Athena Impact Estimator 4.2. Athena LCA database and US LCI database used as the Data Source. TRACI by US EPA used to calculate the midpoint impact to endpoint impact. Estimating Models were sorted following CIQS format into level 3 elements.

The outcome of study shows among all environmental impacts, Fossil Fuel Consumption is the hotspot in production stage and construction stage. A22 Upper Floor Construction and A32 Roof construction elements are consume the most fossil fuel.

Compared with the benchmark of UBC building, the emissions in production stage and construction stage of Chemistry building South wing are also higher than the average, which means there could be more environmental friendly material could be used as alternative option.

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1.0 General Information on the Assessment

Purpose of the assessment

This (Life cycle assessment) LCA study will be used to evaluate the environmental impacts of the Chemistry building South wing at the University of British Columbia. This LCA of the Chemistry building South wing 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 Chemistry building South wing base on the former report. However, because the missing of last LCA report about this building, this report is trying to recover the information as well as create a better draft of Chemistry building South wing's modeling process and sorting the components' category base on CIQS format. The report itself is an educational asset to help disseminate education on LCA and help further the development of this scientific method into sustainability in building construction practices at UBC.

The intended audience of this LCA study are those involved in building development related policy making at UBC. 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.

Identification of building

The Chemistry center building is located in the intersection of Main Mall and University Boulevard, the heart of the campus, as a major heritage landmark. The style of the building could refer back to England in the late 15th century, Collegiate Gothic style. The project was start at 1914 and completed in 1923. Construction ceased in 1915 because of The Great War. The building has a reinforced concrete skeleton with exterior cladding of BC Granite (with a small quantity of field stone). At first, the chemistry building was served as the Science Building, housing Chemistry, Physics, Bacteriology and Public Health. After 1949 it became the Chemistry Building. By now the building was Chemistry alone.

The chemistry building south wing is the additional building added to chemistry center building. The project was built in 1958 to 1963 and referring as B-Block. The total cost for this project is $1,659,665.[1]The main function for this building are using as labs, chemical reagent storage rooms and teaching classrooms for undergraduate

Other Assessment Information

Client for Assessment	**Completed as coursework in Civil Engineering technical elective course at the University of British Columbia.**
Name and qualification of the assessor	Wendi Zhang (MEng Student, 2013)； Rob Greczk (2010)
Impact Assessment method	Athena Impact Estimator for Buildings, Version 4.2.0208；On-Screen Takeoff Pro
Point of Assessment	55 years
Period of Validity	5 years.
Date of Assessment	Completed in December 2013.
Verifier	Student work, study not verified.

Table 1. Assessment Information of Chemistry building South wing

2.0 General Information on the Object of Assessment

Functional Equivalent

Analysis based on a predefined quantity of product or service called the functional unit. As most LCAs are comparative in nature, the functional unit provides a logical basis for comparing the environmental performance of alternatives. For this study, we use Per square meter area constructed as the functional units

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[1] Thompson, Berwick, Pratt & Partners, UBC Reports April 2008

Aspect of Object of Assessment	Description
Building Type	Institutional - Post Secondary
Technical and functional requirements	Office, research, and lecture space for the Department of Chemistry
Pattern of use	Current Building Hours: Monday-Friday 07:00-19:00, Saturday/Sunday/Holidays – Closed Classrooms, Labs, large lecture halls.
Required service life	Assumed to be 100 years

Table 2. Functional Equivalent Definition Summary

Reference Study Period

According to EN 15798, it defines the Life Cycle of products into 4 Stages: Product (A), Construction Process (A), USE (B) and End of life (C).Module D, benefit and load beyond the boundary, is supplement information beyond life cycle.

As this study is a cradle-to-gate assessment, the expected service life of the Chemistry building South wing 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. Also, this study is mainly focus on the first stage of building. What are the environmental impacts of the construction activates of Chemistry building South wing. That's why we do not consider the Modules B C and D.

Object of Assessment Scope

The basement of Chemistry building South wing is mainly use as lecture hall and chemical reagent storage rooms, floor 1 to 3 are mainly use as labs. The facade's material is concrete with brick cladding. Because we only include module A, the majority actives in this stage is related to construction process and activates, we only addressing the structure and envelope of Chemistry building South wing.

CIVL 498C Level 3 Elements		Description	Quantity (Amount)	Units
A11	Foundations	Strip and Pad Footings	1216.8435	m^2

A21	Lowest Floor Construction	Slab on grade on lowest floor	1216.8435	m^2
A22	Upper Floor Construction	Columns, beams, suspended slab floors, stairs	2634.6362	m^2
A23	Roof Construction	Supporting Columns and beams, roof slab	1201.7932	m^2
A31	Walls Below Grade	Exterior below grade walls	736.81369	m^2
A32	Walls Above Grade	Exterior above grade walls	2047.0247	m^2
B11	Partitions	All interior walls	1160.9159	m^2

Table 3. Building Definition Summary

3.0 Statement of Boundaries and Scenarios Used in the Assessment

System Boundary

The selection of the system boundary shall be consistent with the goal of the study. For this study for Chemistry building South wing, we are only modeling processes until construction product. Any processes beyond and after our system boundary, like site preparation, is not part of this study.

EN 15798 suggests four modules in building life cycle: Product (A), Construction Process (A), USE (B), End of life (C) and benefit and load beyond the boundary (D), which is supplement information beyond life cycle. Figure 1.

For building life cycle and its' sub stages, they both have their own upstream and downstream. Upstream is towards energy and resource extraction and downstream is towards use and waste handling. For building life cycle, module A is upstream and modules B, C are downstream. Each module also has its upstream and downstream, like for production stage, the upstream is: raw material supply, and downstream is manufacturing. For Construction Process stage, the upstream is transport and the downstream are construction insulation process.

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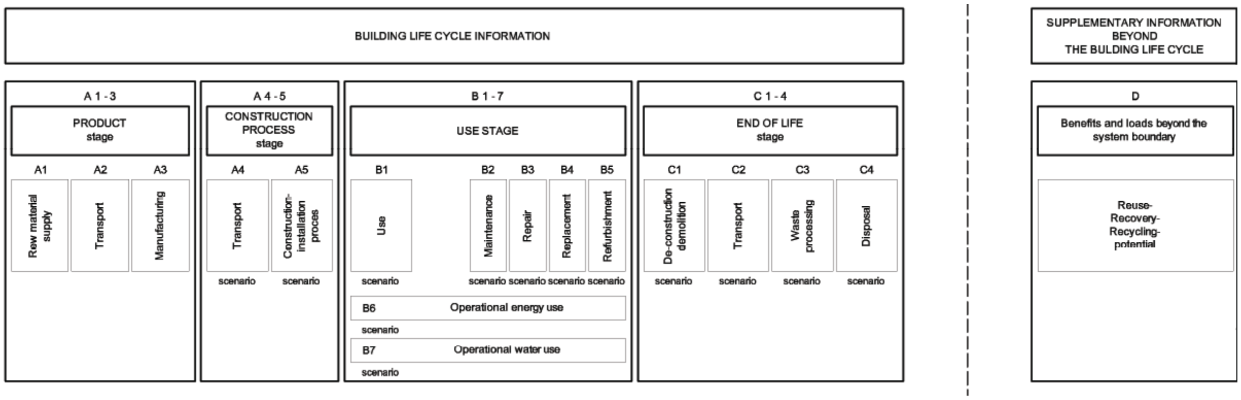

Figure 1. Modular information for the different stages of the building assessment

Product Stage

The product stage contains three sub processes: raw material supply, transport and manufacturing modules.

The energy use in raw material supply include all the actives in order to extract the raw resources, like timber, iron ore, coal, limestone, aggregates and gypsum. The development of life cycle inventory data starts here, by tracking energy use and emissions to air, water and land per unit of resource. In addition to the actual harvesting, mining or quarrying of a resource, data from the extraction phase includes activities such as reforestation and beneficiation (a mining technique that involves separating ore into valuable product and waste). [2]

The transportation of raw resources to the mill or plant defines the boundary between extraction and manufacturing. It is important to understand that LCA does not attempt to address all land-impact measures, many of which are tracked in other environmental metrics or regulatory programs.

Manufacturing is the stage that typically accounts for the largest proportion of embodied energy and emissions associated with the life cycle of a building product. In Athena inventory studies; this stage starts with the delivery of raw resources and other materials to the mill or plant gate and ends with the finished product ready for shipment. The Impact Estimator software combines

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[2] http://www.athenasmi.org/resources/about-lca/technical-details/

resource extraction and manufacturing into a single activity stage for results reporting purposes. The Athena Institute follows international guidelines for product LCAs addressing secondary components and assemblies, data sources and verification, system boundaries, the level of detail expected in inventory studies and a variety of other standard conventions and assumptions, to ensure that all building materials are treated impartially, in a comparable fashion. Athena product LCAs are performed in conjunction with experts in the relevant industries.

Construction Stage

The construction stage is like an additional manufacturing step where individual products, components and sub-assemblies come together in the manufacture of the building.

The transportation in construction stage is considering the transport distance from material/component manufacture place to construction site. The location will determine the electricity and transportation grids that are used in the LCA calcs. For some materials, the transportation doesn't vary that much from location to location, concrete for example, (everywhere has concrete production nearby). But something like large dimension lumber, the only place that produces it is the Pacific Northwest US and British Columbia, so the transportation can make a difference if you're in Vancouver or Atlanta.3

The construction installation module also takes account of the energy used to construct the structural elements of the building and the emissions to air, water and land associated with the on-site construction activity, like storage of products, Installation of the product into the building and Waste management processes on the construction site and waste handling until final disposal.

4.0 Environmental Data

Data Sources

This study used of the Athena LCI Database for material process data, and the US LCI Database for energy combustion and pre-combustion processes for electricity generation and transportation.

The Athena LCI Database developed by The Athena Institute. For the most part of the data, Athena Institute developed our own data in cooperation with industry associations, and that data

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[3] http://calculatelca.com/faqs/

is proprietary to them. Athena Institute develops our data in-house, under contract to trade associations, with the cooperation of several manufacturers and plants across the continent. This way, they arrive at a good cross-sectional industry average formulation and environmental profile for each material. The manufacturing effects of that average formulation are then regionalized for each location by applying local electricity, energy and transportation grids. The Athena Institute is an organization offer building life cycle assessment and they developed Athena Impact Estimator. These tools are industry recognized and respected systems based on a set of comprehensive, comparable databases on a wide variety of building materials, calculating energy use and related emissions to air, water and land over the life cycle of the building.

U.S LCI Database is managed by the National Renewable Energy Laboratory (NREL)

The U.S. Life Cycle Inventory Database will be the recognized source of U.S.-based, quality, transparent life cycle inventory data. The U.S. LCI Database (www.nrel.gov/lci) was initiated in 2003 to fulfill the need for publicly available LCI data. Recent meetings of interested parties have called for an increased effort to advance the database. This meeting was hold A on February 18, 2009, in Washington, D.C.

