Chemistry Building, University of British Columbia
Life Cycle Assessment – Final Report

Cassie Tesche

University of British Columbia

CIVL 498C

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PROVISIO

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

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

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

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CIVL 498C – TERM PROJECT

Executive Summary

This Life Cycle Assessment of the Chemistry building (originally known as the Science Building) has been completed as an extension of the original LCA completed by Adam Jarolim in 2010[1], as part of the UBC LCA Database Project, a growing collection of LCA environmental impact studies completed on academic buildings across the UBC Vancouver campus. This study's purpose is to provide environmental impact information on the Chemistry building, but more importantly to contribute to an aggregate benchmark within the UBC LCA Database Project, which will be used to help UBC make more environmentally sustainable building choices in the future.

The study has been completed using quantities obtained from building drawings and On-Screen Takeoff software, which were then used for modeling the building using various assemblies within the Athena Institute's Impact Estimator software, with the environmental impacts of the Product and Construction Process stages of the building life cycle determined by Impact Estimator.

The initial stage of this project was to review the files from Jarolim's study, including the Impact Estimator files, the Inputs and Assumptions Document, the On-Screen Takeoff file, the building drawings, and Jarolim's final report. Because of software updates to the Impact Estimator, model modifications were necessary in order to get the model to run. The building components were then sorted according to a Canadian Institute of Quantity Surveyors (CIQS) modified Level 3 elemental system, including the respective model assemblies in Impact Estimator and the corresponding entry in the Inputs and Assumptions Documents. Further model modifications were necessary to properly sort the building assemblies. The model was then reviewed for inaccuracies, with corrections made where possible. Impact Estimator was used to generate reference flows for the building through Bill of Materials, as well as the environmental impacts of the building in seven impact categories (fossil fuel consumption, global warming, acidification, human health criteria – respiratory, eutrophication, ozone depletion, and smog formation).

The results of the study of this building are presented in terms of elemental contributions to the overall impacts, as well as the life cycle contributions to the overall impact, and uncertainty in the study is discussed. These results were also used in creating a class benchmark for all of the buildings on campus that have been studied. The Chemistry building impacts have been compared to this benchmark, with further interpretation of the results, in Annex A, and further recommendations for LCA use in Annex B.

[1] Jarolim, Adam. *Life Cycle Assessment Report, Chemistry Building UBC*. Vancouver, 2010. Unpublished student report.

Table of Contents

List of Figures

List of Tables

1.0 General Information on the Assessment

1.1 Purpose of the assessment

Intended Use of Assessment

This life cycle assessment of the Chemistry building has been completed as part of the UBC LCA Database Project, a growing collection of LCA environmental impact studies on academic buildings across the UBC Vancouver campus. This assessment provides information on the environmental impacts of the Chemistry building, but more importantly, it is contributing to an aggregate benchmark within the UBC LCA Database Project that will help UBC make more environmentally sustainable building choices in the future. The Project will help to inform those in policy making and strategic planning, and provide a tool that they can use in their decision making. This assessment, as part of the UBC LCA Database Project, will also be used as an educational tool for future students in the Life Cycle Assessment of Buildings course, and as a demonstration of the potential that LCA holds for helping people make more sustainable choices in their buildings.

Reasons for Carrying Out the Study

The University of British Columbia has earned a reputation as a leader in sustainability, a reputation that it intends to maintain and to strengthen as it grows as a campus and institution. The UBC LCA Database Project aligns with one of the three goals within UBC's Commitment to Sustainability, outlined in the 2012 UBC Strategic Plan:

> "Make UBC a living laboratory in environmental and social sustainability by integrating research, learning, operations, and industrial and community partners"[2]

The UBC LCA Database Project integrates research and learning with campus operations and planning, in working towards more sustainable building choices for the campus, and demonstrates UBC's commitment to sustainability.

Intended Audience

While it is hoped that a wide range of audiences will review this report, including future students in the Life Cycle Assessment of Buildings course, LCA industry members, and other institutions or companies that may wish to learn from UBC's experience in order to develop their own LCA database, the primary intended audience is policy and decision makers from UBC, including those involved in campus operations, the UBC Sustainability Initiative, and UBC Strategic Planning.

Use for Comparative Assertions

While the results of the life cycle assessment of this building are compared to the average results from other buildings on campus later in the report (see Annex A), the main use of this information in terms of making comparative assertions is to provide a benchmark for future

[2] University of British Columbia. *Place and Promise: The UBC Plan*. Vancouver, 2012. Web. http://strategicplan.ubc.ca/files/2009/11/UBC-PP-Layout-Aug2012.pdf, accessed November 15, 2013.

building designs to be compared to. Further discussion of the importance and use of benchmarks is provided in Annex A.

1.2 Identification of building

Table 1 - Building Overview

Size	Basement, 1st, 2nd, 3rd Floor: 62,300 ft^2		
Address	2036 Main Mall, Vancouver, British Columbia		
Primary Uses	Design[3]: Office, research, and lecture space for the departments of Chemistry, Physics, Bacteriology, and Nursing and Public Health Current: Office, research, and lecture space for the Department of Chemistry		
Relevant History[4]	1912 – Competition for building designs opened; Sharp and Thompson selected 1914 – Tender bids for construction called for; all later returned unopened due to start of World War I 1915 – Building frame poured; funds were exhausted and construction stopped October 28, 1922 – UBC students marched in The Great Trek to protest overcrowding at the University's Fairview campus and to push for the development of the Point Grey campus November 8, 1922 – Legislature authorized construction of Point Grey Campus March 26, 1923 – Construction contract with E.J. Ryan Contracting Co., Ltd. September 28, 1923 – Cornerstone of building laid Summer, 1925 – Building completed September 22, 1925 – First lecture held in the Science Building		
Architect	Sharp and Thompson		
Cost	Year:	1925	2012
	Canada All-items CPI[5]:	9.1	121.7

[3] Cavell, Catherine. *The Chemistry (Science) Building, UBC Campus, A History 205 Project*. Vancouver: 1983. Unpublished student report. Available from Rare Books and Special Collections, ASRS Storage at I. K. Barber Learning Centre, University of British Columbia.
[4] Cavell, Catherine. *The Chemistry (Science) Building, UBC Campus, A History 205 Project*. Vancouver: 1983. Unpublished student report. Available from Rare Books and Special Collections, ASRS Storage at I. K. Barber Learning Centre, University of British Columbia.
[5] Statistics Canada. *Table 326-0021 Consumer Price Index (CPI), 2009 basket, annual (2002=100 unless otherwise noted),* CANSIM (database). Accessed November 12, 2013.

	Cost:	$960,778[6] (including $79,800 contract for frame construction)	$12,800,000 (Estimated)
Time to Construct	~ 3 years, with 7 year break during World War I		
Contractors[7]	1915 frame construction – Robert McLean 1923-1925 building completion – E.J. Ryan Contracting Company		

1.3 Other Assessment Information

Table 2 - 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	Cassie Tesche, M.Eng. Clean Energy Student, 2013; Adam Jarolim, BSc. Civil Engineering Student, 2010.
Impact Assessment method	Athena Impact Estimator for Buildings, Version 4.2.0208, using US EPA TRACI impact assessment methodology, 2007.
Point of Assessment	88 years since construction completion.
Period of Validity	5 years.
Date of Assessment	Completed in December 2013.
Verifier	Student work, study not verified.

2.0 General Information on the Object of Assessment

2.1 Functional Equivalent

The functional unit for a life cycle assessment must be carefully chosen to quantify the performance of the object of assessment based on its function so that it can be used as a reference unit. When multiple LCAs are to be used, either in comparison or in aggregate to form a benchmark, both of which are done with this study, it is important to ensure a consistent functional unit (and thereby ensuring a consistent function) so that meaningful conclusions can be drawn. Two buildings of similar size and shape that serve different functions, such as library storage compared to lecture space, may have very different design standards, in this example based on loading, and therefore very different material requirements, and hence different impacts.

[6] Cavell, Catherine. *The Chemistry (Science) Building, UBC Campus, A History 205 Project*. Vancouver: 1983. Unpublished student report. Available from Rare Books and Special Collections, ASRS Storage at I. K. Barber Learning Centre, University of British Columbia.

[7] Cavell, Catherine. *The Chemistry (Science) Building, UBC Campus, A History 205 Project*. Vancouver: 1983. Unpublished student report. Available from Rare Books and Special Collections, ASRS Storage at I. K. Barber Learning Centre, University of British Columbia.

Table 3 - Functional Equivalent Definition for Object of Assessment

Building Type	Institutional
Technical and functional requirements	Technical: Unknown; building pre-dates National Building Code Design functional: Academic Building: Office, research, and lecture space for the Departments of Chemistry, Physics, Bacteriology, and Nursing and Public Health Current functional: Academic Building: Office, research, and lecture space for the Department of Chemistry
Pattern of use	Design occupancy: Unknown Current occupancy of the two classrooms in the original building: 228[8] Current occupancy of office and research space: Unknown Current building hours: Monday-Friday 07:00-19:00, Saturday/Sunday/Holidays - Closed
Required service life	Unknown; assumed 100+ years

2.2 Reference Study Period

According to the standard EN 15978 (Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method), the default length of the reference study period shall be the required service life of the building. Information is not available on the design service life of the Chemistry building; hence, given the age of the building, it has been assumed to be 100+ years. However, there is too much uncertainty surrounding the Use stage, Module B in EN 15978, of the building over its lifetime, so it has been excluded from this study. Also, the role of this building in the University's long term campus plan is unknown and likely to change over time, so there is much uncertainty regarding the End of Life stage, Module C in EN 15978, and it has been excluded as well. Without knowing anything about the End of Life stage, it is impossible to estimate any environmental benefits or loads beyond the End of Life, such as those from reuse or recycling of construction materials, so Module D of EN 15978 is also excluded from this study. There is only enough information available to consider the Product and the Construction Process stages, Module A in EN 15978, with any reasonable degree of certainty in the reference study period.

[8] UBC Scheduling Services. http://www.students.ubc.ca/classroomservices/buildings-and-classrooms/?code=CHEM accessed November 15, 2013

2.3 Object of Assessment Scope

The scope of the product system being studied here is the original Chemistry (Science) building, based on the architectural and construction drawings that are available. Since the building's completion in 1925, additions have been completed in 1958, 1961, and 1963[9]. The Chemistry building, as defined by these drawings and within this study, is now only part of the greater complex of Chemistry buildings, seen in Figure 1,[10] and is known as the Centre Block, or Chemistry D. Chemistry B, C, and E buildings are outside of the scope of this study because the amount of work involved in completing all buildings together is beyond that of an individual term project.

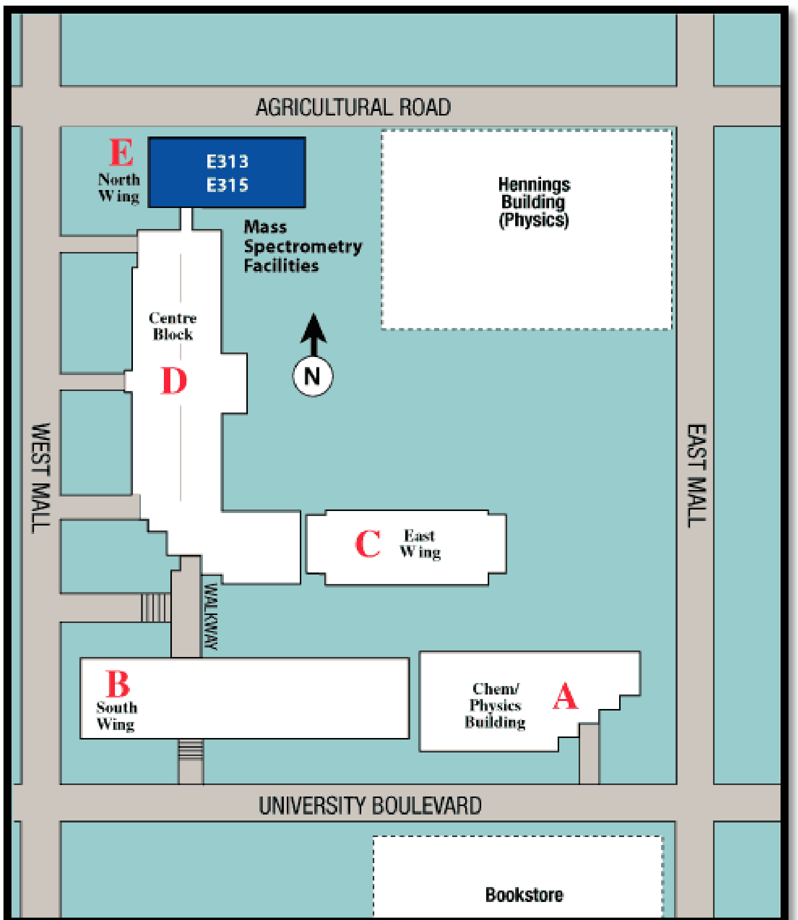

Figure 1 - Chemistry Buildings, UBC[10]

Within the original Chemistry building, only the structure and the envelope of the building are included in this study. Finishes, furnishings, and fixtures are excluded because of the variability of these items over the building's lifetime. There would also be insufficient information available on these items if we wished to include them, and even if all information were available, there would be limits on what life cycle inventory data is available for those items, and on what could be modeled within the Impact Estimator. There would be too much variability between the various buildings on campus depending on their age and specific use. Including finishes, furnishings, and fixtures would introduce too much uncertainty and would not contribute to the strength of the study, and thus the scope of this LCA is limited to the building structure and envelope.

[9] Cavell, Catherine. *The Chemistry (Science) Building, UBC Campus, A History 205 Project*. Vancouver: 1983. Unpublished student report. Available from Rare Books and Special Collections, ASRS Storage at I. K. Barber Learning Centre, University of British Columbia.

[10] Department of Chemistry, Research & Services. http://www.chem.ubc.ca/research-services/house-shops-and-services/mass-spectrometry/microanalysis/map accessed November 17, 2013.

