Life Cycle Assessment of Chemistry Building North Block

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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.

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

CIVL 498 – Life Cycle Assess

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Executive Summary

Life Cycle Analysis (LCA) evaluates the environmental impacts of the inputs and outputs of a product system. 22 buildings on University of British Columbia Point Grey Campus were chosen to complete this study. The study is to peek into LCA by investigating the environmental impacts of buildings using current LCA methods. The works were executed as part of the study for CIVL 498.

As the LCA project of this course has been ran for a few years, this study was based on the results of previous years of study. This year it mainly focused on evaluating the impacts of the selected buildings and improving quality of the data.

Two main software tools are to be utilized to complete this LCA study; OnCenter's OnScreen TakeOff (OST) and the Athena Sustainable Materials Institute's Impact Estimator (IE) for buildings. OST performed the material take-off of the building then its output were input into Athena IE to analyze the impacts.

Detailed assessment methods were described in section 6.0 and the results of this study are displaying under section 7.0.

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1.0 General Information on the Assessment

1.1 Purpose of the assessment

Intended use of the assessment: This life cycle analysis of the Chemistry Building North Block (Chemistry North) at the University of British Columbia was carried out as an exploratory study to evaluate the impacts of the building during its manufacturing and construction phases on the global environment. The LCA study of Chemistry North is also part of a series of 21 other buildings at UBC that are being carried out with the same purposes simultaneously.

Reasons for carrying out the study: The study helps disseminate education on LCA and further the development of this scientific method into sustainability in building construction practices at UBC and the green building industry. Furthermore, all the UBC building LCA studies can be organized together to form a tool providing knowledge for decision making process, also assisting policy/decision makers to establish quantified sustainable guidelines for further use on further UBC construction, renovation and demolition projects.

Intended audience: The results of the study will be communicated to the public, the intended audience could be those who are involved in building construction related decision making at UBC. Other potential audiences could be architects, engineers, contractors involved in design planning. Also on a broader view the industry companies and government groups that engaged or want to become engaged in the green building development.

Intended for comparative assertions: The results of this LCA study are not intended for comparative assertion. However, the studies of the UBC buildings in all can be used to carry out the performance comparison across UBC building over time and between difference materials, structural type and building functions.

1.2 Identification of building[1]

The Chemistry building located in a prominent setting on Main Mall in the centre of the campus. The North Block is small wing attached to the center from its north side (see Figure 1, the red dashed line surrounded area). The Chemistry building is one of the few buildings executed from the original plan for the Campus. The Chemistry Centre was completed in 1925 with the cost of $96,000. Starting 1959 the new wings were added through the years and in 1962 the North wing opened and it's meant to be for the use of research. It had experienced piecemeal renovations on a small scale and as particular needs arose over the years, however these are outside the scope of the study.

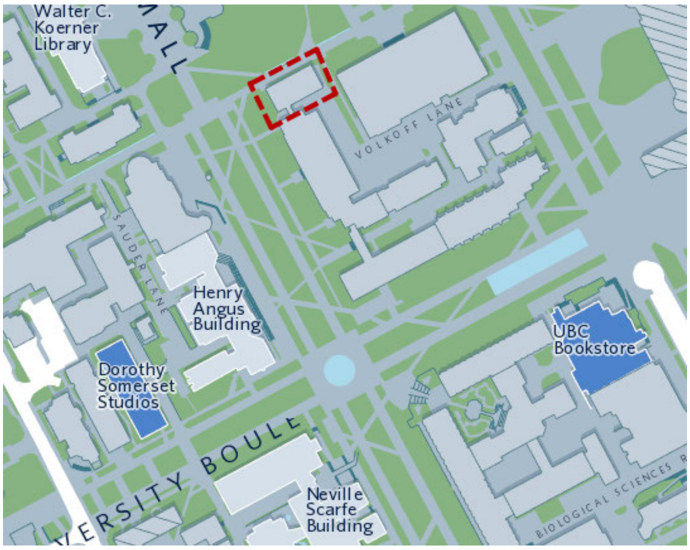

Figure 1. Location of the Chemistry Building North Block

1. http://www.chem.ubc.ca/about/about-department/history

http://www.projectservices.ubc.ca/portfolio/renewal/chemistry-north htm

Under the UBC Renew program the existing space was completely refurbished and reconfigured and now meets state-of-the-art lab research standards. The building was gutted and brought up to current building codes. It received fire and life safety upgrades, seismic upgrades, new ventilation, improved air quality, modernized heating and computer systems, all while promoting sustainability by consuming fewer resources than demolition/construction of a new building.

The overall project cost was approximately $10 Million compared to $15.5 Million for a replacement building. Construction took a total of 12 months (6 months less than a new building) and was completed in June 2007.

1.3 Other assessment information

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

The study is built on the LCA study from previous years. An Athena Impact Estimator file, an Onscreen Takeoff file and an IE inputs document were taken from the results of the previous study. Firstly, a rearrange of the elements in the IE inputs document was executed according to the CIQS Element Format. The Onscreen Takeoff file served as an ancillary and provided reference for the action. Then the new categorized document was referred to update the contents of the original Athena IE file. After the new Athena IE file is generated the estimator is ran to collect the quantified results for the Chemistry North building in Vancouver region as an institutional building type. As this study was a cradle to gate assessment, the expected service life of the building was set to 1 year, which maintenance, operating energy and end of life stages of the building's life cycle were left outside the scope of assessment. The impacts were estimated on the following environmental aspects: Fossil Fuel Consumption, Global Warming, Acidification, Human Health Criteria Respiratory, Eutrophication, Ozone Layer Depletion, and Smog.

Below is the table of summary of the assessment information. The formatted inputs can be viewed in Annex D.

Client for Assessment	Completed as coursework in Civil
Name and qualification of the assessor	Minge Weng (MEng student in Civil Engineering); Previous Author's info is missing
Impact Assessment method	Athena Sustainable Materials Institute's Athena Impact Estimator for Buildings (Version 4.2.0208) [Software]; OnCenter's On Screen Takeoff (Version 3.9.0)
Point of Assessment	52 years
Period of Validity	5 years
Date of Assessment	Completed in December 2013
Verifier	Coursework, study not verified

Table 1. Other Assessment Information

2.0 General Information on the Object of Assessment

2.1 Function equivalent

The purpose of using functional equivalents in this study is to standardize the LCA results from the Chemistry Building North Bock, including:

- Per square meter area constructed
- Per cubic meter constructed
- Per specific functional use area

Following is the concise describe of Chemistry North's functional equivalent.

Aspect of Object of Assessment	Description
Building Type	Laboratory
Technical and Functional Requirements	Air circulation due to fume hood intense synthetic chemistry labs, fire safety and seismic stability
Pattern of Use	
Required Service Life	100 years

Table 2. Functional Equivalent Definition

2.2 Reference study period

According to EN 15978, the default value for the reference study period shall be required service life of the building. But this LCA study was focused solely on the period of the building's life from cradle to gate, meaning the manufacturing and construction phases including all the processes from extraction of the raw material to completion of the construction, exclude operation, maintenance and demolishment of the building.

This study aimed for a focus on the cradle to gate life period of a building. Only addressing the structure and envelop help secure the accuracy. As mentioned on the homepage of Athena Institute the Impact Estimator tool is capable of modeling well over 1200 structural and envelope assembly combinations and is generally applicable to more than 90% of the typical North American building stock. Besides, the end of life module in IE is not fully developed yet, it only accounts for the structural materials for demolition stage. When the digital information of the building was inputted into the Athena Impact Estimator the service life was set 1 year.