Data Adjustments and Substitutions

Inconsistence between the IE inputs and the Athena IE exist. Limitations are set in the Athena tool because of building codes or specifications. For certain parameters, only the number fit in the set range is acceptable, like the thickness of footings has to be between 7.5” to 19.7”. With real thickness built is 30”. Therefore the total volume of footings is set while changing the input value of length and width.

Typos’ errors are also found in the IE input excel. Such as the value in IE input excel doesn’t match the value inputted in Athena IE. All the elements have been went through and checked with Athena tool to correct any errors.

For the Athena limitation, there are also probabilities that we have to replace some material which is not available in Athena. During the production stage, there will be waste in the process, the percentage of the waste/total material is called waste factor. In Athena, it automatically adds this factor into the input value, say, 100 tone of concrete 20 MPa (flyash av). When we go to Bill of material reports, it shows 105 tone of concrete 20 MPa (flyash av). This difference is due to the waste factor. When old data need to be replaced, it is necessary to know the value from Bill of material is a little bit larger than the value of new data input.

Data Quality

Describe the following 5 types of uncertainty, data, model, temporal, spatial and variability between sources.

The data used in this LCA study include the data form material takeoff, life cycle inventory (LCI) flows and the characterization of LCI flows.

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. The measurements generated are formatted into the inputs required for the IE building LCA software to complete the takeoff process. Because Chemistry building South wing was built in 1960', the hand shop drawing couldn't be recognized very clearly. Therefore the inaccurate of material takeoff might exist.

The data used in Athena IE is The Athena LCI Database. The detailed data information is hidden in Athena IE. Assumptions can be accessed through the Athena Institute webpage's Software database overview.[4] However, the data in LCI database also has some limitations, like the construction product, manufacturing and fuel refining/production LCI data is based on North American averages; the transportation distances estimation and modes for construction product transportation as well as construction and demolition wastes is specific to Vancouver, British Columbia; also, the LCI data and modeling parameters in the Impact Estimator were developed by the Athena Institute to reflect current circumstances and technologies.

Characterization factors – Documentation of the US EPA TRACI impact assessment method can be found on the US EPA website3, and documentation for the development of the weighted resource use impact category can be found on the Athena Institute webpage4. Generally speaking, this method characterized LCI flows to reflect their potential to cause damage on average in North America. Qualitative discussion of the uncertainties present in the impact assessment results are contained in this report in the Impact Assessment sub-section of Results and Interpretation

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[4] http://www.athenasmi.org/our-software-data/lca-databases/

5.0 List of Indicators Used for Assessment and Expression of Results

The impact assessment method of the Chemistry building South wing LCA study used two software and two databases. The Athena Impact Estimator developed by the Athena Institute with input and database information/characterization factors from the Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI), developed by the US Environmental Protection Agency (USEPA).5The Athena IE inputs data coming from On-Screen Take off Pro which calculate the material takeoff value.

The Life Cycle Impact Assessment (LCIA) study has two common methods, one is problem-oriented methods (mid points) and the other one is damage-oriented methods (end points)[6] The difference of those two method is the mid points method, flows are classified into environmental themes (impact categories) to which they contribute, while the end points method, it further get into what potential impact it will have. The impact categories selected and the units used to express them (i.e. category indicators) are listed below.

- Global warming potential – kg CO2 equivalents
- Acidification potential – H+ mol equivalents
- Eutrophication potential – kg N equivalents
- Ozone depletion potential – kg CFC-11 equivalents
- Photochemical smog potential – kg NOx equivalents
- Human health respiratory effects potential – kg PM2.5 equivalents
- Fossil fuel consumption – MJ

The general cause/effect chain modeled of impact categories can be described as: emission changes- concentration changes- radiative forcing-climate impacts- societal and ecosystem impacts – economic “damage” See Figure 2 to 6 for each impact categories.

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[5] Attieh, et.al. Life Cycle Assessment of the New SUB Project, 2012

[6] http://www.scienceinthebox.com/en_UK/sustainability/lcia_en.html

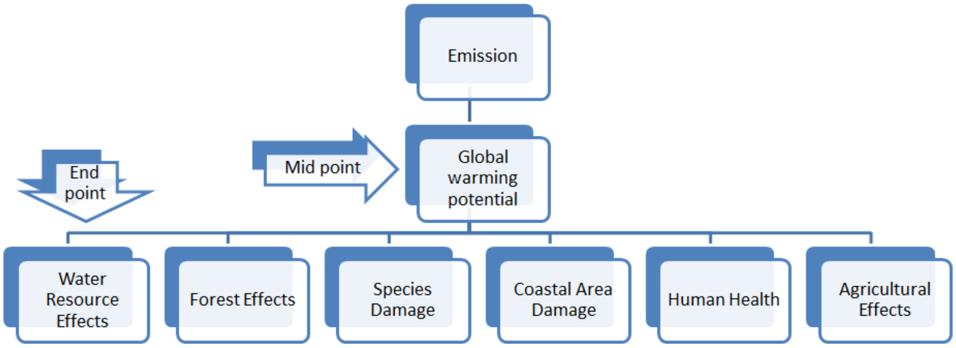

Figure 2. Cause/effect chain for Global Warming Potential

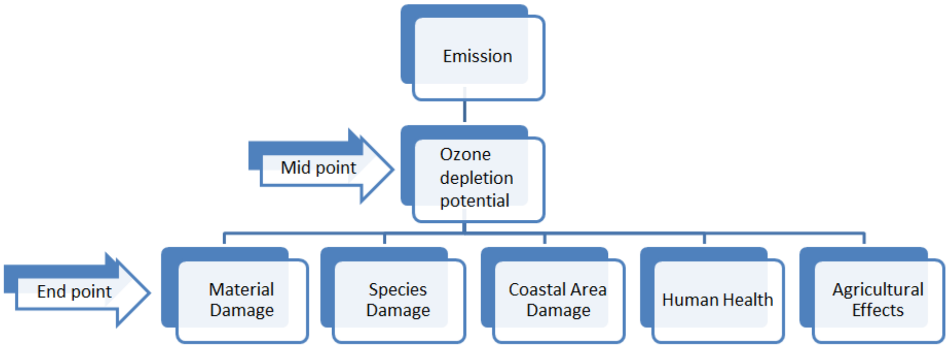

Figure 3. Cause/effect chain for Ozone Depletion Potential

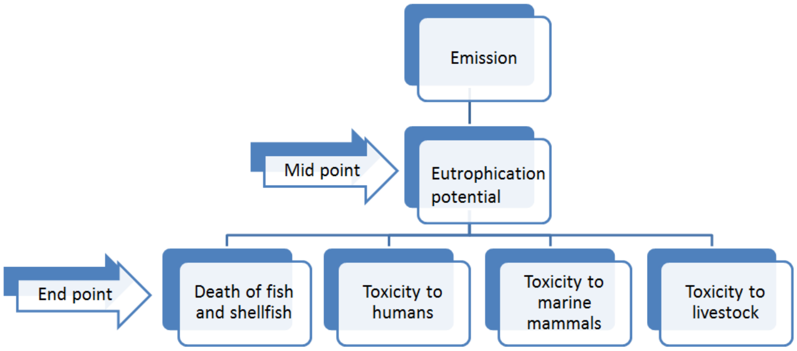

Figure 4. Cause/effect chain for Eutrophication Potential

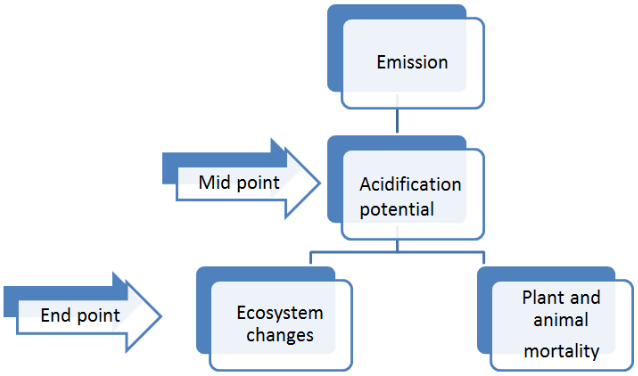

Figure 5. Cause/effect chain for Acidification Potential

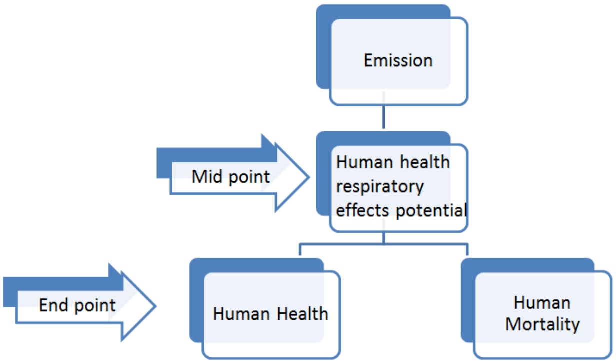

Figure 5. Cause/effect chain for Human health respiratory effects Potential

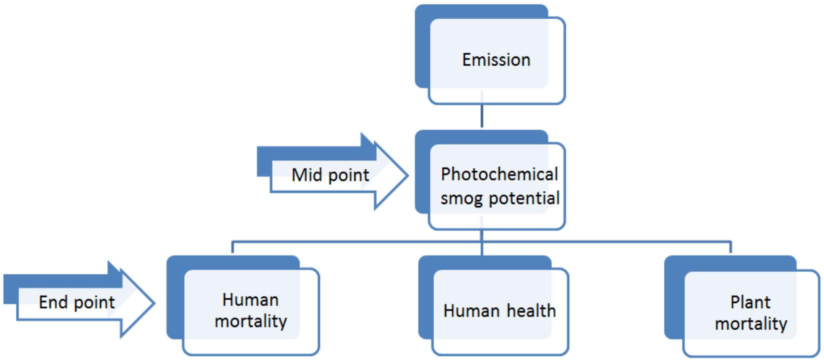

Figure 6. Cause/effect chain for Photochemical smog Potential

6.0 Model Development

In the model development section, two models were developed: On Screen Takeoff Pro model and Athena IE model. In the On Screen Takeoff Pre model, the structural and architectural drawings (scanned and converted to pdf files) were used to identify the building components by using three different types of conditions:

- Linear: Measures the length of a specific component. Example: Wall lengths.
- Area: Calculates the area of a component. Example: Floors or suspended slabs.
- Count: Counts the number of components. Example: Windows, doors.

The measurements generated from On Screen Takeoff Pro 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 Annexe D respectively.

The former IE inputs value and Athena IE model was sorted into a new format, CIQS format, which is Established by Canadian Institute of Quantity Surveyors (CIQS) to standardize a list of elements that enable cost analyses and control on building projects., In this format, the elements ordered hierarchically into four levels to allow different levels of aggregation and summarization as follows:

- Level 1 elements are referred to as ‘Major Group Elements’.
- Level 2 elements are referred to as ‘Group Elements’
- Level 3 elements are referred to as ‘Elements’
- Level 4 elements are referred to as ‘Sub-Elements’

For this Athena IE model, the components were sorted into level 3.

