Chemistry Physics Annex- Whole Building Life Cycle Assessment

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CIVL 498C

March 2010

PROVISO

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

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

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Abstract

Even though LCA is a relatively new method used to assess the environmental impact of different products and processes, it has already been labeled as one of the most comprehensive and rigorous tools available to do so. The following report is part of North America's Largest Environmental Impact Study, *Life Cycle Assessment of UBC Buildings*, and presents a cradle-to-gate LCA study of the Chemistry-Physics Annex academic building located at the UBC using the TRACI methodology. It was found that even if the Chemistry-Physics Annex was built more than 20 years ago, its environmental impact measurements are comparable with much more recently built constructions, which sheds light on how diminutive has been the development of the construction industry over the last two decades towards better buildings practices that are less damaging for the environment. When conducting a sensitivity analysis on the Bill of Materials, it was found that the model is most sensitive to changes on the concrete composition. It is also been reported that a minor investment on improving the buildings insulation system can bring forth enormous energy savings versus the initial embodied energy of the materials used in the construction, with a seven years energy payback period. This translates into potential economic savings a lesser impact on the environment.

1. Introduction

The Chemistry-Physics building, located at 6221 University Boulevard at the UBC, was built on 1989 as the most recent annex for the Chemistry Building, which was originally built on 1915. The first permanent building started at the Point Grey Campus. Due to financial problems of the provincial government due to the onset of the First World War, the construction was interrupted in 1915. The concrete skeleton stood unfinished until, following successful students' 1922 campaign that climaxed in a parade from downtown Vancouver to Pt. Grey, known as "The Great Trek", government floated a loan for the construction of University Buildings at Point Grey [1].

Building System	Specific Characteristics of the Chemistry-Physics Annex
Structure	Concrete columns supporting concreted suspended slabs.
Floors	Concrete Slab on Grade (SOG) in the basement. Suspended slabs for the rest of the floors.
Exterior Walls	There are five different exterior walls, all made of cast in place concrete but with different envelopes. C – 200 mm cast in place concrete C1 – 200 mm cast in place concrete with 22 mm furring channels and 16 mm gypsum board. C2 – 200 mm cast in place concrete with 92 mm steel studs, 88 mm batting (vapor barrier) and 16 mm gypsum board. C3 – Similar to C2 but with 200 mm pipe space. C4 – 200 mm cast in place concrete with 38 mm rigid insulation and 16 mm gypsum board. On the first floor and on the balconies on each floor there are small sections of aluminum framed curtain walls.
Interior Walls	Steel studs and gypsum board partition in every floor.

Openings	Low E tin glazed windows in most exterior walls. Interior doors and made both of solid wood and steel for the mechanical rooms. Exterior doors are made of steel except for the curtain walls.
Roof	Top roof made of 38 mm gravel/filter fabric, 75 mm rigid insulation, 14 mm fiberboard and 13 mm gypsum board. No concrete beam. Small roof made of 38 mm gravel/filter fabric, 13 mm gypsum board, and steel deck over concrete beam.

Table 1 Specific building's characteristics by building system

The Chemistry-Physics Annex is an academic building intended for research and faculty, so the most of the rooms inside can be classified as offices, laboratories, mechanical rooms, and other laboratories with specialized equipment that is shared among most of the laboratories. The building was originally constructed for Chemistry alone, but housed in the beginning also Physics, Bacteriology and Public Health. The construction cost is not available in the UBC records. The main material used for its construction is exposed sandblasted and sealed colored architectural concrete.

2. Goal and Scope.

2.1 Goal of Study

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

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

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

2. 2 Scope of Study

The product system being studied in this LCA is the structure and envelope of the Chemistry-Physics Annex on a <u>square foot finished floor area of academic building basis</u>. In order to focus on design related impacts, this LCA encompasses a cradle-to-gate scope that includes the raw material extraction, manufacturing of construction materials and construction of the structure and envelope of the Chemistry-Physics Annex, as well as associated transportation effects throughout.

2. 3 Tools, Methodology and Data

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

The study will first undertake the initial stage of a materials quantity takeoff, which involves performing linear, area and count measurements of the building's structure and envelope. To accomplish this, OnScreen TakeOff version 3.6.2.25 is used, which is a software tool designed to perform material takeoffs with increased accuracy and speed in order to enhance the bidding capacity of its users. Using imported digital plans, the program simplifies the calculation and measurement of the takeoff process, while reducing the error associated with these two activities. The measurements generated are formatted into the inputs required for the IE building LCA software to complete the takeoff process. These formatted inputs as well as their associated assumptions can be viewed in Annexes A and B respectively.

Using the formatted takeoff data, version 4.0.64 of the IE software, the only available software capable of meeting the requirements of this study, is used to generate a whole building LCA model for the Chemistry-Physics Annex in the Vancouver region as an Institutional building type. The IE software is designed to aid the building community in making more environmentally conscious material and design choices. The tool achieves this by applying a set of algorithms to the inputted takeoff data in order to complete the takeoff process and generate a bill of materials (BoM). This BoM then utilizes the Athena Life Cycle Inventory (LCI) Database, version 4.6, in order to generate a cradle-to-grave LCI profile for the building. In this study, LCI profile results focus on the manufacturing (inclusive of raw material extraction), transportation of construction materials to site and their installation as structure and envelope assemblies of the Chemistry-Physics Annex. As this study is a cradle-to-gate assessment, the expected service life of the Chemistry-Physics Annex is set to 1 year, which results in the maintenance, operating energy and end-of-life stages of the building's life cycle being left outside the scope of assessment.

The IE then filters the LCA results through a set of characterization measures based on the mid-point impact assessment methodology developed by the US Environmental Protection Agency (US EPA), the Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI) version 2.2. In order to generate a complete environmental impact profile for the Chemistry-Physics Annex, all of the available TRACI impact assessment categories available in the IE are included in this study, and are listed as;

- Global warming potential
- Acidification potential
- Eutrophication potential

- Ozone depletion potential
- Photochemical smog potential
- Human health respiratory effects potential
- Weighted raw resource use
- Primary energy consumption

Using the summary measure results, a sensitivity analysis is then conducted in order to reveal the effect of material changes on the impact profile of the Chemistry-Physics Annex. Finally, using the UBC Residential Environmental Assessment Program (REAP) as a guide, this study then estimates the embodied energy involved in upgrading the insulation and window R-values to REAP standards and generates a rough estimate of the energy energy payback period of investing in a better performing envelope.

The primary sources of data used in modeling the structure and envelope of the Chemistry-Physics Annex are the original structural drawings from when the was initially constructed in 1989 The assemblies of the building that are modeled include the foundation, columns and beams, floors, walls and roofs, as well as their associated envelope and/or openings (ie. doors and windows). The decision to omit other building components, such as flooring, electrical aspects, HVAC system, finishing and detailing, etc., are associated with the limitations of available data and the IE software, as well as to minimize the uncertainty of the model. In the analysis of these assemblies, some of the drawings lack sufficient material details, which necessitate the usage of assumptions to complete the modeling of the building in the IE software. Furthermore, there are inherent assumptions made by the IE software in order to generate the bill of materials and limitations to what it can model, which necessitated further assumptions to be made. These assumptions and limitation will be discussed further as they emerge in the Building Model section of this report and, as previously mentioned, all specific input related assumption are contained in the Input Assumptions document in Annex B.