2.3 Object of Assessment Scope

The Chemistry North building is a product of concrete. Its foundation is constituted by cast in place concrete pad footings and strip footings. Built on that is the 4-inch concrete slab on grade. The upper floors type is 2.5-inch thick suspended concrete slab and the roof construction is 2-inch concrete slab. Exterior wall types are cast in place 8-inch and 12-inch thick concrete walls with polystyrene isolation envelop. Interior wall types are cast in place 8-inch thick concrete wall with polystyrene isolation envelop and 6-inch concrete blocks with brick cladding. The characteristic of each element are described in the table below with their quantities.

CIVL 498 Level 3 Elements	Description	Quantity	Units
A11 Foundations	19” thick cast in place concrete pad footings and strip footings	615.9471552	m2
A21 Lowest Floor Construction	5” thick Cast-in-place concrete slab on grade	615.9471552	m2
A22 Upper Floor Construction	Concrete columns & beams; Semi-basement, Ground, 2nd, 3rd floors: 2.5” thick cast in place concrete suspended slabs	1198.825473312	m2
A23 Roof Construction	2” thick cast in place concrete slab with polyisocyanurate foam isolation and standard modified bitumen membrane	332.044755264	m2
A31 Walls Below Grade	8”thich cast in place concrete walls with polystyrene isolation envelop	707.08503744	m2

A32 Walls Above Grade	8" and 12" thick cast in place concrete walls with polystyrene isolation envelop	1295.774440704	m2
B11 Partitions	8" thick cast in place concrete walls with polystyrene isolation envelop and 6"concrete block walls with brick cladding	1925.025311232	m2

Table 3. Building Definition

Modified version of CIQS Level 3 elements was used for a more systemically categorized result. Compare to categorizing by type of elements, in the case of addressing building's structural and envelop it's more logical to look at each structural part of the building. Within each structural part the elements are of similar components and function. In collaboration with Athena IE, the CIQS category also made the impact results of each structural part available. Proportion of contributes between the building parts are also led achievable.

3.0 Statement of Boundaries and Scenarios Used in the Assessment

3.1 System boundary

The system boundary determines the processes that are taken into account for the object of assessment. Manufacturing and construction modules of the building's life cycle composed the scope of study. Along with their upstream and downstream processes that are supporting them, from beginning of the upstream to the end of the downstream was studies and assessed.

In a very general way, manufacturing module's upstream processes are energy generation, raw material harvest/extraction, refining and processing, downstream processes are waste downcycle/treatment, packaging and marketing. For construction module the upstream processes are transportation of products to the site, storage, preparation of the products before use, downstream processes are trimming and maintenance after the installation, site cleanup, and recycle/waste treatment

Below is the figure shows the scope information of this LCA study.

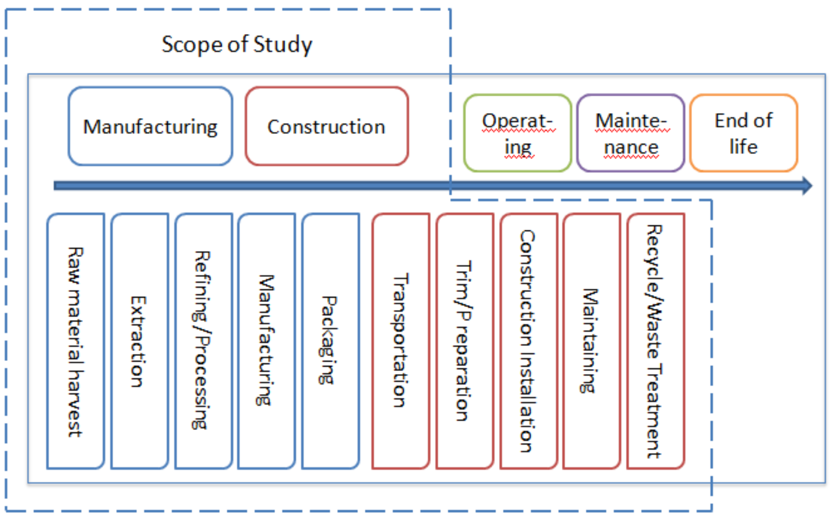

Figure 2. Display of system boundary of the LCA study

3.2 Product Stage[2]

Athena Sustainable Materials Institute state that the energy and emission data is proprietary and they do not release it to the public. Thus a LCI/LCA product report was studied to investigate how Athena the impact estimator deals with the detailed processes within the product stage. Cross Laminated Timber (CLT) Produced in Canada in chosen to look into the trivial.

Each material basis included in the Athena tool is assessed consider the impacts starting with extracting raw material from the earth and ending with the packaging of the products ready to ship. For CLT it includes input raw materials, transportation of materials throughout the cradle to gate life stages.

Works in the background are accomplished in order to fulfill the requirements: energy and fuel in forestry, logging, milling and secondary manufacturing, and Inputs and outputs of the product process are specifically analyzed and are strictly stick to what're in reality. Inputs include rough sawn lumber, 4 types of glue, ancillary materials and sorts of energy such as BC electricity, gasoline, fuel oil, natural gas, biomass, etc. Outputs are CLT and wood portion

- The lumber LCA project was completed in 2009 and developed a Canadian average forest management, harvesting and log transportation process data as well as unit process data for rough milling, drying, and planning.
- Regional survey is done for electricity grid, transportation mode and distances

2. Athena Sustainable Materials Institute. "Life Cycle Assessment of Cross Laminated Timber Produced in Canada". Available online from http://www.athenasmi.org/wp-content/uploads/2013/10/CtoG-LCA-Canadian-CLT.pdf

and even product manufacturing applicable to the product mix for the selected region.

- Moreover, U.S. LCI database, ISO 21930 Sustainability in building construction – Environmental declaration of building products, mid-point indicators form the U.S. EPA Tool for the Reduction and Assessment of Chemical, and Other Environmental Impacts (TRACI) v 4.03 were used for references to help generate data together and fulfill the requirement of the assessment.

The study of the process information considered in the module indicates that the upstream/downstream included in the manufacturing module is well rounded. It has simulated the process really and taken into account every factor that may affect the result. Assumptions and uncertainty certainly exist but they're not avoidable.

3.3 Construction Stage[3]

The process of pouring a concrete wall was studied as an example to collect the process information considered in the database of the transportation and construction installation modules. It provides knowledge of what consist the impact results and what are the assumptions made.

Pouring a cast-in-place wall typically consists of transporting the concrete to the site, assembling the formwork, placing reinforcing rebar in the forms and around

3. Athena Sustainable Materials Institute. "Athena Impact Estimator for Buildings V 4.2 Software and Database Overview". Available online from http://calculatelca.com/wp-content/uploads/2011/11/ImpactEstimatorSoftwareAndDatabaseOverview.pdf

openings, pouring concrete into the forms and maintenance afterwards. Uncertainties in these processes could include the transportation distance, energy consumed by the equipments, waste factors, etc.