Please see table 3 to see the detail of level 3 classifying building elements:

CIVL 498C Level 3 Elements		Description
A11	Foundations	Wall and column footings
A21	Lowest Floor Construction	Slab on grade on lowest floor
A22	Upper Floor Construction	Columns, beams, suspended slab floors, stairs
A23	Roof Construction	Supporting Columns and beams, roof slab

A31	Walls Below Grade	Exterior below grade walls
A32	Walls Above Grade	Exterior above grade walls
B11	Partitions	All interior walls

Table 3. Level 2 Element sorting content

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.

Development of each level 3 element will be discussed here:

A11 Foundation

The foundation component consists of all wall and column footings. From the last year report, assumptions made for the concrete was 4000 psi with average fly ash. 4000 psi is the equivalent to approximately 30MPa of concrete strength, and this concrete strength value is typical for most concrete structural projects.

The basement drawing in On-Screen-Takeoff pro is out of scale, but the former author counted how many footing it has. Therefor the inaccuracy of scale does not affect the result. One typo mistake of footing- typy12 was modified (width changes from 25 ft. to 3.5 ft.)

Project : A11 Foundation

Material	Quantity	Unit
Concrete 30 MPa (flyash av)	111.7687	m3
Rebar, Rod, Light Sections	1.2021	Tonnes

Table 4 Bill of Material of A11 Foundation

A21 Lowest Floor Construction

The Impact Estimator has constraints with the length components and thicknesses, the total volume of concrete used in the SOG was calculated to compensate for the selected SOG thickness as the Impact Estimator only allows the user to use a specific thickness of concrete; Once the concrete thickness was determined, it was assumed that the area of the SOG was square as the square root was taken of the floor area to accommodate the Impact Estimator.

Because the basement drawing in On-Screen-Takeoff pro is out of scale, it affects the outcome of SOG area value. The inaccuracy is solved in this model. And due to the software updates, the missing value of element also filled.

Project : A21 Lowest Floor Construction

Material	Quantity	Unit
6 mil Polyethylene	1145.4646	m2
Concrete 30 MPa (flyash av)	226.7605	m3
Welded Wire Mesh / Ladder Wire	0.9758	Tonnes

Table 5 Bill of Material of A21 Lowest Floor Construction

A22 Upper Floor Construction

The floors of the building were cast-in-place suspended slabs. Each floor and each area varied in thickness based on the area of the building. Each area was taken off with the thickness of each floor identified with the 'Area Condition' takeoff. The thickness was input based on selecting a specific slab thickness after calculating the total volume of concrete per floor. The total volume of concrete was divided by this selected thickness, and the remaining area was made square because of convenience and/or by the constraints placed in the IE

The walls of stairs in basement floor were not measured in On-screen takeoff. Input data were fixed in Athena. Also, might due to the software update, the value of suspend area for beam element was missing. The area value was used as the total area of suspend area of beams.

Project : A22 Upper Floor Construction

Material	Quantity	Unit
Concrete 30 MPa (flyash av)	1728.173	m3
Concrete Blocks	5012.8845	Blocks
Mortar	95.5313	m3
Rebar, Rod, Light Sections	288.4612	Tonnes

Table 6 Bill of Material of A22 Upper Floor Construction

A23 Roof Construction

The roof was a 5.5" suspended concrete slab with 2" expanded polystyrene insulation. The rest of the specifications were not given in the drawings provided. Therefore, it was assumed that the roof consisted of a 4-ply asphalt system with glass felt, and polyethylene (6mm).

Also, the suspend area for beam element was missing. Values were fixed in this model. The area value was used as the total area of suspend area of beams.

Project : A23 Roof Construction

Material	Quantity	Unit
#15 Organic Felt	2740.1795	m2
6 mil Polyethylene	1274.8628	m2
Ballast (aggregate stone)	25237.6682	kg
Blown Cellulose	5051.3698	m2 (25mm)
Concrete 30 MPa (flyash av)	562.0946	m3
Expanded Polystyrene	2492.9133	m2 (25mm)
Galvanized Sheet	1.432	Tonnes
Nails	0.6932	Tonnes
Rebar, Rod, Light Sections	60.3665	Tonnes
Roofing Asphalt	16170.5291	kg
Type III Glass Felt	5480.3589	m2

Table 6 Bill of Material of A23 Roof Construction

A31 Walls below Grade

From the last year report, the walls were determined using the ‘Linear Condition’ function with average fly ash and 4000 psi concrete strength, where applicable. The basement walls on the north and south of the building were cast-in-place concrete. The building envelope consisted of a 2”x4” stud wall, with 2” batt insulation, polyethylene (3mm assumed), and covered with ¾” plaster walls.

The east and west basement walls were constructed with concrete bricks, 2”x2” wood strapping with 2” batt insulation, polyethylene (3mm assumed), and covered with ¾” plaster walls. The stud spacing was increased to 24” as a 2”x2” stud was not available. The 2”x3” stud was used as a greater spacing would require less material, therefore compensating for not having the proper wood strapping size.

Because the basement plan is out of scale, the value of wall is updated and fixed in Athena.

Project : A31 Walls Below Grade

Material	Quantity	Unit
1/2" Regular Gypsum Board	1761.5748	m2
3 mil Polyethylene	849.3993	m2
Aluminum	0.2061	Tonnes
Cold Rolled Sheet	0.0335	Tonnes
Concrete 30 MPa (flyash av)	133.3256	m3
Concrete Brick	174.1235	m2

Double Glazed No Coating Air	-0.1681	m2
EPDM membrane (black, 60 mil)	14.096	kg
Expanded Polystyrene	7.98	m2 (25mm)
FG Batt R11-15	1653.2924	m2 (25mm)
Galvanized Sheet	0.1879	Tonnes
Glazing Panel	0.096	Tonnes
Joint Compound	1.7581	Tonnes
Mortar	3.2331	m3
Nails	0.2153	Tonnes
Paper Tape	0.0202	Tonnes
Rebar, Rod, Light Sections	4.717	Tonnes
Screws Nuts & Bolts	0.2462	Tonnes
Small Dimension Softwood Lumber, kiln-dried	10.4672	m3
Solvent Based Alkyd Paint	66.7777	L

Table 7 Bill of Material of A31 Walls below Grade

A32 Walls Above Grade

The north wall from Floor 1 to Floor 3 was modeled per floor as a curtain wall. The curtain wall was located in the lab testing area, and it is unknown the type of windows were used. It is assumed that the glass is inoperable, single pane unit and translucent. Each floor was modeled individually, and all of the glass was transparent. The area below the window was assumed to contain 2”x2” wood strapping with 2” batt insulation and polyethylene (3mm assumed). The envelope was then finished with ¾” plaster. Since some of these components were not available in the Impact Estimator, 2”x3” strapping, kiln dried spaced 24” on centre (o/c) was used with 1” of regular gypsum wall covering with alkyd paint. The south, east and west walls from Floor 1 to Floor 3 were modeled using concrete brick on the interior and exterior sandwiching a 2”x2” wood stud wall with 2” batt insulation. The south wall consisted of coloured, translucent windows, inoperable with aluminum frames.

No improvement in this part.

Project : A32 Walls Above Grade

Material	Quantity	Unit
1/2" Regular Gypsum Board	1707.6508	m2
3 mil Polyethylene	1055.1586	m2
Aluminum	10.2279	Tonnes
Cold Rolled Sheet	0.4019	Tonnes
Concrete 30 MPa (flyash av)	79.1018	m3
Concrete Blocks	5012.8845	Blocks
Concrete Brick	2088.8322	m2

Double Glazed No Coating Air	4.2176	m2
EPDM membrane (black, 60 mil)	179.7789	kg
Expanded Polystyrene	622.3364	m2 (25mm)
FG Batt R11-15	1601.2937	m2 (25mm)
Galvanized Sheet	0.2656	Tonnes
Glazing Panel	27.6421	Tonnes
Joint Compound	1.7043	Tonnes
Mortar	134.3161	m3
Nails	0.2185	Tonnes
Paper Tape	0.0196	Tonnes
Rebar, Rod, Light Sections	63.0134	Tonnes
Screws Nuts & Bolts	0.5491	Tonnes
Small Dimension Softwood Lumber, kiln-dried	7.1606	m3
Solvent Based Alkyd Paint	0.3622	L

Table 8 Bill of Material of A32 Walls above Grade

B11 Partitions

All the partitions within the building were modeled solely as concrete block walls with no additional components. The IE also modeled these walls with rebar. The drawings did not specify a rebar size, and unfortunately, had to be modeled with a rebar type. In addition, the current/existing partitions were not shown in the drawings provided. These partitions were modeled based on the information collected from the drawings. This includes the walls in the stairwells also.

For the out of scale of basement, the partition volume is changed, but not much. Inputs were update in Athena IE.

Project : B11 Partitions

Material	Quantity	Unit
Concrete Blocks	10144.3916	Blocks
Galvanized Sheet	0.6191	Tonnes
Mortar	193.5817	m3
Nails	0.0196	Tonnes
Rebar, Rod, Light Sections	29.8644	Tonnes
Solvent Based Alkyd Paint	2.9478	L

Table 9 Bill of Material of B11 Partitions

7.0 Communication of Assessment Results

Life Cycle Results

The developed models from last section were used in this section. By generated the bill of material and summary measure table of each level 3 element, we can further compare their performance. The outcome of total building and each level 3 Elements are list in Table 4 below:

	Fossil Fuel Consumption	Global Warming	Acidification	Human Health Criteria – Respiratory	Eutrophication	Ozone Layer Depletion	Smog
	(MJ)	(kg CO2eq)	(moles of H+eq)	(kg PM10eq)	(kg Neq)	(kg CFC-11eq)	(kg O3eq)
Chemistry South Total	21286190.41	1911906.97	13244.68	5011.45	1224.29	8.26E-03	246539.49
A11 Foundations	236022.41	34201.70	220.72	82.53	10.63	1.91E-04	4789.53
A21 Lowest Floor Construction	476685.01	69428.69	450.99	167.87	19.48	3.87E-04	9695.93
A22 Upper Floor Construction	8590278.61	753267.64	5051.84	1435.72	566.04	3.15E-03	98674.05
A23 Roof Construction	3416545.58	233549.66	1534.84	505.04	139.21	9.66E-04	30189.78
A31 Walls Below Grade	505987.83	55595.60	372.68	125.93	22.89	3.00E-04	6864.37
A32 Walls Above Grade	2905939.70	265323.81	2244.26	1678.17	146.71	1.00E-03	28635.60
B11 Partitions	1017795.27	94900.48	631.16	188.98	61.36	4.16E-04	11199.77

Table 10. Summary of environmental impact of each level 3 element

For the hotspots in life cycle stages, product stage and construction stage were compared, see Figure 7. The Fossil Fuel emission in product stage is the hotspot. Further, in Figure 8, level 3 elements are compared to see with components contribute to greatest part FFC. A22 Upper Floor Construction is significant higher than others.