3. Building Model

3.1 Takeoffs:

The software OnScreen Take off was used to perform the takeoffs of the building, 75 different conditions were created to model the entire building, of which linear, area and count conditions were used to model the different assemblies:

- Columns and beams were accounted for using count conditions, and then the specific characteristics of the each column were inputted in the Athena Impact Estimator.
- Floors were modeled as concrete suspended slabs using area conditions.
- Both roof types were modeled using area conditions as well and inputted on the Athena Impact Estimator as steel joist roofs.
- The foundations and the Slab on Grade were also modeled using area conditions. Since there were several types of foundations and some of them exceeded the maximum thickness that is allowed on the Athena Impact Estimator, the area was recalculated in some cases to compensate for the thickness difference.
- Both the windows and doors openings were accounted for using count conditions, and for the windows an area condition was used to measure the area per window.
- All of the different walls were measured using linear conditions.

Even though the use of the OnScreen Take off and the Athena Impact Estimator simplified the work, there were many challenges when performing both the take off and when inputting the data on the Athena I.E. These difficulties occurred due two main reasons: lack of information on the structural drawings provided to perform this LCA, and the quality of the drawings. Some of details on the drawings were missing (since the structural drawings referenced some other drawings that were not provided), and some parts of the drawings were blurry. Below, each assembly group will be introduced and the main assumptions made for each of them will be briefly mentioned. For more details about the assumptions please see the Assumptions Document in Appendix B.

3.2 Modeling and Assumptions:

3.2.1 Foundations: In the Athena I.E, SOG inputs are limited to a maximum of 200 mm thickness. Since the actual thicknesses for the SOG for the Chemistry Physics building is thicker, the area measured in On-Screen Takeoff Pro was readjusted so that the SOG's total volume would be the same even with a thickness of only 200 mm.

In addition the Athena I.E limits the thickness of footings to be between 19 mm and 500 mm thick. Since three of the footings exceeded 200mm, their areas were readjusted in order to maintain the same volume of footing even by using a different thickness. Moreover, The Athena I.E requires inputting the length and width values separately, so the square root of the areas was calculated in order to have both values. By doing this it is being assumed that all the areas were square-shaped. Some other assumptions, such as rebar type, were made in a case by case scenario depending on the footing type. Information of the concrete type and the % of fly-ash were not included in any of the drawings neither for the foundations nor the SOG, because of this it was assumed that all the foundations and SOG were built using 30mPa concrete with average fly-ash

3.2.2 Walls: The main assumptions taken for the walls because information of the concrete type and the % of fly-ash were not included in any of the drawings for the walls, and because of this it was assumed that all the concrete used to build walls was 30mPa concrete with average fly-ash. This assumption applies for all the walls

Furthermore, both frame and glazing types for all the windows were not included in any of the drawings. Upon physical examination they appeared to be metal frame and standard glass. Aluminum frame and Standard Glazing were used as the Athena I.E inputs. When inputting data on the Athena Impact Estimator, only one window type is permitted per wall assembly, however steel stud walls had both types of windows. To solve this particular problem, the total length of the steel stud wall was divided on two different walls for the Athena I.E inputs according to the number of windows (555 fixed windows and 162 operable), so 77% of the total length of the wall has been assigned for fixed windows (1740 m) and 23% for operable windows (508 m). These assemblies were called *Wall_SteelStud_Gypsum_200mm_WindowFixed* and *Wall_SteelStud_Gypsum_200mm_WindowOperable* respectively.

The same ratio mentioned above was used for dividing the doors among the two wall types, 149 doors out of the total (193 doors in total) was assigned to the WindowFixed wall type and the rest, 44 doors were assigned to the OperableWindow wall type. Due to the Athena Impact Estimator limitations when modeling doors, even if some of the doors were slightly different in dimensions, all door openings were classified either as wood doors (solid wood door), or steel doors (steel interior door) and added in the Athena E.I with the standard size 32" x 7", and double doors were counted as two on the On-screen Take-off Pro.

For the steel stud walls, no information on the sheathing type or stud spacing was provided on the drawings. OSB sheathing was used for the Athena I.E due its good performance at a lower price, and typical stud spacing of 400 o.c was also used since is most commonly used. In addition, according to the Athena I.E for non load-bearing steel framed wall used as interior partitions it is recommended to choose 25 Gauge stud weight for this option. Data on stud thickness is also missing, but one of the wall types information was available in the drawings, so the same stud thickness was used to model all the steel stud walls: 32x92. In addition 5/8" Fire-Rated Type X Gypsum Board was used for all the laboratories walls because in the "typical laboratories wall" structural drawing it was mentioned that fire rated board was used, and it was assumed that this feature applied for every door.

3.2.3 Columns and Beams: Data on the Live Load was not provided on the drawings, but 3.6 kPa was chosen because according to the Athena Impact Estimator it represents a typical mechanical/service room loading, and most rooms in the building are either laboratories or mechanical rooms. Beam Type is not specified on the drawings, so concrete will be used as input for the Athena I.E Bay size was measured on each floor. Nevertheless some columns were not built exactly with the same bay and span size, so the median value (6.7 m) was used as an input of the Athena Impact Estimators to avoid having a large impact on the data due some outliers.

3.2.4 Floors: Information of the concrete type and the % of fly-ash were not included in any of the drawings, because of this it was also assumed that all the concrete used to build floors was 30mPa concrete with average fly-ash to ensure consistency with the rest of the assumptions made for concrete assemblies. Just as with the Columns and Beams, live Load information was not provided on the drawings and 3.6 kPa was chosen for the same reasons already mentioned above.

3.2.5 Roofs: For the Steel Joist Roof no information on the decking type or the steel gauge was provided on the drawings, so OSB decking with a thickness of 15 mm was used for the Athena I.E. Information on the Steel gauge and joist type and spacing was also missing, so steel gauge 16 was used as input for the Athena I.E as well as joist 39x203 with a 400 mm spacing since these are the typical values used.

3.2.6 Stairs: Concrete stairs were modeled as footings (*Stairs_Concrete_Main*). Since both stairs on the building had the same thickness and width, the total length of stairs was measured to be used as one single input. And 3 m of material was also added to this input to account for the landings of the steel stairs that connect the 4th floor with the top floor. Yet again Information of the concrete type and the % of fly-ash were not included in any of the drawings, so the concrete used is 30mPa concrete with average fly-ash. The concrete stairs have both 10 and 15 m rebars, but Athena I.E only accepts one type so rebar 15 m will be used as input

3.2.7 Extra Basic Materials: XBM were used five times throughout the take-off in order to account for as many materials as possible and create a thorough model. For more details on how these calculations were done please see Appendix B.

> 3.2.7.1 Concrete Columns in the Basement: there are three concrete columns on the basement that help supporting the balconies located on floors 2nd-4th. To account for this material, the volume for each column was calculated (lenght * width * height) and summed together as one input of Concrete Extra Basic Material.

3.2.7.2 Concrete exterior shafts: The Chemistry-Physics Annex Building has 19 exterior shafts that go from the basement all the way to the roof. The material was accounted for as walls on each floor, however in order to consider the material on the roof, the volume of material used on the roof for each shaft was calculated to include the concrete used for the portion of the shafts on the roof.

3.2.7.3 Concrete Pavers: 300 x 300 mm concrete pavers on the first floor were counted using a linear condition, and then the concrete volume was calculated to account for the material.

3.2.7.4 Emanel Panels on exterior walls: Most of the exterior walls have Emanel Panel on the outside façade. In order to model these panels, standard glazing was used instead of enamel panel which was specified in the drawings because enamel panel is not an input option in the Athena I.E.

3.2.7.5 Steel Stairs connecting the 4th and the 5th floor: The same method that was used to account for the material on the concrete stairs was used for the steel stairs that connect the 4th and the 5th floor.

