UBC Social Ecological Economic Development Studies (SEEDS) Student Report

LIFE CYCLE ASSESSMENT - Wesbrook Building

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University of British Columbia

CIVL 498C

November 18, 2013

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.

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Executive Summary

The objective of this LCA study is to analysis the environmental impacts, which come from product manufacturing and construction process, of the Wesbrook building, which is located at 6174 University Blvd. This building is one lf the oldest academic buildings in the UBC Vancouver campus.

The methods for this study are carried of from general information assessment to the statement of boundaries and scenarios used in the assessment. On-Screen Takeoff is used here for building measurement, in order to get better accuracy. Then all the IE inputs and assumptions are put into Athena Impact Estimator for Buildings, which has one of the largest Life Cycle Inventory (LCI) database in North America, to get the environmental impacts from different impact categories.

This study showed that the reinforced concrete and the modular clay brick structural system contributed the most to the final environmental impacts of the Wesbrook building, and Global Warming Pretention is the biggest impact category in this module. The result of this study can be used for decision makers and further LCA study.

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1.0 General Information on the Assessment

1.1 Purpose of the assessment

1.1.1 Goal of Study

(a) Intended application

(Describes the purpose of the study)

This Life Cycle Assessment (LCA) study of the Wesbrook building at the University of British Columbia is carried out to explore the environmental impacts caused by the product and construction process stages.

At the same time, the result of this study will be used as part of the benchmark in the overall database repository of UBC academic buildings.

(b) Reason for carrying out the study

(Describes the motivation for carrying out the LCA study)

This study helps practices better understanding LCA and its related knowledge. The result from the study can be used as environmental impact references and the establishment of a materials inventory for the Wesbrook building. It will make contribution to the further LCA study of UBC academic buildings.

Through the environmental performance comparisons among these academic buildings, better choice of materials, structural types and construction processes can be made for the further design, so that the sustainability design can be realized.

(c) Intended audience

(Describes those who the LCA study is intended to be interpreted by)

People, who involved in the building development related policymaking at UBC, might be part of the intended audiences. Governments, private industry and other universities whom may want to learn more or become engaged in performing similar LCA studies within their organizations can become the intended audience. At the same time, this study can make contribution to further develop of LCA studies.

(d) Intended for comparative assertions

(State whether the results of this LCA study are to be compared with the results of other LCA studies)

No comparative assertion within this study of Wesbrook building are made, however, as it is a part of a larger database, the study might be used for comparative assertions with other UBC buildings or other academic buildings, which have the similar function.

1.2 Identification of the building

The Wesbrook building, located at 6174 University Blvd, is one of the oldest academic buildings in the UBC Vancouver campus. The building was built in 1950', financed by BC government. Sharp & Thompson, Berwick Pratt, who played a major role in Vancouver and Canadian architecture through the century, were responsible for this project.

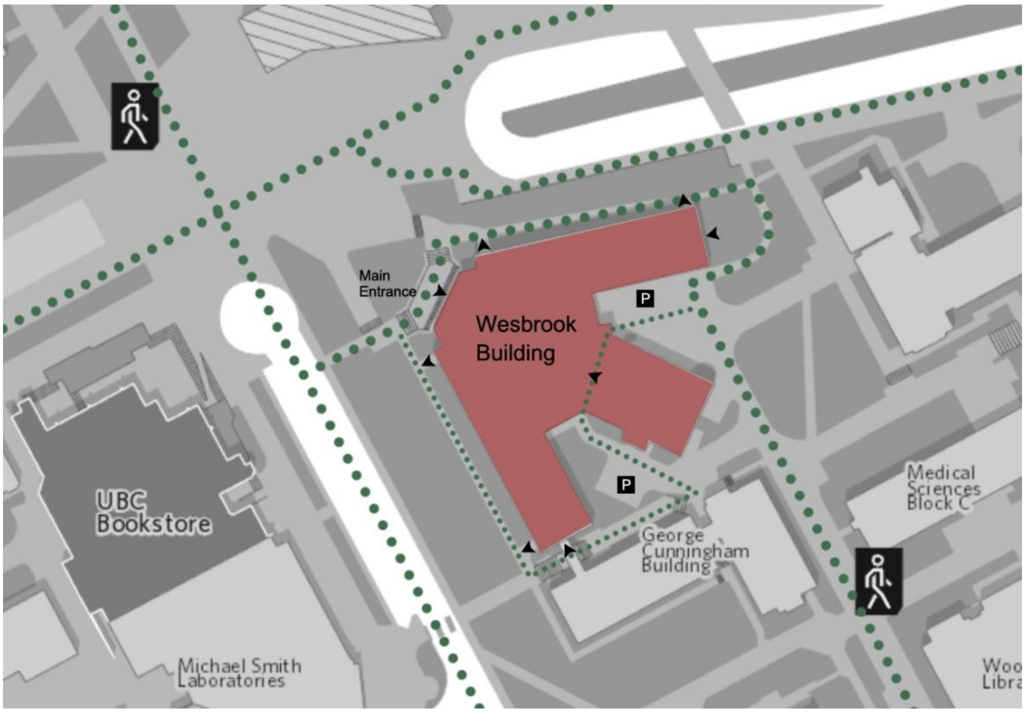


Figure 1 Location of Wesbrook Building

Figure 1 shows a map of this building. Flow line around the building, entrances and exits of it are all signed on the map.

The Wesbrook building was designed as Preventive Medicine Institute, and it became the microbiology department in 1960's. When the microbiology department moved to the new Life Science Center, the building is now occupied by pharmacists.

Figure 2 the Wesbrook Building

Figure 3 the Wesbrook Building

It has three above grade floors and one below grade floor. The gross area of this building is 98705 square feet, which consists of Classroom, offices, activity rooms, testing labs, library, study/research/prep/computer lab rooms and a lecture hall. During the past 60 years, this building has been renovated for several times.

Figure 4&5 Exterior Wall of Wesbrook Building

Figure 4&5 show the exterior walls of this building, which are made of concrete and bricks. The drawing of Wesbrook indicates that concrete is widely used in most parts of structure, so that, it can be assumed that most environmental impacts of this project come from concrete.

1.3 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	First author: Weicen (Kate) Wang, MEng student; Second author: Si Wu, Civil Engineering student. The building is used by pharmacists.
Impact Assessment method	Athena Impact Estimator for Buildings, Version 4.2.0208; On-Screen Takeoff, Version 3.9.0.6
Point of Assessment	63 years.

Period of Validity	5 years.
Date of Assessment	Completed in December 2013.
Verifier	Student work, study not verified.

Table.1 Other Assessment Information

2.0 General Information of the Object of Assessment

2.1 Functional Equivalent

2.1.1 Functional units

(Quantified performance of a product system for use as a reference unit)

The functional units used in this assessment is to normalize the LCA results of the Wesbrook Building include:

- Per institutional post-secondary research building square meter constructed for building total area
- Per institutional post-secondary academic building square meter constructed for functional area

Based on these clearly functional units, better comparisons of environmental impacts on different systems can be realized. Further introduction of this will be made in the *7.0 Communication of Assessment Results*.

2.1.2 Functional equivalent definition

Aspect of Object of Assessment	Description
Building Type	Institutional - Post Secondary - Research
Technical and functional requirements	Classroom, activity rooms, offices, testing labs, library, study/research/prep/computer lab rooms, lecture hall for microbiology department.
Pattern of use	Monday-Friday 07:15-18:00, Saturday/Sunday/Holidays - Closed
Required service life	It is supposed to be around 100 years.

Table.2 Functional equivalent definition template

2.2 Reference Study Period

2.2.1 Required service life

The building was built in 1950', and it has been used for more than 60 years, however, there is not clear information showing how long the service life is, so that, it is assumed to be around 100 years.

2.2.2 Reason for excluding Modules B, C and D

According to EN 15978, building Life Cycle Assessment has four modules. This LCA study only focuses on the environmental impacts caused by building construction. Module A, which contains the Product stage and Construction Process stage, has integrated information of building construction from raw material supply to construction installation. Module B is about the Use stage, Module C describes the End of Use stage, while Module D is the Supplementary Information Beyond the Building Life Cycle. All of them are happened after the finish of building construction, so that Modules B, C and D are excluded in this study.

2.3 Object of Assessment Scope

2.3.1 Description of the building

Cast-in place concrete and modular bricks are two main materials of the Wesbrook building. The interior walls are consisted of cast-in-place walls, which have general painting on it, and brick walls, which are covered by ½" regular gypsum board. Most of the structure parts, in terms of footings, columns, slab-on-grade, beams, floors, stairs, are made of concrete. Suspended concrete slabs are the main material of floors. While open web steel joint roof and precast concrete slab are the two parts of roof, both of them are covered by 3-mil polyethylene and roof asphalt. Modular bricks are used as the inside envelope of exterior walls, which are concrete structure as well. Furthermore, the building envelope has very little insulation, which is only 0.5 inch thick, so that it leads to the inefficient thermal performance. Table-5 below summarizes the elements included in this building.

CIVL 498C Level 3 Elements		Description	Quantity (Amount)	Units
A11	Foundations	Strip footings, concrete columns	2510	m^2
A21	Lowest Floor Construction	Concrete slab-on-grade	2510	m^2
A22	Upper Floor Construction	Concrete suspended slabs (1st, 2nd floors), concrete columns (1st, 2nd floors), concrete beams (1st, 2nd floors), floors (1st, 2nd, and 3rd floors), "cast in place" stairs	3182	m^2
A23	Roof Construction	Concrete suspended slab (3rd floor), concrete beams (3rd floor), concrete columns (3rd floor), steel joint roof, concrete slab	222	m^2
A31	Walls Below Grade	Exterior below grade walls, "cast in place" walls	833	m^2
A32	Walls Above Grade	Exterior above grade walls, "cast in place" walls, brick wall, mortar, gypsum board	3182	m^2
B11	Partitions	All interior walls, "cast in place" walls	2026	m^2

Table.3 Building Definition Template

2.3.2 Reason for only addressing the structure and envelope

This LCA study is based on product stage and construction process stage. Table-5 describes the detail elements referred to in these two stages. All the elements belong to building structure and building envelop.

3.0 Statement of Boundaries and Scenarios Used in the Assessment

3.1 System Boundary

(Set of criteria specifying which unit processes are part of a product system, and which impacts created by the product system is considered)

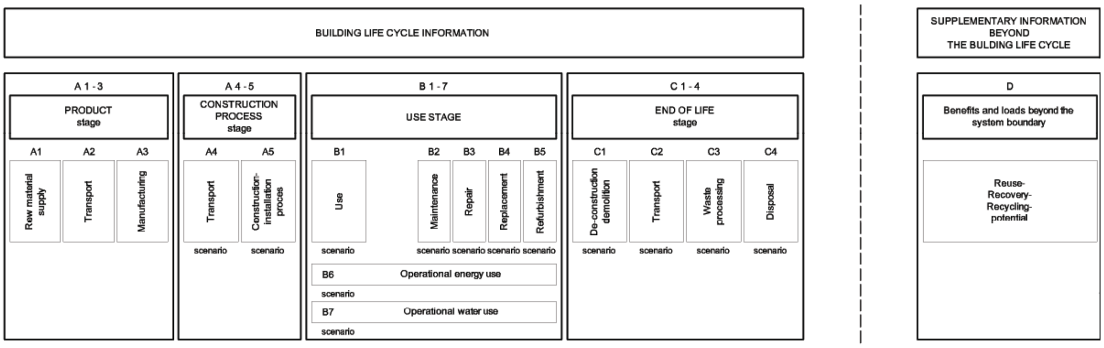


Figure 6 Display of modular information for the different stages of the building assessment

The LCA study of the Wesbrook building only includes Module A, which contains raw material supply, transport, manufacturing for Product stage, and transport, construction installation process for Construction process stage. Any processes beyond or after this system boundary will not be included in this study. For Module A, upstream process can be regarded as the collection of raw materials and variety energy requirement. Once the extracted resources used in next stage is produced, the emissions and construction waste will become the downstream process. Figure 7&8 below show the detail flow chat of upstream and downstream processes in Module A.

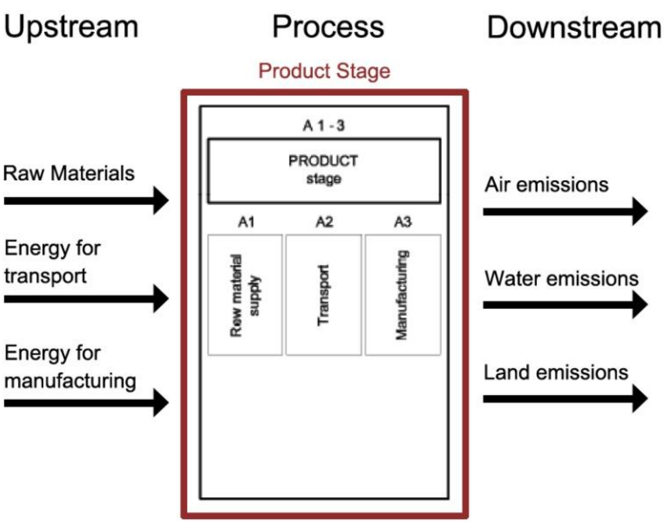


Figure 7 Flow chat for Product stage

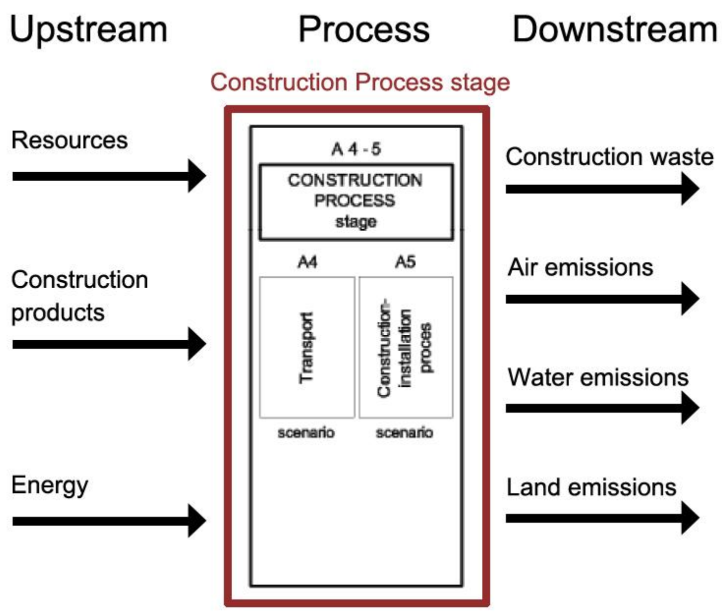


Figure 8 Flow chart for Construction process stage

3.2 Product Stage

(The product stage is also known as 'cradle to gate' for the building products and services that are reference flows for the construction stage of the object of assessment.)