Below are the points of uncertainties that have been taken into account and involved:

- The forms may be moved about the site by forklift or crane and may be assembled by hand or crane for large-scale formwork.
- Rebar is moved around the site using forklifts and/or cranes and would typically be assembled by hand.
- The concrete will arrive on site in a concrete mixing truck and will be poured using a concrete pump or a crane and bucket.
- Both concrete and rebar are assumed to make a 40 km round trip from mixing plant or distributor to the building site. On site waste for concrete is estimated at 5%, and consists of any spillage form 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.
- Whether a wall needs temporary heating for concrete curing is determined by the proportion of the year that the temperature falls below 0 ℃ Thus a proportion of the energy needed has been factored into the construction.

Like in the manufacturing module, detailed processes and possible assumption for the uncertainties in the construction module have been implant into the database of each material basis. According to Athena Institute the deviation of the data from the real one is under 15%.

4.0 Environmental Data

4.1 Data sources

- Athena LCI Database is managed by Athena Sustainable Materials Institute[4]

From the beginning, the Athena Institute has been conducting life cycle research, developing an ever-growing set of comprehensive, comparable life cycle inventory (LCI) databases for building materials and products. Since 2002, the Athena software tools were released, the first tool Athena IE was developed in collaboration with Morrison Hershfield. After that, Athena kept undertaking researches that go into developing, verifying and updating the databases that form the basis of the Athena software tools. To date, Athena has invested more than $2 million on database development.

The Athena Institute has developed data not only for building materials and products but also for energy use, transportation, construction and demolition processes including on-site construction of a building's assemblies, maintenance, repair and replacement effects through the operating life, and demolition and disposal.

4. Athena Sustainable Materials Institute. "LCI Databases". Available online from http://www.athenasmi.org/our-software-data/lca-databases/

- US LCI Database is managed by National Renewable Energy Laboratory[5]

The U.S. LCI Database project began in 2001, when the U.S. Department of Energy (DOE) directed the National Renewable Energy Laboratory (NREL) and the Athena Institute to explore the development of a national public database. The U.S. LCI Database was created and has been made publicly available.

Environmental product labels such as carbon footprints or complete environmental product declarations (EPDs) based on LCA are growing in use as voluntary applications. As areas that are expected to see the expanded used of LCA, LCI databases need to grow and evolve to support and maintain compatibility with new methods.

Now steps are still taking places toward the primary goal of providing a publicly available source of high-quality, transparent U.S.-based LCI data. In order to achieve the goals the manage team developed a list of action items for the next two years and will update and keep the action after two years. These items cover: Project/Data Management meaning fully round and function the LCI project, and build a data quality control process; Expansion/Revision of the Data; Database Development; and Communications.

5. U.S. Department of Energy. "U.S. Life Cycle Inventory Database Roadmap" Available online from http://www nrel.gov/lci/pdfs/45153.pdf

4.2 Data adjustments and substitutions

Chemistry Building North Block was built in 1961. Some materials used in this building are lack of proof to find out. For example all the concrete used is unclear on the strength and percentage of fly ash contained. Live load of the columns and floor slabs are also unknown and the best assumption was applied.

Other than unknown properties, mismatches between the IE inputs and the real measured also existed. Such as the pad footings built in real measured are of 30-inch thickness while they're19-inch in IE inputs. Limitations are set in the Athena tool considering of building codes or specifications. For certain parameter only number value within the set range is acceptable. For example the thickness of footings has to be between 7.5" to 19.7".With real thickness built is 30", a compromise was taken to accommodate the difference. According to the principal the total volume of concrete are the same an equation was used to adjust the length of the pad footings while maintain the thickness that cannot be changed. By adjusting the dimension of the elements the goal was to minimize the deviation.

Trivial errors were also found in the IE input excel document done by human mistake. Such as number value in IE input excel didn't match the value inputted in Athena tool. All the elements had been went through and checked with Athena tool to correct any errors.

The drawings and Onscreen Takeoff were adopted to do error check for the measurement of each element in the building take-off process done by previous student. They also helped in the sorting process as provided visual reference for easily identification of building structure and elements.

4.3 Data quality

Data

Due to assumptions within the LCI database such as the transportation distance, waste factor, the estimated results cannot be taken as real facts but references on potential impacts.

For old buildings the drawings were handmade and scanned to use in the OST. Unknown information exists such as material properties and envelops. Differences between drawings and real building could exist and the fuzziness potentially increased the deviation of measuring. Furthermore the uniformity of the scale between drawings is not guaranteed.

Model

In OST because of the operational method varies from person to person it's impossible to undertake takeoffs in 100 percent accuracy. Error is thus potentially created when using the software.

In Athena IE uncertainties can occur variously: due to inaccuracy of input data, software assumptions, human choices and human mistakes.

Inaccuracy of input data is led at the material take-off level. Software assumptions primarily include the database implant. Uncertainties due to human choices are choices that made under people's assumption. It's not avoidable. It's noted that the walls contained in original Chemistry Building North Block Athena files are of three types regardless of interior or exterior, below grade or above grade. In reality it's most likely not the case. This is due to fuzzy drawings and lack of specification, assumptions had to be properly made in the context to complete the whole study. Human mistakes can happen in inputting numbers, selecting properties, leaving out what shouldn’t be, etc.

Temporal

Chemistry Building North Block was build in 1960’s while a LCA study is applied on it with current standards. Therefore, taking into account the technology advancement the actual impacts should be much larger

Spatial

Spatial difference can affect the use of data. In Athena IE the building region is selected at the first place, it will determine the electricity and transportation grids and even product manufacturing technologies applicable to the product mix for the selected region. A series of survey of region based raw materials/primary energy distribution. Then average value of the results is selected to be used in the LCA calculation. Indicating there’re still inaccuracies existing. Some of the inaccuracies exist even in the same region such as urban versus rural condition, impacts that depend on external factors such as temperature, and treatment processes.

Variability between sources

Several databases were contributed to the final data used. The compatibility and uniformity of the data have potential risks of causing deviations.

5.0 List of Indicators Used for Assessment and Expression of Results[6]

The impact assessment method used in the study of Chemistry Building North Block was the Athena Impact Estimator for Buildings developed by Athena Institute. The database implanted in the tool impact categories used in the final report are described below:

- Fossil fuel consumption – MJ

  The availability of energy relies extensively on the availability of fossil fuels: the oil, natural gas, and coal that together constitute 80 percent of global energy consumption. Combustion of fossil fuel produces green house gas and other pollutants like sulfuric, carbonic, and nitric acids, which fall to Earth as acid rain.

  Possible endpoint impacts: acid rain that damages both natural area and built environment, human diseases such as acute respiratory illness, aggravated asthma, chronic bronchitis and decreased lung function, global energy crisis.

- Global warming potential – kg CO2 equivalents

  GWP is primarily caused by CO2 emission. CO2 emission exists majorly in the industries. Oil extraction, refining, energy generating processes and most product processes emit CO2. CO2 impacts the environment by absorbing infrared radiation and bringing up the air temperature. Thus slow but gradual climate change is caused, negatively affects the water resources, human heath, agricultural effects, forest, etc.

  Possible endpoint impacts: increases in tree mortality in forests, redistribution of the water resources on earth, overwhelming floods and submerged coastal areas, extinction of species, human diseases.

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6. Sianchuk, Rob. "Impact Assessment". October 9th, 2013.

- Acidification potential – H+ mol equivalents

Acidification potential is mainly caused by the emission of SO2 and NOx into the atmosphere. The gases then react with water under certain conditions to generate acidity, and it goes back to the ground in the form of acid rain or snow, cause acidity in soil and ocean systems.