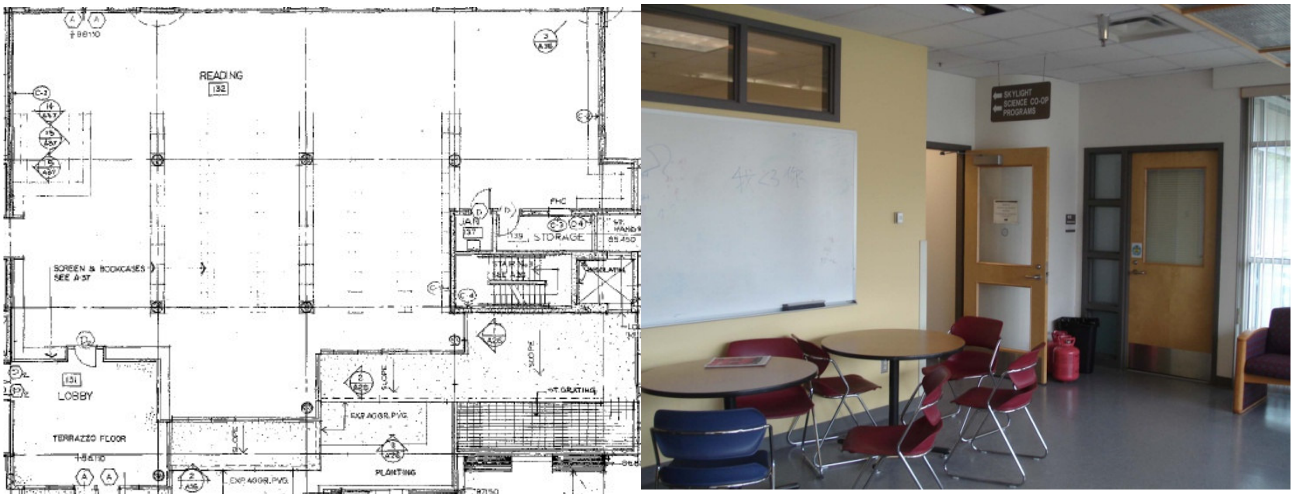
3.2.8 Structure and envelope materials that were not modeled: due to inherent limitations within the Athena Impact Estimator, to ensure consistency among the rest of the projects, and to reduce uncertainty some of the structural assemblies or envelope materials were not modeled. The materials that were left out of the model are:

- Ramp connecting Chemistry-Physics Annex with another building was not modeled because it was considered to be outside of the chosen boundary.
- Glazing on interior doors due Athena I.E limitations on door modeling.
- Ceramic tiles on bathroom's walls to ensure consistency with the rest of the projects.
- Since this model was only concerned on main structural assemblies, handrails, valances on walls, ducts, electric installation, pipes, different details on laboratories such as exhaust vents, sinks and office furniture were also left out of the model.
- There are some differences between what was actually built and the specs on the drawings. One of the main differences was found on the first floor on the

common area, were according to the drawings it was originally designed to be a large, open area. However some partitions were added to that area in order to create a reading area for students. See Picture 1 for details of this example.

- It is also important to mention that some other assemblies could have change, since was access was restricted to all of the laboratories and mechanicals rooms. Access to the fifth floor was totally restricted so to execute a visual inspection with the objective of comparing the structural drawings versus the actual building was impossible. All the known and unknown differences were left out of the model to reduce uncertainty when comparing the different models done as part of this effort to model all of the UBC buildings.

For detailed information on how the calculations associated with the assumptions were made, and for the rest of detailed assumptions that were not mentioned on this document please read the Assumptions Document in Appendix B.



Picture 1- Comparison between a large open area on the structural drawings (left) and what was actually found on site (right).

3.3 Bill of Materials: the following bill of materials was calculated based on the information inputted on the Athena Impact Estimator. Please see Table 2 for the Bill of Materials report generated by the Athena Impact Estimator:

Bill Of Materials Report		
Material	Quantity	Unit
Ballast (aggregate stone)	76185.8501	kg
Oriented Strand Board	17772.0172	m2 (9mm)
Modified Bitumen membrane	10445.3649	kg
5/8" Fire-Rated Type X Gypsum Board	8761.999	m2
Roofing Asphalt	8746.9389	kg
PVC membrane	5965.3017	kg
Concrete 30 MPa (flyash av)	5346.0773	m3
Batt. Rockwool	3681.708	m2 (25mm)
Extruded Polystyrene	3667.2954	m2 (25mm)
6 mil Polyethylene	3551.3261	m2
#15 Organic Felt	2694.9118	m2
5/8" Gypsum Fibre Gypsum Board	2470.5106	m2
Standard Glazing	1816.99	m2
Expanded Polystyrene	1597.5257	m2 (25mm)
Concrete Blocks	1310.269	Blocks
1/2" Moisture Resistant Gypsum Board	1300.145	m2
Batt. Fiberglass	1271.3291	m2 (25mm)
EPDM membrane	1223.343	kg
1/2" Gypsum Fibre Gypsum Board	1129.5411	m2
Commercial(26 ga.) Steel Cladding	833.3331	m2
Blown Cellulose	582.7679	m2 (25mm)
3 mil Polyethylene	508.2929	m2
Rebar, Rod, Light Sections	263.2569	Tonnes
Water Based Latex Paint	224.8398	L
Galvanized Studs	56.059	Tonnes
Aluminum	26.0552	Tonnes
Softwood Plywood	24.0462	m2 (9mm)
Small Dimension Softwood Lumber, kiln-dried	18.5581	m3
Glazing Panel	15.4969	Tonnes
Solvent Based Alkyd Paint	14.1494	L
Joint Compound	12.3376	Tonnes
Mortar	4.1617	m3
Galvanized Sheet	4.1217	Tonnes
Nails	2.4883	Tonnes
Screws Nuts & Bolts	2.005	Tonnes
Welded Wire Mesh / Ladder Wire	1.7425	Tonnes
Paper Tape	0.1416	Tonnes
Hot Rolled Sheet	0.0015	Tonnes

Table 2 Chemistry Physics Annex Bill of Materials Report

Based on Table 2, the top five materials from a quantity perspective are:

1. Ballast (aggregate stone).
2. Oriented strand board.
3. Modified bitumen membrane.
4. 5/8" Fire-Rated Type X Gypsum Board.
5. Roofing asphalt.

However, I personally believe that is necessary to broaden the "top materials" to also include PVC membrane and the Concrete, since these two materials not only are possible strong contributors to the building's performance on each impact categories, but are also large in quantity. See below Table 3 for a shortened version of the Bill of Materials including only those materials that have been classified as "top materials" based on their quantity.

Bill Of Materials Report		
Material	Quantity	Unit
Ballast (aggregate stone)	76185.8501	kg
Oriented Strand Board	17772.0172	m2 (9mm)
Modified Bitumen membrane	10445.3649	kg
5/8" Fire-Rated Type X Gypsum Board	8761.999	m2
Roofing Asphalt	8746.9389	kg
PVC membrane	5965.3017	kg
Concrete 30 MPa (flyash av)	5346.0773	m3

Table 3 Top 7 materials of the Bill of Materials based on the amount of materials.

Out of these seven materials, four of them could have been greatly affected by the assumptions already mentioned on section 3.2. These materials are: Oriented Strand Board, 5/8" Fire-Rated Type X Gypsum Board, Roofing Asphalt and Concrete. Table 4 shows a cross reference between the top seven materials and the assemblies that were modeled which accounted for these quantities.