As mentioned in the building identification before, the main materials used for the Wsebrook building are concrete and brick.

3.2.1 Concrete

Concrete is made of cement and water; different water/cement ratio can generate concrete with different strength. Cement is made by heating limestone (calcium carbonate) with small quantities of other materials to 1450 degree in a kiln (Figure 9). Silica fume, fly ash and natural pozzolans are used as Supplementary Cementing Materials (SCMs), which almost used in every the concrete manufacturing as they can realize better workability and reduce the water required through the production process. Since this building was built 60 years ago, there is no clear information showing which SCM it contains, in this study, it is assumed to be with average amount of fly ash. For all the concrete production, 28 days are the least curing time.

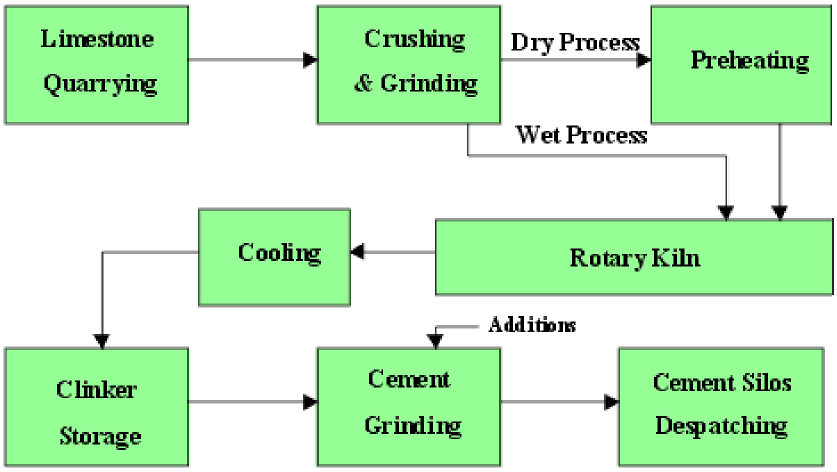


Figure 9 Production of cement

BC Province has its cement manufacture, so that the raw material is transported to the production site by truck. The transportation of precast concrete as well as the concrete used for cast-in-place concrete form production gate to construction site can be realized by truck as well. Fossil fuel consumption will be caused in this process.

The biggest emission in this process is CO_2, as 1 ton of cement generates 1 ton of CO_2. In addition, the reaction of cement and water produces heat exhaust as another form of pollution.

3.2.2 Brick

Bricks are made by placing the cement mixture and aggregates into a mold at the production site, where it is dried and cured, therefore the product stage of it is similar with concrete.

3.3 Construction Stage

(The construction stage covers the processes from the factory gate of the different construction products to the practical completion of the construction work.)

The precast concrete and brick are easy for storage in the construction site; some cover on them is useful. Other concrete elements in this building are cast-in-place concrete, such as cast-in-place walls and cast-in-place roof, which should be built on site.

Pouring a cast-in-place wall typically consists of assembling the formwork and placing reinforcing rebar in the forms and around openings, then pouring concrete into the forms. The concrete will arrive on site in a concrete mixing truck and will be poured using a concrete pump or a crane and bucket. The forms may be assembled by hand or crane for large-scale formwork. Rebar would typically be assembled by hand. A wall might need temporary heating for concrete curing.

On site waste for concrete is estimated at 5%, and consists of any spillage from the forms and the dumping of excess concrete not required on site. Formwork is re-used until its degradation adversely affects the surface finish of the concrete work. On average, a 10% loss of material can be assumed after each use.

4.0 Environmental Data

4.1 Data Sources

4.1.1 Athena LCI Database

The Athena Institute has been originally leading life cycle research, developing an increasing set of all-inclusive and comparable life cycle inventory databases for minority. For now, the experts of Athena conduct research independently to accomplish core program objectives, and work with industry to manager through life cycle inventories. The Athena's databases almost cover every section, the databases are sensitive to distinguish the differences for products produced in various regions; and the databases are using actual process models, which are not rely on government data sources. Most noteworthy is that Athena can provide a software tools to users with an unmatched level of detail and specificity.

4.1.2 US LCI Database

U.S. Life Cycle Inventory (LCI) Database is created between National Renewable Energy Laboratory (NREL) and its partners. The purpose is to help life cycle assessment (LCA) practitioners explain environmental impacts. US

LCI database provides accounting of energy individually, the style can be gate-to-gate, cradle-to-gate and cradle-to-grave; database provides material flows into and out of the environment, which are related to producing a material, component, or assembly in the United States.

4.2 Data Adjustment and Substitutions

Data adjustment and substitutions start with deviation detection in this LCA study. The deviations exist between the construction drawings, which are opened in On-Screen Takeoff, and the inputs documents in both Athena and Excel. There are two solutions for the deviation:

- If Athena has the required data, and this deviation is caused by careless of the previous student, the adjustment is changing the deviation into the right one according to the construction drawings.
- If Athena dose not have the required data, the substitution might be found in another database. Calculation is used here to get the percentage of waste factor, which might be taken into account directly by Athena, and then use the original data minus the waste factor to get the final substitution.

4.3 Data Quality

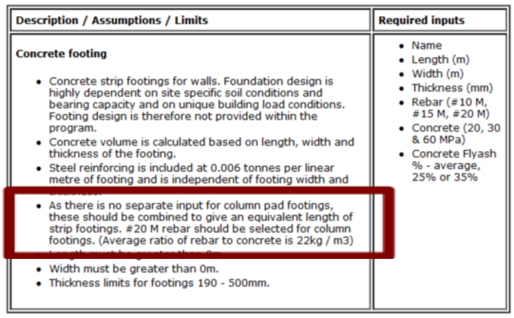
(Data quality describes the characteristics of the data used in terms of its ability to satisfy stated requirements.)

Most data of the Wesbrook building can be found or put into Athena for the impact assessment; only few model, data, spatial and temporal uncertainty types exist in this LCA study.

4.3.1 Model Uncertainty

Due to the lack of information, the concrete type and percentage of fly ash are unsure for “Footing_F1_Strip”. According to the help description: #20M (equal to 3000 psi) rebar should be selected for column footings, so that 3000-psi concrete is used here. See Figure 10&11.

Assembly Name	Input Fields	Input Values	
		Known/Measured	IE Inputs
1.1.1 Footing_F1_Strip			
	Length (ft)	1841	1841
	Width (ft)	1	1
	Thickness (in)	12"	12"
	Concrete (psi)	2500	3000
	Concrete flyash %	-	Average
	Rebar	-	#6



Description / Assumptions / Limits	Required inputs
Concrete footing • Concrete strip footings for walls. Foundation design is highly dependent on site specific soil conditions and bearing capacity and on unique building load conditions. Footing design is therefore not provided within the program. • Concrete volume is calculated based on length, width and thickness of the footing. • Steel reinforcing is included at 0.006 tonnes per linear metre of footing and is independent of footing width and • As there is no separate input for column pad footings, these should be combined to give an equivalent length of strip footings. #20 M rebar should be selected for column footings. (Average ratio of rebar to concrete is 22kg / m3) • Width must be greater than 0m. • Thickness limits for footings 190 - 500mm.	• Name • Length (m) • Width (m) • Thickness (mm) • Rebar (#10 M, #15 M, #20 M) • Concrete (20, 30 & 60 MPa) • Concrete Flyash % - average, 25% or 35%

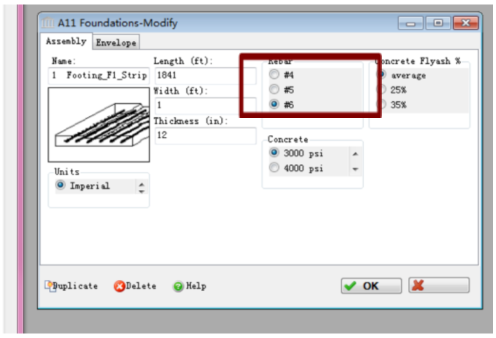


Figure 10&11 Model Uncertainty

4.3.2 Data Uncertainty

In Figure 12, the measurements in On-screen Takeoff show that, the thickness of "Footing_F5_Column" is 21in, however when entering 21in thickness into Athena, it warns that "thickness value mush be>=7.5in and<=19.7in", so that assumption has to be made here due to the data limitation.

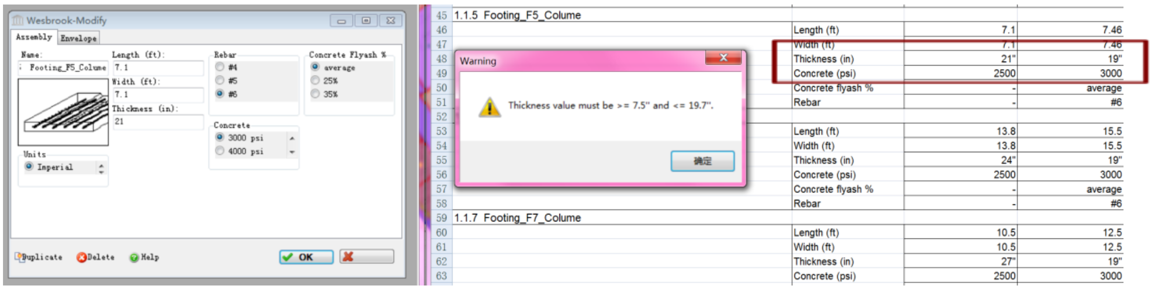


Figure 12 Data Uncertainty

4.3.3 Spatial Uncertainty

When putting the floor width (51ft) and span (479ft) into Athena, it warns that "Span is out of range, choose 0<span<=31.98819". In order to get a similar size of suspended slab, the assumption here is using the measured area of suspended slab divide the possible largest span size, which is allowed in Athena, to get the assumed floor width (Figure 13):

(51ft * 479ft) / 31ft = 788ft

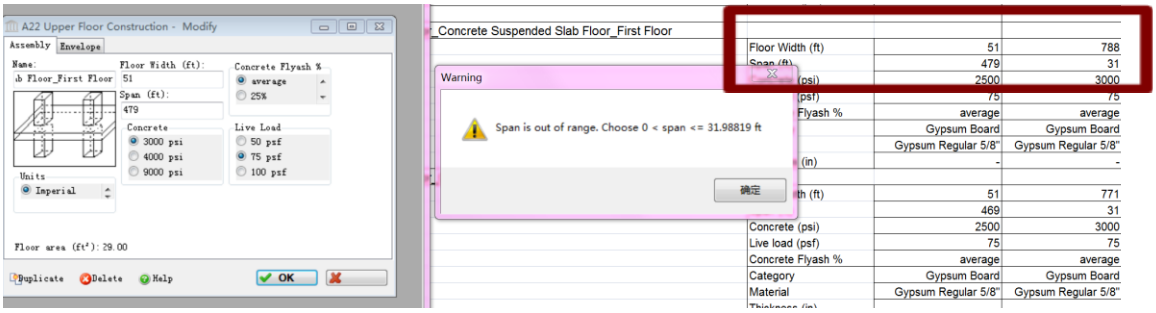


Figure 13 Spatial Uncertainty

4.3.4 Temporal uncertainty

The wesbrook building was built in 1950', however this LCA study is applied on it with current standards. Therefore, taking into account of the developed technology in today's society, the actual impacts should be much larger.

5.0 List of Indicators Used for Assessment and Expression of Results

5.1 Impact Assessment Method

The impact assessment methods used in this LCA study are Athena Impact Estimator for Buildings (Version 4.2.0208), which is the only available software meeting the requirements of this study, and On-Screen Takeoff (Version 3.9.0.6).

5.2 Impact Categories

The environmental impacts in this LCA study are divided into seven categories. Six of them are characterized by US Environmental Protection Agency (US EPA), and the Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI). Fossil fuel consumption is the only one characterized by Athena Institute.

5.2.1 Global warming potential

The cause/effect chain modeled of Global Warming Potential (GWP) can be described in the Figure-9 below. GWP is caused by air emission, which is general known as CO_2. The effect of GWP is enormous and wide, and the endpoint impacts of it range from human health to natural damage.

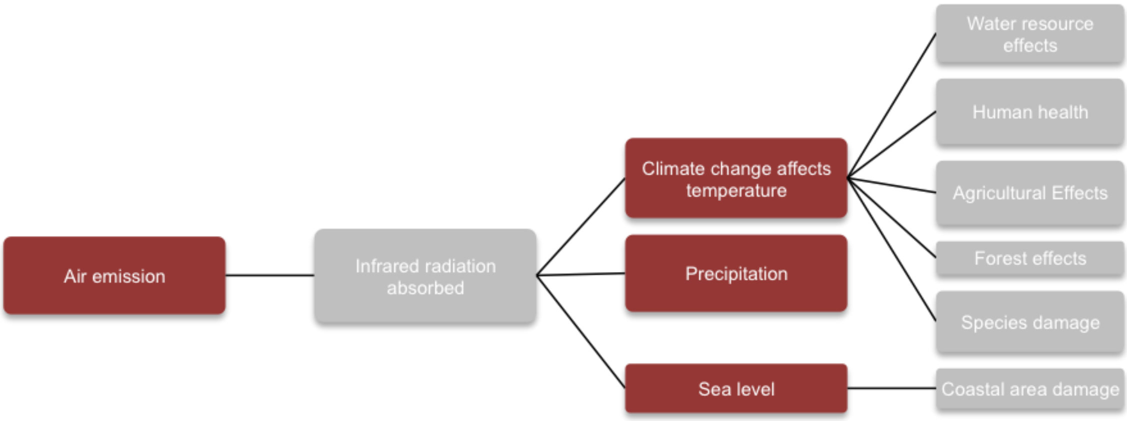


Figure 14 Glow warming potential cause/effect chain

5.2.2 Acidification potential

The cause/effect chain modeled of Acidification Potential (AP) can be described in the Figure-10 below. AP is caused by air emission, which is general known as SO_2. The effect of AP is mostly from leaching, and the endpoint impacts are on the natural environment.