Possible endpoint impacts: damages on natural and manmade environments, mortality of aquatic species, diseases, acid rain.

- Human health respiratory effects potential – kg PM10 equivalents

Reparatory effects are caused by the particles in the air emission that with a certain range of diameter, able float in the air and can be breath in by human. The particles deposits in alveoli and effect human health.

Possible endpoint impacts: coughing/weezing, human mortality, human diseases such as asthma, heart disease, chronic bronchitis, emphysema and pneumonia.

- Eutrophication potential – kg N equivalents

The main causes of eutrophication are natural run-off of nutrients from the soil and the weathering of rocks, run-off of inorganic fertilizer and manure from farms. It tremendously increases the growth of algae and aquatic weed in surface waters. The boom of algae and weed then causes toxics release to poisoning fish and shellfish, blocks up the aquatic transportation and prevent sunlight from going deep into the water.

Possible endpoint impacts: death of fish and shellfish, toxicity to humans, marine mammals and livestock.

- Ozone depletion potential – kg CFC-11 equivalents

Reduction of Ozone layer is caused by emission of ozone-depleting group of chemicals. These chemicals such as Chlorofluorocarbons(CFC) are manmade that are very stable in the atmosphere. They take from 20 to 120 years to break down and all the while they are destroying ozone molecules. Then the UVB that reaches Earth is increased and the stratospheric ozone column is changed.

Possible endpoint impacts: increase the speed of the global warming, cause of human diseases especially skin cancers, damages on plants and species even changing of the DNA.

- Smog potential – kg O3 equivalents

Known as photochemical ozone formation, air emission of VOCx, NOx chemically react in the present of sunlight to generate zone and other pollutants. This process reduces photosynthesis and growth.

Possible endpoint Impacts: human/plant mortality, diseases on human/animals, reduces life of materials, low visibility.

6.0 Model Development

Construction drawing was the only resource of information for the Chemistry North. It along with the OST played an important role in the element modeling. The set of construction drawings were inputted into OST and the take-off was performed on the drawings. Initially the scale needed to be properly set for each drawing, then for each element a colored area was used to cover it. Elements like footings, slabs, walls, columns & beams were modeled in the floor plan with height value found from elevation/section plan of the drawings and inputted. Windows, doors, and stairs were modeled in the elevation and section plan. Once the colored areas were set and the number value in the other dimension was provided, that is when the volume of elements can be calculated, OST was able to perform the take-off of the building.

The output of OST could then be inputted into Athena IE to evaluate the environmental impacts of the building. Athena IE achieves this by applying a set of algorithms to the inputted takeoff data in order to complete the takeoff process and generate a bill of materials. This bill of materials then utilizes the Athena Life Cycle Inventory (LCI) Database in order to generate the cradle to grave LCI profile for the building. US Environmental Protection Agency (US EPA) and the Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI) are also implanted in the Athena IE to filters the LCA results through a set of characterization measures to generate the final environmental impact profile.

Level 3 elements in Chemistry Building North Block were modeled under the instruction of CIQS Elemental Format. Due to Chemistry North is a relatively small building (a basement, a semi-basement and three upper floors) that has a reasonable amount of elements and the previous student did a good job naming them, the sorting went smoothly. Firstly the original Inputs and Assumption documents in excel was looked at, it was categorized by building element type. Then according to the CIQS instruction all footings were sorted under the A11 Foundation; Slab on grade was sorted under A21 Lowest Floor Construction; Columns & beams that support the roof and the roof slab went into A23 Roof

Construction; The rest of columns & beams and floor slabs went into A22 Upper Floor Construction.

Among all the building elements there're only three wall elements categorized by thickness, regardless of exterior or interior, above grade or below grade. The OST tool and drawings were applied to investigate the wall elements. First the proportional scale used was adjusted, and then manual measurement of the walls below grade was executed. The result is then brought into the excel document and walls belong to different level 3 elements were separated from the total wall file.

Reference flow indicates the carrier of the study. In this case it's the building being studied thus Chemistry North building is the reference flow. Below is the table of bill of materials contained in the whole building.

Material	Quantity	Unit
6 mil Polyethylene	4251.6864	m2
Aluminum	3.7207	Tonnes
Cold Rolled Sheet	0.1387	Tonnes
Concrete 20 MPa (flyash av)	660.45	m3
Concrete 30 MPa (flyash av)	1087.5331	m3
Concrete Blocks	8739.6016	Blocks
Concrete Brick	721.0892	m2
Double Glazed Hard Coated Air	282.8404	m2
EPDM membrane (black, 60 mil)	254.4942	kg
Extruded Polystyrene	6165.3273	m2 (25mm)
Galvanized Sheet	6.5628	Tonnes
Modified Bitumen membrane	5868.6769	kg
Mortar	180.3497	m3
Nails	0.6743	Tonnes

Polyiso Foam Board (unfaced)	2093.3952	m2 (25mm)
Rebar, Rod, Light Sections	166.4897	Tonnes
Solvent Based Alkyd Paint	31.2467	L
Welded Wire Mesh / Ladder Wire	0.5566	Tonnes

Table 4. Bill of Materials of Chemistry Building North Block

7.0 Communication of Assessment Results

7.1 Life-Cycle Results

The following pie charts were generated using the Athena IE results. They illustrate the proportioned contribution of the CIQS level 3 elements to the environmental impacts.

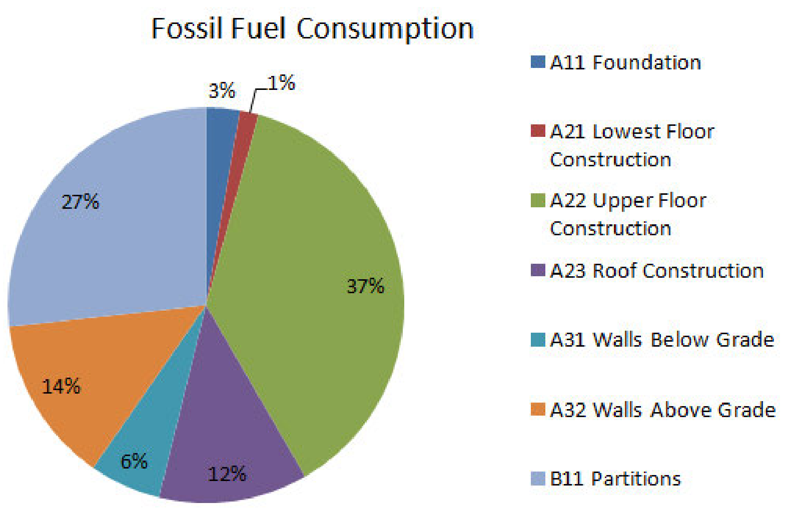
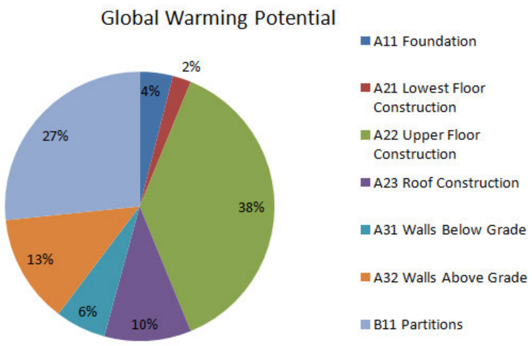


Figure 3. Pie Chart: Percentage Contribution of Level 3 Elements of Fossil Fuel Consumption

The biggest contribution comes from A22 upper floor constructions, then in order B11 partitions, A31 walls above grade and A23 roof construction. Investigation of bill of materials indicates the sequences of contribution to the impacts reflects the sequence of concrete and rebar consumption from high to low of the level 3 elements. This is due to the structure of Chemistry North building is mainly consisted by reinforced concrete, and both concrete and rebar have relatively heavy producing processes. Thus the more they're contained in a level 3 element the more the element contributes most to the environmental impacts.