Bill Of Materials Report		
Material	**Comments**	**Assemblies names**
Ballast (aggregate stone)	Typical roofing aggregate. Can be used to augment aggregate usage elsewhere in project too	*Roof_SteelJoist_Top, Roof_SteelJoist_Small*
Oriented Strand Board	9mm thickness OSB	All the "*Wall_SteelStud_Gypsum_*" walls, and *Roof_SteelJoist_Top, Roof_SteelJoist_Small*
Modified Bitumen membrane	In 2-ply roofing application density is 34 kg/m2 or 695lbs/square (100 sq.ft.).	Roof_SteelJoist_Top
5/8" Fire-Rated Type X Gypsum Board	A gypsum core wall panel with additives to enhance fire resistance of the core and surfaced with paper on front, back, and long edges	*Wall_SteelStud_Gypsum_200mm_WindowFixed , Wall_SteelStud_Gypsum_200mm_WindowOperable, Wall_SteelStud_Gypsum_DoorF_200mm, Wall_SteelStud_Gypsum_DoorB_200mm, Wall_SteelStud_Gypsum_DoorJ_200mm*
Roofing Asphalt	Provided on kg, roofing material.	*Roof_SteelJoist_Top, Roof_SteelJoist_Small*
PVC membrane	Provided on m2	Roof_SteelJoist_Top
Concrete 30 MPa (flyash av)	With flyash concentrations of average (9%) cement replacement .	Concrete Slab-on-Grade (SOG), all the Concrete Footings (Footing_thickness_type), concrete walls (Wall_Concrete_identifier_thickness), Floor_ConcreteSuspendedSlab_200mm, Stairs_Concrete_Main, and all the Concrete Extra Basica Materials (XBM_Columns_Concrete_Basement, XBM_Wall_Concrete_ExteriorShaft, XBM_Walls_Concrete_300x300mm Pavers)

Table 4 Assemblies sources of the Top 7 materials.

It is worthwhile mentioning that all of the assemblies that contributed to the quantities of the top 7 largest materials were subjected to many assumptions and these assumptions will most likely have an impact on the model´s results. Examples of these assumptions are that all of the concrete modeled in the building is 30 MPa concrete with average flyash, but information on the actual concrete used was not available. In addition, details on the sheathing type of the gypsum walls were not provided so OSB was chosen due its better performance. This too is an important assumption, even if OSB provides a good structural performance at a lower cost, assuming that all the gypsum sheathing used was OSB could be also over-simplistic, especially because OSB has the disadvantage of being less moisture resistant.

Many assumptions were made during the modeling of the building affects these materials; nonetheless in order to avoid repetition on this report please refer to section 3.2 for the main assumptions, or see the Assumptions Document in Appendix B. On section 4, a sensitivity analysis will measure the possible effects that these materials could have had on the model, and how those effects could have changed in the assumptions were made differently.

4. Summary Measures

The TRACI impact assessment categories included in this study are listed below. Please see Table 5 for the summary measures by Life Cycle Stage:

- Global warming potential: Global warming potential is a reference measure. GWP is expressed on an equivalency basis relative to CO2. Carbon dioxide is the common reference standard for global warming or greenhouse gas effects. All other greenhouse gases are referred to as having a "CO2 equivalence effect". This effect has a time horizon due to the atmospheric reactivity or stability of the various contributing gases over time. As yet, no consensus has been reached among policy makers about the most appropriate time horizon for greenhouse gas calculations. The International Panel on Climate Change100-year time horizon figures have been used here as a basis for the equivalence index: CO2 Equivalent kg = CO2 kg + (CH4 kg x 23) + (N2O kg x 296). The Athena Impact Estimator uses data developed by a detailed life cycle modeling approach; all relevant process emissions of greenhouse gases are included in the resultant global warming potential index [3].
- Acidification potential: Acidification is a more regional rather than global impact effecting human health when high concentrations of NOx and SO2 are attained. The

AP of an air or water emission is calculated on the basis of its H+ equivalence effect on a mass basis [3].

- Eutrophication potential: is the fertilization of surface waters by nutrients that were previously scarce. When a previously scarce or limiting nutrient is added to a water body it leads to the proliferation of aquatic photosynthetic plant life. This may lead to a chain of further consequences ranging from foul odours to the death of fish. The calculated result is expressed on an equivalent mass of nitrogen (N) basis [3].
- Ozone depletion potential: Stratospheric ozone depletion potential accounts for impacts related to the reduction of the protective ozone layer within the stratosphere caused by emissions of ozone depleting substances (CFCs, HFCs, and halons). The ozone depletion potential of each of the contributing substances is characterized relative to CFC-11 mass equivalent [3].
- Photochemical smog potential: Under certain climatic conditions, air emissions from industry and transportation can produce photochemical smog. The “smog” indicator is expressed on a mass of equivalent NOx basis [3].
- Human health respiratory effects potential: Particulate matter of various sizes (PM10 and PM2.5) have a considerable impact on human health. The EPA has identified "particulates" as the number one cause of human health deterioration due to its impact on the human respiratory system – asthma, bronchitis, acute pulmonary disease, etc. The Athena Institute used TRACI’s "Human Health Particulates from Mobile Sources" characterization factor, on an equivalent PM2.5 basis [3].
- Weighted raw resource use: The Athena Impact Estimator approach to account for the raw resource use, was to survey a number of resource extraction and environmental specialists across Canada to develop subjective scores of the relative effects of different resource extraction activities. The scores reflect the expert panel ranking of the effects of extraction activities relative to each other for each of several impact dimensions. The scores were combined into a set of resource-specific index numbers, which are applied in the Impact Estimator as weights to the amounts of raw resources used to manufacture each building product. [3].
- Primary energy consumption: primary energy is reported in mega-joules (MJ). Embodied primary energy includes all energy, direct and indirect, used to transform

or transport raw materials into products and buildings, including inherent energy contained in raw or feedstock materials that are also used as common energy sources. In addition, the Impact Estimator captures the indirect energy use associated with processing, transporting, converting and delivering fuel and energy [3].

As it was already mentioned on the Goal and Scope, the expected service life of the Chemistry-Physics Annex is set to 1 year, which results in the maintenance, operating energy and end-of-life stages of the building's life cycle being left outside the scope of assessment.

Summary Measure Table By Life Cycle Stages							
	Manufacturing			**Construction**			**Total Effects**
	Material	Transportation	**Total**	Material	Transportation	**Total**	
Primary Energy	22302816	663364.6865	**22966181**	1078647.8	1404431.414	**2483079**	**25449259.96**
Weighted Resource Use	15951783	439.8094508	**15952223**	24988.187	867.1960176	**25855.38**	**15978077.91**
Global Warming Potential	2160670.8	1163.068721	**2161834**	74109.744	2399.231024	**76508.98**	**2238342.854**
Acidification Potential	917741.38	396.375366	**918137.8**	36177.681	771.9108243	**36949.59**	**955087.3486**
HH Respiratory Effects	7713.5569	0.477869707	**7714.035**	40.590937	0.928447804	**41.51938**	**7755.554128**
Eutrophication Potential	960.35227	0.412649083	**960.7649**	35.547755	0.800686625	**36.34844**	**997.1133632**
Ozone Depletion Potential	0.0112024	4.7908E-08	**0.011202**	1.109E-10	9.82886E-08	**9.84E-08**	**0.011202525**
Smog Potential (kg NOx	11236.086	8.935787731	**11245.02**	881.87367	17.26425415	**899.1379**	**12144.15985**

Table 5 Summary measures by Life Cycle Stage

In order to facilitate comparison with the rest of the models performed during this term, the summary measures were also expressed on a square foot finished floor area of academic building basis. The value provided was 85,326 ft2; however since it is unsure how this value was calculated, and in order to guarantee method consistency when calculating the square footage. The square foot of finished floor area was measured on the Onscreen Take-Off. The value calculated using this method was 7,967 m2 which when converted to square feet is 85,756.07 ft2. The value is similar to the one provided, so we can reach to the conclusion that the measuring method used was adequate. Table 6 presents the summary measures by square foot finished floor area.