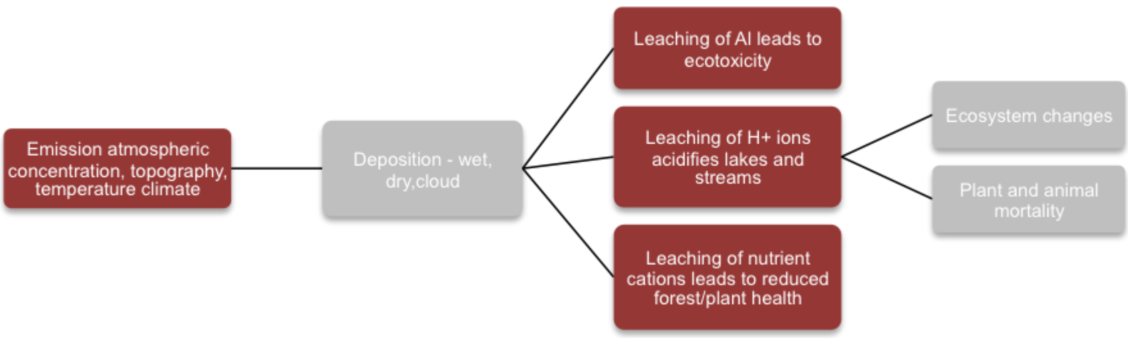


Figure 15 Acidification potential cause/effect chain

5.2.3 Human health criteria – respiratory

The cause/effect chain modeled of Human Health (HH) can be described in the Figure-11 below. HH is caused by air emission, which is inhaled by human. The effect of HH is related to Particulate Matter (PM), which might lead to directly endpoint impacts on human.

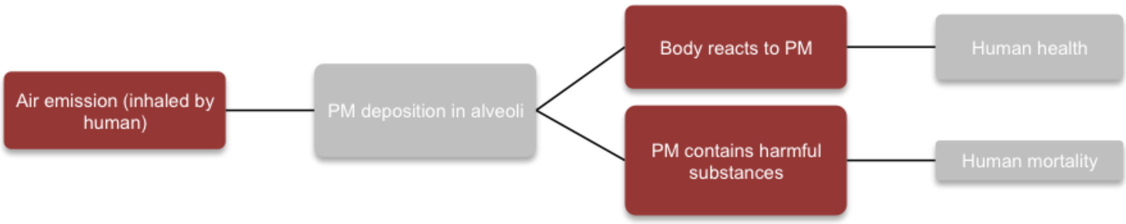


Figure 16 Human health criteria cause/effect chain

5.2.4 Eutrophication potential

The cause/effect chain modeled of Eutrophication Potential (EP) can be described in the Figure-12 below. EP is caused by water emission, which is arrival to nutrient limited aquatic ecosystem. Toxicity is the biggest endpoint impact of EP.

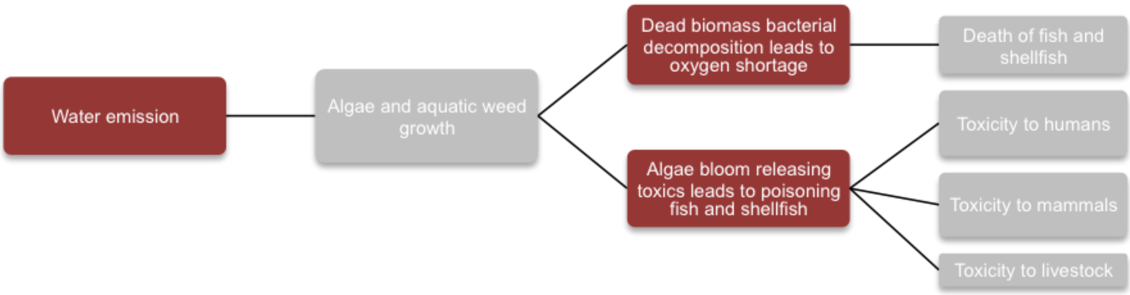


Figure 17 Eutrophication potential cause/effect chain

5.2.5 Ozone depletion potential

The cause/effect chain modeled of Ozone Depletion Potential (ODP) can be described in the Figure-13 below. ODP is caused by air emission, and due to the depletion, more and more UVB coming into earth. The endpoint impacts of ODP are similar to GWP, expect it might lead to material damage.

Figure 18 Ozone depletion potential cause/effect chain

5.2.6 Smog potential

The cause/effect chain modeled of Smog Potential (SP) can be described in the Figure-14 below. SP is caused by air emission; it might affect on the human health, and even lead to the death.

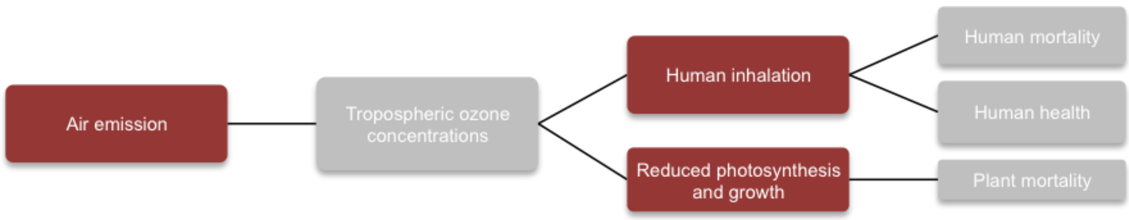


Figure 19 Smog potential cause/effect chain

5.2.7 Fossil fuel consumption

The cause/effect chain modeled of Fossil fuel consumption can be described in the Figure-15 below. Fossil fuel consumption is required by the increasing energy use worldwide. Long-time fossil fuel consumption might bring huge impacts to human health.

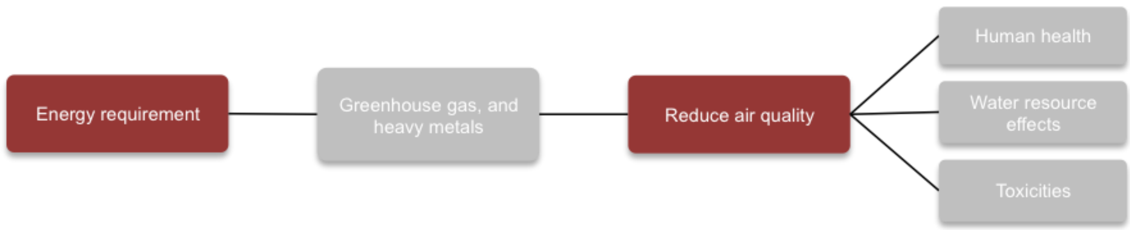


Figure 20 Fossil fuel consumption cause/effect chain

6.0 Model Development

6.1 Modeling actions

6.1.1 Modeling and sorting of Level 3 elements

The modeling and sorting of this LCA study is based on Canadian Institute of Quantity Surveyors (CIQS) elemental format. In this standard, an element is defined as a major component common to most buildings, fulfilling the same function irrespective of its design, specification or construction. Table 4 indicates the Level 3 elements in this report.

Level 1	Level 2	Level 3
A Shell	A1 Substructure	A11 Foundations
	A2 Structure	A21 Lowest Floor Construction
		A22 Upper Floor Construction
		A23 Roof Construction
	A3 Exterior Enclosure	A31 Walls Below Grade
		A32 Walls Above Grade
B Interiors	B1 Partitions & Doors	B11 Partitions

Table.4 Level 3 Elements list

The Wesbrook building has four floors in all, one below grade level and three above grade levels. According to the CIQS level 3 sorting:

A11 Foundations

Concrete strip footings and column footings consist of the foundation elements, supporting the whole building.

A21 Lowest Floor Construction

Concrete slab-on-grade is the only floor construction for basement, which belongs to lowest floor.

A22 Upper Floor Construction

All columns and beams, which supporting the second and third floors are upper floor construction. In additional, the concrete suspended slab on the first, second and third floors belong to this category, as well as stairs.

A23 Roof Construction

All columns and beams, which supporting the roof, are roof construction, as well as all the roof elements.

A31 Walls Below Grade

All the exterior walls of basement, as well as their envelope and windows are walls below grade.

A32 Walls Above Grade

All the exterior walls of first, second and third floors, as well as their envelope and windows are walls above grade. The modular clay brick wall, mortar between brick and regular gypsum board, which are used on the exterior walls also belong to this category.

B11 Partitions

All the interior walls of the building, as well as the doors and windows in them are partitions.

6.1.2 Methods summarization

This LCA study is based on the report of the previous student. After sorting the IE inputs and assumptions documents in Microsoft Excel according to the CIQS Level 3 Elements, the sorting results are put into the Athena Impact Estimator. Then is the deviation detection between the construction drawings and inputs documents, which is introduced in *4.2 Data Adjustment and Substitutions*. After deviation detection, a Bill of Materials is created through Athena to generate a cradle-to-grave LCI profile for the building. In this study, LCI profile results focus on the raw material supply, transportation of construction materials to site and their installation as structure and envelope assemblies of the Wesbrook building.

On-Screen Takeoff used here to perform linear, area and count measurements of the building's structure and envelope. The deviation detection can be realized through the measurements, so that the IE inputs used for the takeoff process can be more accurate.

6.2 Model Improvement

The first action of model improvement is go thought the model in On-Screen Takeoff, checking if all the measurements are correct. Once the deviation is detected, put the right data into the Inputs excel form. Accurate measured data can improve the quality of IE Inputs.

There are some difference between IE Inputs and measured data, based on the previous student's work, some of them were made by careless. The improvement action here is change all the IE Inputs according to the measured data. If the change cannot be realized due to the limitation of Athena, assumption might need to be made, which is introduced in *4.3 Data Quality*.

Data adjustment and substitutions, which is mentioned in *4.0 Environmental Data* is another used in this study for improvement action.

6.3 Bill of Materials

(Reference flows are measuring of the outputs from processes in a given product system required to fulfill the function expressed by the functional unit)

The tables below list the Bill of Materials of the Wesbrook building, and each Level 3 Element. These results come from Athena Impact Estimator.

Material	Quantity	Unit
1/2" Regular Gypsum Board	22124.0423	m2
3 mil Polyethylene	2841.6794	m2
5/8" Regular Gypsum Board	10069.9441	m2
6 mil Polyethylene	2592.7768	m2
Aluminum	41.2462	Tonnes
Concrete 20 MPa (flyash av)	3928.3615	m3
Concrete 30 MPa (flyash av)	1203.2427	m3
Double Glazed No Coating Air	1167.0896	m2
EPDM membrane (black, 60 mil)	1662.2419	kg
Galvanized Decking	1.7104	Tonnes

Glazing Panel	0.9126	Tonnes
Joint Compound	10.0500	Tonnes
Metric Modular (Modular) Brick	10788.7329	m2
Mortar	638.4939	m3
Nails	1.9963	Tonnes
Open Web Joists	3.1079	Tonnes
Paper Tape	0.1153	Tonnes
Precast Concrete	228.9053	m3
Rebar, Rod, Light Sections	504.9637	Tonnes
Roofing Asphalt	19925.4280	kg
Small Dimension Softwood Lumber, kiln-dried	17.2627	m3
Stucco over porous surface	41.5160	m2
Water Based Latex Paint	159.9846	L
Welded Wire Mesh / Ladder Wire	5.1651	Tonnes

Table.5 BOM of The Wesbrook building

Material	Quantity	Unit
Concrete 20 MPa (flyash av)	340.1019	m3
Rebar, Rod, Light Sections	7.5603	Tonnes

Table.6 BOM of A11 Foundations

Material	Quantity	Unit
5/8" Regular Gypsum Board	2688.5883	m2
6 mil Polyethylene	2592.7768	m2
Concrete 20 MPa (flyash av)	263.1816	m3
Joint Compound	2.6833	Tonnes
Nails	0.0252	Tonnes
Paper Tape	0.0308	Tonnes
Welded Wire Mesh / Ladder Wire	2.2652	Tonnes

Table.7 BOM of A21 Lowest Floor Construction

Material	Quantity	Unit
5/8" Regular Gypsum Board	7382.9979	m2
Concrete 20 MPa (flyash av)	2180.0318	m3
Concrete 30 MPa (flyash av)	759.2233	m3

Joint Compound	7.3684	Tonnes
Nails	0.0691	Tonnes
Paper Tape	0.0846	Tonnes
Rebar, Rod, Light Sections	362.7570	Tonnes
Stucco over porous surface	66.4257	m2
Water Based Latex Paint	7.1450	L

Table.8 BOM of A22 Upper Floor Construction

Material	Quantity	Unit
3 mil Polyethylene	2746.0402	m2
Concrete 20 MPa (flyash av)	66.1845	m3
Concrete 30 MPa (flyash av)	444.0193	m3
Galvanized Decking	1.7104	Tonnes
Open Web Joists	3.1079	Tonnes
Precast Concrete	228.9053	m3
Rebar, Rod, Light Sections	109.2438	Tonnes
Roofing Asphalt	19925.4280	kg
Welded Wire Mesh / Ladder Wire	2.9000	Tonnes

Table.9 BOM of A23 Roof Construction

Material	Quantity	Unit
3 mil Polyethylene	106.8324	m2
Aluminum	7.0702	Tonnes
Concrete 20 MPa (flyash av)	243.9246	m3
Double Glazed No Coating Air	156.9136	m2
EPDM membrane (black, 60 mil)	286.9696	kg
Nails	0.2474	Tonnes
Rebar, Rod, Light Sections	6.0027	Tonnes

Table.10 BOM of A31 Walls Below Grade

Material	Quantity	Unit
1/2" Regular Gypsum Board	22124.0423	m2
3 mil Polyethylene	146.0038	m2
Aluminum	34.1760	Tonnes
Concrete 20 MPa (flyash av)	404.7424	m3

Double Glazed No Coating Air	1010.1760	m2
EPDM membrane (black, 60 mil)	1375.2722	kg
Glazing Panel	0.9126	Tonnes
Metric Modular (Modular) Brick	10788.7329	m2
Mortar	638.4939	m3
Nails	1.3552	Tonnes
Rebar, Rod, Light Sections	12.8220	Tonnes
Small Dimension Softwood Lumber, kiln-dried	5.3654	m3
Water Based Latex Paint	48.3370	L

Table.11 BOM of A32 Walls Above Grade

Material	Quantity	Unit
Concrete 20 MPa (flyash av)	340.6919	m3
Nails	0.2994	Tonnes
Rebar, Rod, Light Sections	11.5315	Tonnes
Small Dimension Softwood Lumber, kiln-dried	11.8973	m3
Water Based Latex Paint	107.1820	L

Table.12 BOM of B11 Partitions

7.0 Communication of Assessment Results

7.1 Results of impact categories

The figures below make comparisons of the environmental impacts, which caused by the seven impact categories, between product stage and construction process stage.