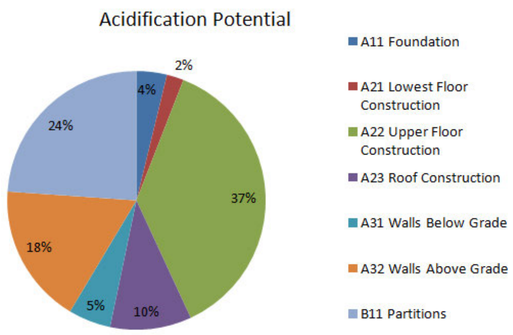
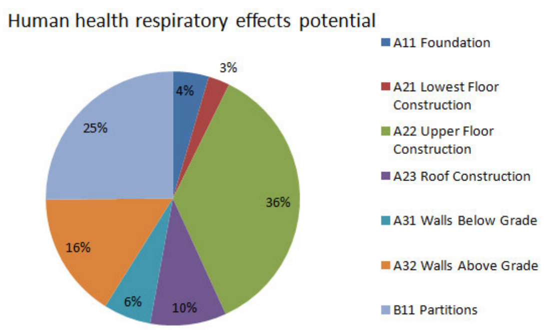


Figure 4. Pie Chart: Percentage Contribution of Level 3 Elements to Global Warming Potential

Figure 5. Pie Chart: Percentage Contribution of Level 3 Elements to Acidification Potential



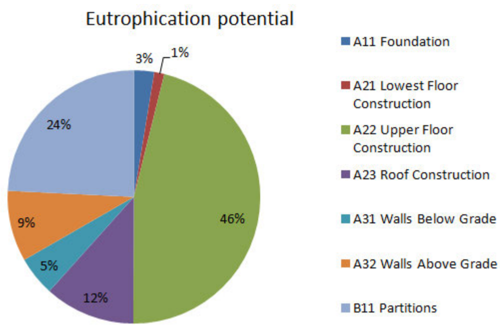
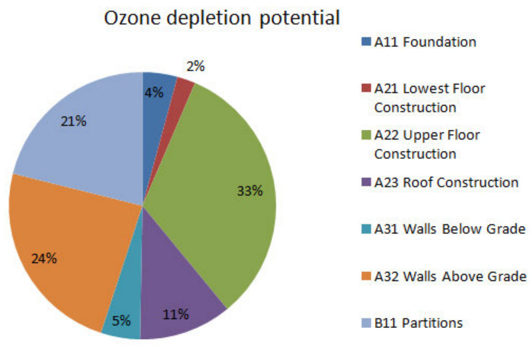


Figure 6. Pie Chart: Percentage Contribution of Level 3 Elements to Respiratory Effect Potential

Figure 7. Pie Chart: Percentage Contribution of Level 3 Elements to Eutrophication Potential



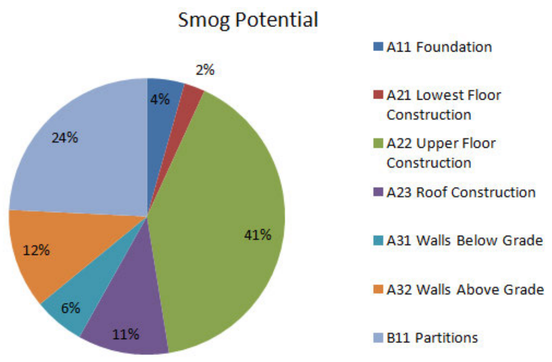


Figure 8. Pie Chart: Percentage Contribution of Level 3 Elements to Ozone Depletion Potential

Figure 9. Pie Chart: Percentage Contribution of Level 3 Elements to Smog Potential

Bar charts were generated to visually express the impacts of the level 3 elements in their manufacturing module and construction modules of life cycle. The proportions of contribution between the two modules are similar among the 7 environmental impacts categories, thus only one chart is shown. The figure below indicates the process of manufacturing consumes around 7 times more fossil fuel than the process of construction, that’s why sustainable decisions need to be made at early stages of life cycle. Also, when improving the sustainability of the processes, the ones in the manufacturing module could be considered first for more effectiveness.

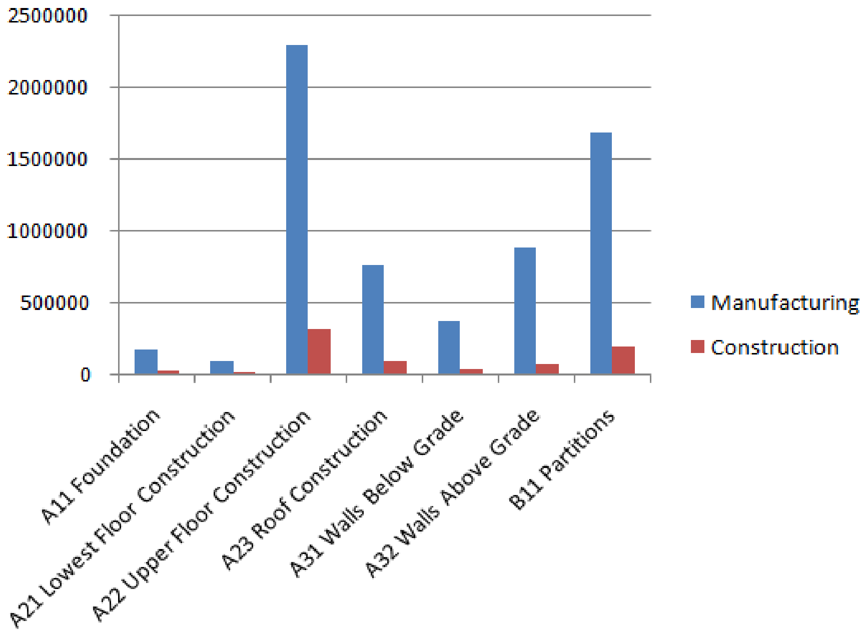


Figure 10. Bar Chart: Comparison of Fossil Fuel Consumption between Manufacturing and Construction Modules

The annexes A – D contain supportive documents of this LCA study that provide the reader with further interpretation of the results. In Annex A – Interpretation of assessment results, the result of this study is reviewed in the context of all the LCA studies executed this year; In Annex B – Recommendations for LCA use, the concern, practice, issues in application of LCA are described; Annex C – Author Reflection reflects the experience of the author during this study; Annex D – IE inputs and assumptions made display of the takeoff document generated by Onscreen Takeoff, the elements had been sorted into CIQS level 3 element format and updated in the Athena IE to generate impact results for each element.