Summary Measure Table of Life Cycle Stages by Square foot of finished floor area							
	Manufacturing			**Construction**			**Total Effects**
	Material	Transportation	**Total**	Material	Transportation	**Total**	
Primary Energy	260.07273	7.73548337	**267.8082**	12.578092	16.3770488	**28.95514**	**296.7633508**
Weighted Resource Use	15951783	0.00512861	**186.0186**	0.2913868	0.010112357	**0.301499**	**186.3200716**
Global Warming Potential	2160670.8	0.013562523	**25.2091**	0.8641924	0.027977389	**0.89217**	**26.10127472**
Acidification Potential	917741.38	0.004622126	**10.70639**	0.4218673	0.009001238	**0.430869**	**11.13725595**
HH Respiratory Effects	7713.5569	5.57243E-06	**0.089953**	0.0004733	1.08266E-05	**0.000484**	**0.090437374**
Eutrophication Potential	960.35227	4.81189E-06	**0.011203**	0.0004145	9.33679E-06	**0.000424**	**0.011627321**
Ozone Depletion Potential	0.0112024	5.58655E-13	**1.31E-07**	1.293E-15	1.14614E-12	**1.15E-12**	**1.30632E-07**
Smog Potential (kg NOx	11236.086	0.0001042	**0.131128**	0.0102835	0.000201318	**0.010485**	**0.141612824**

Table 6 Summary measures (LCS) by square foot finished floor area.

When comparing the values on Table 6 with the values from previous models done on other UBC buildings [4], it was found that these values fall within an acceptable range. They are 28% higher than the average from the rest of the finished models, but this average also includes buildings that had both wood on its structure assemblies and the interior walls. When comparing the Chemistry Physics Building Annex with other concrete buildings, the variance is only of 7% versus the average for most of the categories, and slightly higher for the Ozone Depletion Potential (59%).

Figure 1 presents a graph comparing the values versus similar buildings previously modeled. The dashed yellow line represents the average of these five compared buildings. It is evident from the graph that the final results for the Chemistry Physics Building Annex are close to the average values in all of the impact categories.

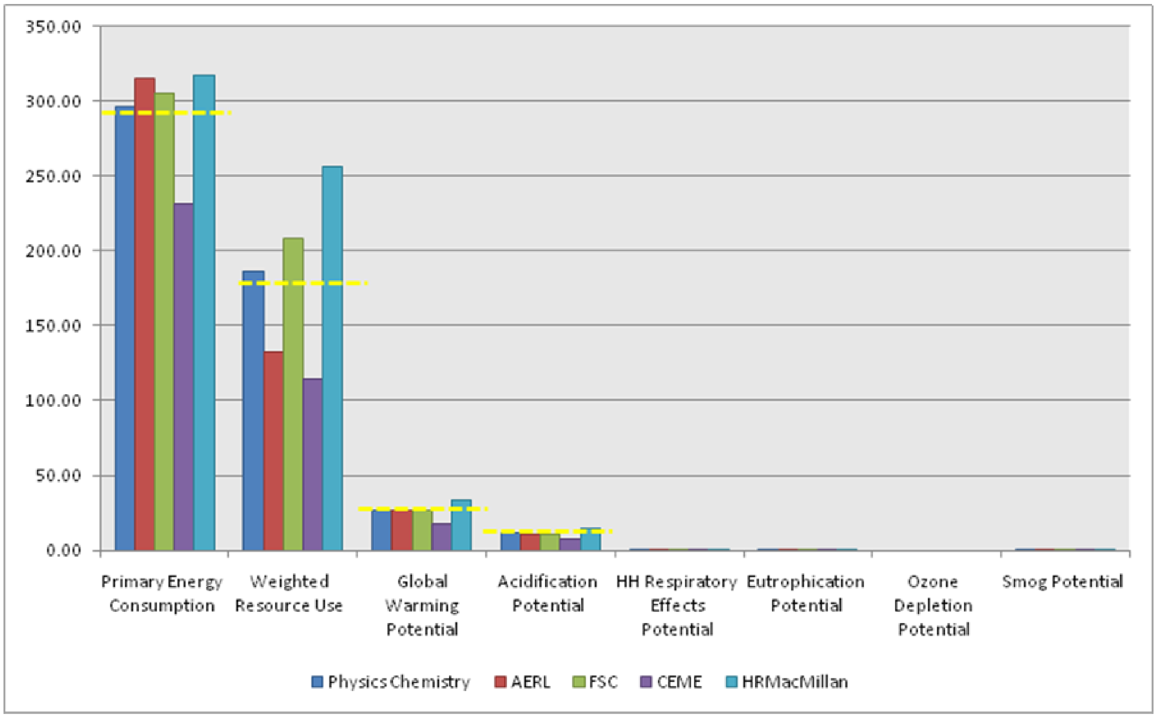


Figure 1 Comparison of summary measures (LCS) by square foot finished floor area of similar UBC buildings.

4.1 Sensitivity Analysis

It is recognized that a LCA practitioner has to deal with uncertainty and variability all throughout the process when performing a LCA study. LCA predicts potential effects, and estimates risks [5]. Because of this, one could argue that results of LCA would be meaningless, as the uncertainties associated with these results would overshadow the results themselves [6]; however in order to reduce the impact of uncertainty on a study we can explicitly incorporate it. One way to incorporate uncertainty on any LCA study is to perform sensitivity analyses, which could even improve the credibility of an LCA study because it may show that the contribution of an "uncertain input data" to the outcome of the model is small or negligible, or it may express the result as a probability, thereby stating the degree of uncertainty [7]. To address this issue, the results of a sensitivity analysis done on the seven top materials will be presented on this section.

The results of the first sensitivity analysis are shown on Table 7. The analysis was done by increasing the quantity of the studied by 10%, so that we can measure the impact on that material over the total impact of the building.

Impact Category	% Difference by changing Material 1	% Difference by changing Material 2	% Difference by changing Material 3	% Difference by changing Material 4	% Difference by changing Material 5	% Difference by changing Material 6	% Difference by changing Material 7
Primary Energy Consumption	0.00%	0.37%	0.20%	0.19%	0.35%	0.19%	3.79%
Weighted Resource Use	0.05%	0.30%	0.01%	0.06%	0.01%	0.01%	8.81%
Global Warming Potential	0.00%	0.06%	0.04%	0.12%	0.17%	0.07%	6.62%
Acidification Potential	0.00%	0.05%	0.06%	0.15%	0.20%	0.14%	6.18%
HH Respiratory Effects Potential	0.15%	0.04%	0.04%	0.15%	0.12%	0.05%	5.26%
Eutrophication Potential	0.00%	0.23%	0.01%	0.03%	0.06%	0.02%	3.60%
Ozone Depletion Potential	0.00%	6.60%	0.00%	0.00%	0.00%	0.00%	2.71%
Smog Potential	0.00%	0.02%	0.05%	0.04%	0.14%	0.05%	6.55%

Table 7 Sensitivity Analysis results by increasing 10% the amount of the top 7 materials.