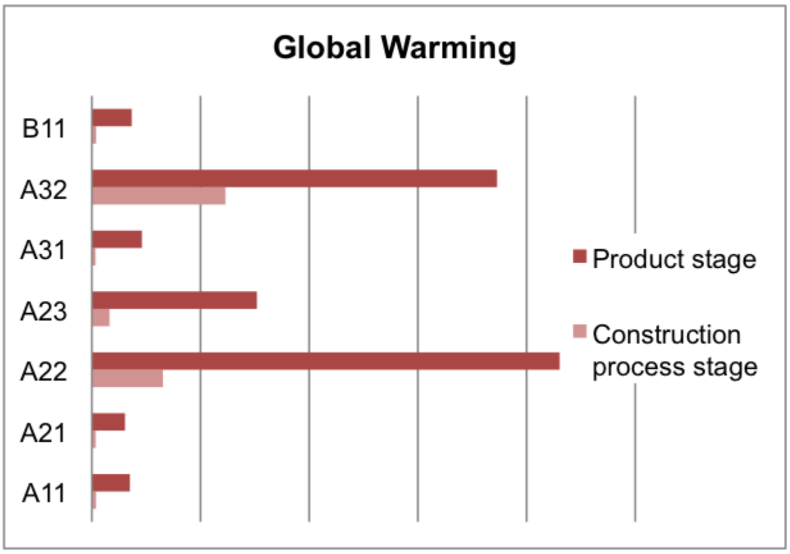


Figure 21 Comparison of Global warming

As mentioned above, Global Warming consists of the biggest impact in this study. From Figure 21, it shows that in these two stages, product stage has a significant higher Global warming impact. At the same time, among these Level 3 Elements, A22, A23 and A32 occupy large parts of the impact.

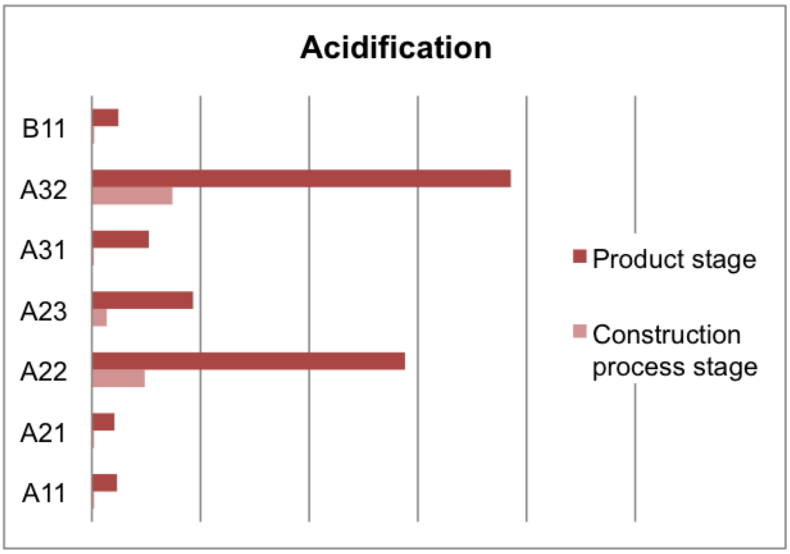


Figure 22 Comparison of Acidification

From Figure 22, it shows that in these two stages, product stage has a significant higher Acidification impact. At the same time, among these Level 3 Elements, A22 and A32 occupy large parts of the impact.

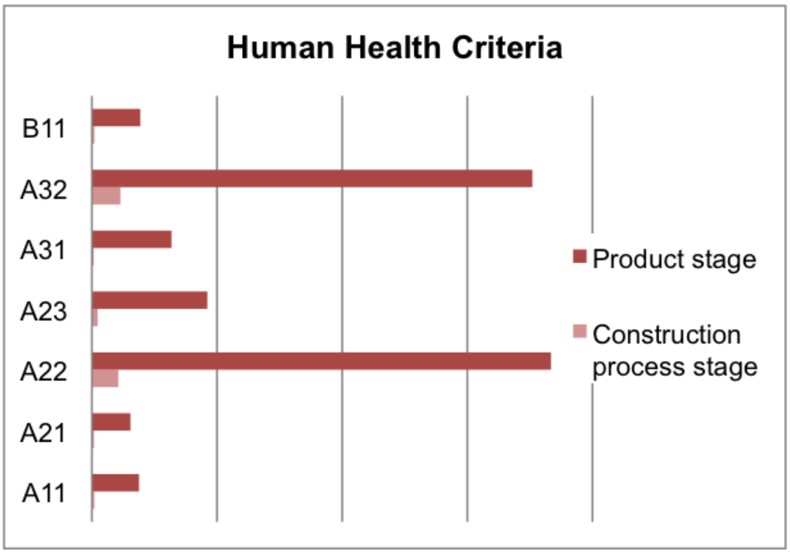


Figure 23 Comparison of Human health criteria

From Figure 23, it shows that in these two stages, product stage has a significant higher Human health criteria impact. At the same time, among these Level 3 Elements, A22 and A32 occupy large parts of the impact.

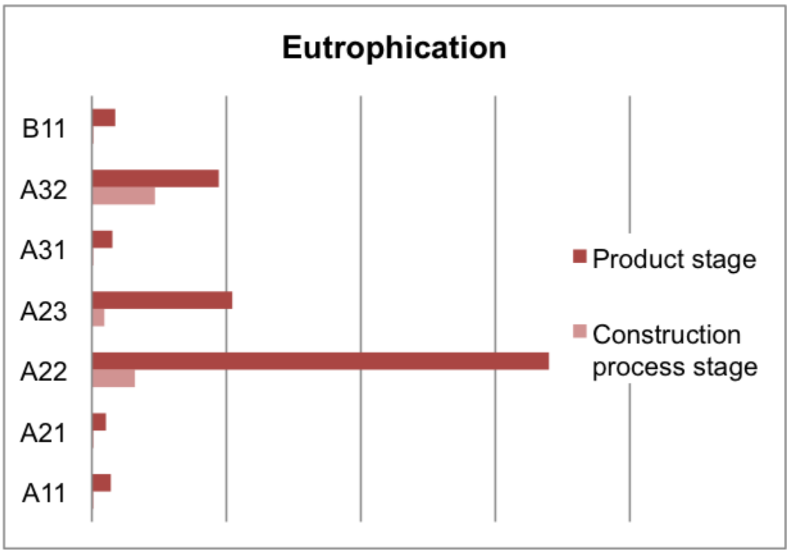


Figure 24 Comparison of Eutrophication

From Figure 24, it shows that in these two stages, product stage has a relative higher Eutrophication impact. At the same time, among these Level 3 Elements, A23 and A32 occupy large parts of the impact.

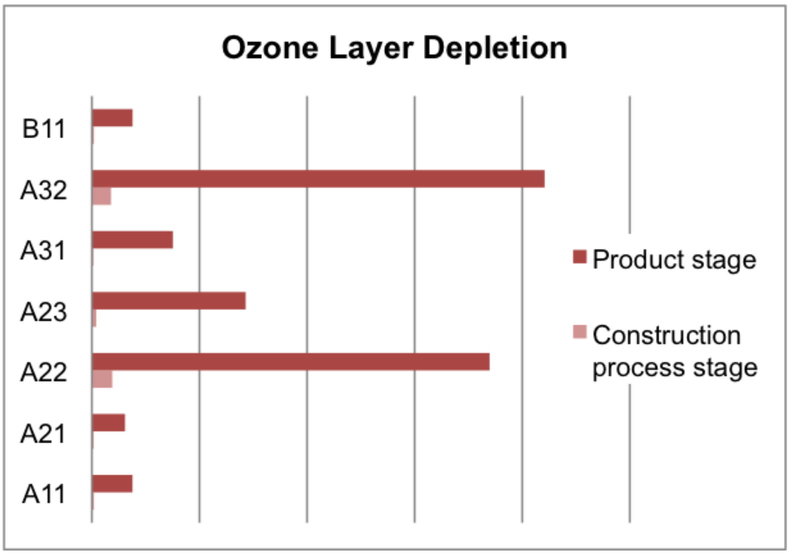


Figure 25 Comparison of Ozone depletion potential

From Figure 25, it shows that in these two stages, product stage has a significant higher Ozone layer depletion impact. At the same time, among these Level 3 Elements, A22, A23 and A32 occupy large parts of the impact.

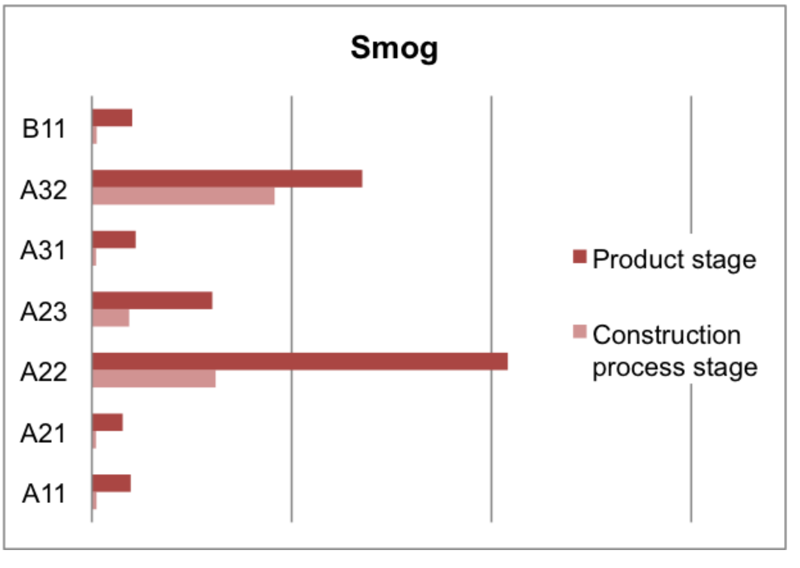


Figure 26 Comparison of Smog

From Figure 26, it shows that in these two stages, product stage has a relative higher Smog impact. At the same time, among these Level 3 Elements, A23 and A32 occupy large parts of the impact.

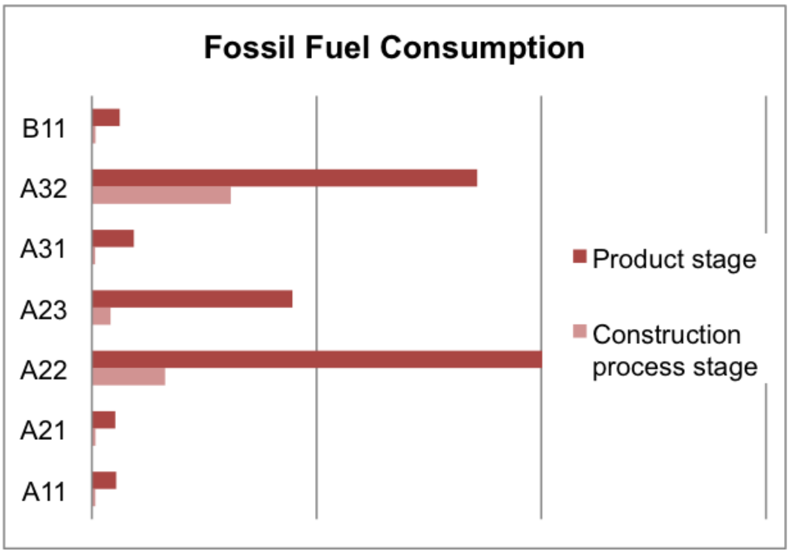


Figure 27 Comparison of Fossil fuel consumption

From Figure 27, it shows that in these two stages, product stage has a relative higher Fossil fuel consumption impact. At the same time, among these Level 3 Elements, A23 and A32 occupy large parts of the impact.

7.2 Impact hotspots for Level 3 Elements

The figures below indication the percentage of impact caused by different structure components in Level 3 Elements. Red square highlight the hotspot for each Level 3 Elements. Hotspot is assumed to be the component, which has a higher impact percentage.