Annex A – Interpretation of Assessment Results

Benchmark Development

Within industrial sectors and indeed, individual industrial plants, there is always a need to improve efficiency. Even if environmental considerations are not the driving force, economic factors may provide the spur. However, it is impossible to make changes and demonstrate that the changes have been effective if there is no standard against which to measure the improved system. This is the basis of benchmarking.[7]

The role of common goal & scope is to unify the standard of the LCA studies that have been involved as part of the benchmark. Only with uniform scope & contents of study the separately executed studies can be compared together or the results could be used to calculate the average level. The functional unit serves for the unity of the studies as a scale. If the study was not carried out under the same scope or scale, the value of considering them as one series of study or comparing their results is decreased, benchmark cannot be forms as well.

UBC Academic Building Benchmark

Below are the bar charts that display the comparison of two common environmental impacts between the benchmark and the Chemistry North. The benchmark is calculated on November 17th, 2013.

7. Boustead Consulting USA. "Using LCAs for Benchmarking". Available from http://www.bousteadusa.com/UsingLCAs/benchmarking.html

Compare to the benchmark the performance of Chemistry North is a lot better especially in A31 Walls Below Grade, A22 Upper Floor Construction and A32 Walls above grade.

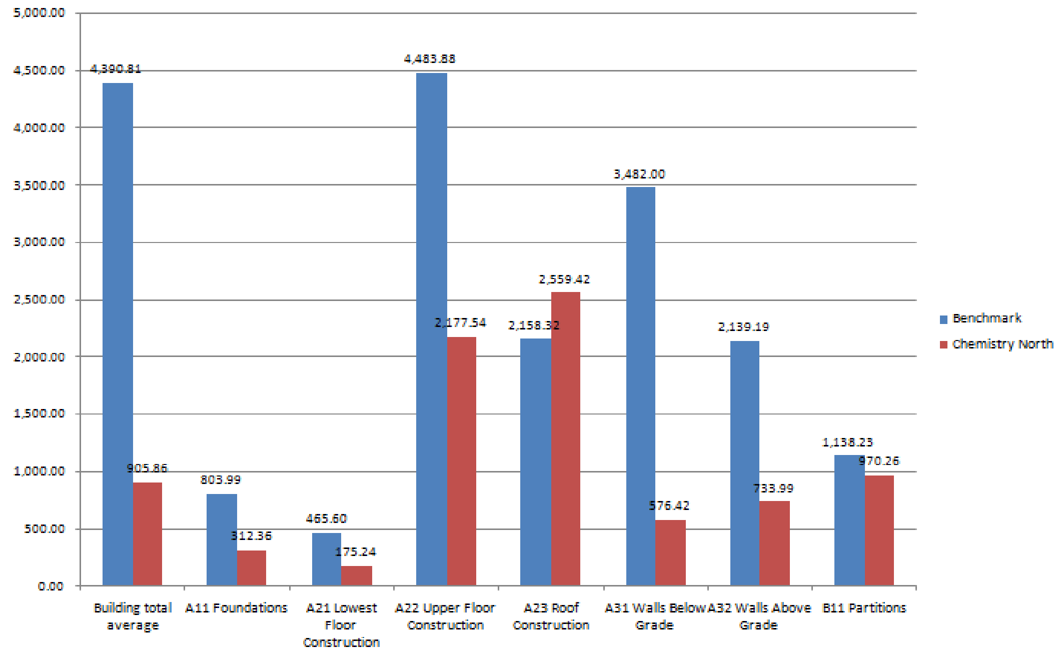


Figure 11. Bar Chart: Comparison of the Chemistry North Performance with Benchmark on Fossil Fuel Consumption

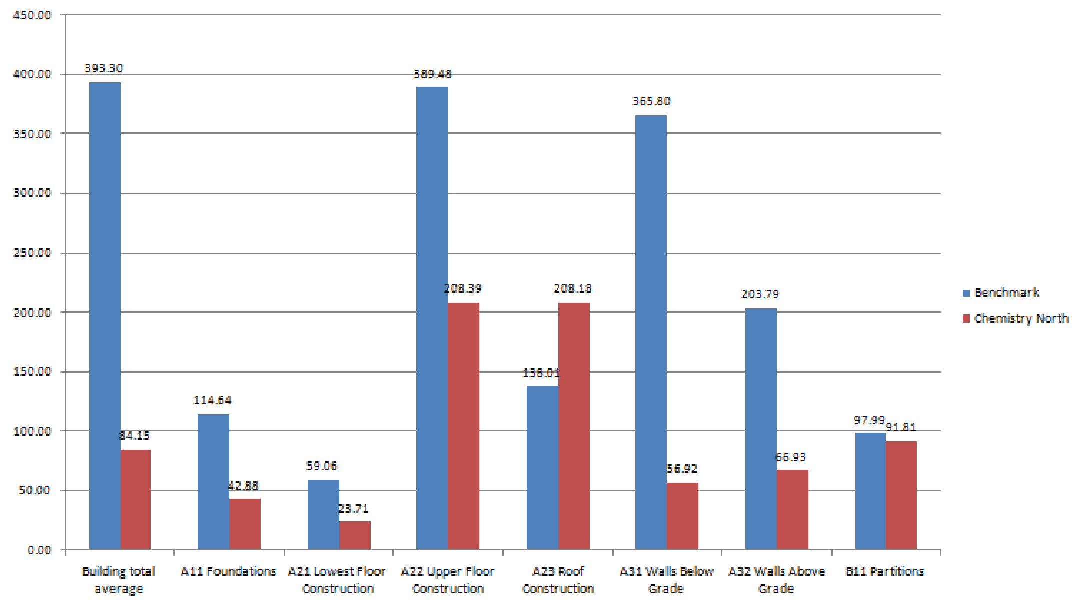


Figure 12. Bar Chart: Comparison of the Chemistry North Performance with Benchmark on Global Warming Potential

Annex B – Recommendations for LCA Use

- Consideration of life cycle modules beyond cradle to gate stages is essential. As the length of maintenance 10 or more times the construction stage, the impact of the building can comes more from the maintenance phase rather than product and construction. The choices made in design phase also affect the service life/replace period of the assemblies and the resources consumed later than the construction phase until its demolishment compose the impacts of the stages beyond product and construction.
- LCA can affect material choice related decision making during the design stage, even the mechanical and architectural design can be influenced. LCA provides a lifelong simulation of the impacts the product will have during each stage of its life cycle.By looking at the impacts hotspots and improve accordingly the most effective decisions can be made, and by changing the product properties and associated material used the impacts will swing and tell things. LCA can be used as a reference along with quality, cost, time, and other variables to help designer make optimum decisions.
- The results of previous years of study are available and are very helpful documents to the preparation of this LCA study report. In the data and model there may exist inaccuracies and uncertainties, but the concept of the study is well rounded and uniform. As for the quality of benchmarks, major buildings are doing way better than the benchmark
- Issues exist in applications such as prioritizing impact categories and their interpretation. Once the impact results are out tradeoffs need to be made when using as a reference to help decision making. Due to decision making could happen in any life stage of the product, different materials vary largely in the distribution of impacts, and regional factors have to be taken in to account, when practicing the situation is more complicated.

And how to tradeoff between the product characteristics, product sustainability and practicality become a knotty issue.

- 1. Find a building has been done the LCA study that is going near the end of the maintenance period.