Most of the materials included on the first sensitivity analysis did not have an important effect on the overall quantity of the model. Only Material 7 (concrete) had an important effect on the model, so a second sensitivity analysis was performed. The results are shown in Table 8. The five scenarios studied on this second analysis were:

8. Changing Concrete from 30 MPa to 20 Mpa
9. Changing Concrete from 30 MPa to 60 Mpa
10. Changing fly ash % from average to 25%
11. Changing fly ash % from average to 35%
12. Increasing standard glazing by 10% (taking into account the 404% scrap percentage on the Athena Impact Estimator) since this was one of the major assumptions made due the impossibility of modeling exterior "enamel panels" on the Athena Impact Estimator.

Impact Category	% Difference with 20 Mpa Concrete	% Difference with 60 Mpa Concrete	% Difference with 25% fly ash	% Difference with 35% fly ash	% Difference by changing std glazing
Primary Energy Consumption	-6.18%	2.98%	-3.51%	-5.41%	0.01%
Weighted Resource Use	-3.02%	3.29%	-2.29%	-2.65%	0.01%
Global Warming Potential	-13.07%	6.13%	-8.17%	-12.81%	0.04%
Acidification Potential	-12.30%	5.76%	-7.64%	-11.98%	0.05%
HH Respiratory Effects Potential	-8.62%	4.15%	-5.50%	-8.59%	0.18%
Eutrophication Potential	-7.35%	3.42%	-4.55%	-7.14%	0.03%
Ozone Depletion Potential	-5.66%	2.62%	-3.50%	-5.48%	0.00%
Smog Potential	-13.40%	6.23%	-8.29%	-13.00%	0.05%

Table 8 Second Sensitivity Analysis results.

As we can see on the results of the second sensitivity analysis, any change either on the concrete type or on the fly ash percentage has a great impact on the overall results of the model. On the other hand, changing the amount of the standard glazing used to model the enamel panels did not had an significant impact on the model, so on further LCA studies it is recommended to check the possibility of modeling enamel panels differently, maybe by using a combination of glazing and metal; which are the two main components of enamel. Figure 2 displays a summary of the sensitivity analysis performed on each of the 12 different scenarios. It comes as no surprise that based on this analysis is clear that the model is more sensitivity to changes on either the concrete quantity (scenario 7) or the concrete composition (scenarios 8 to 11).

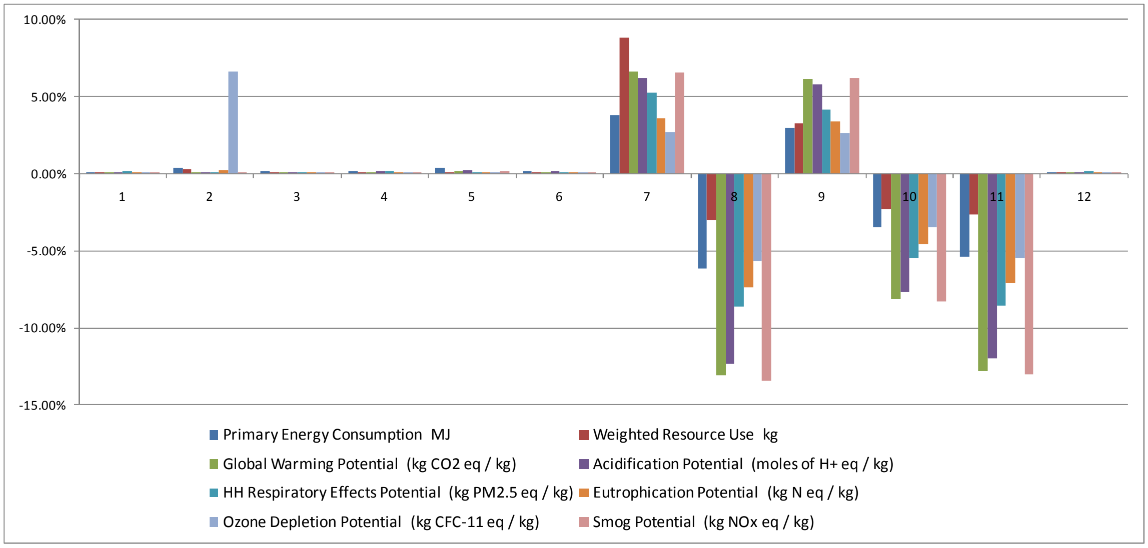


Figure 2 Sensitivity Analysis results for each scenario.

By changing the concrete type from 30 MPa to 20MPa the Global Warming Potential, Acidification Potential, and Smog Potential dropped -13.07%, -12.30% and -13.40% respectively which shows that the model is highly sensitive to the concrete composition used, so if we could have more detailed information on the concrete used we could eliminate a great deal of uncertainty on the model. Likewise the percentage of fly ash also had a large impact on Global Warming Potential, Acidification Potential, and Smog Potential. These three categories dropped -12.81%, 11.98% and 13.00% respectively by changing the fly ash percentage from average to 35%. This effect is understandable once we take into account that all these categories are related to air emissions, and the production of concrete is one of the major contributors of air emissions on the planet.

Sensitivity analysis may also help on the design phase of every building when deciding which materials to use when erecting the building to reduce its future overall impact, and when renovations are needed for an already existing building so that the new materials used help to reduce the buildings impact. Even if the sensitivity analysis performed for this model was not extensive, and it only included eight of the materials in the Bill of Materials, is important to mention stress that it is a powerful tool to measure a building´s impact, and is recommended to use an extensive version of this analysis when the results are to be used on real life applications.

In the next section of this report, an analysis on the building performance will be done to discuss the materials, components, and/or assemblies that improve the building performance from an embodied energy and/or operating energy perspective.

5. Buildings Performance

The purpose of this section is to evaluate the quality and effectiveness of the insulation in the Chemistry-Physics Building Annex. In order to do this a simple heat Loss model was used which strived to describe the rate at which the building loses heat with the current insulating system. To guaranty consistency with the rest of the models performed, the building will be regarded as a simple box in which energy is flowing from higher (inside of the building) to lower temperatures. This energy exchange will be measured taking into account only four three different assemblies: the exterior walls, exterior windows and the roof, and a number of factors that would only elevate the complexity of the building will be left out of this analysis since it would add uncertainty to the model.

The exterior wall, windows and roof areas were measured using the OnScreen TakeOff. Based on the measured areas, Resistivity Values (R) were assigned to each of the assemblies, and a weighted average is assigned for the entire building (R_t). When measuring the area, only drawings for the east, and south elevations were available, so the north elevation was assumed to be similar to the south, and the east elevation was calculated by multiplying the wall length by the height on each floor. The total window was subtracted from the measured exterior walls.

		R-Value (ft2.degF.h/BTU)	
	Total Area (ft2)	**'Current' Building**	**'Improved' Building**
Exterior Wall	38776.34144	1.44	18
Window	7,717.72	3.45	3.45
Roof	16318.08819	14.76	40
Weighted Average	62812.1534	5.15	21.93

Table 9 R-Values for Current and Improved buildings conditions.

According to the drawings provided, the type of insulation used in some of the walls is batt insulation and rigid insulation (modeled as Polystyrene Extruded), however only C4 and C3 wall types had insulation added on the model (based on the information provided on the structural drawings), so an averaged R-value for the exterior walls was used (walls C4 and C3 represent 10.1% and 1.6% respectively of the total exterior walls). The specific type of windows was not mentioned on the drawings, but they were modeled as "Low E Silver Argon Filled Glazing", so to have consistency among the entire model the insulation will also be considered the same. Table 9 shows the measured areas, the assigned R-values for each of the assemblies and the calculated current R_t value for the building. In order to increase the R-value for the building insulation material was added on the Athena Impact Estimator both to the roof and the exterior walls.