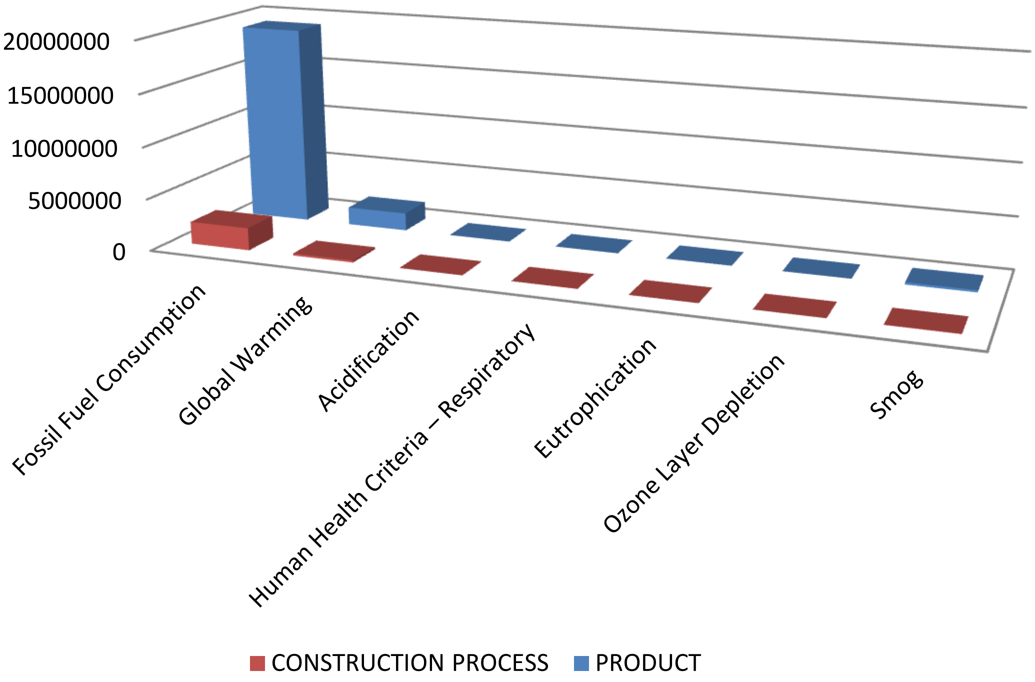

Figure 7. Environmental Impacts Comparison in product and construction stage

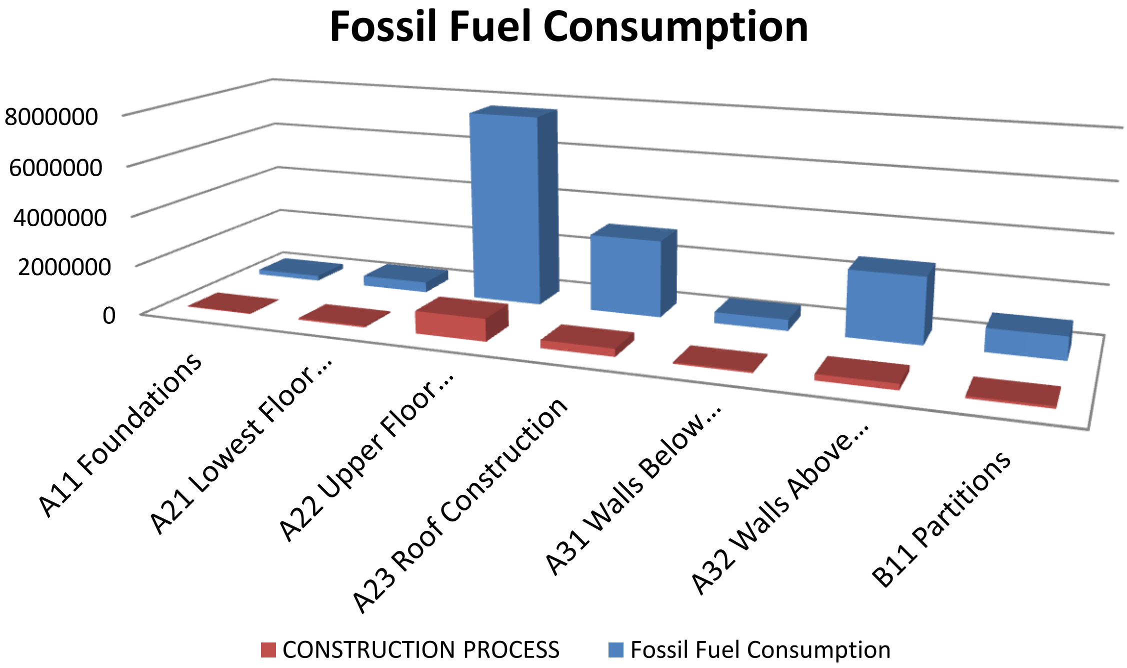

Figure 8. Fossil Fuel Consumption Comparison in product and construction stage for level 3 elements

From the Figure9 to 15, A22 Upper Floor Construction is the hotspots for most impact categories, except in “Human Health Criteria – Respiratory”, which the A32 Wall above Grade is hotspot. Chemistry building South wing was built in 1958, the main material is concrete which contribute to majority of Global Warming Potential (GWP), Fossil Fuel Consumption (FFC) and other environmental impact, For all suspended slabs (floor 1, 2, 3) are sorting under A22 Upper Floor Construction, the volume of total concrete in A22 is higher than others. From the pie chart, we can also see the A32 Roof construction and A32 Wall above Grade also has a large impact on environment.

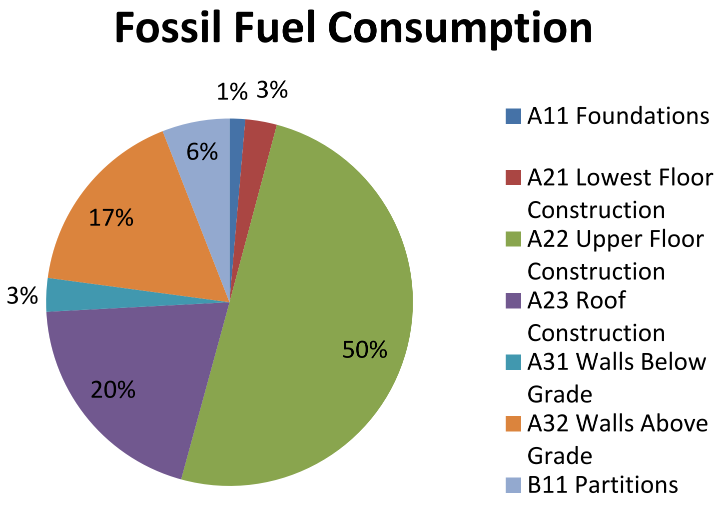

Figure 9. Percentage of Fossil Fuel Consumption for level 3 elements

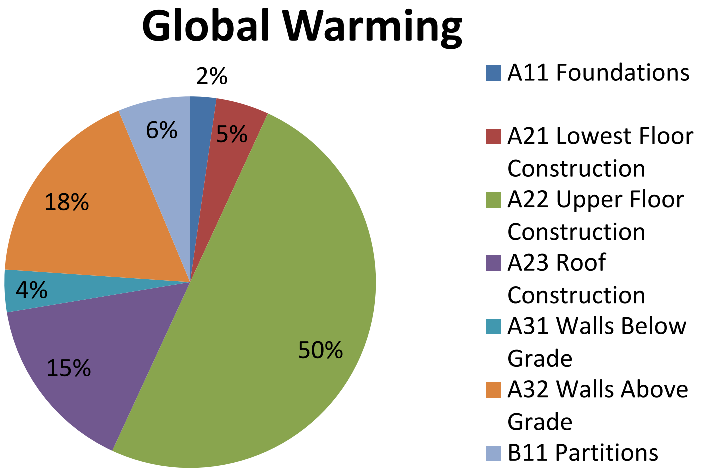

Figure 10. Percentage of Global Warming Potential for level 3 elements

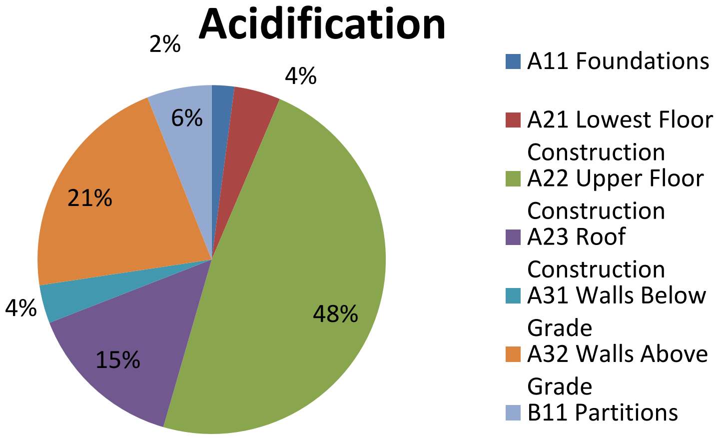

Figure 11. Percentage of Acidification Potential for level 3 elements

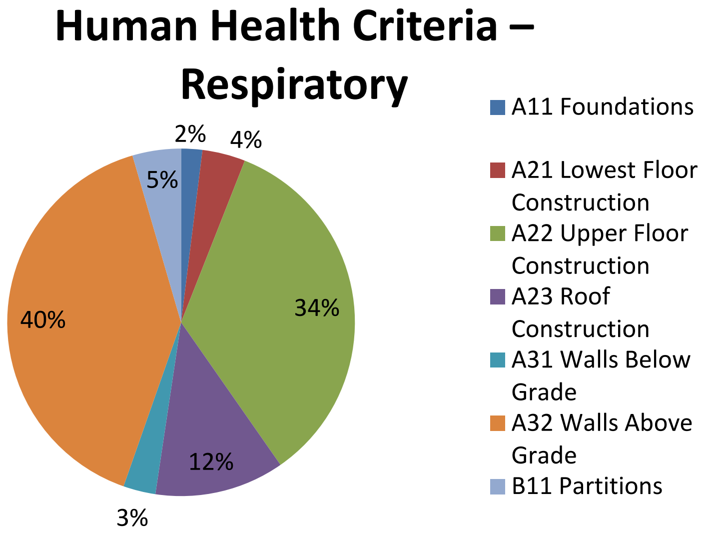

Figure 12. Percentage of Human health respiratory effects Potential for level 3 elements