The main structural elements of the original Chemistry building are primarily concrete, including the footings, slab on grade, cast in place walls, columns and beams throughout, and suspended slabs of all floors and the roof. The exterior is built from granite and other fieldstone[11]. Table 4 summarizes the building components and shows them sorted into a modified Canadian Institute of Quantity Surveyors (CIQS) system of Level 3 Elements. This sorting was done so that further comparisons can be done beyond the total building effects, so that the LCA information and database can be used in parallel with building design. It allows practitioners to see what element of their building is the largest contributor to a given impact so that other design choices for that element can be considered. The CIQS format is also commonly used for presenting life cycle costing information, making it possible for decision-makers to consider economic criteria side by side with environmental data.

Table 4 - Building Definition Summary

CIVL 498C Level 3 Elements	Chemistry Building Components	Quantity (Amount)	Units	Description of Quantity Measured
A11 Foundations	Concrete footings	1654	m^2	total area of slab on grade
A21 Lowest Floor Construction	Concrete slab on grade	1654	m^2	total area of slab on grade
A22 Upper Floor Construction	Concrete columns and beams with concrete suspended slabs	5796	m^2	sum of the total area of all upper floors measured from the outside face of the exterior walls
A23 Roof Construction	Concrete columns and beams with concrete suspended slab; roof system modeled as 4 ply built up asphalt roof system, inverted, with rock-wool glass felt, thickness 8”[12]	1802	m^2	sum of the total area of the roof measured from the outside face of the exterior walls
A31 Walls Below Grade	Cast-in-place; brick, modeled with concrete cinder blocks; stone exterior cladding modeled as stone ballast	1723	m^2	sum of total surface area of the exterior walls below grade
A32 Walls Above Grade	Brick, modeled with concrete cinder blocks; stone exterior cladding modeled as stone ballast	3988	m^2	sum of total surface area of the exterior walls above grade

[11] Jarolim, Adam. *Life Cycle Assessment Report, Chemistry Building UBC*. Vancouver, 2010. Unpublished student report.
[12] Jarolim, Adam. *Life Cycle Assessment Report, Chemistry Building UBC*. Vancouver, 2010. Unpublished student report.

B11 Partitions	Cast-in-place; plaster on brick, modeled with stucco on concrete cinder blocks	8481	m^2	sum of total surface area of the interior walls

3.0 Statement of Boundaries and Scenarios Used in the Assessment

3.1 System Boundary

As discussed in section 2.2, this study includes only Module A of EN 15798, consisting of the Product stage and the Construction Process stage. Modules B (Use stage), C (End of Life stage), and D (Benefits and loads beyond the system boundary) are excluded. As such, this study considers the raw material supply, transport, and manufacturing processes of the Product stage, the transport and construction-installation processes of the Construction Process stage, as well as the upstream and downstream processes associated with each of the Product and Construction Process unit processes. Examples of upstream processes include generation of the electricity used in manufacturing, and the extraction and refining of the fuels used in the transport processes, while downstream processes include things like disposal of waste materials during the construction processes

3.2 Product Stage

The Product stage includes all processes necessary to get the construction processes to the manufacturing gate, hence the term “cradle to gate”. It includes such processes as extraction of the raw materials, the collection and transport of materials and wastes from the extraction site to the manufacturing and disposal sites, the manufacturing process of the product, production of the energy used in the manufacturing process, as well as the actual energy itself, the production of co-products during the manufacturing process, and the collection and transport of the products and waste to the “gate” and the disposal site, respectively.

3.3 Construction Stage

The Construction Process stage includes all processes necessary to get the different construction products from the manufacturer’s gate to its place within the final construction work. This includes processes such as transportation from the manufacturer to the construction site, installation of the product on site, construction processes on site, transportation of materials on site, waste management processes on site, and final waste disposal.

4.0 Environmental Data

4.1 Data Sources

The Athena Impact Estimator uses its own data from the Athena LCI Database, which it has developed over time as a result of its own research with assistance from industry in obtaining a thorough life cycle inventory for a given product.[13] Usually the Athena Institute develops its data in-house, under contract to trade associations and in cooperation with several manufacturers and plants across North America so that the resulting data is a good cross-sectional industry average formulation and environmental profile for the material being studied; the Athena Institute then applies local electricity, energy, and transportation data to the manufacturing effects to provide regionalized data.[14] These data files are downloaded with the software, and are not available on their own because they are proprietary and because they require the data integration that is performed by the Impact Estimator.[15] In an attempt to make their data more transparent, however, the Athena Institute makes available many of the LCA/LCI studies that it uses in its database.[16]

The databases also contain data on

- energy use
- transportation
- construction and demolition processes including on-site construction of a building's assemblies
- maintenance
- repair and replacement effects through operating life
- demolition and disposal[17]

The Impact Estimator also draws on data in the U.S. Life Cycle Inventory (USLCI) Database, which was initiated partly by the Athena Institute and contains data contributed by the Athena Institute.[18] The USLCI database a publicly available database that is managed by the National Renewable Energy Laboratory of the Department of Energy in the United States.[19]

The U.S. Life Cycle Inventory (LCI) Database is a publicly available database that allows users to objectively review and compare analysis results that are based on similar data collection and analysis methods.

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[13] Athena Sustainable Materials Institute. *LCI Databases*. http://www.athenasmi.org/our-software-data/lca-databases/ accessed November 18, 2013
[14] Athena Sustainable Materials Institute. *Frequently Asked Questions*. http://calculatelca.com/faqs/#ie4b_databases accessed November 18, 2013
[15] Athena Sustainable Materials Institute. *LCA Background Data.* http://calculatelca.com/software/impact-estimator/lca-database-reports/ accessed November 18, 2013
[16] Athena Sustainable Materials Institute. *Publications*. http://www.athenasmi.org/resources/publications/ accessed November 18, 2013
[17] Athena Sustainable Materials Institute. *LCI Databases*. http://www.athenasmi.org/our-software-data/lca-databases/ accessed November 18, 2013
[18] Athena Sustainable Materials Institute. *Frequently Asked Questions*. http://calculatelca.com/faqs/#ie4b_databases accessed November 18, 2013
[19] National Renewable Energy Laboratory. *U.S. Life Cycle Inventory Database*. http://www.nrel.gov/lci/about.html accessed November 18, 2013

4.2 Data Adjustments and Substitutions

Because of the age of the building and the limited information available on the construction drawings about the materials used, and the limited number of ways to model the building in Impact Estimator, there are a number of large material type inaccuracies. The brick walls have been modeled as concrete cinder blocks, while the exterior field stone has been modelled as ballast. Slightly more similar modeling materials may be available, but the slight improvement in accuracy of the results was judged to be insignificant given the amount of uncertainty in the model, discussed in the next section, that cannot be improved upon. To model the actual building more accurately, extensive research would need to be done to estimate the impacts of manufacturing, transporting, and constructing these materials using the technologies (and therefore the energy and electricity mixes) of the early twentieth century. Instead, my area of focus was in ensuring that the quantities were properly modeled in the Impact Estimator.

4.3 Data Quality and Uncertainties

There are five main sources of uncertainty in an LCA: data, model, temporal, spatial, and variability between sources. As discussed below, a large amount of uncertainty is present in this study, largely owing to the age of the building rather than the quality of the data in the LCI databases used. This uncertainty should be kept in mind when considering the results of the study.

Data

Data uncertainty refers to the uncertainty in how the data used in an LCA was obtained, such as the data collection methods and the allocation methods used to produce the data. Inaccurate or non-existent data also falls under this category. This is a large source of uncertainty in this study, due to the age of the drawings and the minimal information that was provided on the products and processes used. Assumptions were made during the study, outlined in section 6.0 and in the Assumptions document in Table 9, that introduce data uncertainty.

Model

Model uncertainty refers to the unknowns in how the LCA is being done within the model. Some LCA software are more transparent and are clear about how their model is putting together all of the data and calculating its results. Because the Impact Estimator software is proprietary, the inner workings of the model are not available to the public. Users must provide their inputs, trust the software, and take whatever outputs it gives without being able to really see how the model turns the inputs into outputs. An example of this is the variance in the bill of materials for the exact same assemblies depending on how they are organized into projects. When all assemblies from the elemental projects were duplicated into a single Whole Building project, the resultant bill of materials was different from the bill of materials determined as the sum of the bill of materials from each of the elemental projects, as mentioned in section 6.0. With the high level of model uncertainty in using the Impact Estimator software, it is impossible to know where this difference is coming from.

Temporal

Temporal uncertainty refers to uncertainty related to time impacts, whether the variance in emissions over time, the age of the data, or how impacts of certain emissions can change over time. This is a huge source of uncertainty in this study. The data used in the LCI Databases are new compared to when the Chemistry building was actually constructed, and it is unlikely that the emission factors that are used in the model accurately reflect the actual emissions and impacts caused in the manufacturing of the products in the building and during the construction process. As such, the results of this study should be taken more as the impacts that would be associated with reconstructing the Chemistry building today, rather than an accurate reflection of actual impacts.

Spatial

Spatial uncertainty refers to the regional differences in emissions in manufacturing and construction processes. For example, a manufacturing process that uses much electricity would have far higher impacts when done in Alberta compared to British Columbia because of the very different electricity mixes. The Impact Estimator attempts to eliminate as much of this uncertainty as possible by allowing users to select the location of their building and adjusting the data that is used in the model accordingly, but a level of uncertainty still remains. An example of spatial uncertainty related to the study of the Chemistry building would be the difference between where the actual granite and other fieldstone was taken from compared to what the model assumes for ballast, which is how the exterior stone was modelled. Impacts from the transportation processes during an LCA can be particularly subject to spatial uncertainty

Variability Between Sources

While attempts are made to standardize the methods and processes used during an LCA study, there will always still be a level of variability in the results of a study of the same product or system, depending on who is doing the study and what assumptions have been made. This introduces another level of uncertainty, the variability of data between sources. Product category rules are a good example of an attempt to reduce this variability within a given product category, so that the LCA data submitted to the LCI database for similar products has less variability due to variance in methods, and any differences in the data are due to actual differences in production of the product.

5.0 Indicators Used for Assessment and Expression of Results

The impact assessment method used by the Athena Impact Estimator is the Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI), developed by the US Environmental Protection Agency. The TRACI impact assessment method includes the impact categories described below that were used in this project, as well as human cancer and non-cancer criteria, ecotoxicity, land use, and water use[20].

Table 5 - Impact Categories Used in This Project

Impact	Description of Cause/Effect	Category	Possible Endpoint

[20] United States Environmental Protection Agency. *Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI)*. http://www.epa.gov/nrmrl/std/traci/traci.html accessed November 15, 2013

Category	Chain Being Modeled	Indicator	Impacts
Fossil Fuel Consumption	Consumption of non-renewable fossil fuel energy reserves	MJ	▪ depletion of fossil fuel reserves
Global Warming	Gases in the atmosphere lead to increased absorption of radiation and the "greenhouse" effect	kg CO_2 eq	▪ climate change ▪ increase in frequency and severity of extreme weather events
Acidification	Deposition of acid	moles of H^+ eq	▪ ocean acidification leading to coral extinction ▪ acid rain
Human Health Criteria – Respiratory	Particulate matter in the atmosphere, when breathed in, can irritate and damage the human respiratory system	kg PM_{10} eq	▪ increase in frequency and severity of asthma, bronchitis, etc.
Eutrophication	Increase in nutrients in an aquatic ecosystem due to added nitrates and phosphates	kg N eq	▪ hypoxia ▪ decreased biodiversity
Ozone Depletion	Interruption of ozone cycle by chemicals and gases, leading to ozone depletion	kg CFC-11 eq	▪ increased radiation reaching earth, contributing to further global warming ▪ increase in rates of skin cancers
Smog Formation	Contribution to ground level ozone	kg O_3 eq	▪ human health effects, including asthma, bronchitis

6.0 Model Development

6.1 Chemistry Building Model

The Chemistry building was initially modelled by Adam Jarolim as a combination of assemblies in Impact Estimator, based on quantities taken off from the architectural and construction drawings using On-Screen TakeOff software, and other information from the drawings. The information contained on the drawings with regards to materials and specifications is very limited relative to what can be found on more current drawings, so assumptions often had to be made, as outlined in the Impact Estimator Inputs Assumption Document, included as Table 9 in Annex D. Any additions, corrections, and changes that I have made are highlighted with red text.

When I received the model, I had to add a number of properties to the model in order to run the Impact Estimator, as the software had changed since the model was originally created in 2010, including the building height and the new Supported Area field for the beam and column assemblies.

During my portion of the project, the building components were sorted into their corresponding CIQS Level 3 element, as were the assemblies in Impact Estimator, and the entries in the

Impact Estimator Inputs Document and the Impact Estimator Inputs Assumptions Document, Table 8 and Table 9 respectively. In doing so, a number of assemblies had to be split so that portions of the building could be sorted properly. For example, some of the cast-in-place foundation walls had to be split into A31 Walls Below Grade, and some into B11 Partitions. To do so, the corresponding quantity takeoff was found in the On-Screen Takeoff file, duplicated, and each was adjusted to include only the portion of the wall included under each element. Next, the corresponding assembly in Impact Estimator was duplicated and adjusted to match the new quantities, and sorted appropriately. The Inputs and Assumptions Documents also had to be updated. Assemblies that were adjusted are distinguished by [1/2] or [2/2] in the assembly name.

The only building components classified under element A11 Foundations are the concrete footings, which have been modeled in IE as concrete footing assemblies. Quantities for the footings were determined using an area condition in On-Screen Takeoff. The measured area had to be adjusted to compensate for the maximum footing thickness of 19.7", as the actual footing thicknesses varied from 2' to 3'6". Without specifications from the drawings, assumptions had to be made about concrete strength, assumed to be 4000 psi, and flyash content, assumed to be average.

Element A21 Lowest Floor Construction contains the slabs on grade and basement floor concrete slabs. It should be noted that other modellers may have chosen to sort the basement floor slab under A22 Upper Floor Construction, however, as there is not a full floor between the slab on grade and the basement floor, I chose to sort it as stated. These building components were modeled as concrete slabs. Assumptions include a concrete strength of 3000 psi, average fly ash, and that a 3 mil polyethylene vapour barrier was used.[21] Some calculations, found in the Assumptions document, were necessary to adjust the slab thickness from actual to the possible values of 4" and 8" in Impact Estimator.