  2. Make use of the LCA study to analyze the impacts of the maintenance.

  3. Find possible hotspots where impacts could be reduced.

  4. See if real change that improves the environmental performance can be adopted.

Annex C – Author Reflection

- As sustainability has become a worldwide popular topic since the 21's, regardless of the industry its understandings have been advanced and diffused as more applications being developed. I knew sustainability briefly and accumulatively from hearing lectures & presentations. But no systemic learning was done. Also this was my first time hearing and getting in touch with LCA. As described in this report one of its purposes is to disseminate the education which is imperative. CIVL 498C gave us a comprehensive understanding of the LCA and its surrounded concepts. Starting with the terminologies applied in the LCA study to process-simulating exercises, and to final real practice.
- What I found interested about this course was a new area I've not been to, the less stressful test methods, group learning/activities versus individual assignments, and hands-on real practices.

- LCA is a big topic contains many parts and resources. It’s easy to get to know what it is about, but the more you get in the more is there to explore. Two and a half month is a very short time to take a bit and digest the LCA cake. Confusions (on terminology, on methodology, on collaboration of software, on expectation of final result) kept coming out during the whole process and especially near the end when a full study report is required to generate individually. After all it was interesting experience exploring new knowledge area along with real practice.

Table 5. CEBA 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.	DA = developed & 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 data, and synthesis of information in order to reach valid conclusions.	IDA = introduced, developed & applied	
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	
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.		
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.	D = developed	
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.	N/A = not applicable	
10 Ethics and Equity	An ability to apply professional ethics, accountability, and equity.	DA = developed & applied	
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.	N/A = not applicable	
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.	D = developed	

Annex D – Impact Estimator Inputs and Assumptions

Table 6. CIQS Sorted Level 3 Elements

CIQS Level 3 Elements	Assembly Type	Assembly Name	Input Fields	Known/Measured Information	IE Inputs
A11 Foundations					
	1.2 Concrete Footing				
		1.2.1 Footing_F1			
			Length (ft)	11	17.37
			Width (ft)	10	10.00
			Thickness (in)	30	19
			Concrete (psi)	3000	3000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.2 Footing_F2			
			Length (ft)	9.5	15
			Width (ft)	10	10.00
			Thickness (in)	30	19
			Concrete (psi)	3000	3000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.3. Footing_F3			
			Length (ft)	4	6.3
			Width (ft)	4	4
			Thickness (in)	30	17.7
			Concrete (psi)	3000	3000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.4 Footing_SF1			
			Length (ft)	345	345
			Width (ft)	1.4	1.4
			Thickness (in)	12	12
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.5 Footing_SF2			
			Length (ft)	204	204
			Width (ft)	3.1	3.10
			Thickness (in)	18	18
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.6 Footing_SF3			
			Length (ft)	20	20
			Width (ft)	1.6	1.60
			Thickness (in)	12	12
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.7 Footing_SF4			
			Length (ft)	78	98.5
			Width (ft)	2.1	2.1
			Thickness (in)	24	19
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.8 Footing_SF5			
			Length (ft)	18	18
			Width (ft)	3.3	3.30
			Thickness (in)	18	18
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.9 Footing_SF6			
			Length (ft)	10	10
			Width (ft)	3	3.00
			Thickness (in)	18	18
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5

		1.2.10 Footing_SF7			
			Length (ft)	28	28
			Width (ft)	2.8	2.8
			Thickness (in)	18	18
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.11 Footing_SF8			
			Length (ft)	8	8
			Width (ft)	2.5	2.5
			Thickness (in)	18	18
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.12 Footing_SF9			
			Length (ft)	10	10
			Width (ft)	5.4	5.4
			Thickness (in)	18	18
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.13 Footing_SF10			
			Length (ft)	75.00	75.00
			Width (ft)	1.20	1.20
			Thickness (in)	18.00	18
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.14 Footing_SF11			
			Length (ft)	26.00	26.00
			Width (ft)	2.00	2.00
			Thickness (in)	18.00	18
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.14 Footing_SF12			
			Length (ft)	15.00	15.00
			Width (ft)	4.00	4.00
			Thickness (in)	18.00	18
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
A21 Lowest Floor Construction					
	1.1 Concrete Slab-on-Grade				
		1.1.1 SOG_5"			
			Length (ft)	104.00	130.00
			Width (ft)	51.00	51.00
			Thickness (in)	5	4
			Concrete (psi)	3000	3000
			Concrete flyash %	-	average
A22 Upper Floor Construction					
	3.1 Concrete Columns & Beams				
		3.1.1 Column1_Concrete_Sub-Basement			
			Number of Beams	0	0
			Number of Columns	5	5
			Floor to floor height (ft)	11.8	11.8
			Bay sizes (ft)	16.8	16.8
			Supported span (ft)	16.8	16.6
			Live load (psf)	-	75
		3.1.2 Column2_Concrete_Sub-Basement			
			Number of Beams	0	0
			Number of Columns	3	3
			Floor to floor height (ft)	11.8	11.8
			Bay sizes (ft)	9.5	9.5
			Supported span (ft)	9.5	9.5
			Live load (psf)	-	75

3.1.3 Column3_Concrete_Sub-Basement			
	Number of Beams	0	0
	Number of Columns	5	5
	Floor to floor height (ft)	11.8	11.8
	Bay sizes (ft)	15.8	15.8
	Supported span (ft)	15.8	15.8
	Live load (psf)	-	75
3.1.4 Column4_Concrete_Sub-Basement			
	Number of Beams	0	0
	Number of Columns	2	2
	Floor to floor height (ft)	11.8	11.8
	Bay sizes (ft)	7.5	10
	Supported span (ft)	7.5	10
	Live load (psf)	-	75
3.1.5 Column5_Concrete_Sub-Basement			
	Number of Beams	0	0
	Number of Columns	24	24
	Floor to floor height (ft)	11.8	11.8
	Bay sizes (ft)	9.5	10
	Supported span (ft)	9.5	10
	Live load (psf)	-	75
3.1.6 Column1_Concrete_Diaphragm Beam_Basement			
	Number of Beams	58	58
	Number of Columns	4	4
	Floor to floor height (ft)	11.8	11.8
	Bay sizes (ft)	16.8	16.8
	Supported span (ft)	16.8	16.8
	Live load (psf)	-	75
3.1.7 Column2_Concrete_Basement			
	Number of Beams	0	0
	Number of Columns	4	4
	Floor to floor height (ft)	11.8	11.8
	Bay sizes (ft)	18	18
	Supported span (ft)	18	18
	Live load (psf)	-	75
3.1.8 Column3_Concrete_Basement			
	Number of Beams	0	0
	Number of Columns	2	2
	Floor to floor height (ft)	11.8	11.8
	Bay sizes (ft)	7.5	10
	Supported span (ft)	7.5	10
	Live load (psf)	-	75
3.1.9 Column4_Concrete_Basement			
	Number of Beams	0	0
	Number of Columns	24	24
	Floor to floor height (ft)	11.8	11.8
	Bay sizes (ft)	9.5	10
	Supported span (ft)	9.5	10
	Live load (psf)	-	75
3.1.10 Column_BeamA-D_Typical interior_Mainfloor			
	Number of Beams	6	6
	Number of Columns	5	5
	Floor to floor height (ft)	11.8	11.8
	Bay sizes (ft)	19.1	19.1
	Supported span (ft)	19.1	19.1
	Live load (psf)	-	75
3.1.11 Column_Diaphragm Beam_Typical exterior_Mainfloor			
	Number of Beams	58	58
	Number of Columns	24	24
	Floor to floor height (ft)	11.8	11.8
	Bay sizes (ft)	9.5	10
	Supported span (ft)	9,5	10
	Live load (psf)	-	75
3.1.12 Column_BeamA-D_Typical interior_Secondfloor			
	Number of Beams	6	6
	Number of Columns	5	5
	Floor to floor height (ft)	11.8	11.8
	Bay sizes (ft)	19.1	19.1
	Supported span (ft)	19.1	19.1
	Live load (psf)	-	75