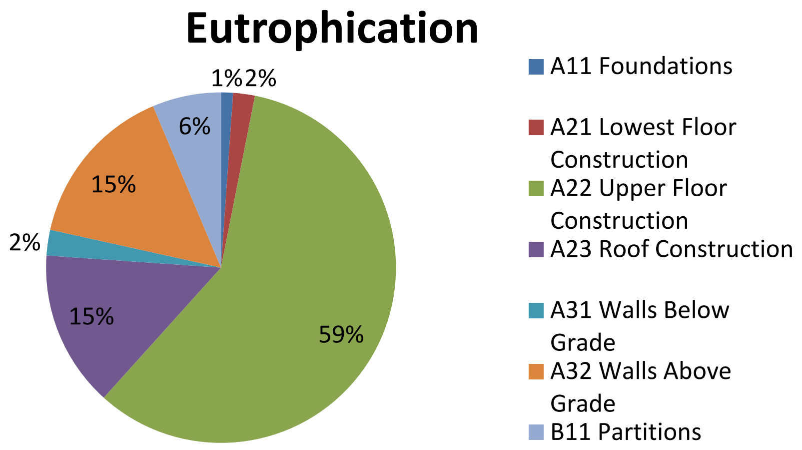

Figure 13. Percentage of Eutrophication Potential for level 3 elements

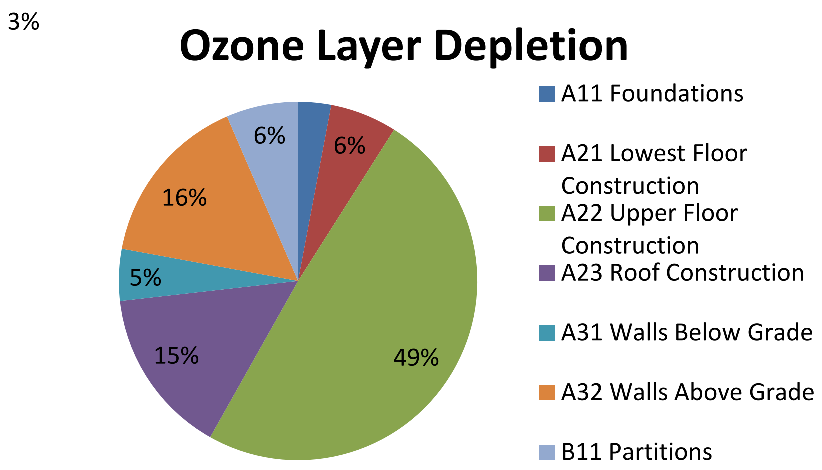

Figure 14. Percentage Ozone Depletion Potential for level 3 elements

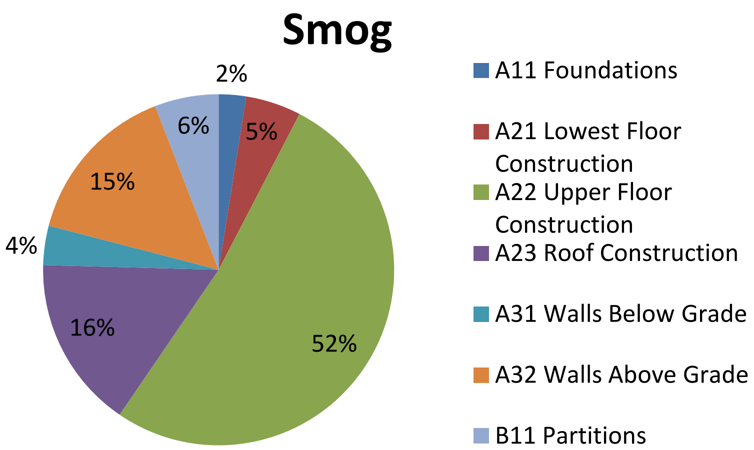

Figure 15. Percentage Photochemical smog Potential for level 3 elements

Further, we compared impact categories in the three weighted elements, to see which one is most sensitive. From last discussion, A32 Wall above Grade contribute most to “Human Health Criteria – Respiratory”, however, in this part, we can see FFC is still the main emission for building components. See Figure 16 to 18

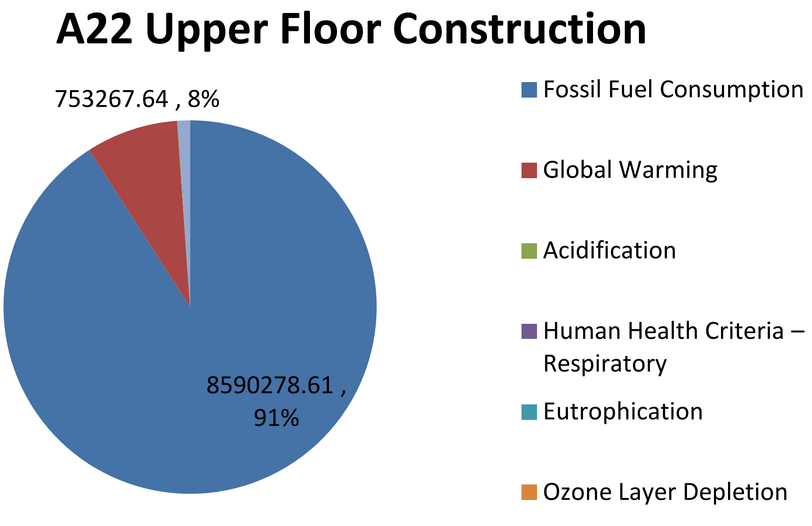

Figure 16. Environmental Impacts of A22 Upper Floor Construction

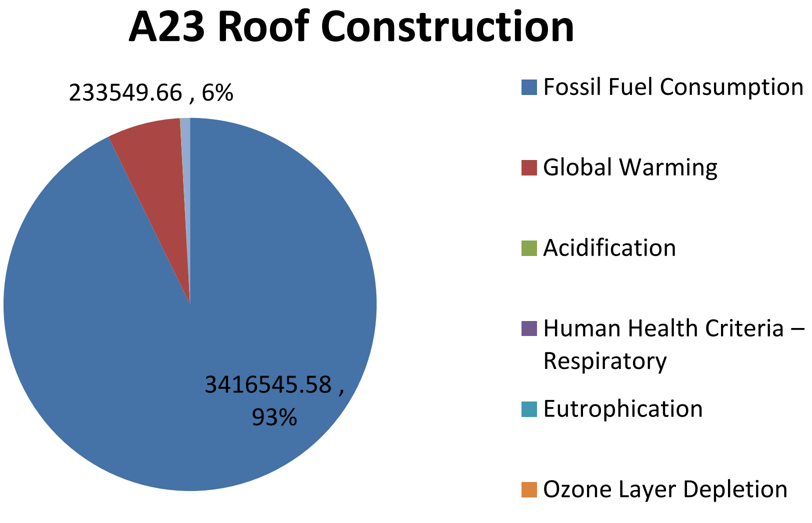

Figure 17. Environmental Impacts of A23 Roof Construction

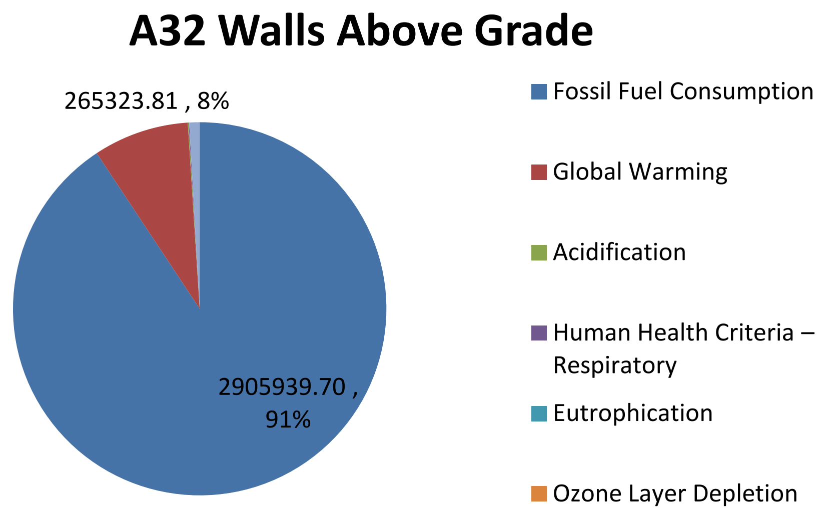

Figure 18. Environmental Impacts of A32 Wall above Grade.

Annex A - Interpretation of Assessment Results

Benchmark Development

The concept of LCA Benchmarking is trying to measure building impact category using a specific indicator. This indicator here is the emission value per sq. m^2. Only by address this common goal & scope, different building could be compared.

UBC Academic Building Benchmark

From the Figure 19, we can see the Chemistry building South wing has a little higher amount of energy consumption comparing with the UBC academic building benchmark. It means compared with other building in UBC, Chemistry building South wing has more potential to improve its environmental performance. The probably reason might be due to the majority material used in building structure, Concrete, has a larger environmental impacts than other materials. Also, the material used in roof construction might have big environmental impacts.

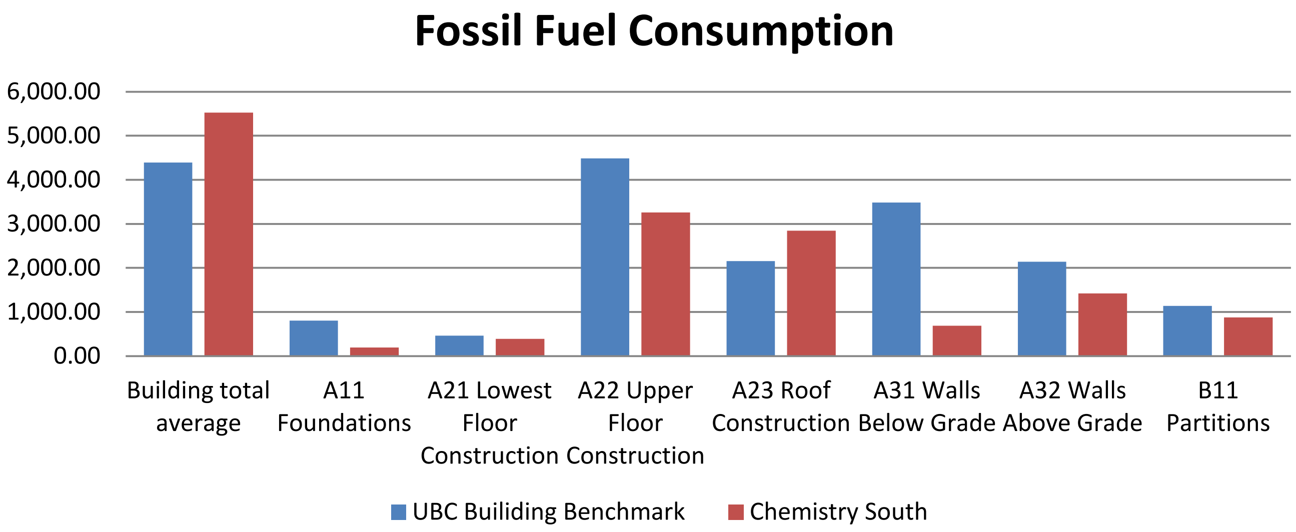

Figure 19. Fossil Fuel Consumption Comparison between Benchmark and Chemistry building South wing