Element A22 Upper Floor Construction contains the stairs, concrete columsn and beams for the basement, 1st, 2nd, and 3rd floors, and concrete suspended slabs for the 1st, 2nd, and 3rd floors. Stairs were modeled as foundations because this was the only place in Impact Estimator that rebar specifications can be added. Linear and area conditions were used in On-Screen Takeoff to determine the amount of concrete. Assumptions for the stairs include concrete strength of 3000 psi and average fly ash. The concrete columns and beams assembly was used to model the columns and beams. Assumptions include a live load of 75 psf, which is appropriate for an institutional structure.[22] The concrete suspended slabs, as before, used assumptions of 3000 psi concrete and average fly ash, and an assumed live load of 75 psf.

Element A23 Roof Construction consists of the concrete columns and beams supporting the roof and the small penthouse on top of the building, and the concrete roof slab. It is recognized

[21] Jarolim, Adam. *Life Cycle Assessment Report, Chemistry Building UBC*. Vancouver, 2010. Unpublished student report.
[22] Jarolim, Adam. *Life Cycle Assessment Report, Chemistry Building UBC*. Vancouver, 2010. Unpublished student report.

that the roof area under the penthouse (and supporting columns and beams underneath) could be moved to A22 Upper Floor Construction, but because of the small area of the penthouse and for the sake of simplicity it was left under Roof Construction. The assumed live loading for the columns and beams was 75 psf. Detailed information on the roof system was not available, so it was assumed to be a 4 ply Built Up Asphalt Roof System – inverted, with Rockwool glass felt at a thickness of 8”.[23] A 3 mil polyethylene vapour barrier was also assumed. The actual roof system in place could be determined by arranging for a visit to the site, for any future modeling of this building, but as seen later in section 7.1, the element A23 consists of only ~10% of most impacts.

Element A31 Walls Below Grade consists of cast in place foundation walls and concrete block walls. Cast in place walls used the linear condition in On-Screen Takeoff and were grouped by their specific height, with assumptions of concrete strength of 3000 psi, average fly ash, a 3 mil polyethylene vapour barrier, and #5 rebar since #4 is not available in Impact Estimator. During my stage of modeling, a number of these assemblies had to be split up into the exterior walls (in this element) and the interior walls sorted under B11 Partitions. The revised quantities from On-Screen Takeoff can be seen in the Inputs and Assumptions Documents in Annex D. Concrete block walls were also estimated using the linear condition in On-Screen Takeoff, with the main assumption for the assembly in Impact Estimator being that concrete cinder blocks, with a standard width of 8”, are the best available replacement for the brick walls.[24] The length of the wall was adjusted where needed to account for walls wider than 8”. Assumptions for these assemblies include #4 rebar, a 3 mil polyethylene vapour barrier, and stucco in place of plaster on interior surfaces.

Element A32 Walls Above Grade consists of more of the concrete block walls, as described above, as well as the exterior stone cladding, which was modeled as stone ballast. Assumptions were made to calculate the mass of ballast needed in the model (see the Assumptions Document), and because the actual mass was greater than the limit accepted by Impact Estimator, 1/3 of the actual mass has been entered as the assembly, and the resulting bill of materials and impacts was multiplied by 3.

Element B11 Partitions is comprised of interior cast in place foundation walls, some of which were split off from the appropriate exterior walls as described earlier for A31, and concrete block walls. Assumptions described above for both wall types were repeated in these assemblies as well.

6.2 Reference Flows

Reference flows are the materials needed for a product system to perform the function used in the definition of the functional unit. In this study, our reference flows are generated by the Bill of Materials that the Impact Estimator software provides for each project, showing what materials

[23] Jarolim, Adam. *Life Cycle Assessment Report, Chemistry Building UBC*. Vancouver, 2010. Unpublished student report.
[24] Jarolim, Adam. *Life Cycle Assessment Report, Chemistry Building UBC*. Vancouver, 2010. Unpublished student report.

are used by the modeled components. Table 6 contains the Bill of Materials for each of the CIQS Level 3 elemental projects, as well as a summary Bill of Materials for the whole building. It should be noted that, as mentioned in section 4.3, when all assemblies in the elemental projects were duplicated into a single Whole Building project, the output Bill of Materials from Impact Estimator was different from that shown below.

Table 6 - Bills of Materials

Material	Quantity	Units
Project: A11 Foundations		
Concrete 30 MPa (flyash av)	249	m^3
Rebar, Rod, Light Sections	0.37	Tonnes
Project: A21 Lowest Floor Construction		
3 mil Polyethylene	1127	m^2
Concrete 20 MPa (flyash av)	276	m^3
Rebar, Rod, Light Sections	11.0	Tonnes
Welded Wire Mesh / Ladder Wire	0.96	Tonnes
Project: A22 Upper Floor Construction		
Concrete 20 MPa (flyash av)	729	m^3
Concrete 30 MPa (flyash av)	606	m^3
Rebar, Rod, Light Sections	217	Tonnes
Project: A23 Roof Construction		
#15 Organic Felt	8217	m^2
3 mil Polyethylene	1912	m^2
Ballast (aggregate stone)	113525	kg
Concrete 20 MPa (flyash av)	266	m^3
Concrete 30 MPa (flyash av)	221	m^3
Galvanized Sheet	2.15	Tonnes
MW Batt R11-15	15148	m^2 (25mm)
Polyethylene Filter Fabric	0.15	Tonnes
Rebar, Rod, Light Sections	88.0	Tonnes
Roofing Asphalt	13345	kg
Project: A31 Walls Below Grade		
3 mil Polyethylene	1785	m^2
Concrete 20 MPa (flyash av)	207	m^3
Concrete Blocks	9030	Blocks
Mortar	173	m^3
Nails	0.012	Tonnes
Rebar, Rod, Light Sections	30.9	Tonnes
Small Dimension Softwood Lumber, kiln-dried	0.47	m^3
Stucco over porous surface	918	m^2
Unclad Wood Window Frame	403	kg
Water Based Latex Paint	113	L
Project: A32 Walls Above Grade		
Ballast (aggregate stone)	1289141	kg

Concrete Blocks	45841	Blocks
Mortar	877	m^3
Nails	0.0078	Tonnes
Rebar, Rod, Light Sections	174	Tonnes
Small Dimension Softwood Lumber, kiln-dried	0.31	m^3
Stucco over porous surface	3962	m^2
Unclad Wood Window Frame	2111	kg
Water Based Latex Paint	484	L
Project: B11 Partitions		
3 mil Polyethylene	405	m^2
Concrete 20 MPa (flyash av)	80.1	m^3
Concrete Blocks	84624	Blocks
Mortar	1616	m^3
Nails	0.34	Tonnes
Rebar, Rod, Light Sections	252	Tonnes
Small Dimension Softwood Lumber, kiln-dried	13.4	m^3
Stucco over porous surface	7315	m^2
Water Based Latex Paint	907	L
Project: All Elements		
#15 Organic Felt	8217	m^2
3 mil Polyethylene	5228	m^2
Ballast (aggregate stone)	1402665	kg
Concrete 20 MPa (flyash av)	1558	m^3
Concrete 30 MPa (flyash av)	1076	m^3
Concrete Blocks	139494	Blocks
Galvanized Sheet	2.15	Tonnes
Mortar	2665	m^3
MW Batt R11-15	15148	m^2 (25mm)
Nails	0.36	Tonnes
Polyethylene Filter Fabric	0.15	Tonnes
Rebar, Rod, Light Sections	772.29	Tonnes
Roofing Asphalt	13345	kg
Small Dimension Softwood Lumber, kiln-dried	14.15	m^3
Stucco over porous surface	12195	m^2
Unclad Wood Window Frame	2515	kg
Water Based Latex Paint	1505	L
Welded Wire Mesh / Ladder Wire	0.96	Tonnes

7.0 Communication of Assessment Results

7.1 Life Cycle Results

After resorting and refining the model in Impact Estimator, a Summary Measures Report was generated for each of the elemental projects, showing the calculated impacts for the seven impact categories discussed in section 5.0. Figure 2 shows the relative contributions of each element to the total impact generated by the building, for each of the impact categories. From this figure, it can be seen that the partitions (interior walls) are the largest contributor for all except the respiratory human health criteria, for which walls above grade is the largest contributor. If this building was still in the design stage, the designers could look closer at these hotspots to determine what assemblies are the cause, and to consider alternative design choices.

The uncertainties discussed in section 4.3 should be kept in mind when considering the results of this study.

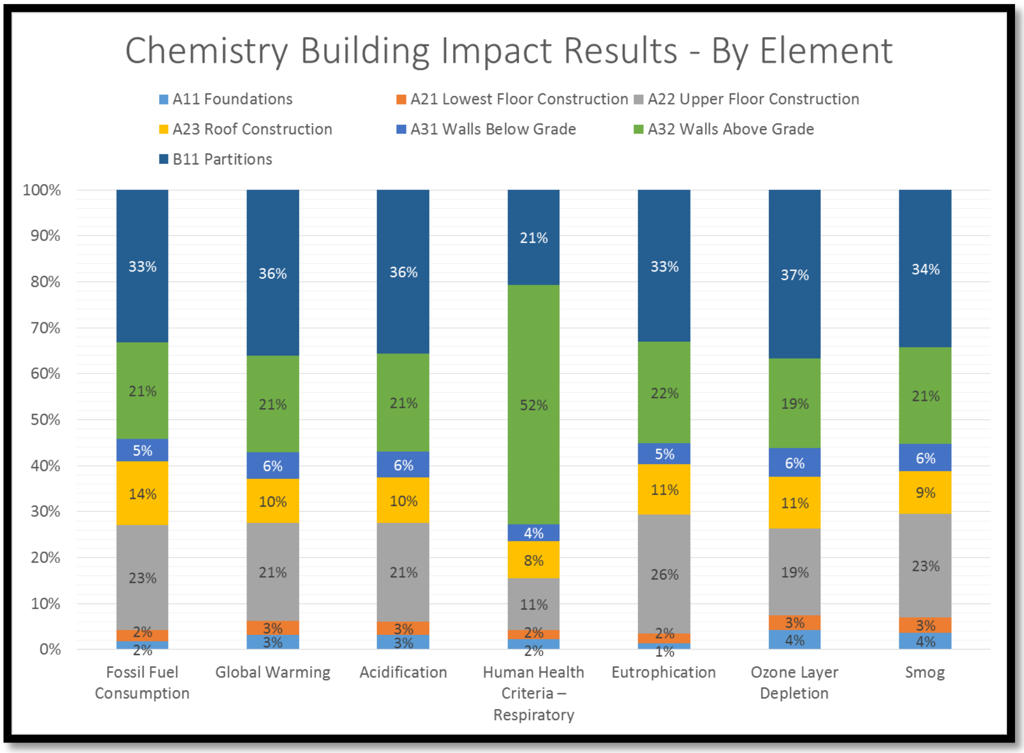

Figure 2 - Chemistry Building Life Cycle Assessment Impact Results - By Element

The Summary Measure Report data was also compiled by life cycle stage. Figure 3 shows the relative contributions of each of the product stage and construction process stage. The product stage is the majority contributor in all of the impact categories by quite a margin. As before, if this building were still in the design stage, the designers could investigate what assemblies are the biggest contributors and try to find alternative products to use in their design that have a lesser impact.

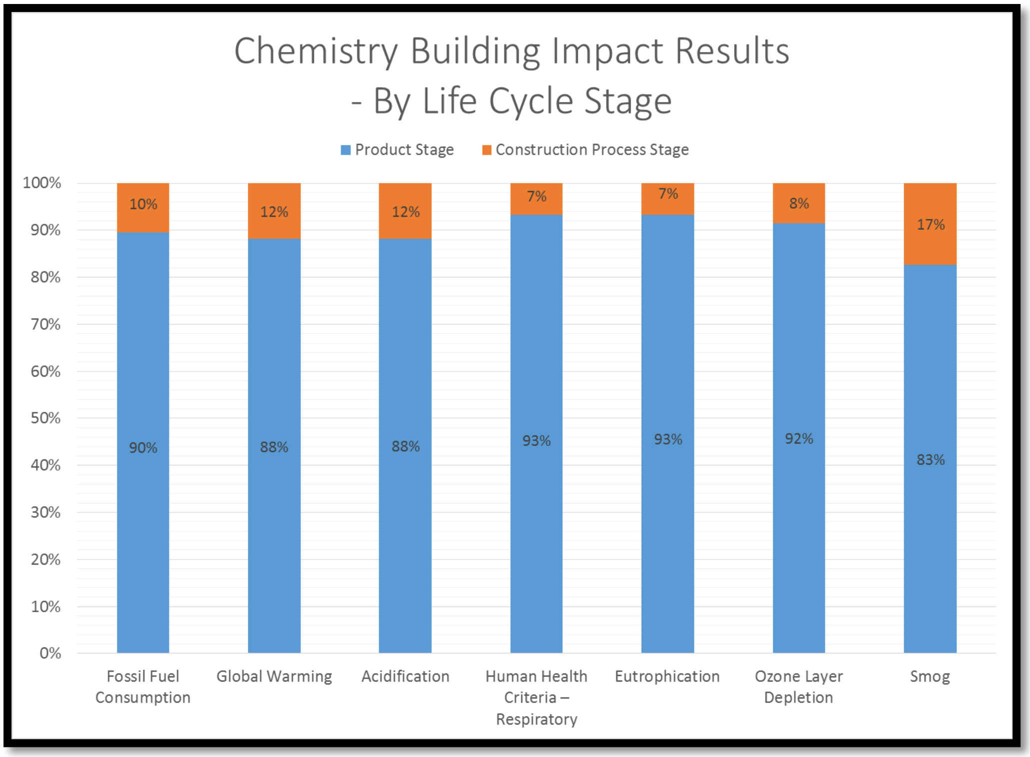

Figure 3 - Chemistry Building Life Cycle Impact Results - By Life Cycle Stage

7.2 Further Discussion of Results – Annexes

The results of this LCA study are examined beyond the scope of the EN 15978 requirements for a building declaration in the Annexes of this report as follows:

Annex A – Interpretation of Assessment Results, Benchmarking

Annex B – Recommendations for LCA Use

Annex C – Author Reflection

Annex D – Impact Estimator Inputs and Assumptions

Annex E - Additional Inaccuracies or Improvements Beyond Scope of Study

Annex A - Interpretation of Assessment Results

Benchmark Development

Benchmarking plays an important role in LCA because it gives meaning to the results by putting them into context. Knowing that the Chemistry building had a fossil fuel consumption for the whole building of 3553 MJ/m^2 is great, and there is value in being able to see which elements and life stages are the greatest contributors to that fossil fuel consumption. With the introduction of benchmarks, however, that number gains new meaning by comparing it to the average value found during LCA of similar buildings by putting it into context. By establishing a benchmark, it can be determined whether 3553 MJ/m^2 is considered to be high or low.