Using equation 1 the annual maximum, minimum and mean heat loss was calculated for both "current" and "improved" conditions:

$$Q = (1/R) \times A \times \Delta T) \qquad \text{(Eq1)}$$

Where, R = Calculated R-Value in ft2 ºF h/BTU (these are the Imperial units); A = Assembly of interest ft2, and ΔT = Inside Temperature – Outside Temperature in ºF (these are given in the Performance_InputSheet.xls calculation sheet). Once the heat loss values were calculated, the initial invested embodied energy into materials (in Joules) for each of the 'Current' and 'Improved' buildings was added at year zero (0). Using those values, an "Annual Energy Usage (J)" plot was made for 80 years of operation for both the embodied materials energy and the heat loss were in order to calculate the "energy payback" period of investing in a better insulation system. Figure 3 shows the results of these calculations.

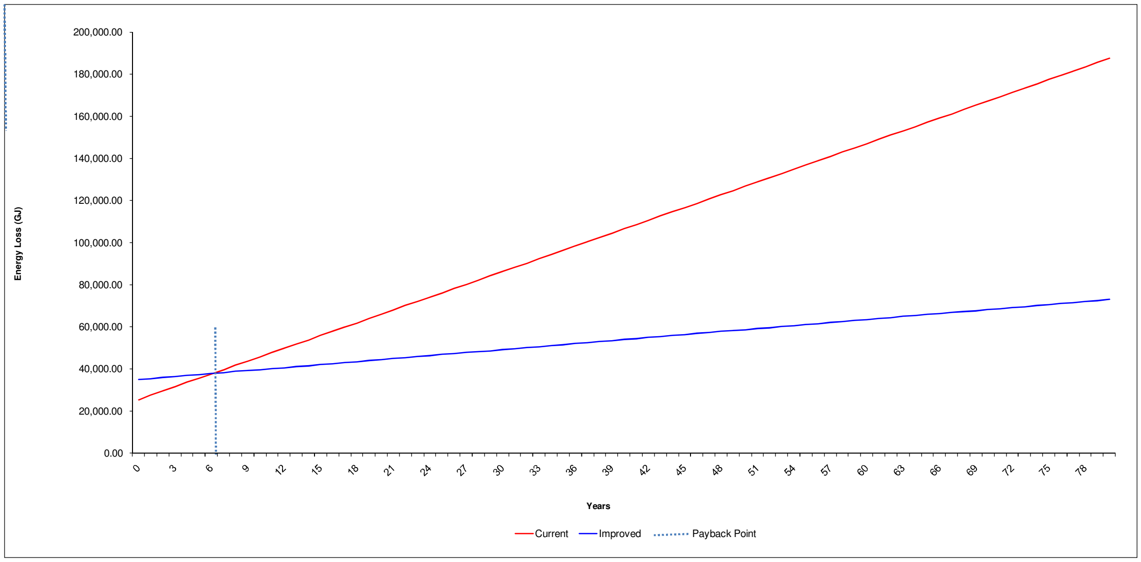


Figure 3 Heat Losses per year for Current and Improved Insulation Conditions

5.1 Comments on Changing the Insulation

The energy payback period of adding extra insulation on the roof is less than seven years. If we take into account that the building was originally constructed on 1989, by adding only 132 mm of Extruded Polystyrene on the roof, and 84.12 mm on some of the exterior walls; which would represent only a 37.1% increase (9447597.07 MJ) over the total primary energy consumption, as early as 1996 the building would have already reach the energy payback period. And by 2010 the building would have already saved 150,146,292.04 MJ, which represents much more than the total energy embodied on the actual construction of the building (590% compared to the modeled primary energy). Based only on this parameter I would strongly recommend to perform this type of analysis every time a building is designed. The analysis is simple, and the results suggest that the energy performance of a building can increase dramatically over the years by increasing the original investment by a small fraction, and eventually one would end up saving much more energy that the total embodied materials energy used originally on the construction.

Nevertheless even if from an “embodied materials energy” perspective the huge benefits of investing on extra insulation are obvious, we still need to take into account several factors such as logistics issued of increasing the insulation once the original structure has been installed, structural concerns of adding more weight to the roof and how this would affect the rest of the materials (i.e. foundations and columns), the specific needs for the roofs, how the building users might affect the performance of the building insulation system, budget limitations, and last but not least the environmental impacts associated with increasing the insulation thickness for the roof. Even if the Primary Energy Impact Category increased only 37.1%, the rest of the categories are also affected such as the Smog Potential which increased by 79%, so it raises the question on how to calculate the “payback” period for the rest of the categories.

6.0 Conclusions

The results of an LCA study done on the Chemistry-Physics Annex Building were presented throughout this report. The most important outcomes of this LCA study are the establishment of a materials inventory and environmental impact references for the Chemistry-Physics Annex. Additionally a sensitivity analysis and a basic Heat Loss model were performed to measure the impact of changing materials both on the energy consumption model of the building and its environmental impact. The key findings of this project are summarized below:

- When comparing the Chemistry Physics Building Annex category impacts with other concrete buildings, is only 7% higher than the average for most of the categories and slightly higher for the Ozone Depletion Potential (59%).
- Based on the Bill of Materials we can conclude that the larger materials from a quantity perspective are not necessarily the drives for the building´s impact. Seven different materials were studied based on their quantity and the Pareto Law (80% of the effects are caused by 20% of the causes); which was applied based on the materials quantity, and it was found that 18% of the materials amount for 80% of total quantity of raw materials used in construction.
- As it was expected, the concrete type and the fly ash percentage had the greater impact on the overall results of the model. It has been proven that increasing the

amount of fly-ash used on the concrete composition could be beneficial to the structural properties of the concrete. Fly ash had a large impact on Global Warming Potential, Acidification Potential, and Smog Potential. These three categories dropped -12.81%, 11.98% and 13.00% respectively by changing the fly ash percentage from average to 35%. This is an important finding and it should be taken into consideration when designing new buildings at the UBC, and if possible increasing the quantity of fly ash used on future project.

- Furthermore, when looking into the buildings energy performance it was found that by adding only 132 mm of Extruded Polystyrene on the roof, and 84.12 mm on some of the exterior walls; which would represent only a 37.1% increase over total primary energy consumption, the energy payback period is less than seven years. And by 2010 the building would have already saved 590% more energy than the one used initially on the construction. However as it was already pointed out, these are the results of a very simple heat loss model, and there are much more factors that play an important role that need to be considered.

6.1 Future Work

Even if the main findings of this model have been presented, the work is far from finished. In order to do perform a more comprehensive study is important to perform an in-depth study of materials and energy flows in order to justify the results and recommendations from both the sensitivity analysis and the building's energy performance sections.

When choosing the "top materials" for the sensitivity analysis that not all of the materials have the same unit, so using the method for choosing the "top materials" might not have been the most adequate. If further LCA work were to be done on this building, then it is recommended to choose the top materials based on their impact over the total buildings environmental impact, but in order to do this it would have been necessary to perform a sensitivity analysis on each material on the BoM.

Finally, for a future and more in-depth work it would be beneficial to perform the LCA study with the complete set of both architectural and structural drawings. This would reduce the uncertainty associated with the lack of information, and it would also facilitate the process.