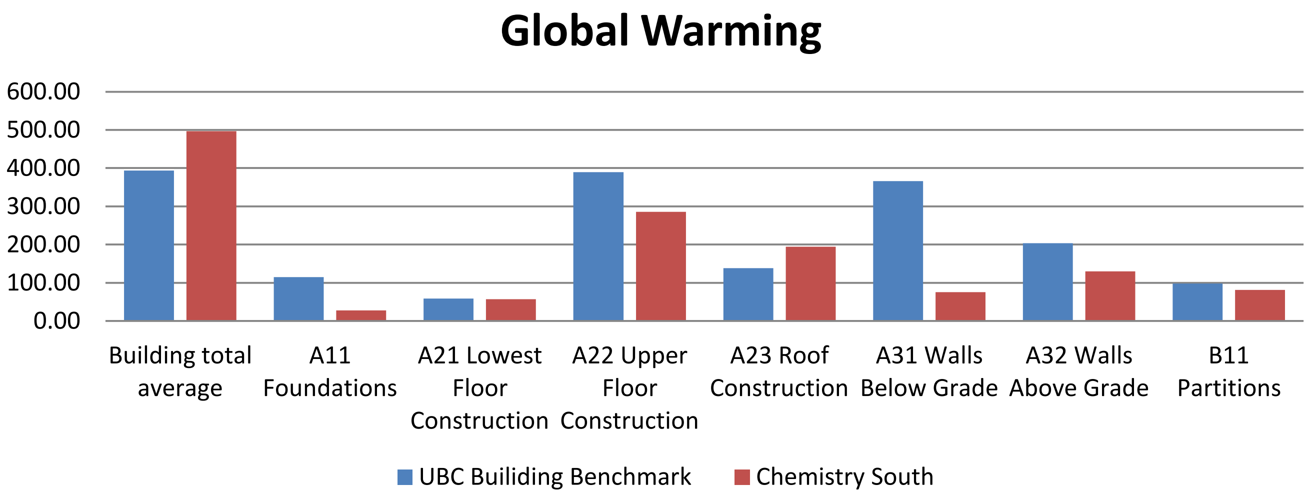

Figure 20. Global Warming Potential Comparison between Benchmark and Chemistry building South wing

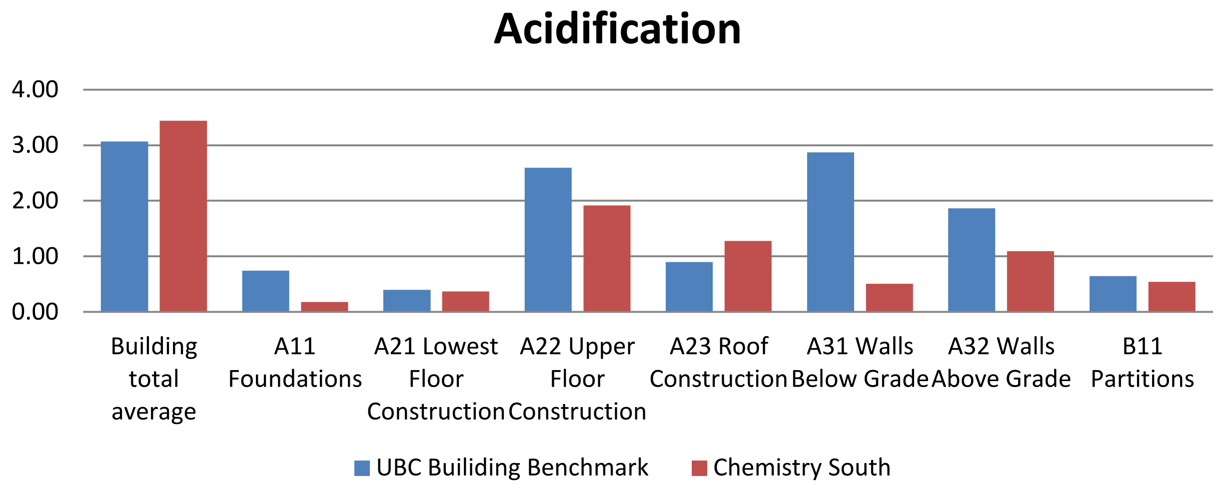

Figure 21. Acidification Potential Comparison between Benchmark and Chemistry building South wing

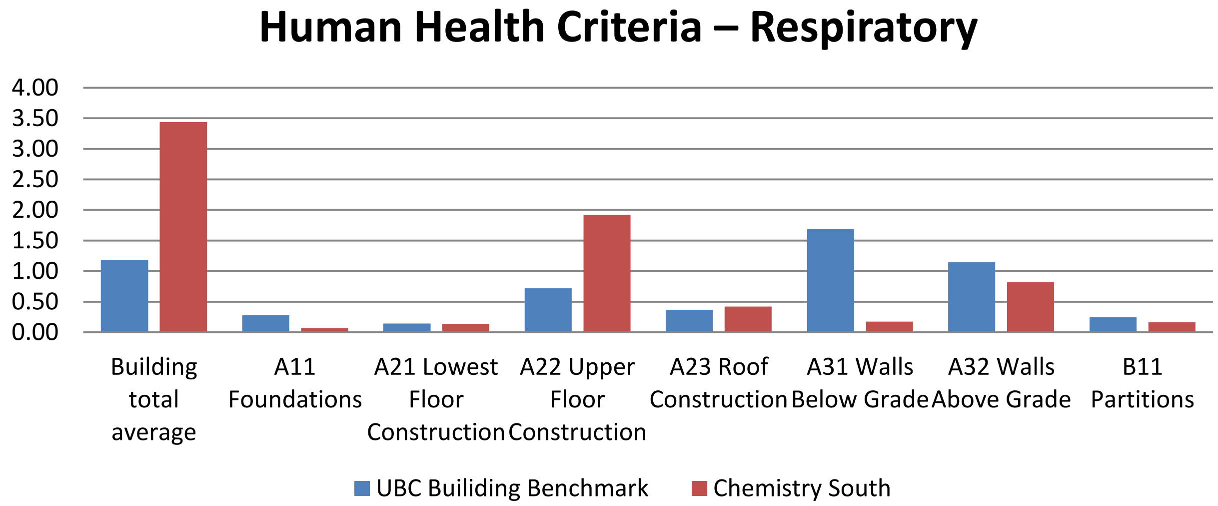

Figure 22. Human health respiratory effects Potential Comparison between Benchmark and Chemistry building South wing

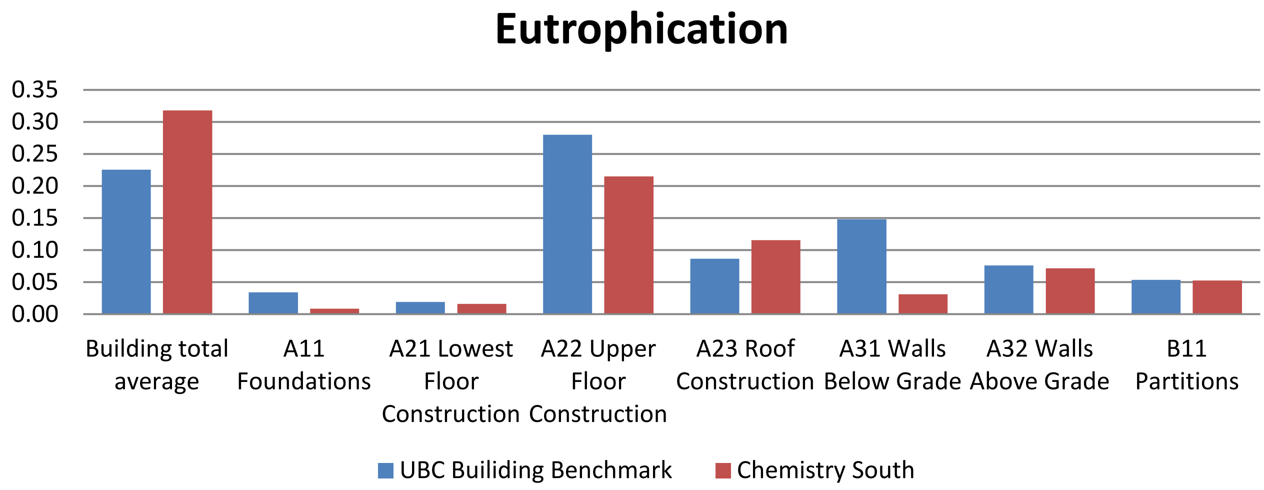

Figure 23. Eutrophication Potential Comparison between Benchmark and Chemistry building South wing

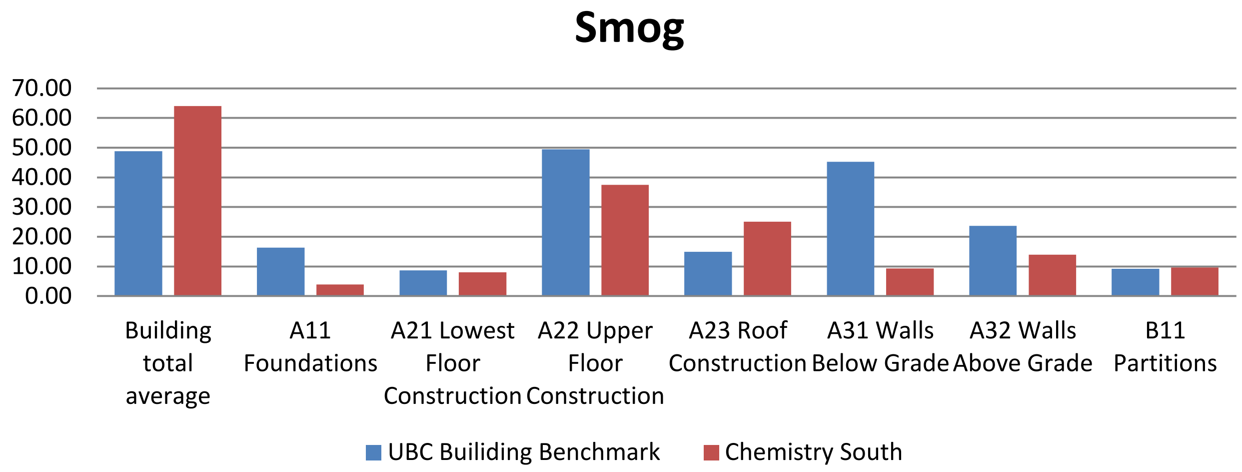

Figure 24. Photochemical smog Potential Comparison between Benchmark and Chemistry building South wing

See Figure 25 to 27, Chemistry building South wing's cost is lower than most of the building, however the GWP is higher than most. In order to consider the relation with cost and GWP relation for each building, we further converted two kinds of building into similar scale. (Figure 27) There is a tendency that higher budget building has less GWP. This is just a tendency, no evidence shows the direct relation between building cost and GWP.