In order to make these comparisons to the benchmark, however, it is important to ensure that the results are for functionally equivalent buildings, and that similar methods were used to obtain the results. This includes ensuring a common goal and scope for each LCA building study, and consistency in the model development used across buildings.

UBC Academic Building Benchmark

Figure 4 through Figure 10 show the results of the Chemistry building compared to the class benchmark, taken at 7:00 pm on November 15, 2013. (Benchmarks used in the various building studies in the class will vary depending on when the benchmark data was taken and how many buildings' results had been contributed.) All seven impact categories are considered.

The data uncertainties discussed earlier in the report should be kept in mind when looking at this comparison.

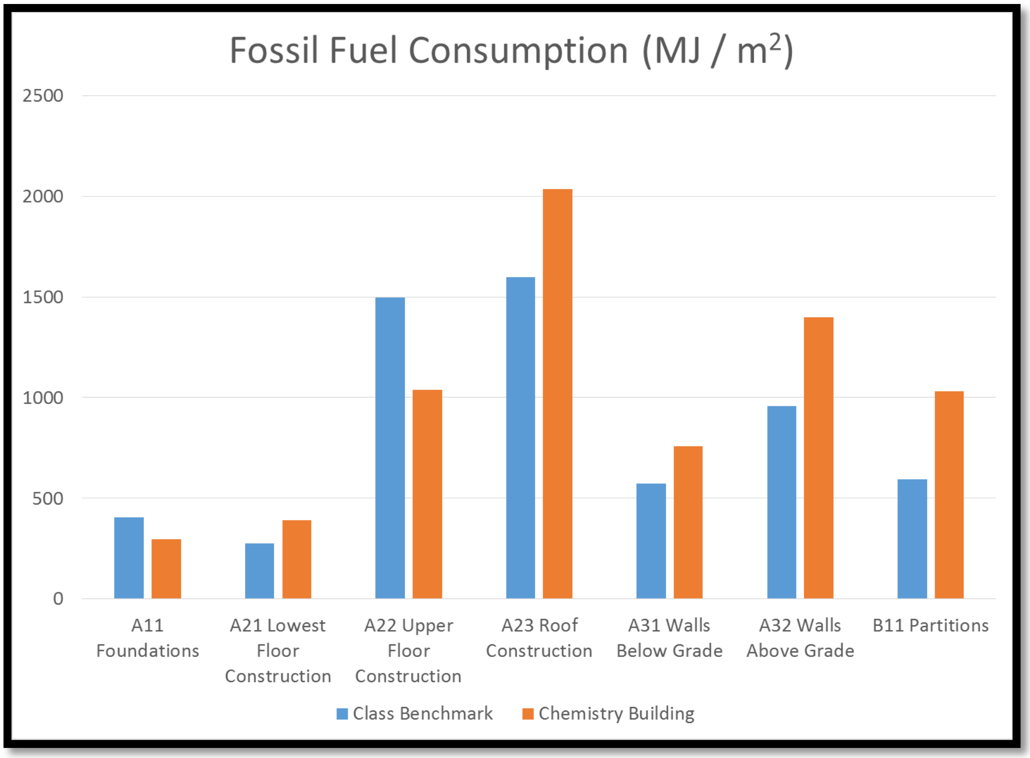

Figure 4 - Comparison of Chemistry Building to Class Benchmark - Fossil Fuel Consumption

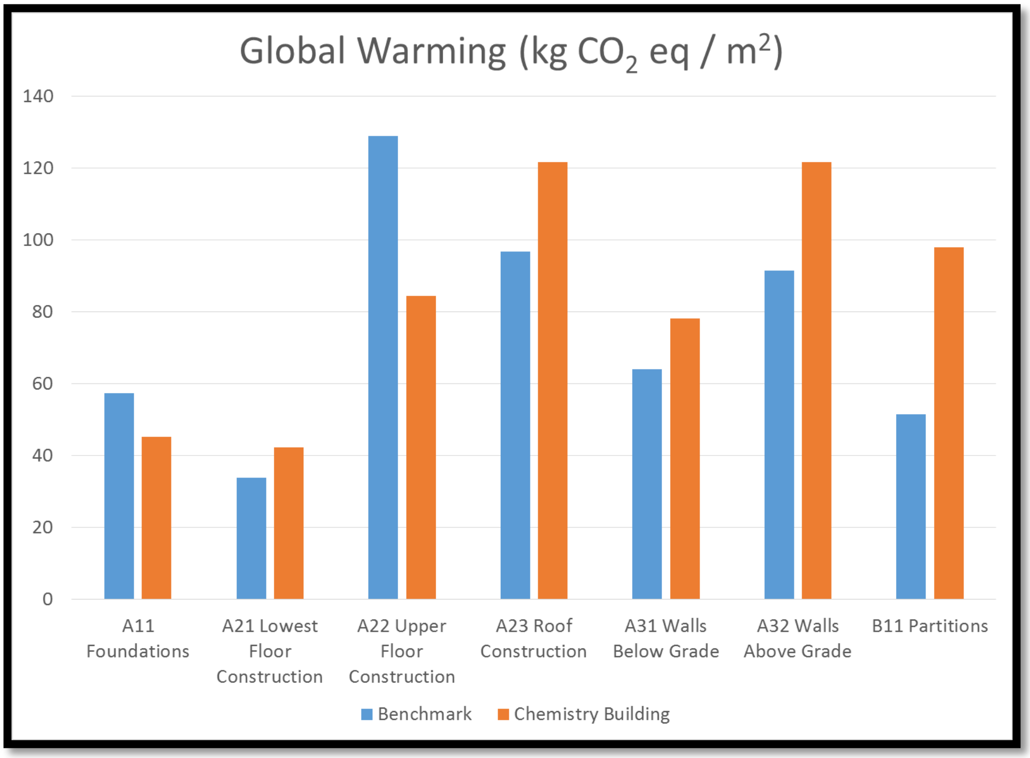

Figure 5 - Comparison of Chemistry Building to Class Benchmark - Global Warming Potential

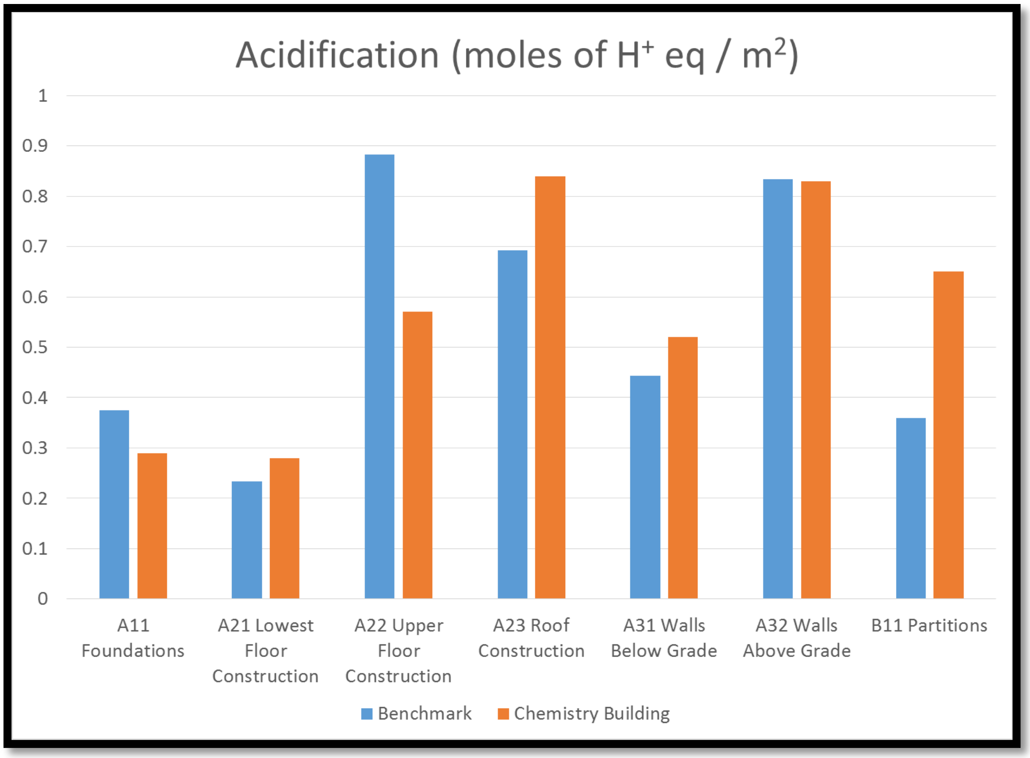

Figure 6 - Comparison of Chemistry Building to Class Benchmark - Acidification

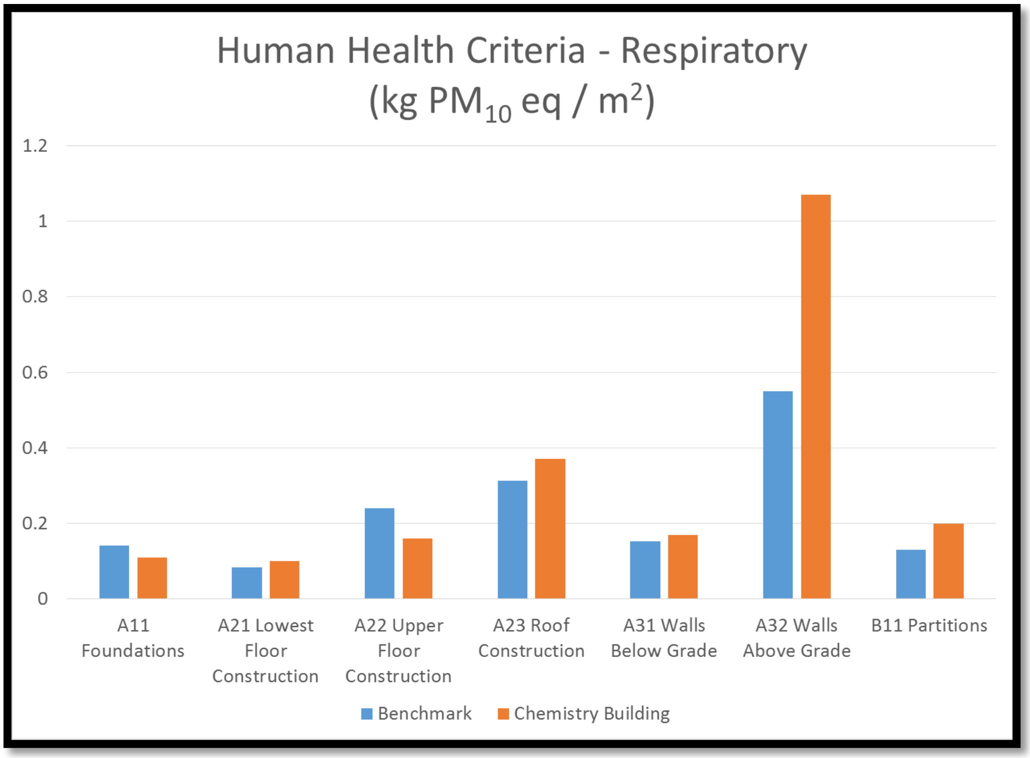

Figure 7 - Comparison of Chemistry Building to Class Benchmark - Human Health Criteria (Respiratory)