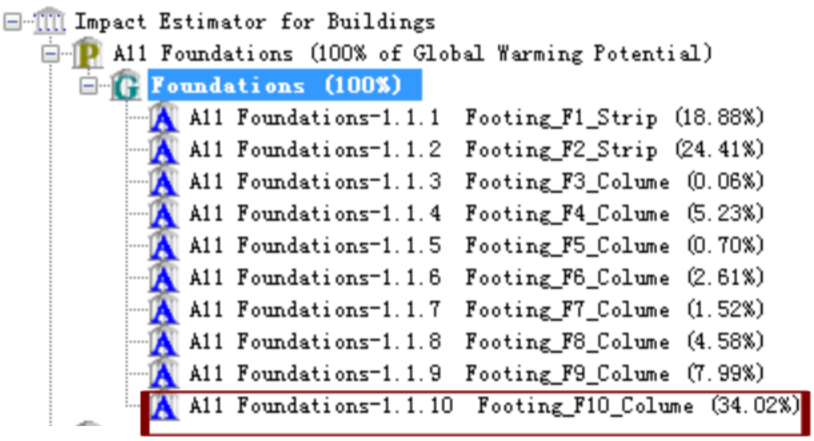


Figure 28 Hotspot of A11 Foundations

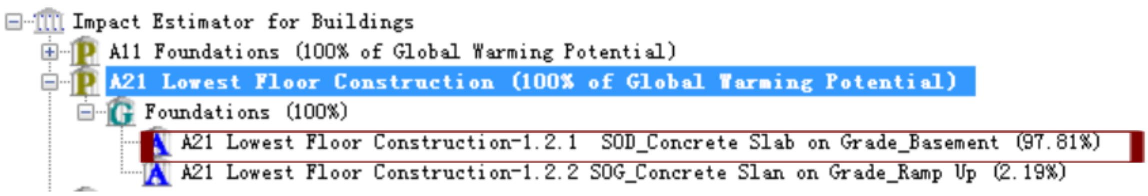


Figure 29 Hotspot of A21 Lowest Floor Construction

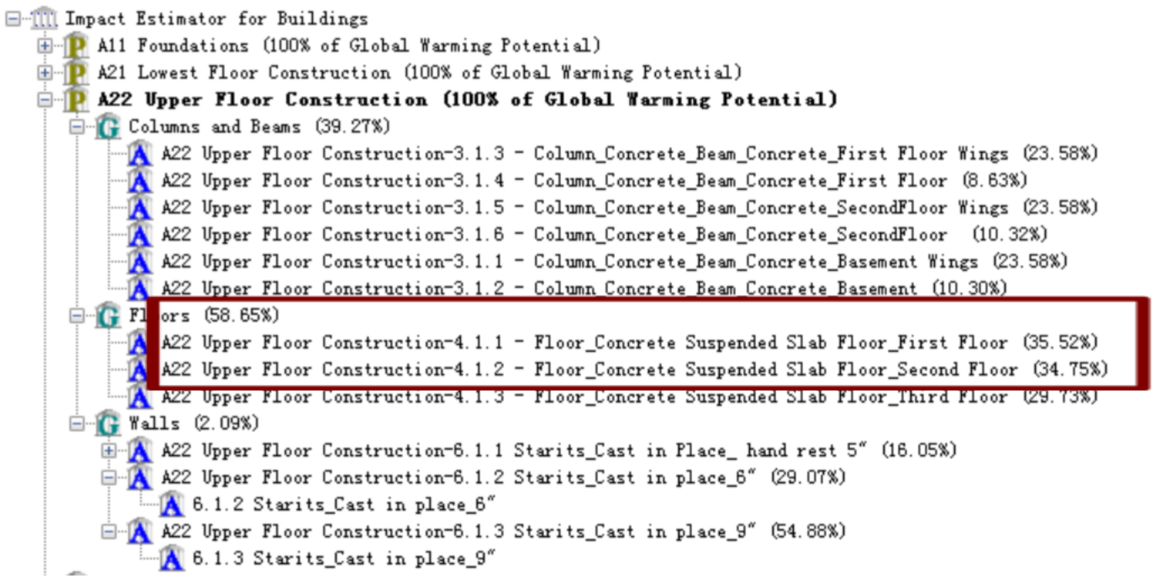


Figure 30 Hotspot of A22 Upper Floor Construction

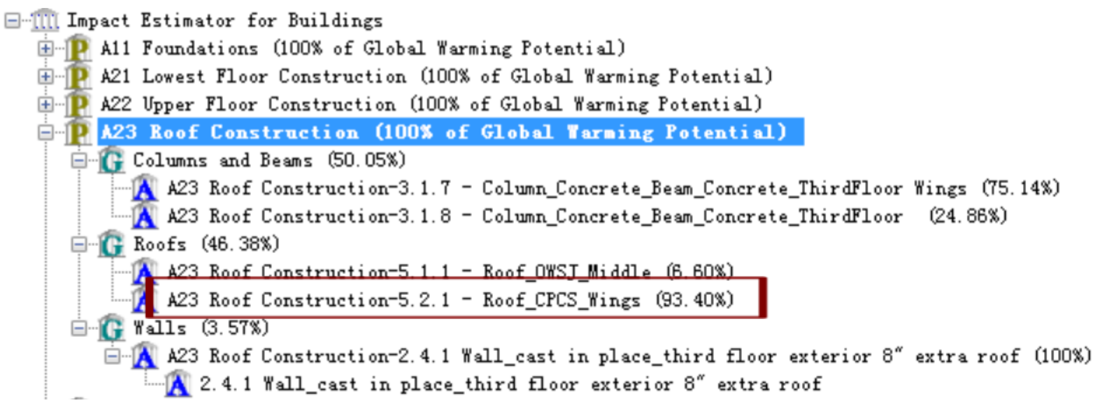


Figure 31 Hotspot of A23 Roof Construction

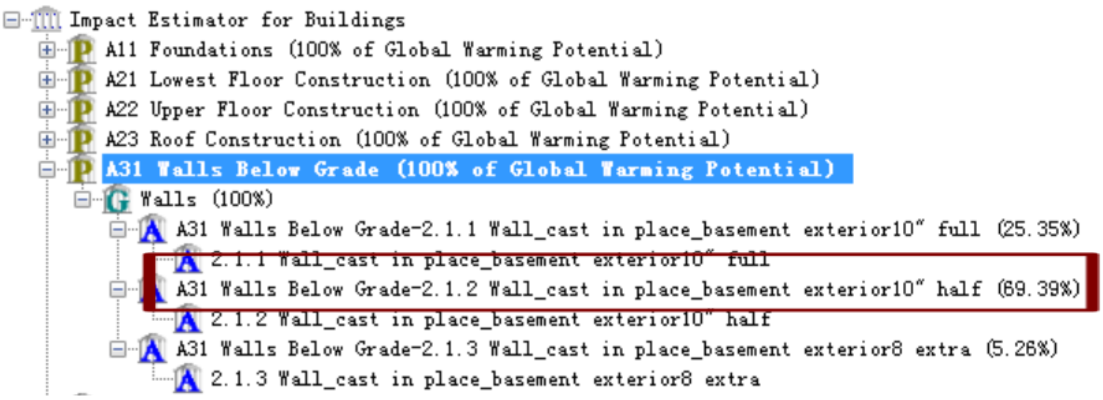


Figure 32 Hotspot of A31 Walls Below Grade

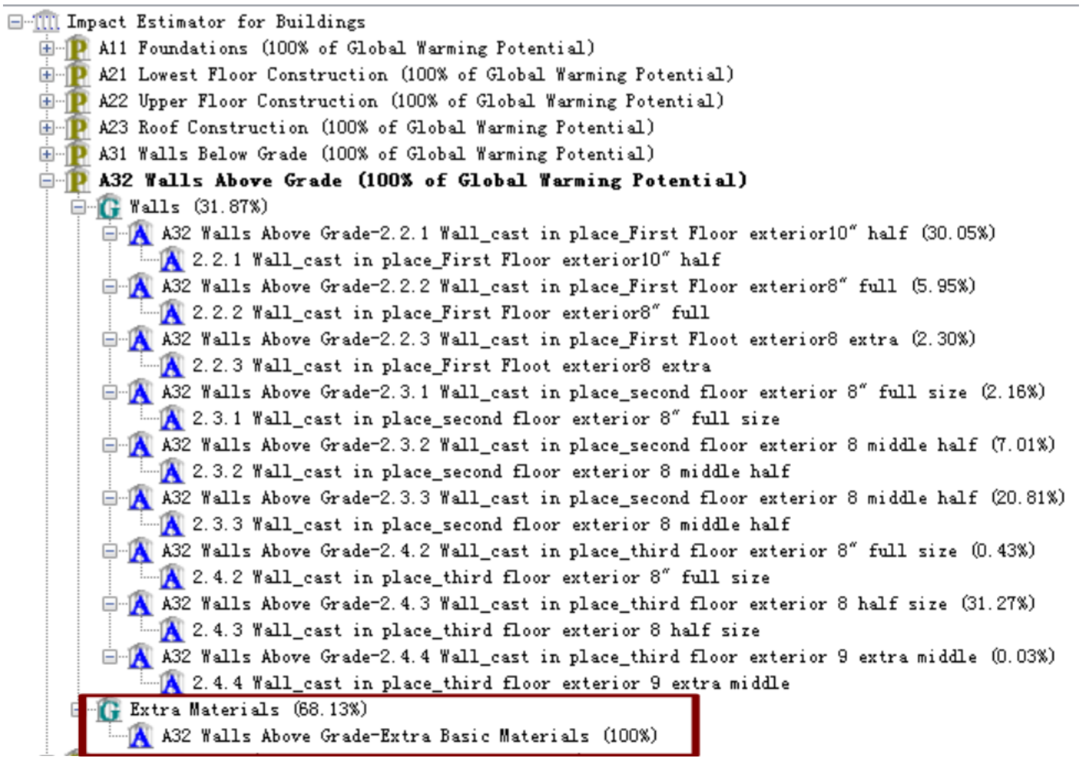
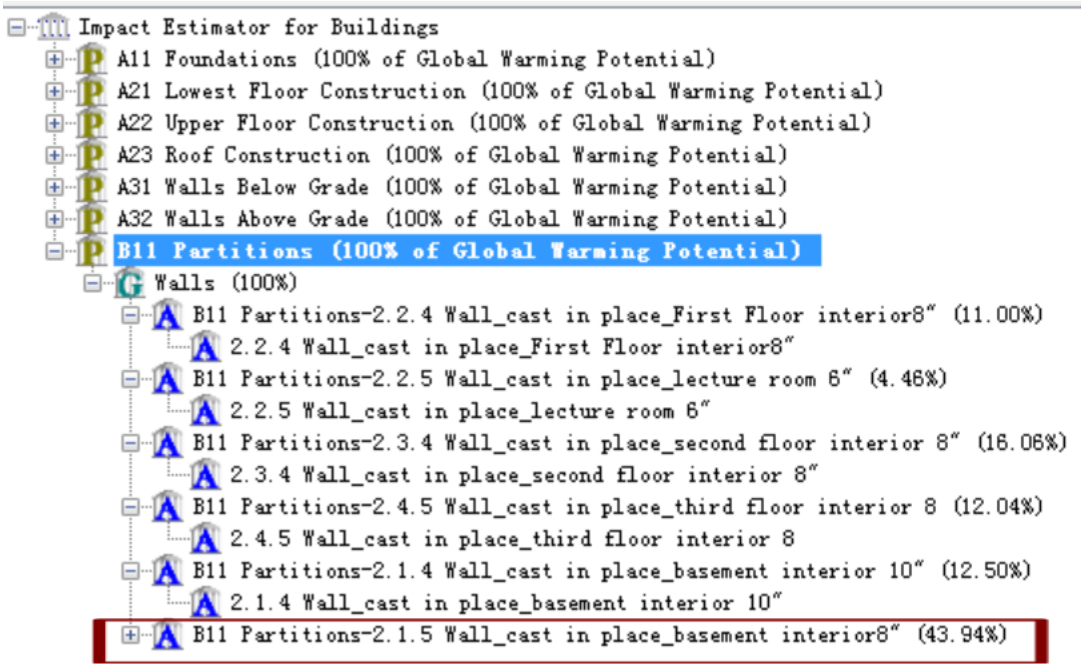


Figure 33 Hotspot of A32 Walls Above Grade



Fi

gure 34 Hotspot of B11 Partitions

7.3 Application of Functional units

Impact Categories & Process Modules	Manufacturing	Transport	Construction-installation Process	Transport	Total
Fossil Fuel Consumption (MJ)	24769151.58	935947.9129	1740841.849	3230143.109	30676084.45
Global Warming (Kg CO2eq)	2163221.562	57774.58273	159690.8828	247195.0683	2627882.096
Acidification (Moles of H+eq)	17500.21799	345.902217	1306.106347	1148.683291	20300.90985
Human Health Criteria – Respiratory (Kg PM10eq)	4947.404187	9.820828022	234.3961779	35.53848179	5227.159675
Eutrophication (Kg Neq)	1165.343024	24.28175297	73.87690621	82.85702951	1346.358713
Ozone Layer Depletion (Kg CFC-11eq)	0.011246767	0.000002347	0.000470103	9.86E-06	0.011729072
Smog (Kg O3eq)	230440.2692	12244.73749	34283.84294	40618.27515	317587.1248
Total Impacts of each process	27186426.39	1006347.238	1936430.955	3519223.531	33648428.11
Impacts / building total area (9170 m2)	2800	104	199	362	3465

Table.13 Impact / Building gross area

The Table-2 indicates how these environmental impacts distribute on the four process modules, as well as the total impacts on each square meter of the Wesbrook building. Comparisons can be made among these process modules within this building, or with the other buildings, which use the similar modules.

Impact Categories	Functional Spaces	Classrooms	Office Spaces	Testing labs	Library	Study/Research/ Prep/Computer lab rooms	Storage rooms	Stairwells/Halls/ Atriums	Washrooms/ Locker rooms	Mechanical rooms	Auditorium/ Lecture Halls
	Total Impacts	19.19%	15.86%	13.29%	3.28%	18.80%	7.82%	4.92%	7.85%	4.49%	4.49%
Fossil Fuel Consumption (MJ)	30676084.5	5886741	4865227	4076851.6	1006176	5767103.877	2398870	1509263.355	2408073	1377356	1377356.2
Global Warming (Kg CO2eq)	2627882.1	504290.6	416782	349245.53	86194.53	494041.834	205500.4	129291.7991	206288.7	117991.9	117991.91
Acidification (Moles of H+eq)	20300.9099	3895.745	3219.72	2697.9909	665.8698	3816.571052	1587.531	998.8047646	1593.621	911.5109	911.51085
Human Health Criteria – Respiratory (Kg PM10eq)	5227.15968	1003.092	829.028	694.68952	171.4508	982.7060189	408.7639	257.176256	410.332	234.6995	234.69947
Eutrophication (Kg Neq)	1346.35871	258.3662	213.532	-178.9311	44.16057	253.115438	105.2853	66.24084868	105.6892	60.45151	60.451506
Ozone Layer Depletion (Kg CFC-11eq)	0.01172907	0.002251	0.00186	0.0015588	0.000385	0.002205066	0.000917	0.00057707	0.000921	0.000527	0.0005266
Smog (Kg O3eq)	317587.125	60944.97	50369.3	42207.329	10416.86	59706.37946	24835.31	15625.28654	24930.59	14259.66	14259.662
Total Impacts / functional spaces		6457133	5336641	4471518.2	1103668	6325904.485	2631307	1655502.663	2641402	1510814	1510814.4

<u>Table.14 Impact / Each function space</u>

The Table-3 shows how the total environmental impacts distribute on different categories, as well as the impacts on each functional space of the Wesbrook building. Comparisons can be made among these functional spaces within this building, or with the other buildings, which have the similar functional spaces.

Reference

- Previous report of the Wesbrook building
- Wikimapia: http://wikimapia.org/1911804/Wesbrook-Building
- CIVL529 Class notes
- Athena LCI Database: http://www.athenasmi.org/our-software-data/lca-databases/
- US LCI Database: http://www.nrel.gov/lci/
- CIVL 498C Class notes

Annex A – Interpretation of Assessment Results

A.1 Benchmark Development

Benchmarking in LCA is made up of a series of average results from the analysis of a numbers of buildings with similar functions. Based on benchmarking, students can make comparison between the data in a typical building and the average results, and then evaluation of that building can be realized.

In order to create a benchmarking, collection of data should start at the beginning, any change of the data, which is enrolled in benchmarking, will lead to the change of the total benchmarking. In this LCA study, as students keep on updating their data, the benchmark is changing all the time.