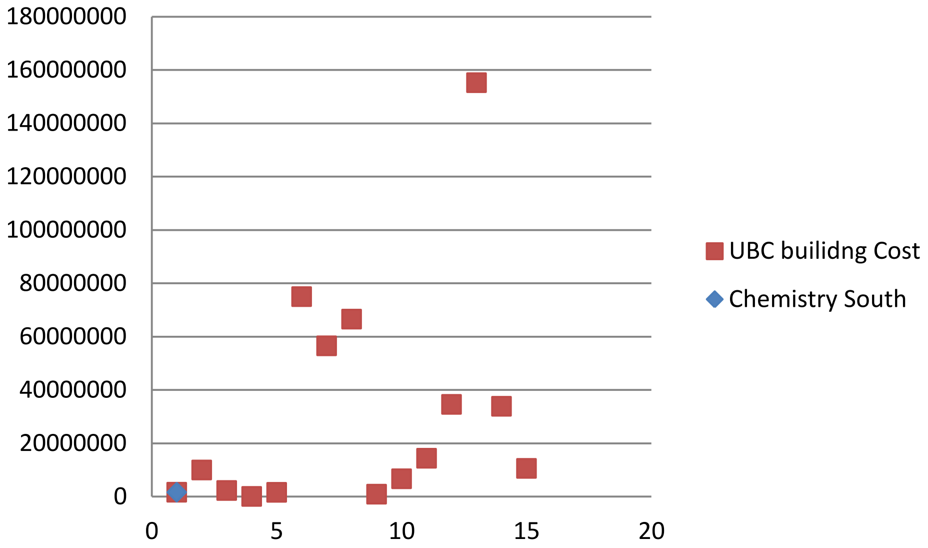

Figure 25. Comparison of building cost between UBC buildings and Chemistry building South wing

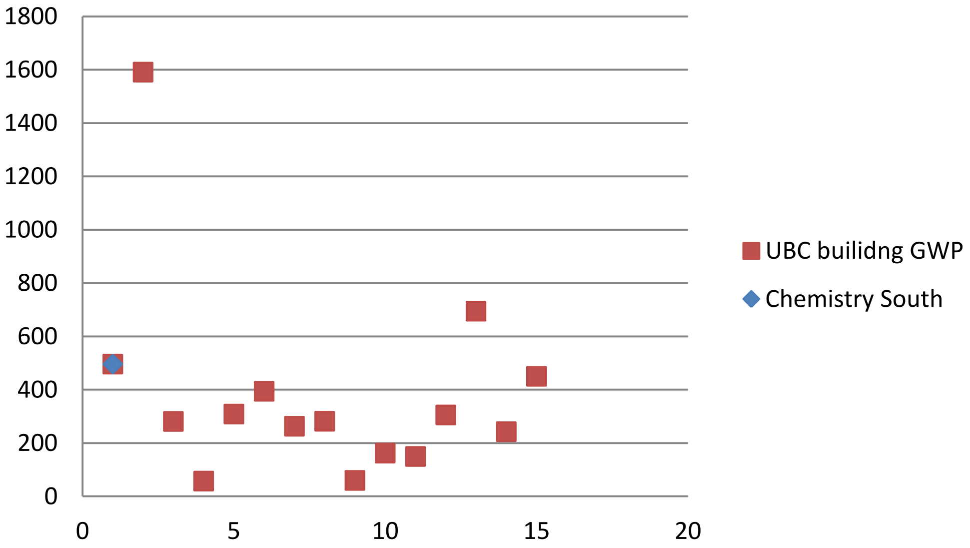

Figure 26. Comparison of GWP between UBC buildings and Chemistry building South wing

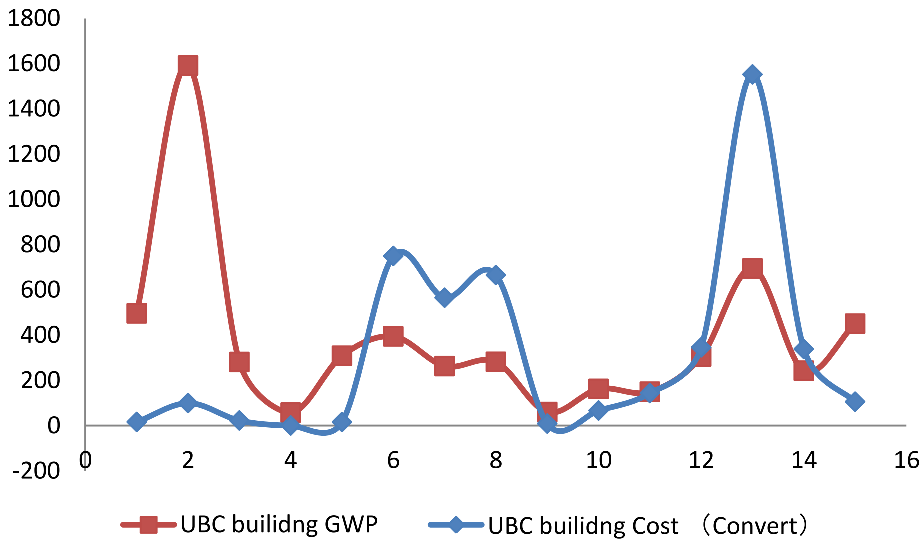

Figure 27. Comparison of building cost and GWP between UBC buildings and Chemistry building South wing

Annex B - Recommendations for LCA Use

LCA study is the life time study from the products' "Birth to the Grave". For a building itself, the four stages comes to the whole life time. Furthermore, the energy use in operation stage contributes the most of energy consumption in building life, because the operation period is much larger than any other period in the rest of stages. Therefore the passive design in building is recommend for designers. However, for data collection in operation stage, it is harder to track the information. UBC now has the on time energy record which could be further used in LCA studies. Also, the waste management of building demolish stage is also a key factor for environment. A proper way to recycle or degradation material will led to less long term effects to earth.

By doing the LCA study, people involved in the project will understand how decision in early stage will have a great effect on building. Like the effect/cause graph, the early little changes will change the result better in late big changes. The LCA study of product and construction stage will give reader a better understanding of material selection and its environmental impact.

The LCI data is the fundamental but important parts in LCA study. There are lots of uncertainties and assumptions in the LCA study. In this study, the IE input coming from material takeoff also has some limitations. First is the knowledge of drafter. The drafter without any civil or architecture background will have difficult even in understand the drawing. Second is the inconsistence of drawing itself. Most buildings in UBC have a long history and the hand drawing can not be read clearly after decades. Further, the option in Athena will not cover all components, data adjustments are need. Then the question comes to how to find the Availability and quality data.

Prioritizing impact categories are different from person to person. In the aversion survey in the class, most people think the GWP is the priority one. During the discussion we found people with different background will treat the problem differently. Students coming from one particular area will give a high value in certain problems, like the student coming from China, smog or HH air are big concerns for them. The impact categories could be divided into two parts: the long term impacts which comes slower and might cause global effects as well as harder to recover; and the short term impacts which comes faster in particular area as well as rise a huge impact on local environment and social problems.

First, for myself, since the product and construction stage are already done, I can save the energy on use stage by not waste energy in the daily life. Also, I will talk about it to some friends who don’t know or have a little understanding of LCA. LCA is a big topic which include many sub topic related to many disciplines. People will find their own interested point relate to their background.

Annex C - Author Reflection

Reflect on your experience completing this final project in the course. Make sure to cover the following points in your discussions.

- Mark and briefly comment on which of the 12 CEAB graduate attributes you believe you had to demonstrate during your final project experience (see **CEAB Graduate Attributes.xls** on course wikispace Final Project Page under Stage 4). Just fill in the table and paste it in this section of your final report.

One of the good things about this course is it gives people a whole picture of LCA and not require for much background knowledge. The terminology use is a little hard for a beginner, but the introduction for LCI, LCIA, LCCA are useful. The final project is a good practice for student to have a better understanding of how to do a LCA and what should be covered in a report. The most interesting thing is to know how LCA works and know the "black box" in Athena.

	Graduate Attribute			
	Name	Description	Select the content code most appropriate for each attribute from the dropdown menue	Comments on which of the CEAB graduate attributes you believe you had to demonstrate during your final project experience.
1	Knowledge Base	Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.	IDA = introduced, developed & applied	Can understand the backgroud of LCA study and writing a report

2	Problem Analysis	An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.	DA = developed & applied	
3	Investigation	An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.	IA = introduced & applied	Getting into the detail of every single input of Athena IE to check the inaccuracy
4	Design	An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal	IA = introduced & applied	The Comparison between all the elements and stages

	considerations.		
5 Use fo Engineering Tools	An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.	IDA = introduced, developed & applied	Well understand of material takeoff and Athena
6 Individual and Team Work	An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.	DA = developed & applied	

7	Communication	An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.	DA = developed & applied
8	Professionalism	An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.	IA = introduced & applied
9	Impact of Engineering on Society and the Environment	An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety,	

		legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.	
10	Ethics and Equity	An ability to apply professional ethics, accountability, and equity.	
11	Economics and Project Management	An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.	IA = introduced & applied
12	Life-long Learning	An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of	DA = developed & applied

knowledge.

Annex D – Impact Estimator Inputs and Assumptions

Assembly Group	Quantity	Units	Assembly Type	Assembly Name	Input Fields	Input Values	
						Known/Measured	**IE Inputs**
A11 Foundation	1216.8435	m2					
			1.2 Concrete Footing				
				1.2.1 Footing_Type10			
					Length (ft)	12.5	16.5
					Width (ft)	6.25	6.25
					Thickness (in)	26	19.7
					Concrete (psi)	-	4000
					Concrete flyash %	-	average
					Rebar	#10, #6	#6
				1.2.2 Footing_Type11			
					Length (ft)	45.5	14.4
					Width (ft)	3	#REF!
					Thickness (in)	24	#REF!
					Concrete (psi)	-	4000
					Concrete flyash %	-	average
					Rebar	#4	#4
				1.2.3. Footing_Type12			
					Length	38.5	47

	(ft)		
	Width (ft)	3.5	3.5
	Thickness (in)	24	19.7
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#4	#4
1.2.4 Footing_Type13			
	Length (ft)	14	14
	Width (ft)	3	3
	Thickness (in)	18	18
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#6, #4	#4
1.2.5 Footing_Type14			
	Length (ft)	5	5
	Width (ft)	2.5	2.50
	Thickness (in)	16	16
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#6, #4	#4
1.2.6 Footing_Type2			
	Length (ft)	34	44.9
	Width (ft)	8.5	8.50
	Thickness (in)	26	19.7
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#8, #11	#6
1.2.7 Footing_Type3			
	Length (ft)	18	23.76
	Width (ft)	9	9
	Thickness (in)	26	19.7