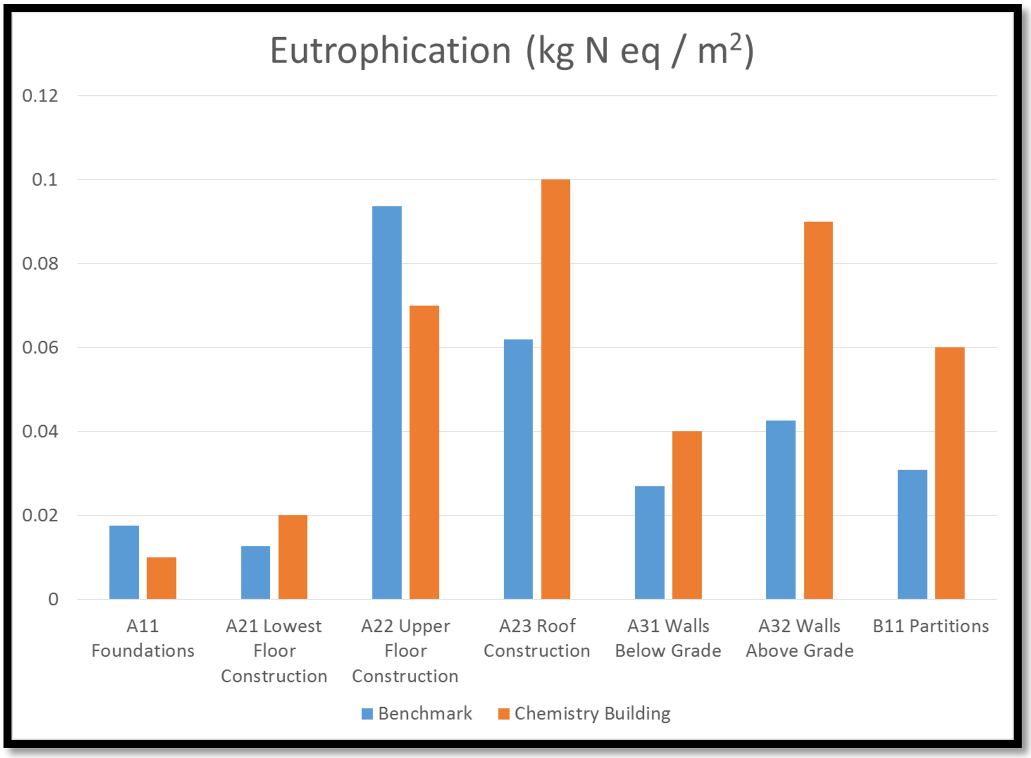

Figure 8 - Comparison of Chemistry Building to Class Benchmark - Eutrophication

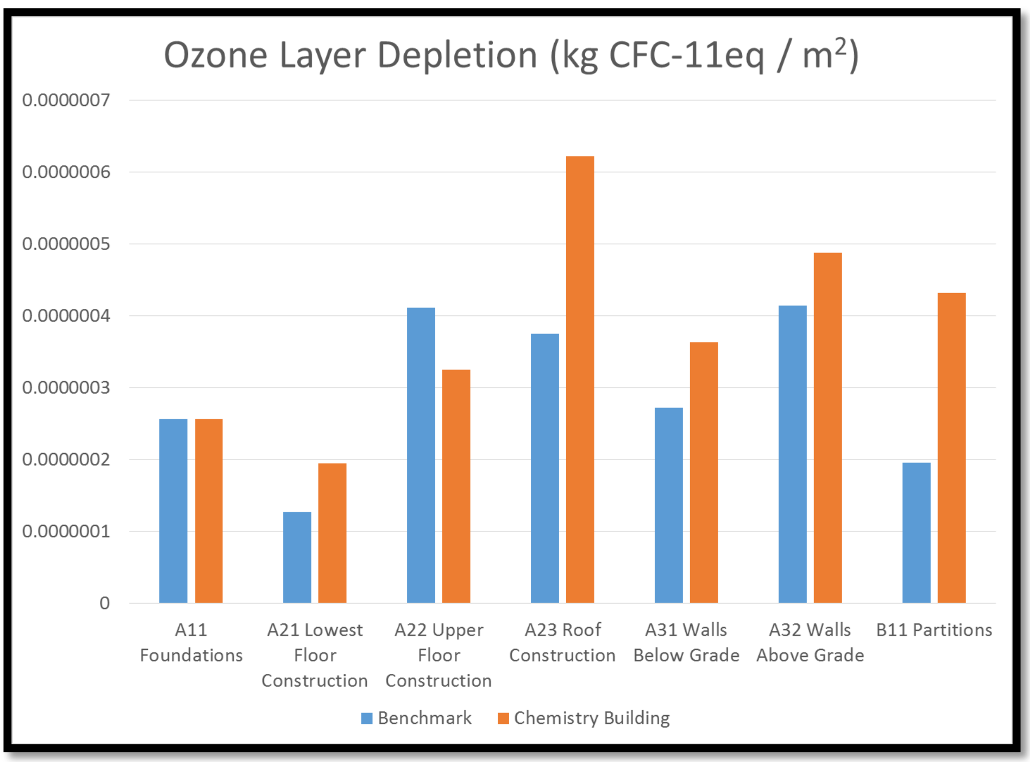

Figure 9 - Comparison of Chemistry Building to Class Benchmark - Ozone Layer Depletion

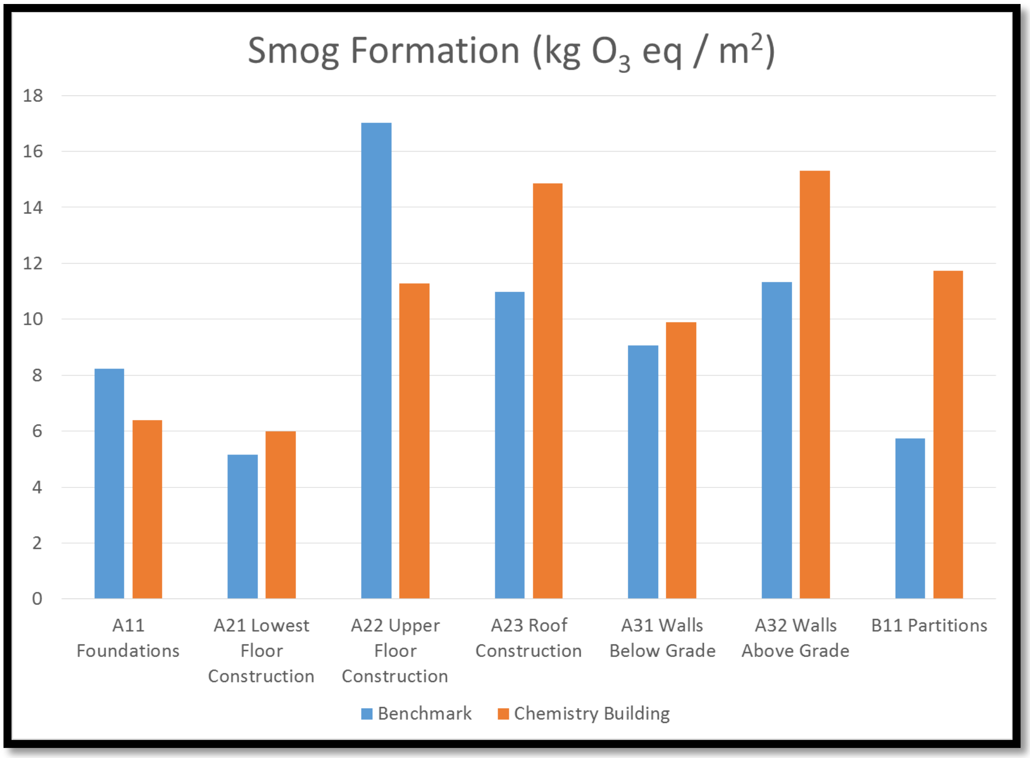

Figure 10 - Comparison of Chemistry Building to Class Benchmark - Smog Formation

The building cost and total global warming potential of the nine buildings that had cost information available at the time of benchmarking are shown in the scatter plot of **Error! eference source not found.** with the data point for the Chemistry building labeled. It can be seen that the Chemistry building lies in the higher range for the ratio of global warming potential to cost. Possible explanations include that the age of the building, as it was built in a time long before there was consideration given to the global warming potential of construction products or processes. Another possibility is that because it was built before the National Building Code of Canada was established, it is over designed for its purposes and therefore contains more materials than more recent buildings might.

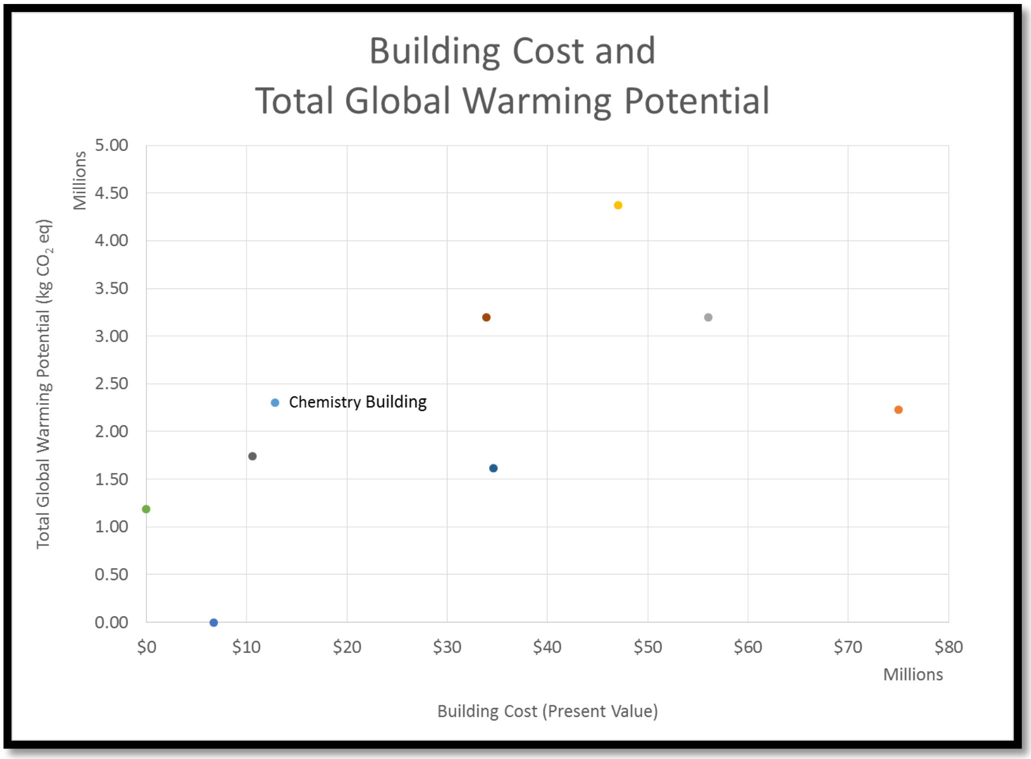

Figure 11 - Building Cost and Total Global Warming Potential of UBC Buildings

Annex B - Recommendations for LCA Use

As the recent development and progress in the field of life cycle assessment of buildings shows, LCA has an important role in the future of building design. As environmental concerns become more and more important, whether due to genuine stakeholder values or concern for reputation, more and more companies will be seeking to make more sustainable building choices. Life cycle analysis, though there are many challenges ahead, can help provide the information that is needed to make these more sustainable choices.

While the consideration of only the product and construction process stages in an LCA study provides an opportunity to make more sustainable choices in the products and materials that are going into the building, there is a great opportunity lost by excluding the operating and end of life stages. Similar to when looking at life cycle costing, by considering the operations and maintenance stage, designers can know whether investing in what seems like less sustainable products in the building design, possibly through more materials or more environmentally intense manufacturing processes, will be offset by the savings during operations. For example, if a building could consume 10% less natural gas for heating over a 60+ year lifespan, it may be worth investing (environmentally) in more insulation at the design stage, to get a net savings over the lifetime of the building. Also, by excluding the end-of-life phase, the results will not show the full environmental impacts. Two design options may be similar in the product, construction process, and operations phase, but one may contain materials that can be recycled while the other materials must be landfilled.

As is the challenge with any growing new field, there are challenges during development. Since LCA for building design is such a new field, there are inherent challenges in its development. As discussed earlier in the report, the existence of benchmarks is important to put the results of LCA into context, but these benchmarks don't really exist yet. The UBC LCA Database Project is one of the first of its kind, and future LCA databases will hopefully have similar data eventually, but for all types of buildings (commercial, industrial, residential, and institutional), so that designers can compare their design to averages of similar buildings. There is also the growing pain of data availability, as LCA must be done on each construction product and process before it can be added to the LCI database. As the field grows, more and more information will be available, reducing uncertainty.

Another challenge in LCA is prioritizing the different impact categories. While one design option may be a clear winner in terms of global warming potential, if the decision maker values local impacts like eutrophication and respiratory human health criteria, the chosen design may not be the one that with the far lesser global warming potential impact. The use of weighted decision making tools can help stakeholders with these decisions, but in prioritizing any one impact over another, the values of the stakeholders become embedded in the decision, and what one person may consider to be an environmentally sustainable design may not align with what others' definitions when they read "sustainable".

UBC's decision to pursue the UBC LCA Database Project is a big first step, but there is still much work to be done. As more classes of students in the LCA of Buildings course study more buildings on campus, and review and revise previous students' studies of buildings, more data will be available and more accurate benchmarks can be established. All the data in the database doesn't do anything on its own, however, and UBC must commit to using it in their future building designs, through their strategic and campus planning and by providing the information to design consultants on future buildings.

Annex C - Author Reflection

What sparked my interest in this course was the first few classes of my Energy and the Environment course, in which we were introduced to the concept of Life Cycle Assessment as it applies to energy systems. The principle of looking at the whole picture in LCA is a very important concept and I wanted to learn more about it in all of its applications, so when I heard about the LCA of buildings course I signed up. Prior to this year I had no experience with LCA, or sustainability of buildings. It was very interesting to learn about the history of LCA and its current state, the structure and standards involved in LCA, which are so critical to have when making comparisons based on LCA results, the application of LCA in a whole building design, and about some of uncertainties that are involved in LCA. Though it was challenging at times to learn two new softwares, On-Screen Takeoff and Impact Estimator, it was very rewarding to see the results, and I can see myself possibly using them in the future.

I think that the most rewarding part of this course, like in some others at UBC, is the fact that I have contributed to something with meaning. My hours and hours of time, though they come with the reward of learning, and this report will not simply be graded and thrown away. I am impressed by UBC's commitment to sustainability and I am excited to have been a part of it.

Table 7 outlines my opinions on which of the Canadian Engineering Accreditation Board graduate attributes I demonstrated over the course of this project.

Table 7 - CEAB Graduate Attributes Demonstrated During Project

Graduate Attribute	Description	Selected Content Code	Comments
1 - Knowledge Base	Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.	IDA = introduced, developed & applied	Developed and demonstrated knowledge of LCA standards, processes, software, result reporting
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.	IDA = introduced, developed & applied	Had to apply problem solving skills throughout all stages of the project
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.	ID = introduced & developed	

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.	N/A = not applicable	Had to adapt the model in some ways, but did not really do any design
5 - Use of Engineering Tools	An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.	IDA = introduced, developed & applied	Learned and applied On-Screen Takeoff software and Athena Impact Estimator software over the course of the project
6 - Individual and Team Work	An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.	IA = introduced & applied	Teamwork in classroom exercises
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.	IDA = introduced, developed & applied	Written communication of technical information in a detailed final report; Understand and respond to instructions during the various stages of the project; Class presentation of results to LCA and UBC communities
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.	A = applied	Professionalism demonstrated during future final class presentation to UBC and LCA community

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.	IDA = introduced, developed & applied	Project and course are an exercise in the concept of sustainable design and development, and environmental stewardship
10 - Ethics and Equity	An ability to apply professional ethics, accountability, and equity.	IDA = introduced, developed & applied	Giving proper credit to references in the report
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.	I = introduced	Had to investigate method of determining present value of past money (chose Consumer Price Index approach)
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.	DA = developed & applied	Had to identify the degree of knowledge needed to successfully use the software for our purposes and teach myself through the user guides and online training videos

Annex D – Impact Estimator Inputs and Assumptions

Changes that I have made to these documents, besides resorting them, are highlighted in red text.