A.2 UBC Academic Building Benchmark

A.2.1 Results of comparison with class benchmark

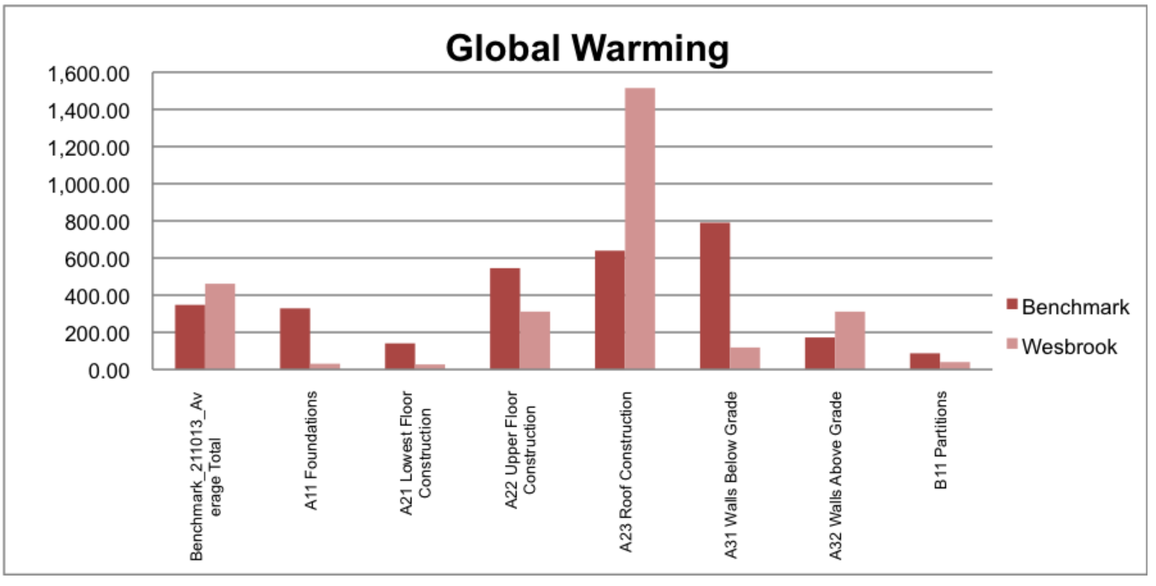


Figure 35 Global warming Comparison

The comparison between the Wsebrook building and class benchmark indicates that the Wsebrook building has a little higher global warming impact than the benchmark, especially Level 3 Elements - A23, the impact caused by it is twice than the average.

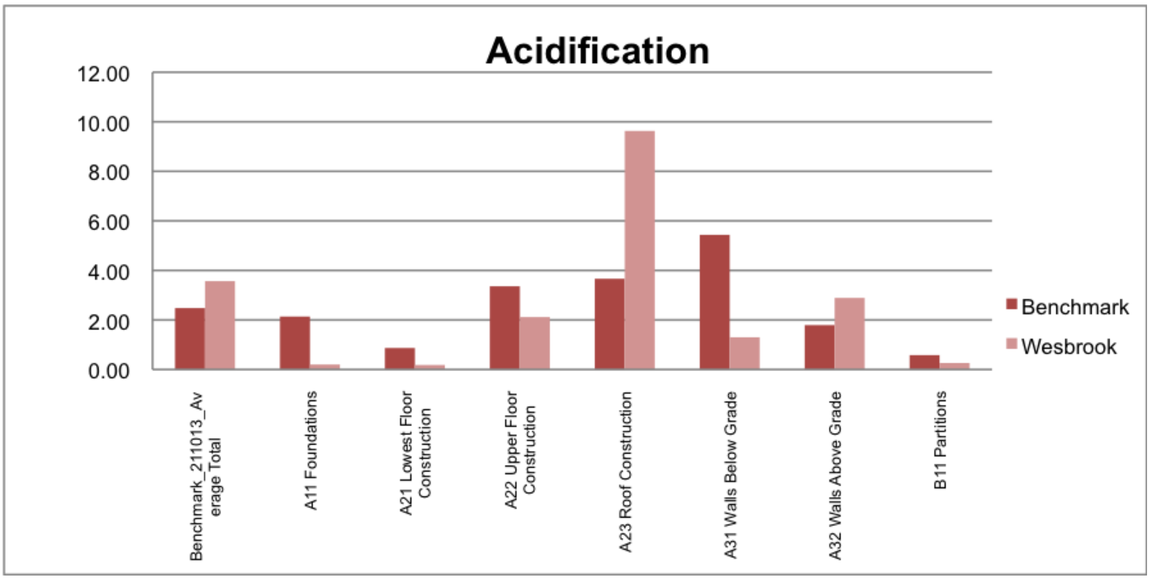


Figure 36 Acidification Comparison

The comparison between the Wsebrook building and class benchmark indicates that the Wsebrook building has a little higher acidification impact than the benchmark. Level 3 Elements - A23 and A32 contribute most to this impact.

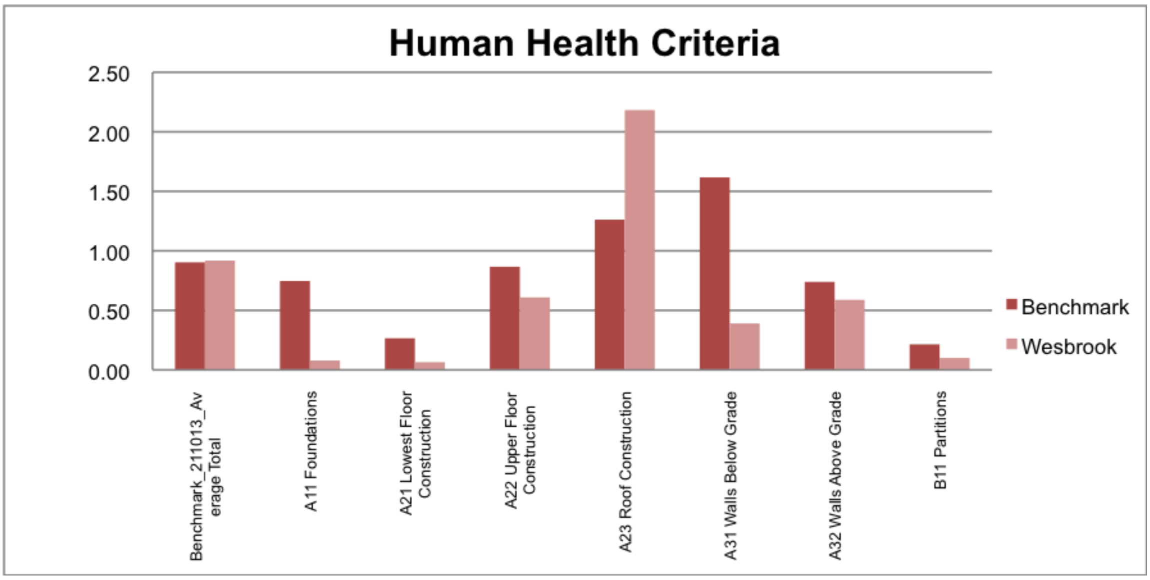


Figure 37 Human health criteria Comparison

The comparison between the Wsebrook building and class benchmark indicates that the Wsebrook building has a same human health criteria impact with the benchmark. However, Level 3 Elements - A23 still has a higher impact.

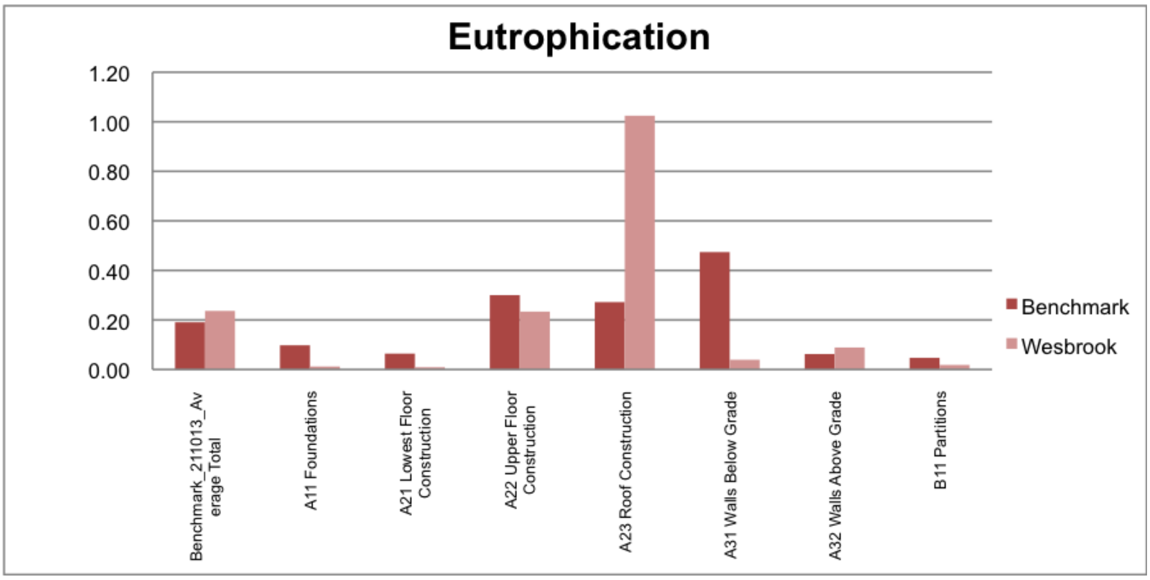


Figure 38 Eutrophication Comparison

The comparison between the Wsebrook building and class benchmark indicates that the Wsebrook building has a little higher eutrophication impact than the benchmark. Level 3 Elements - A23 still made a big amount of impact.

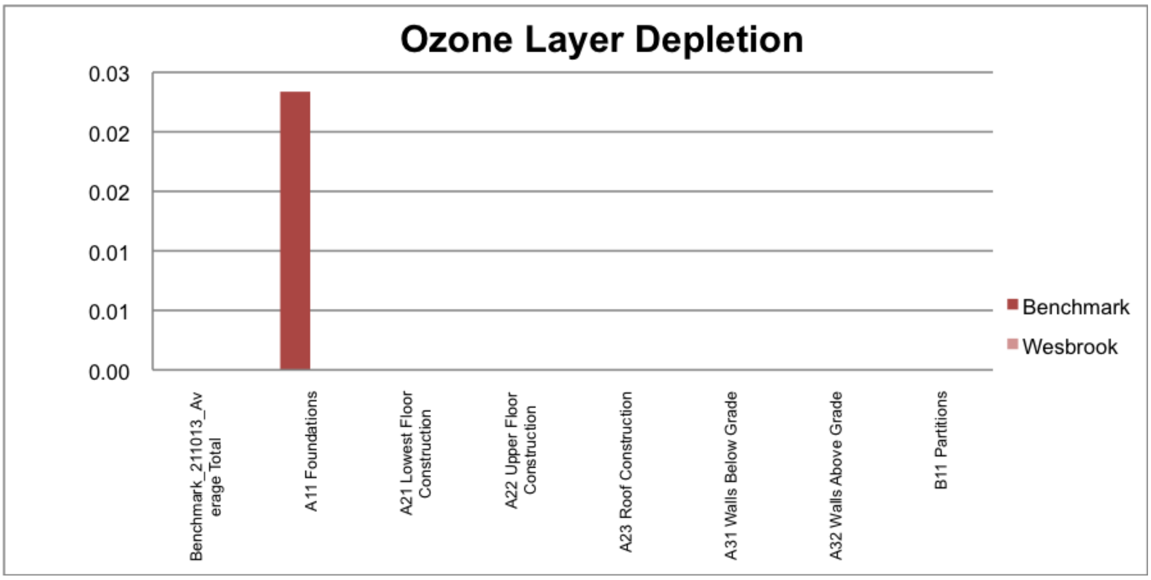


Figure 39 Ozone layer Comparison

The data of ozone layer depletion is quite small, which is quite difficult to point out, so that little comparison can be made in this part.

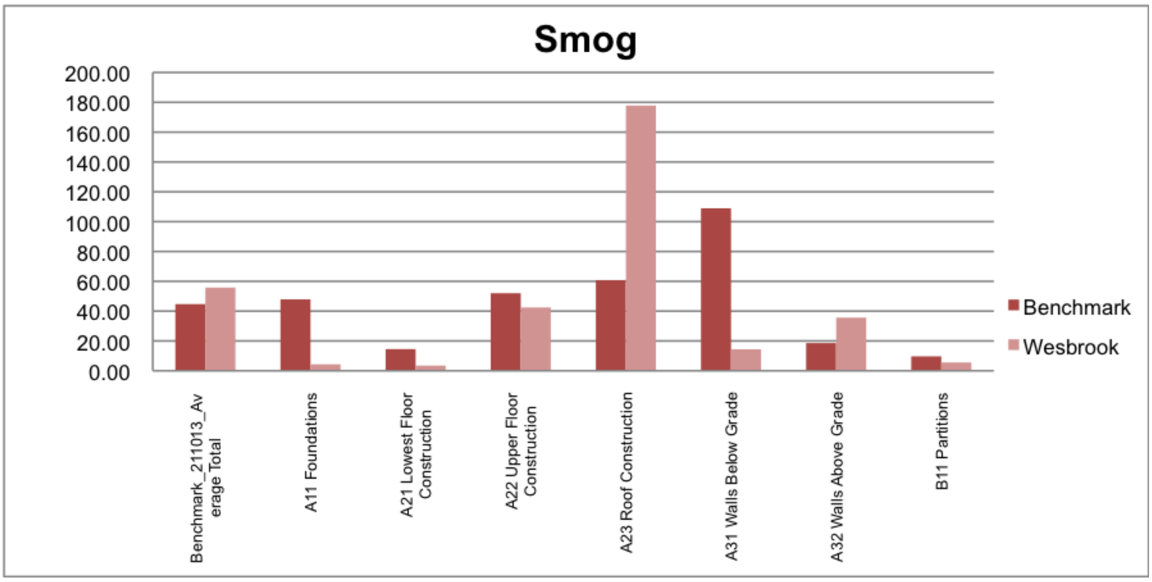


Figure 40 Smog Comparison

The comparison between the Wsebrook building and class benchmark indicates that the Wsebrook building has a little higher smog impact than the benchmark. Level 3 Elements - A23 still made a big amount of impact.