	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#11, #8	#6
1.2.8 Footing_Type4			
	Length (ft)	7	15.84
	Width (ft)	7	3.50
	Thickness (in)	26	19.7
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#10, #7	#6
1.2.9 Footing_Type5			
	Length (ft)	12	15.84
	Width (ft)	3.5	3.50
	Thickness (in)	26	19.7
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#9, #10	#6
1.2.10 Footing_Type6			
	Length (ft)	15.2	20.02
	Width (ft)	9.6	9.59
	Thickness (in)	26	19.7
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#10, #8, #11	#6
1.2.11 Footing_Type7			
	Length (ft)	10.5	13.86
	Width (ft)	14.5	14.50
	Thickness (in)	26	19.7
	Concrete (psi)	-	4000
	Concrete flyash %	-	average

	Rebar	#11. #5, #10	#6
1.2.12 Footing_Type8			
	Length (ft)	5.42	14.3
	Width (ft)	5.42	5.42
	Thickness (in)	26	19.7
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#5, #6	#6
1.2.13 Footing_Type9			
	Length (ft)	4	5.3
	Width (ft)	3.5	3.50
	Thickness (in)	26	19.7
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#9, #11	#6
1.2.14 Footing_Type1			
	Length (ft)	17.5	23.1
	Width (ft)	3	3
	Thickness (in)	26	19.7
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#11, #9	#6
1.2.15 Footing_2'8"			
	Length (ft)	117	117
	Width (ft)	2.67	2.67
	Thickness (in)	12	12
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	-	#5
1.2.16 Footing_3'9"			
	Length	38	38

	(ft)		
	Width (ft)	3.75	3.75
	Thickness (in)	12	12
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	-	#5
1.2.17 Footing_2'			
	Length (ft)	78.00	78.00
	Width (ft)	2.00	2.00
	Thickness (in)	12.00	12
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	-	#6
1.2.18 Footing_Type16			
	Length (ft)	7.00	7.00
	Width (ft)	3.50	3.50
	Thickness (in)	15.00	15
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#4	#4
1.2.19 Footing_3'2"			
	Length (ft)	31.00	31.00
	Width (ft)	3.17	3.17
	Thickness (in)	12.00	12
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	-	#5
1.2.20 Footing_Type17			
	Length (ft)	11.00	11.70
	Width (ft)	5.50	5.50
	Thickness (in)	23.00	19.7

					Concrete (psi)	-	4000
					Concrete flyash %	-	average
					Rebar	#7, #5	#6
A21 Lowest Floor Construction	1216.8435	m2					
			1.1 Concrete Slab-on-Grade				
				1.1.1 SOG_125mm			
					Length (ft)	222.00	197.00
					Width (ft)	59.00	59.00
					Thickness (in)	5	8
					Concrete (psi)	-	4000
					Concrete flyash %	-	average
A22 Upper Floor Construction	2634.6362	m2					
			4.1 Concrete Suspended Slab				
				4.1.1 Floor1_ConcreteSuspendedSlab_200mm			
					Floor Width (ft)	398.5	398.5
					Span (ft)	30	30
					Concrete (psi)	4000	4000
					Concrete flyash %	-	average
					Life load (psf)	-	100
			4.2 Concrete Suspended Slab				
				4.2.1			

	Floor2_ConcreteSuspendedSlab_200mm			
		Floor Width (ft)	273.4	273.4
		Span (ft)	30	30
		Concrete (psi)	4000	4000
		Concrete flyash %	-	average
		Life load (psf)	-	75
4.3 Concrete Suspended Slab				
	4.3.1 Floor3_ConcreteSuspendedSlab_200mm			
		Floor Width (ft)	273.4	273.4
		Span (ft)	30	30
		Concrete (psi)	4000	4000
		Concrete flyash %	-	average
		Life load (psf)	-	75
		Category	Vapour Barrier	Vapour Barrier
		Material	-	Polyethylene 6 mil
		Thickness	-	-
3.1 Concrete Column				
	3.1.1 Column_Concrete_Beam_Basement_Floor1			
		Number of Beams	65	65
		Number of Columns	52	52
		Floor to floor height (ft)	12	12
		Bay sizes (ft)	25.67	25.67
		Supported span (ft)	18.58	18.58
		Live load	-	100

					(psf)		
				3.1.3 Column_Concrete_Beam_Floor2_Floor3			
					Number of Beams	84	84
					Number of Columns	72	72
					Floor to floor height (ft)	13	13
					Bay sizes (ft)	19.5	19.5
					Supported span (ft)	18.1	18.1
					Live load (psf)	-	100
				1.2.15 Stairs_Concrete_Total Length			
					Length (ft)	277	277
					Width (ft)	5.25	5.25
					Thickness (in)	8	8
					Concrete (psi)	-	4000
					Concrete flyash %	-	average
					Rebar	#5, #6	#6
				1.2.15 Stairs_Concrete_LectureHall_Total Length			
					Length (ft)	60	60
					Width (ft)	45	45
					Thickness (in)	8	8
i					Concrete (psi)	-	4000
					Concrete flyash %	-	average
					Rebar	#4	#4
A23 Roof Construction	1201.7932	m2					
			5.2 Concrete				

		Roof					
			5.2.1 Roof_Concrete				
					Roof Width (ft)	431.2	3554.22
					Roof Length (ft)	30.00	17.35
					Decking Type	Concrete	Concrete
					Decking Thickness	5	5.00
				Envelope	Category	Roof Envelopes	Roof Envelopes
					Material	4 ply built up asphalt roof system(inverted)	4 ply built up asphalt roof system(inverted)
					Thickness	-	-
					Category	Cellulose, Glass Felt	Cellulosel, Glass Felt
					Material	4"	4"
					Thickness	-	-
					Category	Insulation	Insulation
					Material	Polyisocyanurate Foam	Polyisocyanurate Foam
					Thickness	2"	2"
					Category	Vapour Barrier	Vapour Barrier
					Material	-	Polyethylene 6 mil
					Thickness	-	-
			3.1.4 Column_Concrete_Beam_Floor3_Roof				
					Number of Beams	76	76
					Number of Columns	71	71
					Floor to floor height (ft)	13	13
					Bay sizes (ft)	14.333	14.333
					Supported span (ft)	19	19
					Live load (psf)	-	75
A31 Walls Below Grade	736.81369	m2					

			2.1 Cast In Place				
				2.1.1 Wall_Cast-in-Place_Basement_230mm			
					Length (ft)	439	439.00
					Height (ft)	14	14
					Thickness (in)	9	8
					Concrete (psi)	-	4000
					Concrete flyash %	-	average
			2.2 Concrete Block Wall		Rebar	-	#5
				2.2.3 Wall_ConcreteBrick_200mm_ShortBrickAddIn_Basement			
					Length (ft)	119	119
					Height (ft)	15	15
					Rebar	-	-
				Envelope	Category	Cladding	Cladding
					Material	Brick - Modular (metric)	Brick - Modular (metric)
					Thickness	-	-
					Category	Insulation	Insulation
					Material	Batt	Batt
					Thickness	2"	2"
					Category	Stud	Stud
					Material	Wood	Wood
					Thickness	4"	2'X4"
					Category	Covering	Covering
					Material	Plaster	1" gypsum
					Thickness	3/4"	1"
					Rebar	-	-
				Door Opening	Number of Doors	-	-
					Door Type	-	Steel Interior Door, 50% glazing
A32 Walls Above Grade	2047.0247	m2					
			2.1 Cast				

	In Place				
		2.1.2 Wall_Cast-in-Place_Elevator_200mm			
			Length (ft)	53	53
			Height (ft)	51.00	51.00
			Thickness (in)	varies	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
	2.2 Concrete Block Wall				
		2.2.4 Wall_ConcreteBrick_200mm_ShortBrickAddIn_Floor1			
			Length (ft)	334	334
			Height (ft)	13	13
			Rebar	-	-
		Envelope	Category	Cladding	Cladding
			Material	Brick - Modular (metric)	Brick - Modular (metric)
			Thickness	-	-
			Category	Insulation	Insulation
			Material	Batt	Batt
			Thickness	2"	2"
			Category	Stud	Stud
			Material	Wood	Wood
			Thickness	2"	2"X2"
			Category	Covering	Covering
			Material	Plaster	1" gypsum
			Thickness	3/4"	1"
			Rebar	-	-
		Door Opening	Number of Doors	2	2
			Door Type	Steel Interior Door, 50% glazing	Steel Interior Door, 50% glazing
		2.2.5 Wall_ConcreteBrick_200mm_ShortBrickAddIn_Floor2			

	Length (ft)	246	246
	Height (ft)	13	13
	Rebar	-	-
Envelope	Category	Cladding	Cladding
	Material	Brick - Modular (metric)	Brick - Modular (metric)
	Thickness	-	-
	Category	Insulation	Insulation
	Material	Batt	Batt
	Thickness	2"	2"
	Category	Stud	Stud
	Material	Wood	Wood
	Thickness	2"	2"X2"
	Category	Covering	Covering
	Material	Plaster	1" gypsum
	Thickness	3/4"	1"
	Rebar	-	-
Door Opening	Number of Doors	2	2
	Door Type	Steel Interior Door, 50% glazing	Steel Interior Door, 50% glazing
2.2.4 Wall_ConcreteBrick_200mm_ShortBrickAddIn_Floor3			
	Length (ft)	247	247
	Height (ft)	13	13
	Rebar	-	-
Envelope	Category	Cladding	Cladding
	Material	Brick - Modular (metric)	Brick - Modular (metric)
	Thickness	-	-
	Category	Insulation	Insulation
	Material	Batt	Batt
	Thickness	2"	2"
	Category	Stud	Stud
	Material	Wood	Wood
	Thickness	2"	2"X2"
	Category	Covering	Covering
	Material	Plaster	1" gypsum
	Thickness	3/4"	1"
	Rebar	-	-
Door Opening	Number of Doors	2	2

					Door Type	Steel Interior Door, 50% glazing	Steel Interior Door, 50% glazing
				2.3.3 Wall_CurtainWall_Total			
					Length (ft)	660	660
					Height (ft)	13	13
					Percent Viewable Glazing	95	95
					Percent Spandrel Panel	5	5
					Thickness of Insulation (in)	2	2
					Spandrel Type (Metal/Glass)	Metal	Metal
				Door Opening	Number of Doors	16	16
					Door Type	-	Steel Interior Door, 50% glazing
B11 Partitions	1160.9159	m2					
			2.2 Concrete Block Wall				
				2.2.1 Wall_ConcreteBlock_Partition_250mm_total			
					Length (ft)	688	688
					Height (ft)	12	12
					Rebar	-	#4
					Category	Cladding	Cladding
					Material	Brick - Modular (metric)	Brick - Modular (metric)
					Thickness	10	10
				2.2.2 Wall_ConcreteBlock_Partition_Stairwell_25			

	0mm_total			
		Length (ft)	80	80
		Height (ft)	53	53
		Rebar	-	#4
		Category	Cladding	Cladding
		Material	Brick - Modular (metric)	Brick - Modular (metric)
		Thickness	10	10