Table 8 - Impact Estimator Inputs Document

Element	Quantity	Units	Assembly Type and Drawing for Takeoff	Assembly Name	Input Fields	Input Values		
						Known/ Measured	IE Inputs	
Project			132-06-82A		Building Height (ft) (New input)	78	78	
A11 Foundations	1,654	m^2						
			1.2 Concrete Footing					
			132-07-002	1.2.1 Footing_Thickness 2'				
					Length (ft)	22.58	25.38	
					Width (ft)	22.58	25.38	
					Thickness (in) (Corrected here; fine in model)	24	19	
					Concrete (psi)	4000	4000	
					Concrete flyash %	-	average	
					Rebar	#6	#6	
				1.2.2 Footing_Thickness 2' 6”				
					Length (ft)	45.35	56.99	
					Width (ft)	45.35	56.99	
					Thickness (in) (Corrected here; fine in model)	30	19	
					Concrete (psi)	4000	4000	
					Concrete flyash %	-	average	
					Rebar	#6	#6	
				1.2.3. Footing_Thickness 3'				
					Length (ft)	11.27	15.51	
					Width (ft)	11.27	15.51	

			Thickness (in)	36	19	
			Concrete (psi)	4000	4000	
			Concrete flyash %	-	average	
			Rebar	#6	#6	
		1.2.4 Footing_Thickness 3'6"				
			Length (ft)	22.96	34.13	
			Width (ft)	22.96	34.13	
			Thickness (in)	42	19	
			Concrete (psi)	4000	4000	
			Concrete flyash %	-	average	
			Rebar	#6	#6	
A21 Lowest Floor Construction 1,654 m^2						
	1.1 Concrete Slab-on-Grade					
	132-07-002	1.1.1 SOG_Basement				
			Length (ft)	108.94	108.94	
			Width (ft)	108.94	108.94	
			Thickness (in)	6	4	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
	4.1 Concrete Suspended Slab 6"					
	132-07-003	4.1.1 Floors_Basement [4.1.1 - 1/2]				
			Floor Width (ft)	918.1	918.1	
			Span (ft)	13.08	13.08	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Life load (psf)	-	75	
A22 Upper Floor Construction 5,796 m^2						
	1.3 Concrete Stairs					
	132-07-010 132-06-077	1.3.1 Stairs_Thickness 7"				
			Length (ft)	39.65	39.65	
			Width (ft)	39.65	39.65	

			Thickness (in) (Corrected here; fine in model)	7	8	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Rebar	#4	#4	
		1.3.2 Stairs_Thickness 11”				
			Length (ft)	10.29	10.29	
			Width (ft)	10.29	10.29	
			Thickness (in)	11	11	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Rebar	#6	#6	
	3.1 Concrete Column and Beam Basement					
	132-07-003	3.1.1 Column_Beams_Basement: 1				
			Number of Beams	27	27	
			Number of Columns	46	46	
			Floor to floor height (ft)	6.83	6.83	
			Bay sizes (ft)	26.67	26.67	
			Supported span (ft)	13.08	13.08	
			Live load (psf)	-	75	
			Supported Area (ft2) (New input)		349	
		3.1.2 Column_Beams_Basement: 2				
			Number of Beams	2	2	
			Number of Columns	4	4	
			Floor to floor height (ft)	6.83	6.83	
			Bay sizes (ft)	32.5	32.5	
			Supported span (ft)	16	16	
			Live load (psf)	-	75	
			Supported Area (ft2) (New input)		521	
		3.1.3 Column_Beams_Basement: 3				
			Number of Beams	2	2	
			Number of Columns	2	2	

			Floor to floor height (ft)	6.83	6.83	
			Bay sizes (ft)	12.17	12.17	
			Supported span (ft)	16	16	
			Live load (psf)	-	75	
			Supported Area (ft2) (New input)		195	
	3.2 Concrete Column and Beams 1st/2nd/3rd Floors					
	1st - 132-07-004 2nd - 132-07-006 3rd - 132-07-008	3.2.1 Column_Beams_1st/2nd/3rd: 1				
			Number of Beams	113	113	
			Number of Columns	197	197	
			Floor to floor height (ft)	13.17	13.17	
			Bay sizes (ft)	26.67	26.67	
			Supported span (ft)	13.08	13.08	
			Live load (psf)	-	75	
			Supported Area (ft2) (New input)		349	
		3.2.2 Column_Beams_1st/2nd/3rd: 2				
			Number of Beams	6	6	
			Number of Columns	12	12	
			Floor to floor height (ft)	13.17	13.17	
			Bay sizes (ft)	32.5	32.5	
			Supported span (ft)	16	16	
			Live load (psf)	-	75	
			Supported Area (ft2) (New input)		521	
		3.2.3 Column_Beams_1st/2nd/3rd: 3				
			Number of Beams	6	6	
			Number of Columns	6	6	
			Floor to floor height (ft)	13.17	13.17	
			Bay sizes (ft)	12.17	12.17	
			Supported span (ft)	16	16	
			Live load (psf)	-	75	
			Supported Area (ft2) (New input)		195	
	4.1 Concrete Suspended Slab 6”					

	1st - 132-07-004 2nd - 132-07-006 3rd - 132-07-008	4.1.1 Floors_1st/2nd/3rd [4.1.1 - 2/2]				
			Floor Width (ft)	3700.8	3700.8	
			Span (ft)	13.08	13.08	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Life load (psf)	-	75	
	4.2 Concrete Suspended Slab 10"					
	1st - 132-07-004 2nd - 132-07-006	4.2.1 Floors_1st/2nd				
			Floor Width (ft)	123.1	123.1	
			Span (ft)	16	16	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Life load (psf)	-	75	
A23 Roof Construction 1,802 m^2						
	3.3 Concrete Column and Beams Roof					
	132-07-009	3.3.1 Column_Beams_Roof: 1				
			Number of Beams	40	40	
			Number of Columns	66	66	
			Floor to floor height (ft)	21	21	
			Bay sizes (ft)	26.67	26.67	
			Supported span (ft)	13.08	13.08	
			Live load (psf)	-	75	
			Supported Area (ft2) (New input)		349	
		3.3.2 Column_Beams_Roof: 2				
			Number of Beams	2	2	
			Number of Columns	4	4	
			Floor to floor height (ft)	21	21	
			Bay sizes (ft)	32.5	32.5	
			Supported span (ft)	16	16	
			Live load (psf)	-	75	
			Supported Area (ft2) (New input)		521	

		3.3.3 Column_Beams_Roof: 3				
			Number of Beams	2	2	
			Number of Columns	2	2	
			Floor to floor height (ft)	21	21	
			Bay sizes (ft)	12.17	12.17	
			Supported span (ft)	16	16	
			Live load (psf)	-	75	
			Supported Area (ft2) (New input)		195	
	3.4 Concrete Column and Beams Penthouse					
	132-07-009	3.4.1 Column_Beams_Penthouse: 1				
			Number of Beams	4	4	
			Number of Columns	6	6	
			Floor to floor height (ft)	10.67	10.67	
			Bay sizes (ft)	12.17	12.17	
			Supported span (ft)	15.83	15.3	
			Live load (psf)	-	75	
			Supported Area (ft2) (New input)		193	
	5.1 Concrete Suspended Slab					
	132-07-009	5.1.1 Roof				
			Roof Width (ft)	1482.9	1482.9	
			Span (ft)	13.08	13.08	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Life load (psf)	-	75	
		Envelope	Category	4ply Built up Asphalt Roof	4ply Built up Asphalt Roof System	

				System – inverted	– inverted	
			Material	Rockwool glass felt	Rockwool glass felt	
			Thickness(inches)	-	8	
			Category	Vapour Barrier	Vapour Barrier	
			Material	-	Polyethylene 3 mil	
A31 Walls Below Grade 1,723 m^2						
	2.1 Cast In Place					
	132-07-002	2.1.3 Walls_Foundation South 13'				
			Length (ft)	127	127	
			Height (ft)	13	13	
			Thickness (in)	8	8	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Rebar	#4	#5	
		Envelope	Category	Vapour Barrier	Vapour Barrier	
			Material	Polyethylene 3 mil	Polyethylene 3 mil	
			Thickness	-	-	
		2.1.4 Walls_Foundation South:2 14'4" [2/2]				
			Length (ft)	255	255	
			Height (ft)	14.33	14.33	
			Thickness (in)	8	8	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Rebar	#4	#5	
		Envelope	Category	Vapour Barrier	Vapour Barrier	
			Material	Polyethylene 3 mil	Polyethylene 3 mil	
			Thickness	-	-	

		2.1.5 Walls_Foundation West 13'6" [2/2]				
			Length (ft)	128	128	
			Height (ft)	13.5	13.5	
			Thickness (in)	8	8	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Rebar	#4	#5	
		Envelope	Category	Vapour Barrier	Vapour Barrier	
			Material	Polyethylene 3 mil	Polyethylene 3 mil	
			Thickness	-	-	
		2.1.6 Walls_Foundation West:2 11'				
			Length (ft)	77	77.00	
			Height (ft)	11	11	
			Thickness (in)	8	8	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Rebar	#4	#5	
		Envelope	Category	Vapour Barrier	Vapour Barrier	
			Material	Polyethylene 3 mil	Polyethylene 3 mil	
			Thickness	-	-	
		2.1.7 Walls_Foundation North 10'				
			Length (ft)	28	28	
			Height (ft)	10	10	
			Thickness (in)	8	8	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Rebar	#4	#5	
		Envelope	Category	Vapour Barrier	Vapour Barrier	
			Material	Polyethylene 3 mil	Polyethylene 3 mil	

			Thickness	-	-	
		2.1.8 Walls_Foundation North:2 6'				
			Length (ft)	28	37.33	
			Height (ft)	6	6	
			Thickness (in)	16	12	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Rebar	#4	#5	
		Envelope	Category	Vapour Barrier	Vapour Barrier	
			Material	Polyethylen e 3 mil	Polyethylene 3 mil	
			Thickness	-	-	
		2.1.9 Walls_Foundation Southeast Wing 3'6"				
			Length (ft)	212	212	
			Height (ft)	3.5	3.5	
			Thickness (in)	8	8	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Rebar	#4	#5	
		Envelope	Category	Vapour Barrier	Vapour Barrier	
			Material	Polyethylen e 3 mil	Polyethylene 3 mil	
			Thickness	-	-	
	132-06-077	2.1.11 Walls_Basement Exterior 3				
			Length (ft)	119	119.00	
			Height (ft)	11.33	11.33	
			Thickness (in)	8	8	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Rebar	#4	#5	
		Envelope	Category	Vapour Barrier	Vapour Barrier	
			Material	Polyethylen	Polyethylene	

				e 3 mil	3 mil	
			Thickness	-	-	
	2.2 Concrete Block Wall					
	132-06-077	2.2.1 Walls_Basement Exterior 1				
			Length (ft)	677	677	
			Height (ft)	11.33	11.33	
			Rebar	#4	#4	
		Window Opening	Number of Windows	38	38	
			Total Window Area (ft2)	785	785	
			Frame Type	Wood Frame	Wood Frame	
			Glazing Type	-	None	
		Door Opening	Number of Doors	6	6	
			Door Type	-	Solid Wood	
		Envelope	Category	Cladding	Cladding	
			Material	Stone	Aggregate (XBM 6.1)	
			Thickness	-	-	
			Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	
			Category	Vapour Barrier	Vapour Barrier	
			Material	Polyethylene 3 mil	Polyethylene 3 mil	
			Thickness	-	-	
		2.2.2 Walls_Basement Exterior 2				
			Length (ft)	40	80	
			Height (ft)	11.33	11.33	
			Rebar	#4	#4	
		Window Opening	Number of Windows	2	2	
			Total Window Area (ft2)	48	48	

			Frame Type	Wood Frame	Wood Frame	
			Glazing Type	-	None	
		Envelope	Category	Cladding	Cladding	
			Material	Stone	Aggregate (XBM 6.1)	
			Thickness	-	-	
			Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	
			Category	Vapour Barrier	Vapour Barrier	
			Material	Polyethylene 3 mil	Polyethylene 3 mil	
			Thickness	-	-	
A32 Walls Above Grade 3,988 m^2						
	2.2 Concrete Block Wall					
	1st - 132-06-078 2nd - 132-06-079 3rd - 132-06-080	2.2.5 Walls_1st: Exterior 1				
			Length (ft)	806	806	
			Height (ft)	13.167	13.167	
			Rebar	#4	#4	
		Window Opening	Number of Windows	50	50	
			Total Window Area (ft2)	2148	2148	
			Frame Type	Wood Frame	Wood Frame	
			Glazing Type	-	None	
		Door Opening	Number of Doors	4	4	
			Door Type	-	Solid Wood	
		Envelope	Category	Cladding	Cladding	
			Material	Stone	Aggregate (XBM 6.1)	
			Thickness	-	-	

			Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	
		2.2.6 Walls_1st: Exterior 2				
			Length (ft)	38	76	
			Height (ft)	13.167	13.167	
			Rebar	#4	#4	
		Window Opening	Number of Windows	2	2	
			Total Window Area (ft2)	88	88	
			Frame Type	Wood Frame	Wood Frame	
			Glazing Type	-	None	
		Envelope	Category	Cladding	Cladding	
			Material	Stone	Aggregate (XBM 6.1)	
			Thickness	-	-	
			Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	
		2.2.9 Walls_2nd: Exterior 1				
			Length (ft)	775	775	
			Height (ft)	13.167	13.167	
			Rebar	#4	#4	
		Window Opening	Number of Windows	60	60	
			Total Window Area (ft2)	2213	2213	
			Frame Type	Wood Frame	Wood Frame	
			Glazing Type	-	None	
		Envelope	Category	Cladding	Cladding	
			Material	Stone	Aggregate	