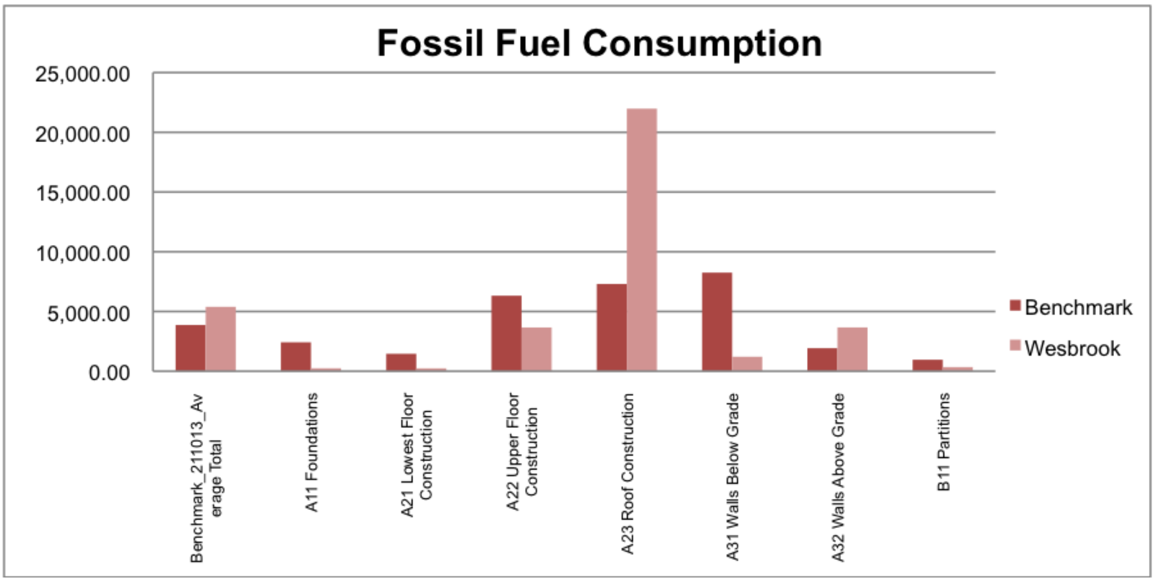


Figure 41 Fossil fuel consumption Comparison

The comparison between the Wsebrook building and class benchmark indicates that the Wsebrook building has a little higher fossil fuel consumption impact than the benchmark. Level 3 Elements - A23 still made a big amount of impact, as well as A32.

A.2.2 Results of comparison with the other buildings

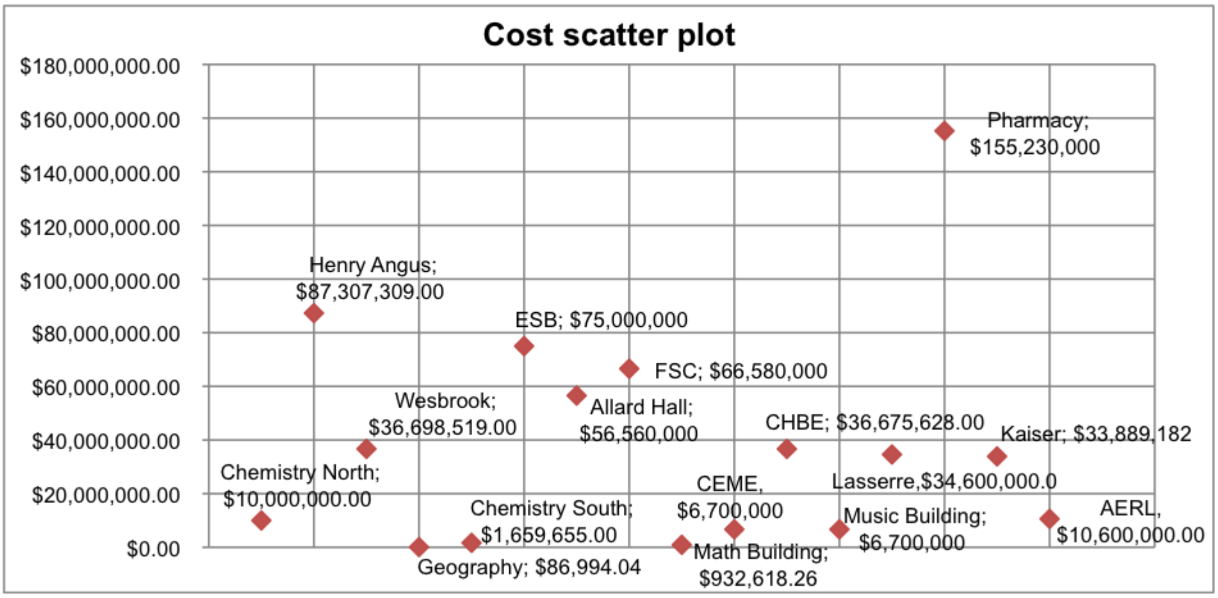


Figure 42 Cost scatter plots

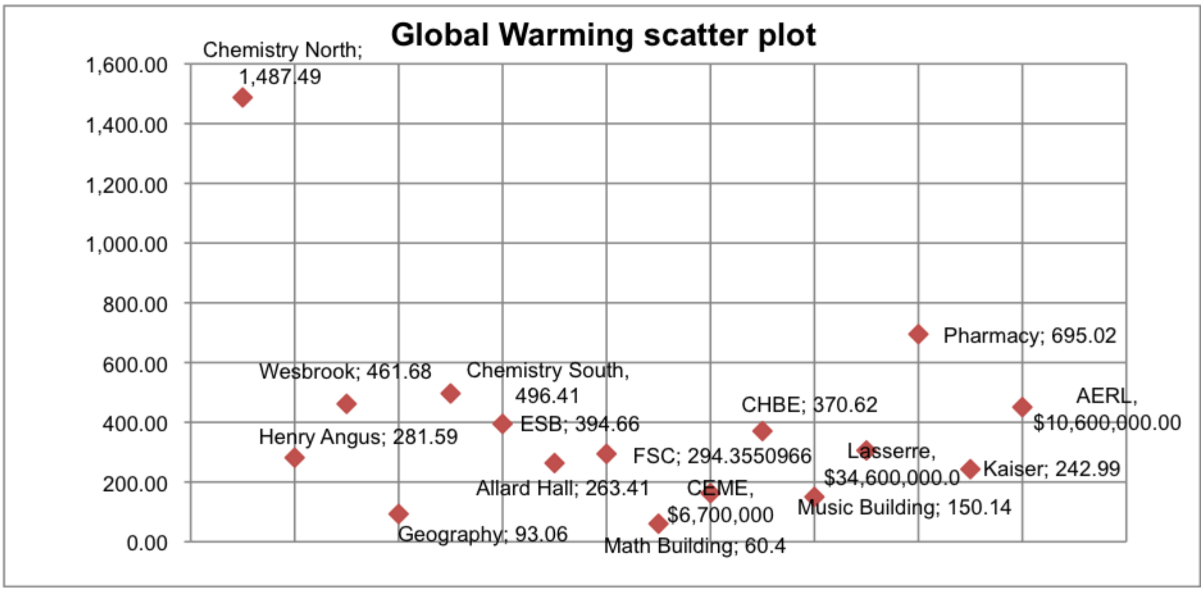


Figure 43 Global warming scatter plots

The Figure 42 and 43 show that, among the 16 buildings, the Wesbook building is on the 5th rank of cost, similar with CHBE. For the global warming potential impacts, it ranks 5th as will, almost same with Pharmacy building. Generally, these two figures indicate that the higher cost, the higher global warming impact.

Annex B – Recommendation for LCA Use

The product and construction stages are a short period compared with duration of building using. Through the use of building, environmental impact might come from a variety of aspects, in terms of mechanical systems use, water resources use, energy consumption, and the occupant in the building will also create environmental impacts. All of them happen in a long term. Module A can be chose as the start point of LCA, however, once it is done, the other modules should catch up to fulfill the results.

LCA is a good method for early decision-making, which is quite important to the development of a building. It can help designer choose better material to reduce the environmental impact. For example, during the reaction of concrete manufacturing, adding fly ash can reduce the water requirement and the heat emission. However, different percentages of fly ash will lead to different results. The excessive use of it might bring damage to the structure of concrete. In Athena, we can compare the outputs of different amount of fly ash and get the optimal choice.

In this LCA study, because of the long history of the Wesbrook building, parts of the data were missing, so that, assumption has to be made. At the same time, all the drawings of this building are hand drawings, measurement cannot reach that detail. Both of these factors will affect the accuracy of LCA result. Furthermore, the data and models are handled by two authors in different time. Lack of communication between them might lead to the misunderstanding for parts of the information.

There is no doubt that GWP is the priority impact, due to the tremendous emission of CO_2. Ozone layer depletion becomes more and more serious in today's society, since almost every family use refrigerate. Same situation happens on fossil fuel consumption, as the significant increasing vehicles. The impacts from AP and EP see not that close with people's daily life. Human health criteria and smog are few to be talked about. The categories could be divided according the endpoint of effect. For instance, impacts, which have directly effect on human health, could be combined together, other impacts, which might cause serious natural disaster could be put into one category.

Steps to operationalize LCA methods:

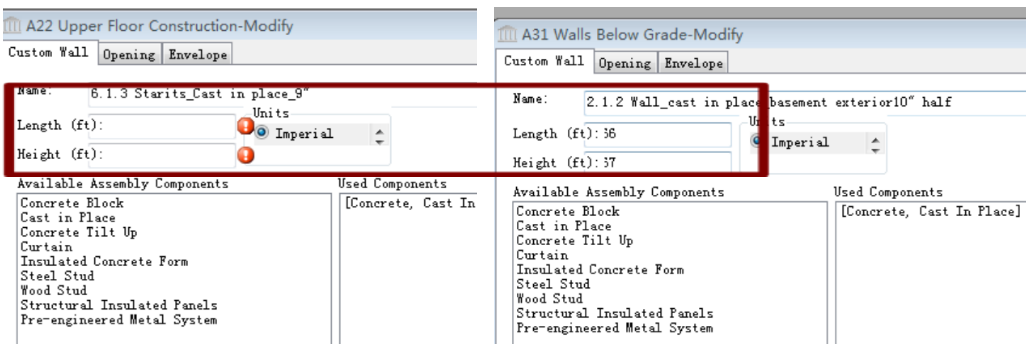
- Get familiar with all the drawings, in terms of size, function, and space etc. of the building.
- Make sure the goal and scope of this LCA study.
- Collect and sort the data.
- Analysis and classify the environmental impacts which might be caused by this building.
- Enter all the inputs into Athena, base on the impact categories to make assessment.
- Conclude all the results.

Annex C – Author Reflection

I'm taking a course called Sustainable Building Science Program (SBSP) Topic this semester, which has some similar topics with this course, we also analysis the LCA of CIRS building in that course. In this course, history and current state of LCA, structure of LCA, development of a whole building LCA study and uncertainty in LCA are introduced.

I'm so glad that through this course and the final project I have a deeper understanding of LCA. More and more people talk about LCA now, after this course, I think I can join them, talk about it, instead of being a listener. Since my background is architecture, I'll try to combine LCA with my future architecture design.

The part interested me in this final project is the "cause/effect chain" of the impact categories, which help me get a better understanding the environmental impacts. Not only in this final project, but also in my future study, I can utilize that knowledge. Furthermore, I learned the different methods used for impact assessment from this report, as well as the interesting software. However, I met a small problem during using Athena, I put the picture below to show the issue. I'm not sure whether it caused by the display of my laptop, or it is the software's problem.



(The display of these two boxes is overlapping, so that I cannot check the data after I entering into it, and I'm worried if it affects the final outputs. This problem happened on 50% of my input elements.)

CEAB Graduate Attributes

	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.	IA = introduced & applied	
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	DA = developed & applied	

		data, and synthesis of information in order to reach valid conclusions.		
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 considerations.	IDA = introduced, developed & applied	When meeting some complex problems, I'd like to get familiar with them first, try to find the order inside them, classify them into small categories, in order to make them simple. Then, I'll find my own way to rebuild the categories.
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.	DA = developed & applied	
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.	IA = introduced & applied	

10	Ethics and Equity	An ability to apply professional ethics, accountability, and equity.	IDA = introduced, developed & applied	At this part, I think I always try my best to observe the rule.
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.	DA = developed & 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 knowledge.	IA = introduced & applied	

Annex D – Impact Estimator Inputs and Assumptions

General Description

Project Name:	Wesbrook
Project Location:	Vancouver
Gross square (square ft):	98705
Building Life Expectancy:	1 year
Building Type:	Intitutional
Operating Energy Consumption:	TBA

Assembly Group	Assembly Type	Assembly Name	Input Fields	Input Values	
				Known/Measured	IE Inputs
A11 Foundations					
	1.1 Concrete Footing				
		1.1.1 Footing_F1_Strip			
			Length (ft)	1841	1841
			Width (ft)	1	1
			Thickness (in)	12"	12"
			Concrete (psi)	2500	3000
			Concrete flyash %	-	Average
			Rebar	-	#6
		1.1.2 Footing_F2_Strip			
			Length (ft)	718.5	718.5
			Width (ft)	2'7"	2'7"
			Thickness (in)	18"	18"
			Concrete (psi)	2500	3000
			Concrete flyash %	-	average
			Rebar	-	#6
		1.1.3 Footing_F3_Column			
			Length (ft)	2.83	2.83
			Width (ft)	2.83	2.83
			Thickness (in)	10"	10"
			Concrete (psi)	2500	3000
			Concrete flyash %	-	average
			Rebar	-	#6
		1.1.4 Footing_F4_Column			
			Length (ft)	22.4	22.4
			Width (ft)	22.4	22.4
			Thickness (in)	15"	15"
			Concrete (psi)	2500	3000
			Concrete flyash %	-	average

		Rebar	-	#6
	1.1.5 Footing_F5_Column			
		Length (ft)	7.1	7.1
		Width (ft)	7.1	7.1
		Thickness (in)	21"	19.7"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#6
	1.1.6 Footing_F6_Column			
		Length (ft)	13.8	13.8
		Width (ft)	13.8	13.8
		Thickness (in)	24"	19.7"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#6
	1.1.7 Footing_F7_Column			
		Length (ft)	10.5	10.5
		Width (ft)	10.5	10.5
		Thickness (in)	27"	19.7"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#6
	1.1.8 Footing_F8_Column			
		Length (ft)	18.3	18.3
		Width (ft)	18.3	18.3
		Thickness (in)	30"	19.7"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#6
	1.1.9 Footing_F9_Column			
		Length (ft)	24.2	24.2
		Width (ft)	24.2	24.2
		Thickness (in)	33"	19.7"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#6
	1.1.10 Footing_F10_Column			
		Length (ft)	50	50
		Width (ft)	50	50
		Thickness (in)	38"	19.7"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average