		3.1.13 Column_Diaphragm Beam_Typical exterior_Secondfloor			
			Number of Beams	58	58
			Number of Columns	24	24
			Floor to floor height (ft)	11.8	11.8
			Bay sizes (ft)	9.5	10
			Supported span (ft)	9,5	10
			Live load (psf)	-	75
	4.1 Concrete Slab				
		4.1.1 Floor_concrete_Basement_2.5"			
			Floor Width (ft)	105.8	105.8
			Span (ft)	53.7	30
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Life load (psf)	-	75
		4.1.2 Floor_concrete_Mainfloor_2.5"			
			Floor Width (ft)	105.8	105.8
			Span (ft)	53.7	30
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Life load (psf)	-	75
		4.1.3 Floor_concrete_Secondfloor_2.5"			
			Floor Width (ft)	105.8	105.8
			Span (ft)	53.7	30
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Life load (psf)	-	75
		4.1.4 Floor_concrete_Thirdfloor_2.5"			
			Floor Width (ft)	105.8	105.8
			Span (ft)	53.7	30
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Life load (psf)	-	75
		4.1.2 Floor_concrete_Thirdfloor_4.5"			
			Floor Width (ft)	9.5	9.5
			Span (ft)	21.9	21.9
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Life load (psf)	-	75
A23 Roof Construction					
		3.1.14 Column_BeamA-D_Typical interior_Thirdfloor			
			Number of Beams	6	6
			Number of Columns	5	5
			Floor to floor height (ft)	11.8	11.8
			Bay sizes (ft)	19.1	19.1
			Supported span (ft)	19.1	19.1
			Live load (psf)	-	75
		3.1.15 Column_Diaphragm Beam_Typical exterior_Thirdfloor			
			Number of Beams	58	58
			Number of Columns	24	24
			Floor to floor height (ft)	11.8	11.8
			Bay sizes (ft)	9.5	10
			Supported span (ft)	9,5	10
			Live load (psf)	-	75
	5.1 Concrete Slab				
		5.1.1 Roof_concrete slab_2"			
			Roof Width (ft)	105.8	105.8
			Span (ft)	53.7	30
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Life load (psf)	-	75
		5.1.2 Roof_concrete slab_4.5"			
			Roof Width (ft)	18.1	18.1
			Span (ft)	22.1	22.1
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Life load (psf)	-	75

A31 Walls Below Grade					
	2.1 Cast In Place				
		2.1.1 Wall_Cast-in-place_8"			
			Length (ft)	645	645.00
			Height (ft)	11.8	11.8
			Thickness (in)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
A32 Walls Above Grade					
	2.1 Cast In Place				
		2.1.1 Wall_Cast-in-place_8"			
			Length (ft)	817	817.00
			Height (ft)	11.8	11.8
			Thickness (in)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		2.1.3 Wall_Cast-in-place_12"			
			Length (ft)	365	365
			Height (ft)	11.8	11.8
			Thickness (in)	1	1
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
B11 Partitions					
		2.1.1 Wall_Cast-in-place_8"			
			Length (ft)	1090	1,090.00
			Height (ft)	11.8	11.8
			Thickness (in)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		2.1.2 Wall_Concrete Block_6"			
			Length (ft)	666	666
			Height (ft)	11.8	11.8
			Thickness (in)	8	8
			Concrete (psi)	4000	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Window Opening	Number of Windows	70	70
			Total Window Area (ft2)	3213	3213
			Frame Type	Fixed, Aluminum Frame	ixed, Aluminum Frame
			Glazing Type	-	Low E Tin Glazing
		Door Opening	Number of Doors	52	52
			Door Type	-	Steel Interior Door

Table 7. IE Inputs Assumption

Level 3 Elements	Assembly Type	Assembly Name	Specific Assumptions
A11 Foundation			
	1 2 Concrete Footing	1.2.1 Footing_F1	The thickness of the footing was adjusted to accommodate the Impact Estimator Limitation of Footing thickness to be under 19.7".The thickness and the width are maintained, length were adjusted using the following equation: Measured(length x width x thickness)=Cited(length x width x thickness) 11' x 10' x 30"/12=X' x 10' x 19"/12 Thus, X=17 37'
	1 2 Concrete Footing	1.2.2 Footing_F2 1.2.3 Footing_F3 1.2.7 Footing_SF4 have the same limitation problem and are adjusted using the same method.	Same method as above
A21 Lowest Floor Construction			
	1.1 Concrete Slab-on-Grad	1.1.1 SOG_5"	Due to the limited slab thickness options in the Athena tool, either 4" or 8" has to be chosen. But in real the SOG was built with the thickness of 5". The width and the thickness are maintained and the length is to be adjusted with the following equation: Measured (length x width x thickness) = Cited (length x width x thickness) 104' x 51' x 5"/12 = X' x 51' x 4"/12 Thus, X=130'
	3.1 Concrete Columns & B	3.1.2 Column2_Concrete_Sub-Basement 3.1.4 Column4_Concrete_Sub-Basement 3.1.5 Column5_Concrete_Sub-Basement 3.1.8 Column3_Concrete_Basement 3.1.9 Column4_Concrete_Basement 3.1.11 Column_Diaphragm Beam_Typical exterior_Mainfloor 3.1.13 Column_Diaphragm Beam_Typical exterior_Secondfloor	Limitation for Bay Size in Athena IE is >10 ft. Thus in these beam properties when the bay size is less than 10 ft, 10 ft is assumed and inputted.
	4.1 Concrete Slab	4.1.1 Floor_concrete_Basement_2.5" 4.1.2 Floor_concrete_Mainfloor_2.5" 4.1.3 Floor_concrete_Secondfloor_2.5" 4.1.4 Floor_concrete_Thirdfloor_2.5"	Limitation for slab span is less than 31 9' thus 30' is assumed to input into the Athena IE. Investigated has been done the measured slab span has beyond the maximum value, it's not safe. Most likely errors were generated at the measured information collection steps.
A23 Roof Construction			
	3.1 Concrete Columns & B	3.1.15 Column_Diaphragm Beam_Typical exterior_Thirdfloor	Limitation for Bay Size in Athena IE is >10 ft. Thus in these beam properties when the bay size is less than 10 ft, 10 ft is assumed and inputted.
A31 Walls Below Grade			
	2.1 Cast In Place	2.1.1 Wall_Cast-in-place_8"	Rebar # 5 was actually used but due to lack of options (only # 4 and # 6) rebar # 4 is assumed that was used.
A32 Walls Above Grade			
	2.1 Cast In Place	2.1.1 Wall_Cast-in-place_8"	Rebar # 5 was actually used but due to lack of options (only # 4 and # 6) rebar # 4 is assumed that was used.
General	All the concrete used in the building is unclear on the strength and percentage of fly ash contained.		