					(XBM 6.1)	
			Thickness	-	-	
			Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	
		2.2.10 Walls_2nd: Exterior 2				
			Length (ft)	40	80	
			Height (ft)	13.167	13.167	
			Rebar	#4	#4	
		Window Opening	Number of Windows	2	2	
			Total Window Area (ft2)	86	86	
			Frame Type	Wood Frame	Wood Frame	
			Glazing Type	-	None	
		Envelope	Category	Cladding	Cladding	
			Material	Stone	Aggregate (XBM 6.1)	
			Thickness	-	-	
			Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	
		2.2.13 Walls_3rd: Exterior 1				
			Length (ft)	799	799	
			Height (ft)	21	21	
			Rebar	#4	#4	
		Window Opening	Number of Windows	33	33	
			Total Window Area (ft2)	988	988	
			Frame Type	Wood Frame	Wood Frame	
			Glazing Type	-	None	

		Envelope	Category	Cladding	Cladding	
			Material	Stone	Aggregate (XBM 6.1)	
			Thickness	-	-	
			Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	
		2.2.14 Walls_3rd: Exterior 2				
			Length (ft)	33	66	
			Height (ft)	21	21	
			Rebar	#4	#4	
		Window Opening	Number of Windows	2	2	
			Total Window Area (ft2)	84	84	
			Frame Type	Wood Frame	Wood Frame	
			Glazing Type	-	None	
		Envelope	Category	Cladding	Cladding	
			Material	Stone	Aggregate (XBM 6.1)	
			Thickness	-	-	
			Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	
	132-07-009	2.2.17 Walls_Penthouse: Exterior 1				
			Length (ft)	338	338	
			Height (ft)	10.67	10.67	
			Rebar	#4	#4	
		Window Opening	Number of Windows	10	10	
			Total Window Area (ft2)	187	187	
			Frame Type	Wood	Wood Frame	

						Frame		
					Glazing Type	-	None	
				Envelope	Category	Cladding	Cladding	
					Material	Stone	Aggregate (XBM 6.1)	
					Thickness	-	-	
					Category	Cladding	Cladding	
					Material	Plaster	Stucco on porous surface	
					Thickness	-	-	
			6.1 Stone Cladding					
				6.1.1 XBM_Stone Ballast				
					Weight (lbs) (Corrected here; fine in model)	2 706 734.2	902245	
B11 Partitions	8,481	m^2						
			2.1 Cast In Place					
			132-07-002	2.1.1 Walls_Foundation Trench 3'3"				
					Length (ft)	67	67.00	
					Height (ft)	3.25	3.25	
					Thickness (in)	8	8	
					Concrete (psi)	3000	3000	
					Concrete flyash %	-	average	
					Rebar	#4	#5	
				Envelope	Category	Vapour Barrier	Vapour Barrier	
					Material	Polyethylene 3 mil	Polyethylene 3 mil	
					Thickness	-	-	
				2.1.2 Walls_Foundation Elevator 3'6"				
					Length (ft)	31	31	
					Height (ft)	3.5	3.5	
					Thickness (in)	8	8	

			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Rebar	#4	#5	
		Envelope	Category	Vapour Barrier	Vapour Barrier	
			Material	Polyethylene 3 mil	Polyethylene 3 mil	
			Thickness	-	-	
		2.1.4 Walls_Foundation South:2 14'4" [1/2]				
			Length (ft)	80	80	
			Height (ft)	14.33	14.33	
			Thickness (in)	8	8	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Rebar	#4	#5	
		Envelope	Category	Vapour Barrier	Vapour Barrier	
			Material	Polyethylene 3 mil	Polyethylene 3 mil	
			Thickness	-	-	
		2.1.5 Walls_Foundation West 13'6" [1/2]				
			Length (ft)	179	179	
			Height (ft)	13.5	13.5	
			Thickness (in)	8	8	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Rebar	#4	#5	
		Envelope	Category	Vapour Barrier	Vapour Barrier	
			Material	Polyethylene 3 mil	Polyethylene 3 mil	
			Thickness	-	-	
		2.1.10 Walls_Foundation Trench 1'9" (Was missing from IE but is present here so I created an assembly for it in IE)				
			Length (ft)	125	125.00	

			Height (ft)	1.75	1.75	
			Thickness (in)	8	8	
			Concrete (psi)	3000	3000	
			Concrete flyash %	-	average	
			Rebar	#4	#5	
		Envelope	Category	Vapour Barrier	Vapour Barrier	
			Material	Polyethylene 3 mil	Polyethylene 3 mil	
			Thickness	-	-	
	2.2 Concrete Block Wall					
	B - 132-06-077 1st - 132-06-078 2nd - 132-06-079 3rd - 132-06-080	2.2.3 Walls_Basement Interior 1				
			Length (ft)	535	535	
			Height (ft)	11.33	11.33	
			Rebar	#4	#4	
		Door Opening	Number of Doors	25	25	
			Door Type	-	Solid Wood	
		Envelope	Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	
		2.2.4 Walls_Basement Interior 2				
			Length (ft)	1268	951	
			Height (ft)	11.33	11.33	
			Rebar	#4	#4	
		Door Opening	Number of Doors	24	24	
			Door Type	-	Solid Wood	
		Envelope	Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	
		2.2.7 Walls_1st: Interior 1				
			Length (ft)	418	418	

			Height (ft)	13.02	13.02	
			Rebar	#4	#4	
		Door Opening	Number of Doors	17	17	
			Door Type	-	Solid Wood	
		Envelope	Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	
		2.2.8 Walls_1st: Interior 2				
			Length (ft)	1294	971	
			Height (ft)	13.167	13.167	
			Rebar	#4	#4	
		Door Opening	Number of Doors	28	28	
			Door Type	-	Solid Wood	
		Envelope	Category	Gypsum Board	Gypsum Board	
			Material	Gypsum Regular 1/2”	Gypsum Regular ½"	
			Thickness	-	-	
		2.2.11 Walls_2nd: Interior 1				
			Length (ft)	543	543	
			Height (ft)	13.167	13.167	
			Rebar	#4	#4	
		Door Opening	Number of Doors	15	15	
			Door Type	-	Solid Wood	
		Envelope	Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	
		2.2.12 Walls_2nd: Interior 2				
			Length (ft)	1222	917	
			Height (ft)	13.167	13.167	

			Rebar	#4	#4	
		Door Opening	Number of Doors	26	26	
			Door Type	-	Solid Wood	
		Envelope	Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	
		2.2.15 Walls_3rd: Interior 1				
			Length (ft)	606	606	
			Height (ft)	13.167	13.167	
			Rebar	#4	#4	
		Door Opening	Number of Doors	24	24oc	
			Door Type	-	Solid Wood	
		Envelope	Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	
		2.2.16 Walls_3rd: Interior 2				
			Length (ft)	1262	946	
			Height (ft)	13.167	13.167	
			Rebar	#4	#4	
		Door Opening	Number of Doors	22	22	
			Door Type	-	Solid Wood	
		Envelope	Category	Cladding	Cladding	
			Material	Plaster	Stucco on porous surface	
			Thickness	-	-	

Table 9 - Impact Estimator Inputs Assumptions Document

Element	Quantity	Units	Assembly Group	Assembly Type and Drawing for Takeoff	Assembly Name	Specific Assumptions
Project				132-06-82A		
A11 Foundations	1,654	m^2				
			1 Foundation	The Impact Estimator, SOG inputs are limited to being either a 4" or 8" thickness. Since the actual SOG thicknesses for the Chemistry building were not exactly 4" or 8" thick, the areas measured in OnScreen required calculations to adjust the areas to accommodate this limitation. The Impact Estimator limits the thickness of footings to be between 7.5" and 19.7" thick. As there are a number of cases where footing thicknesses exceed 19", their widths were increased accordingly to maintain the same volume of footing while accommodating this limitation. Lastly, the concrete stairs were modelled as footings (ie. Stairs_Concrete_TotalLength).		
				1.2 Concrete Footing		
				132-07-002	1.2.1 Footing_Thickness 2'	The area of this footing slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7". The thicknesses were set at 19" and the following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Footing Slab Area) x (Actual Slab Thickness/12))/(19/12)] = sqrt[(510 x (24"/12))/(19"/12)] = 25.38 ft Assume no vapour barrier Assume concrete 4000 psi

			1.2.2 Footing_Thickness 2'6”	The area of this footing slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. The thicknesses were set at 19” and the following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Footing Slab Area) x (Actual Slab Thickness/12))/(19/12)] = sqrt[(2057 x (30”/12))/(19”/12)] = 56.99 ft Assume no vapour barrier Assume concrete 4000 psi
			1.2.3 Footing_Thickness 3'	The area of this footing slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. The thicknesses were set at 19” and the following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Footing Slab Area) x (Actual Slab Thickness/12))/(19/12)] = sqrt[(127 x (36”/12))/(19”/12)] = 15.51 ft Assume no vapour barrier Assume concrete 4000 psi

			1.2.4 Footing_Thickness 3'6"	The area of this footing slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7". The thicknesses were set at 19" and the following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Footing Slab Area) x (Actual Slab Thickness/12))/(19/12)] = sqrt[(527 x (42"/12))/(19"/12)] = 34.13 ft Assume no vapour barrier Assume concrete 4000 psi
A21 Lowest Floor Construction 1,654 m^2				
	1 Foundation	The Impact Estimator, SOG inputs are limited to being either a 4" or 8" thickness. Since the actual SOG thicknesses for the Chemistry building were not exactly 4" or 8" thick, the areas measured in OnScreen required calculations to adjust the areas to accommodate this limitation. The Impact Estimator limits the thickness of footings to be between 7.5" and 19.7" thick. As there are a number of cases where footing thicknesses exceed 19", their widths were increased accordingly to maintain the same volume of footing while accommodating this limitation. Lastly, the concrete stairs were modelled as footings (ie. Stairs_Concrete_TotalLength).		
		1.1 Concrete Slab-on-Grade		

<table>
<tr><td rowspan="3"></td><td></td><td>132-07-002</td><td>1.1.1 SOG_Basement</td><td>The area of this slab had to be adjusted so that the thickness fit into the 4" thickness specified in the Impact Estimator. The following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab;

= sqrt[((Measured Slab Area) x (Actual Slab Thickness))/(4”/12)]

= sqrt[(17802 x (6”/12))/(4”/12)]

= 108.94 ft

Assume 3 mil polyethylene vapour barrier

Assume concrete 3000 psi</td></tr>
<tr><td>4 Floors</td><td colspan="3">The Impact Estimator calculated the thickness of the material based on floor width, span, concrete strength, concrete flyash content and live load. The only assumptions that had to be made in this assembly group were setting the live load to 75psf, as well as setting the concrete strength 3,000 and fly ash to average.</td></tr>
<tr><td></td><td colspan="3">4.1 Concrete Suspended Slab 6”</td></tr>
</table>

		132-07-003	4.1.1 Floors_Basement [4.1.1 - 1/2]	To enter the area of the floors in to the Impact Estimator the width and span need to be designated. The following calculation was done to determine the total width (in feet) for all floors from the measured area. The smaller range of the span size, 13.08 ft, was used in the calculation: = (Sum of ~~all~~ basement floor areas) / (Span size) =(12009) / (13.08) =918.1 ft Assume concrete 3000 psi Assume live loading to be 75 psf Assume average fly ash Assume no envelope
A22 Upper Floor Construction 5,796 m^2				
	1 Foundation	The Impact Estimator, SOG inputs are limited to being either a 4” or 8” thickness. Since the actual SOG thicknesses for the Chemistry building were not exactly 4” or 8” thick, the areas measured in OnScreen required calculations to adjust the areas to accommodate this limitation. The Impact Estimator limits the thickness of footings to be between 7.5” and 19.7” thick. As there are a number of cases where footing thicknesses exceed 19”, their widths were increased accordingly to maintain the same volume of footing while accommodating this limitation. Lastly, the concrete stairs were modelled as footings (ie. Stairs_Concrete_TotalLength).		
		1.3 Concrete Stairs		

		132-07-010 132-06-077	1.3.1 Stairs_Thickness 7”	The thickness of the stairs was estimated to be 7 inches based on the cross-section structural drawings. The following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Concrete Stair Volume) / (Slab Thickness/12)] = sqrt[917 /(7”/12)] = 39.65 ft Assume concrete 3000 psi
			1.3.2 Stairs_Thickness 11”	The thickness of the stairs was estimated to be 11 inches based on the cross-section structural drawings. The following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Concrete Stair Volume) / (Slab Thickness/12)] = sqrt[97 /(11”/12)] = 10.29 ft Assume concrete 3000 psi
	3 Columns and Beams	The method used to measure column sizing was completely depended upon the metrics built into the Impact Estimator. That is, the Impact Estimator calculates the sizing of beams and columns based on the following inputs; number of beams, number of columns, floor to floor height, bay size, supported span and live load. Since the live loading was not located within the provided building information, a live load of 75psf on all four floors and the basement level were assumed.		
		3.1 Concrete Column and Beams Basement		

		132-07-003	3.1.1 Column_Beams_Basement: 1	Assume live loading to be 75 psf Some beams that are slightly larger and smaller where incorporated into this count Supported area = Bay size X Supported Span = 26.67 ft X 13.08 ft = 349 ft2
			3.1.2 Column_Beams_Basement: 2	Assume live loading to be 75 psf Supported area (ft2) = Bay size X Supported span = 32.5 ft X 16 ft = 521 ft2
			3.1.3 Column_Beams_Basement: 3	Assume live loading to be 75 psf Supported area (ft2) = Bay size X Supported span = 12.17 ft X 16 ft = 195 ft2
		3.2 Concrete Column and Beams 1st/2nd/3rd Floors		
		1st - 132-07-004 2nd - 132-07-006 3rd - 132-07-008	3.2.1 Column_Beams_1st/2nd/3rd: 1	Assume live loading to be 75 psf Some beams that are slightly larger and smaller where incorporated into this count Supported area = Bay size X Supported Span = 26.67 ft X 13.08 ft = 349 ft2
			3.2.2 Column_Beams_1st/2nd/3rd: 2	Assume live loading to be 75 psf Supported area = Bay size X Supported Span = 32.5 ft X 16 ft = 521 ft2