		Rebar	-	#6
A21 Lowest Floor Construction				
	2.1 Concrete Slab-on-Grade			
	2.1.1 SOD_Concrete Slab on Grade_Basement			
	Envelope	Length (ft)	162.2	162.2
		Width (ft)	162.2	162.2
		Thickness (in)	4"	4"
		Concrete (psi)	2500	3000
		Concrete flyash %	average	average
		Category	Gypsum Board	Gypsum Board
		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
		Thickness (in)	-	-
		Category	Vapour Barrier	Vapour Barrier
		Material	Polyethylene 6 mil	Polyethylene 6 mil
		Thickness (in)	-	-
	2.1.2 SOG_Concrete Slab on Grade_Ramp Up			
	Envelope	Length (ft)	25.9	25.9
		Width (ft)	25.9	25.9
		Thickness (in)	4"	4"
		Concrete (psi)	2500	3000
		Concrete flyash %	average	average
		Category	-	-
		Material		-
		Thickness (in)	-	-
A22 Upper Floor Construction				
	3.1 Columns and Beams			
	3.1.1 - Column_Concrete_Beam_Concrete_Basement Wings			
		Number of Columns	44	44
		Number of Beams	20	20
		Floor to Floor Height (ft)	12'6"	12'6"
		Bay Sizes (ft)	24.5	24.5
		Supported Span	25	25
		Live Load (psf)	100	100
	3.1.2 - Column_Concrete_Beam_Concrete_Basement			
		Number of Columns	61	61
		Number of Beams	20	20

		Floor to Floor Height (ft)	12'6"	12'6"
		Bay Sizes (ft)	16.7	16.7
		Supported Span	16.7	16.7
		Live Load (psf)	100	100
	3.1.3 - Column_Concrete_Beam_Concrete_First Floor Wings			
		Number of Columns	44	44
		Number of Beams	20	20
		Floor to Floor Height (ft)	12'6"	12'6"
		Bay Sizes (ft)	24.5	24.5
		Supported Span	25	25
		Live Load (psf)	100	100
	3.1.4 - Column_Concrete_Beam_Concrete_First Floor			
		Number of Columns	56	56
		Number of Beams	20	20
		Floor to Floor Height (ft)	12'6"	12'6"
		Bay Sizes (ft)	16	16
		Supported Span	16	16
		Live Load (psf)	100	100
	3.1.5 - Column_Concrete_Beam_Concrete_SecondFloor Wings			
		Number of Columns	44	44
		Number of Beams	20	20
		Floor to Floor Height (ft)	12'6"	12'6"
		Bay Sizes (ft)	24.5	24.5
		Supported Span	25	25
		Live Load (psf)	100	100
	3.1.6 - Column_Concrete_Beam_Concrete_SecondFloor			
		Number of Columns	58	58
		Number of Beams	27	27
		Floor to Floor Height (ft)	12'6"	12'6"
		Bay Sizes (ft)	16.1	16.1
		Supported Span	16.1	16.1
		Live Load (psf)	100	100
3.2 Floor_ Concrete Suspended Slab Floor				
	3.2.1 - Floor_Concrete			

	Suspended Slab Floor_First Floor			
		Floor Width (ft)	51	788
		Span (ft)	479	31
		Concrete (psi)	2500	3000
		Live load (psf)	75	75
		Concrete Flyash %	average	average
		Category	Gypsum Board	Gypsum Board
		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
		Thickness (in)	-	-
	3.2.2 - Floor_Concrete Suspended Slab Floor_Second Floor			
		Floor Width (ft)	51	771
		Span (ft)	469	31
		Concrete (psi)	2500	3000
		Live load (psf)	75	75
		Concrete Flyash %	average	average
		Category	Gypsum Board	Gypsum Board
		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
		Thickness (in)	-	-
	4.1.3 - Floor_Concrete Suspended Slab Floor_Third Floor			
		Floor Width (ft)	51	659.7
		Span (ft)	401	31
		Concrete (psi)	2500	3000
		Live load (psf)	75	75
		Concrete Flyash %	average	average
		Category	Gypsum Board	Gypsum Board
		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
		Thickness (in)	-	-
3.3 Starirs_Cast in place				
	3.3.1 Starits_Cast in Place_ hand rest 5"			
		Length (ft)	200	200
		Height (ft)	3' 3"	3' 3"
		Thickness (in)	5"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
		Category	Cladding	Cladding
	Envelope	Material	Stucco - over porous surface	Stucco - over porous surface

		Thickness	0.1"	0.1"
	3.3.2 Starits_Cast in place_6"			
		Length (ft)	34.64	34.64
		Width (ft)	34.64	34.64
		Thickness (in)	6"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
	Envelope	Category	Gypsum Board	Gypsum Board
		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
		Thickness (in)	-	-
	3.3.3 Starits_Cast in place_9"			
		Length (ft)	47.6	47.6
		Width (ft)	47.6	47.6
		Thickness (in)	9"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
	Envelope	Category	Gypsum Board	Gypsum Board
		Material	Gypsum Regular 5/8"	Gypsum Regular 5/8"
		Thickness (in)	-	-
A23 Roof Construction				
4.1 Columns and Beams				
	4.1.1 - Column_Concrete_Beam_Concrete_ThirdFloor Wings			
		Number of Columns	58	58
		Number of Beams	28	28
		Floor to Floor Height (ft)	12'6"	12'6"
		Bay Sizes (ft)	24.5	24.5
		Supported Span	25	25
		Live Load (psf)	100	100
	4.1.2 - Column_Concrete_Beam_Concrete_ThirdFloor			
		Number of Columns	26	26
		Number of Beams	23	23
		Floor to Floor Height (ft)	12'6"	12'6"
		Bay Sizes (ft)	19	19
		Supported Span	19	19
		Live Load (psf)	100	100
4.2				

	Open Web Steel Joint Roof				
		4.2.1- Roof_OWSJ_Middle			
		Envelope	Roof Width (ft)	40	40
			Span (ft)	46.5	46.5
			Live load (psf)	75	75
			Decking Type	Open Web Steel Joint Roof	Open Web Steel Joint Roof
			Concrete Topping	With	With
			Category	Roof enlveopes	Roof enlveopes
			Material	Roof Asphalt	Roof Asphalt
			Thickness (in)	0.5"	0.5"
			Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 3 mil	Polyethylene 3 mil
			Thickness (in)	-	-
	4.3 Concrete Precast Concerete Slab				
		4.3.1 - Roof_CPCS_Wings			
		Envelope	Bay Size (ft)	24	24
			Span (ft)	22	22
			Number of Bays	46	46
			Live load (psf)	75	75
			Concrete Topping	With	With
			Category	Roof enlveopes	Roof enlveopes
			Material	Roof Asphalt	Roof Asphalt
			Thickness (in)	0.5"	0.5"
			Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 3 mil	Polyethylene 3 mil
			Thickness (in)	-	-
	4.4 Third Floor				
		4.4.1 Wall_cast in place_third floor exterior 8" extra roof			
			Length (ft)	858	858
			Height (ft)	2"	2"
			Thickness (in)	10"	12"
			Concrete (psi)	2500	3000
			Concrete flyash %	-	average
			Rebar	-	#5

		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 3 mil	Polyethylene 3 mil
			Thickness	-	-
A31 Walls Below Grade					
	5.1 Basement				
		5.1.1 Wall_cast in place_basement exterior10" full			
			Length (ft)	251	251
			Height (ft)	14'4"	14'4"
			Thickness (in)	10"	12"
			Concrete (psi)	2500	3000
			Concrete flyash %	-	average
			Rebar	-	#5
			Category	-	-
			Material	-	-
			Thickness	-	-
		5.1.2 Wall_cast in place_basement exterior10" half			
			Length (ft)	434	434
			Height (ft)	14' 4"	14' 4"
			Thickness (in)	10"	12"
			Concrete (psi)	2500	3000
			Concrete flyash %	-	average
			Rebar	-	#5
			Category	-	-
			Material	-	-
			Thickness	-	-
		5.1.3 Wall_cast in place_basement exterior8 extra			
			Length (ft)	406	406
			Height (ft)	2' 8"	2' 8"
			Thickness (in)	8"	8"
			Concrete (psi)	2500	3000
			Concrete flyash %	-	average
			Rebar	-	#5
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 3 mil	Polyethylene 3 mil
			Thickness	-	-
		Window	Number of Windows	131	131
			Total Window Area (ft2)	2,183.00	2,183.00

		Fixed/Operable	Operable	Operable
		Frame Type	Aluminum	Aluminum
		Glazing Type	Standard Glazing	Standard Glazing
A32 Walls Above Grade				
6.1 First Floor				
	6.1.1 Wall_cast in place_First Floor exterior10" half			
		Length (ft)	544	544
		Height (ft)	15' 4"	15' 4"
		Thickness (in)	10"	12"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
		Category	-	-
		Material	-	-
		Thickness	-	-
	Window	Number of Windows	150	150
		Total Window Area (ft2)	4,000.00	4,000.00
		Fixed/Operable	Operable	Operable
		Frame Type	Aluminum	Aluminum
		Glazing Type	Standard Glazing	Standard Glazing
	6.1.2 Wall_cast in place_First Floor exterior8" full			
		Length (ft)	274	274
		Height (ft)	12' 6"	12' 6"
		Thickness (in)	8"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
		Category	-	-
		Material	-	-
		Thickness	-	-
	Door	Number of Doors	7	7
		Door Type	Aluminum Exterior Door 80% Glazing	Aluminum Exterior Door 80% Glazing
	Window	Number of Windows	5	5
		Total Window Area (ft2)	200.00	200.00
		Fixed/Operable	Fixed	Fixed
		Frame Type	Aluminum	Aluminum
		Glazing Type	Standard Glazing	Standard

				Glazing
	2.2.3 Wall_cast in place_First Floot exterior8 extra			
		Length (ft)	547	547
		Height (ft)	2' 8"	2' 8"
		Thickness (in)	8"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
		Category	Vapour Barrier	Vapour Barrier
		Material	Polyethylene 3 mil	Polyethylene 3 mil
		Thickness	-	-
6.2 Second Floor				
	6.2.1 Wall_cast in place_second floor exterior 8" full size			
		Length (ft)	110	110
		Height (ft)	12' 6"	12' 6"
		Thickness (in)	8"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
		Category	-	-
		Material	-	-
		Thickness	-	-
	6.2.2 Wall_cast in place_second floor exterior 8 middle half			
		Length (ft)	165	165
		Height (ft)	12' 6"	12' 6"
		Thickness (in)	8"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
		Category	-	-
		Material	-	-
		Thickness	-	-
	Window	Number of Windows	42	42
		Total Window Area (ft2)	1,053.00	1,053.00
		Fixed/Operable	Operable	Operable
		Frame Type	Aluminum	Aluminum
		Glazing Type	Standard Glazing	Standard Glazing
	6.2.3 Wall_cast in			

	place_second floor exterior 8 middle half			
	Window	Length (ft)	468	468
		Height (ft)	12' 6"	12' 6"
		Thickness (in)	8"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
		Category	-	-
		Material	-	-
		Thickness	-	-
		Number of Windows	126	126
		Total Window Area (ft2)	3,360.00	3,360.00
		Fixed/Operable	Operable	Operable
		Frame Type	Aluminum	Aluminum
		Glazing Type	Standard Glazing	Standard Glazing
6.3 Third Floor				
	6.3.1 Wall_cast in place_third floor exterior 8" full size			
	Eenvelope	Length (ft)	81	100
		Height (ft)	14' 6"	14' 6"
		Thickness (in)	8"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
		Category	-	-
		Material	-	-
		Thickness	-	-
	Door	Number of Doors	0	69
		Door Type	Solid Wood Door	Solid Wood Door
	6.3.2 Wall_cast in place_third floor exterior 8 half size			
	Door	Length (ft)	651	651
		Height (ft)	14' 6"	14' 6"
		Thickness (in)	8"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
		Number of Doors	5	11
		Door Type	Aluminum Exterior Door 80% Glazing	Aluminum Exterior Door 80% Glazing
	Window	Number of Windows	174	174

		Total Window Area (ft2)	4,641.00	4,641.00
		Fixed/Operable	Operable	Operable
		Frame Type	Aluminum	Aluminum
		Glazing Type	Standard Glazing	Standard Glazing
	6.3.3 Wall_cast in place_third floor exterior 9 extra middle			
	Eenvelope	Length (ft)	84	84
		Height (ft)	3"	3"
		Thickness (in)	9"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
		Category	Vapour Barrier	Vapour Barrier
		Material	Polyethylene 3 mil	Polyethylene 3 mil
		Thickness	-	-
6.4 Brick Wall				
	6.4.1 Modular Clay Brick Wall_ 4" thick			
		Area (Sf)	110599	110599
6.5 Mortar				
	6.5.1 Mortar Between Bricks			
		Volume (yd^3)	726.19	726.19
6.6 Regular Gypsum board				
	6.6.1 Regular Gypsum board 1/2 "			
		Area (Sf)	216492	216492
B11 Partitions				
7.1 Basement				
	7.1.1 Wall_cast in place_basement interior 10"			
		Length (ft)	121	121
		Height (ft)	12' 6"	12' 6"
		Thickness (in)	10"	12"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
		Category	-	-
		Material	-	-

		Thickness	-	-
	7.1.2 Wall_cast in place_basement interior8"			
		Length (ft)	683	683
		Height (ft)	12' 6"	12' 6"
		Thickness (in)	8"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
		Category	-	-
		Material	-	-
		Thickness	-	-
	Door	Number of Doors	10	46
		Door Type	Solid Wood Door	Solid Wood Door
7.2 First Floor				
	7.2.1 Wall_cast in place_First Floor interior8"			
		Length (ft)	244	244
		Height (ft)	12' 6"	12' 6"
		Thickness (in)	8"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
		Category	-	-
		Material	-	-
		Thickness	-	-
	Door	Number of Doors	4	65
		Door Type	Solid Wood Door	Solid Wood Door
	7.2.2 Wall_cast in place_lecture room 6"			
		Length (ft)	63	63
		Height (ft)	12'	12'
		Thickness (in)	6"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
7.3 Second Floor				
	7.3.1 Wall_cast in place_second floor interior 8"			
		Length (ft)	284	284
		Height (ft)	12' 6"	12' 6"
		Thickness (in)	8"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average

		Rebar	-	#5
		Category	-	-
		Material	-	-
		Thickness	-	-
		Number of Doors	3	42
		Door Type	Solid Wood Door	Solid Wood Door
7.4 Third Floor				
	7.4.1 Wall_cast in place_third floor interior 8			
		Length (ft)	170	170
		Height (ft)	12' 6"	12' 6"
		Thickness (in)	8"	8"
		Concrete (psi)	2500	3000
		Concrete flyash %	-	average
		Rebar	-	#5
		Category	-	-
		Material	-	-
		Thickness	-	-