			3.2.3 Column_Beams_1st/2nd/3rd: 2	Assume live loading to be 75 psf Supported area = Bay size X Supported span = 12.17 X 16= 195 ft2
	4 Floors	The Impact Estimator calculated the thickness of the material based on floor width, span, concrete strength, concrete flyash content and live load. The only assumptions that had to be made in this assembly group were setting the live load to 75psf, as well as setting the concrete strength 3,000 and fly ash to average.		
		4.1 Concrete Suspended Slab 6"		
		1st - 132-07-004 2nd - 132-07-006 3rd - 132-07-008	4.1.1 Floors_1st/2nd/3rd [4.1.1 - 2/2]	To enter the area of the floors in to the Impact Estimator the width and span need to be designated. The following calculation was done to determine the total width (in feet) for all floors from the measured area. The smaller range of the span size, 13.08 ft, was used in the calculation: = (Sum of all floor areas except basement) / (Span size) =(60415-12009) / (13.08) =3700.8 ft Assume concrete 3000 psi Assume live loading to be 75 psf Assume average fly ash Assume no envelope
		4.2 Concrete Suspended Slab 10"		

		1st - 132-07-004 2nd - 132-07-006	4.2.1 Floors_1st/2nd	To enter the area of the floors in to the Impact Estimator the width and span need to be designated. The following calculation was done to determine the total width (in feet) for all floors from the measured area. The larger range of the span size, 16 ft, was used in the calculation to get a thicker slab that more closely represents the 10" thickness: = (Sum of all floor areas) / (Span size) =(1969) / (16) =123.1 ft Assume concrete 3000 psi Assume live loading to be 75 psf Assume average fly ash Assume no envelope
A23 Roof Construction 1,802 m^2				
	3 Columns and Beams	The method used to measure column sizing was completely depended upon the metrics built into the Impact Estimator. That is, the Impact Estimator calculates the sizing of beams and columns based on the following inputs; number of beams, number of columns, floor to floor height, bay size, supported span and live load. Since the live loading was not located within the provided building information, a live load of 75psf on all four floors and the basement level were assumed.		
		3.3 Concrete Column and Beams Roof		

		132-07-009	3.3.1 Column_Beams_Roof: 1	Assume live loading to be 75 psf Some beams that are slightly larger and smaller where incorporated into this count Supported area = Bay size X Supported span =26.67 X 13.08 = 349 ft2
			3.3.2 Column_Beams_Roof: 2	Assume live loading to be 75 psf Supported area = Bay size X Supported Span = 32.5 ft X 16 ft = 521 ft2
			3.3.3 Column_Beams_Roof: 3	Assume live loading to be 75 psf Supported area = Bay size X Supported Span = 12.17 ft X 16 ft = 195 ft2
		3.4 Concrete Column and Beams Penthouse		
		132-07-009	3.4.1 Column_Beams_Penthouse : 1	Assume live loading to be 75 psf Supported area = Bay size X Supported Span = 12.17 ft X 15.83 ft = 193 ft2
	5 Roof	The live load was assumed to be 75 psf and the concrete strength was set to3000psi.		
		5.1 Concrete Suspended Slab		

		132-07-009	5.1.1 Roof	To enter the area of the roof in to the Impact Estimator the width and span need to be designated. The following calculation was done to determine the total width (in feet) for all roofs from the measured area. The smaller range of the span size, 13.08 ft, was used in the calculation: = (Sum of all floor areas) / (Span size) =(19396) / (13.08) =1482.9 ft Assume 4 ply Built up Asphalt Roof System – inverted, with Rockwool glass felt at a thickness of 8”. Assume 3 mil polyethylene vapour barrier
A31 Walls Below Grade 1,723 m^2				
	2 Walls			
		2.1 Cast In Place		
		132-07-002	2.1.3 Walls_Foundation South 13'	Assume concrete 3000 psi Assume 3 mil polyethylene vapour barrier
		132-07-002	2.1.4 Walls_Foundation South:2 14'4" [2/2]	Assume concrete 3000 psi Assume 3 mil polyethylene vapour barrier

			2.1.5 Walls_Foundation West 13'6" [2/2]	Assume concrete 3000 psi Assume 3 mil polyethylene vapour barrier
			2.1.6 Walls_Foundation West:2 11'	Assume concrete 3000 psi Assume 3 mil polyethylene vapour barrier
			2.1.7 Walls_Foundation North 10'	Assume concrete 3000 psi Assume 3 mil polyethylene vapour barrier
			2.1.8 Walls_Foundation North:2 6'	This wall was increased by a factor in order to fit the 12" thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/12"] = (28") * [(16")/12"] = 37.33 feet Assume concrete 3000 psi Assume 3 mil polyethylene vapour barrier
			2.1.9 Walls_Foundation Southeast Wing 3'6"	Assume concrete 3000 psi Assume 3 mil polyethylene vapour barrier

		132-06-077	2.1.11 Walls_Basement Exterior 3	Assume concrete 3000 psi Assume 3 mil polyethylene vapour barrier Assume rebar #4 Assume plaster on interior walls. Use stucco on porous surface as surrogate
		2.2 Concrete Block Wall		
		132-06-077	2.2.1 Walls_Basement Exterior 1	Assume concrete block for brick walls. The standard width of a concrete block is 8”. This corresponds to the measured wall width. Assume rebar #4 Assume solid wood, fixed, windows with no glazing Assume solid wood doors Stone cladding will be added as aggregate in the Extra Basic Materials section 6.1 Assume 3 mil polyethylene vapour barrier Assume plaster on interior walls. Use stucco on porous surface as surrogate

			2.2.2 Walls_Basement Exterior 2	Assume concrete block for brick walls. The standard width of a concrete block is 8”. Since the wall width is 16” use twice the length of block wall; = (Wall length(ft)) * (Width/8”) =(40) * (16/8) = 80 ft Assume rebar #4 Assume solid wood, fixed, windows with no glazing Stone cladding will be added as aggregate in the Extra Basic Materials section 6.1 Assume 3 mil polyethylene vapour barrier Assume plaster on interior walls. Use stucco on porous surface as surrogate
A32 Walls Above Grade 3,988 m^2				
	2 Walls			
		2.2 Concrete Block Wall		

			2.2.5 Walls_1st: Exterior 1	Assume concrete block for brick walls. The standard width of a concrete block is 8”. This corresponds to the measured wall width. Assume rebar #4 Assume solid wood, fixed, windows with no glazing Assume solid wood doors Stone cladding will be added as aggregate in the Extra Basic Materials section 6.1 Assume plaster on interior walls. Use stucco on porous surface as surrogate
		1st - 132-06-078 2nd - 132-06-079 3rd - 132-06-080	2.2.6 Walls_1st: Exterior 2	Assume concrete block for brick walls. The standard width of a concrete block is 8”. Since the wall width is 16” use twice the length of block wall; = (Wall length(ft)) * (Width/8”) =(38) * (16/8) = 76 ft Assume rebar #4 Assume solid wood, fixed, windows with no glazing Stone cladding will be added as aggregate in the Extra Basic Materials section 6.1 Assume plaster on interior walls. Use stucco on porous surface as surrogate

2.2.9 Walls_2nd: Exterior 1	Assume concrete block for brick walls. The standard width of a concrete block is 8". This corresponds to the measured wall width. Assume rebar #4 Assume solid wood, fixed, windows with no glazing Stone cladding will be added as aggregate in the Extra Basic Materials section 6.1 Assume plaster on interior walls. Use stucco on porous surface as surrogate
2.2.10 Walls_2nd: Exterior 2	Assume concrete block for brick walls. The standard width of a concrete block is 8". Since the wall width is 16" use twice the length of block wall; = (Wall length(ft)) * (Width/8") =(40) * (16/8) = 80 ft Assume rebar #4 Assume solid wood, fixed, windows with no glazing Stone cladding will be added as aggregate in the Extra Basic Materials section 6.1 Assume plaster on interior walls. Use stucco on porous surface as surrogate

		2.2.13 Walls_3rd: Exterior 1	Assume concrete block for brick walls. The standard width of a concrete block is 8”. This corresponds to the measured wall width. Wall Height: Slab top to slab bottom + 7'8” for attic walls and decorative on the perimeter of the roof. Assume rebar #4 Assume solid wood, fixed, windows with no glazing Stone cladding will be added as aggregate in the Extra Basic Materials section 6.1 Assume plaster on interior walls. Use stucco on porous surface as surrogate

		2.2.14 Walls_3rd: Exterior 2	Assume concrete block for brick walls. The standard width of a concrete block is 8”. Since the wall width is 16” use twice the length of block wall; = (Wall length(ft)) * (Width/8”) =(33) * (16/8) = 66 ft Wall Height: Slab top to slab bottom + 7'8” for attic walls and decorative on the perimeter of the roof. Assume rebar #4 Assume solid wood, fixed, windows with no glazing Stone cladding will be added as aggregate in the Extra Basic Materials section 6.1 Assume plaster on interior walls. Use stucco on porous surface as surrogate

		132-07-009	2.2.17 Walls_Penthouse: Exterior 1	Assume concrete block for brick walls. The standard width of a concrete block is 8”. This corresponds to the measured wall width. Assume rebar #4 Assume solid wood, fixed, windows with no glazing Stone cladding will be added as aggregate in the Extra Basic Materials section 6.1 Assume plaster on interior walls. Use stucco on porous surface as surrogate
	6 Extra Basic Materials	To model the stone cladding on all the exterior wall, ballast, or stone aggregate, will be used as a surrogate The surface area of each exterior will be multiplied by the thickness and then multiplied by the density to determine the mass of stone required.		
		6.1 Stone Cladding		

			6.1.1 XBM_Stone Ballast	Assume that ballast is an appropriate approximation of exterior stone cladding. Assume density of stone to be 2515 (kg/m^3) * 0.0624 = 156.9 (lbs/ft^3) *http://www.simetric.co.uk/si_materials.htm Total weight calculations: =(Exterior Surface Area(ft^2)) * (Cladding Thickness(ft)) * (Density(lbs/ft^3)) =(51754) * (4"/12) * (156.9) =2 706 734.2 lbs Impact Estimator only allows ballast material only to be up to 6 digits so 902244.7 was add separately in the estimator, then the summary measures were multiplied by 3 and added to the original summary table.
B11 Partitions 8,481 m^2				
	2 Walls			
		2.1 Cast In Place		
		132-07-002	2.1.1 Wall_Foundation Trench 3'3"	Assume concrete 3000 psi Assume 3 mil polyethylene vapour barrier
			2.1.2 Walls_Foundation Elevator 3'6"	Assume concrete 3000 psi Assume 3 mil polyethylene vapour barrier

			2.1.4 Walls_Foundation South:2 14'4" [1/2]	Assume concrete 3000 psiAssume 3 mil polyethylene vapour barrier
			2.1.5 Walls_Foundation West 13'6" [1/2]	Assume concrete 3000 psi Assume 3 mil polyethylene vapour barrier
			2.1.10 Walls_Foundation Trench 1'9"	Assume concrete 3000 psi Assume 3 mil polyethylene vapour barrier This assembly didn't appear to be in the IE model, but it is listed in the report and in this document, so I copied Foundation_Trench 3'3" assembly and modified it according to the inputs given on the Inputs sheet
		2.2 Concrete Block Wall		
		B - 132-06-077 1st - 132-06-078 2nd - 132-06-079 3rd - 132-06-080	2.2.3 Walls_Basement Interior 1	Assume concrete block for brick walls. The standard width of a concrete block is 8”. This corresponds to the measured wall width. Assume rebar #4 Assume solid wood doors Assume no interior windows since not specified on plans Assume plaster on interior walls. Use stucco on porous surface as surrogate

			2.2.4 Walls_Basement Interior 2	Assume concrete block for brick walls. The standard width of a concrete block is 8”. Since the width of the wall is not 8” the following calculation was done in order to determine appropriate Length (in feet) inputs the wall; = (Wall length(ft)) * (Width/8”) =(1268) * (6/8) = 951 ft Assume rebar #4 Assume solid wood doors Assume no interior windows since not specified on plans Assume plaster on interior walls. Use stucco on porous surface as surrogate
			2.2.7 Walls_1st: Interior 1	Assume concrete block for brick walls. The standard width of a concrete block is 8”. This corresponds to the measured wall width. Assume rebar #4 Assume solid wood doors Assume no interior windows since not specified on plans Assume plaster on interior walls. Use stucco on porous surface as surrogate

			2.2.8 Walls_1st: Interior 2	Assume concrete block for brick walls. The standard width of a concrete block is 8”. Since the width of the wall is not 8” the following calculation was done in order to determine appropriate Length (in feet) inputs the wall; = (Wall length(ft)) * (Width/8”) =(1294) * (6/8) = 971 ft Assume rebar #4 Assume solid wood doors Assume no interior windows since not specified on plans Assume plaster on interior walls. Use stucco on porous surface as surrogate
			2.2.11 Walls_2nd: Interior 1	Assume concrete block for brick walls. The standard width of a concrete block is 8”. This corresponds to the measured wall width. Assume rebar #4 Assume solid wood doors Assume no interior windows since not specified on plans Assume plaster on interior walls. Use stucco on porous surface as surrogate

			2.2.12 Walls_2nd: Interior 2	Assume concrete block for brick walls. The standard width of a concrete block is 8”. Since the width of the wall is not 8” the following calculation was done in order to determine appropriate Length (in feet) inputs the wall; = (Wall length(ft)) * (Width/8”) =(1222) * (6/8) = 917 ft Assume rebar #4 Assume solid wood doors Assume no interior windows since not specified on plans Assume plaster on interior walls. Use stucco on porous surface as surrogate
			2.2.15 Walls_3rd: Interior 1	Assume concrete block for brick walls. The standard width of a concrete block is 8”. This corresponds to the measured wall width. Assume rebar #4 Assume solid wood doors Assume no interior windows since not specified on plans Assume plaster on interior walls. Use stucco on porous surface as surrogate