References:

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[7] Reinout Heijungsa and Mark A.J. Huijbregts, A Review of Approaches to Treat Uncertainty in LCA, Published in: Proceedings of the 2nd Biennial Meeting of iEMSs, Complexity and integrated resources management, 14-17 June 2004, Osnabrück, Germany, p.p.: 332-339

IE Inputs Document - Chemistry Physics

Assembly Group	Assembly Type	Assembly Name	Input Fields	Input Values	
				Known/ Measured	EIE Inputs
1 Foundation					
	1.1 Concrete Slab-on-Grade				
		1.1.1 SOG_290			1928.5
			Length (m)	36.47	43.91
			Width (m)	36.47	43.91
			Thickness (mm)	290	0.2
			Concrete (mPa)	-	30
			Concrete flyash %	-	average
	1.2 Concrete Footing				
		1.2.1 Footing_200_Pit			
			Length (m)	2	2
			Width (m)	2	2
			Thickness (mm)	200	200
			Concrete (mPa)	-	30
			Concrete flyash %	-	average
			Rebar	15	15
		1.2.2 Footing_250_E_widestrip			
			Length (m)	12.80624847	12.80624847
			Width (m)	12.80624847	12.81
			Thickness (mm)	250	250
			Concrete (mPa)	-	30
			Concrete flyash %	-	average
			Rebar	15	15
		1.2.3 Footing_250_L			
			Length (m)	1.732050808	1.732050808
			Width (m)	1.732050808	1.732050808
			Thickness (mm)	250	250
			Concrete (mPa)	-	30

			Concrete flyash %	-	average
			Rebar	15	15
		1.2.4 Footing_250_Multi_2			
			Length (m)	3	3
			Width (m)	3	3
			Thickness (mm)	250	250
			Concrete (mPa)	-	30
			Concrete flyash %	-	average
			Rebar	15	15
		1.2.5 Footing_300_F_widestrip			
			Length (m)	4.242640687	4.242640687
			Width (m)	4.242640687	4.24
			Thickness (mm)	300	300
			Concrete (mPa)	-	30
			Concrete flyash %	-	average
			Rebar	20	20
		1.2.6 Footing_450_H_widestrip			
			Length (m)	5.291502622	5.291502622
			Width (m)	5.291502622	5.29
			Thickness (mm)	450	450
			Concrete (mPa)	-	30
			Concrete flyash %	-	average
			Rebar	20	20
		1.2.7 Footing_450_K_widestrip			
			Length (m)	2.828427125	2.828427125
			Width (m)	2.828427125	2.828427125
			Thickness (mm)	450	450
			Concrete (mPa)	-	30
			Concrete flyash %	-	average
			Rebar	15	15
		1.2.8 Footing_500_A			
			Length (m)	9.110433579	9.110433579
			Width (m)	9.110433579	9.11
			Thickness (mm)	500	500
			Concrete (mPa)	-	30
			Concrete flyash %	-	average
			Rebar	20	20
		1.2.9 Footing_500_G			
			Length (m)	7.615773106	7.615773106
			Width (m)	7.615773106	7.62
			Thickness (mm)	500	500
			Concrete (mPa)	-	30
			Concrete flyash %	-	average
			Rebar	15	15
		1.2.10 Footing_500_J			
			Length (m)	4	4
			Width (m)	4	4.00
			Thickness (mm)	500	500

			Concrete (mPa)	-	30
			Concrete flyash %	-	average
			Rebar	15	15
		1.2.11 Footing_500_Multi			
			Length (m)	8.246211251	8.246211251
			Width (m)	8.246211251	8.25
			Thickness (mm)	500	500
			Concrete (mPa)	-	30
			Concrete flyash %	-	average
			Rebar	20	20
		1.2.12 Footing_600_D			
			Length (m)	5.196152423	9
			Width (m)	5.196152423	9.00
			Thickness (mm)	600	200
			Concrete (mPa)	-	30
			Concrete flyash %	-	average
			Rebar	20	20
		1.2.13 Footing_650_C			
			Length (m)	7.211102551	13
			Width (m)	7.211102551	13.00
			Thickness (mm)	650.00	200
			Concrete (mPa)	-	30
			Concrete flyash %	-	average
			Rebar	20	20
		1.2.14 Footing_750_B		26	97.49999999
			Length (m)	5.099019514	9.874208829
			Width (m)	5.099019514	9.87
			Thickness (mm)	750.00	200
			Concrete (mPa)	-	30
			Concrete flyash %	-	average
			Rebar	25	20
2 Walls					
	2.1 Concrete				
		2.1.1 Wall_Concrete_200mm			
			Length (m)	1394	1,394.00
			Height (m)	3.96	3.96
			Thickness (mm)	200	200
			Concrete (MPa)	-	30
			Concrete flyash %	-	average
			Rebar	15	15
		Door Opening	Number of Doors	6	6
			Door Type	-	Steel Interior Door
		2.1.2 Wall_Concrete_250mm			
			Length (m)	57	71.25
			Height (m)	3.96	3.96
			Thickness (mm)	250	200
			Concrete (MPa)	-	30
			Concrete flyash %	-	average

			Rebar	15	15
		2.1.3 Wall_Concrete_C4_200mm			
			Length (m)	265	265
			Height (m)	3.96	3.96
			Thickness (mm)	200	200
			Concrete (MPa)	-	30
			Concrete flyash %	-	average
			Rebar	15	15
		Door Opening	Number of Doors	13	13
			Door Type	-	Steel Interior Door
		Envelope	Category	Insulation	Insulation
			Material	Rigid Insulation	Polystyrene Extruded
			Thickness (mm)	38.1	1.5"
		Envelope 2	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board	Gypsum Board
			Thickness (mm)	12.7	0.5 "
		2.1.4 Wall_Concrete_Half_Exterior_200mm			
			Length (m)	751	751.00
			Height (m)	1.98	1.98
			Thickness (mm)	200	200
			Concrete (MPa)	-	30
			Concrete flyash %	-	average
			Rebar	10	15
	2.2 Concrete Block Wall				
		2.2.1 Wall_ConcreteBlock_200mm			
			Length (m)	26	26
			Height (m)	200	200
			Rebar	-	15
	2.3 Steel Stud				
		2.3.1 Wall_SteelStud_Gypsum_200mm_WindowFixed			
			Length (m)	2248	1740
			Height (m)	3.96	3.96
			Sheathing Type	-	OSB
			Stud Spacing	-	400 o.c
			Stud Weight	-	25
			Stud Thickness	-	39x92
		Window Opening Fixed	Number of Windows	555	555
			Frame Type	-	Aluminum Frame

			Glazing Type	-	Standard Glazing
			Total Window Area (m^2)	1	1
		Door Opening	Number of Doors	193	149
			Door Type	-	Solid Wood Door
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board Fire Rated	Gypsum Board Fire Rated
			Thickness (mm)	16	0.5 "
		2.3.1b Wall_SteelStud_Gypsum_200mm_WindowOperable			
			Length (m)	2248	508
			Height (m)	3.96	3.96
			Sheathing Type	-	OSB
			Stud Spacing	-	400 o.c
			Stud Weight	-	25
			Stud Thickness	-	39x92
		Window Opening Operable	Number of Windows	162	162
			Frame Type	-	Aluminum Frame
			Glazing Type	-	Standard Glazing
			Total Window Area (m^2)	1	1
		Door Opening	Number of Doors	193	44
			Door Type	-	Solid Wood Door
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board Fire Rated	Gypsum Board Fire Rated
			Thickness (mm)	16	0.5 "
		2.3.2 Wall_SteelStud_Gypsum_DoorF_200mm			
			Length (m)	3	3
			Height (m)	3.96	3.96
			Sheathing Type	-	OSB
			Stud Spacing	-	400 o.c
			Stud Weight	-	25
			Stud Thickness	-	39x92
		Door Opening	Number of Doors	4	4

			Door Type	-	Steel Interior Door
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board Fire Rated	Gypsum Board Fire Rated
			Thickness (mm)	16	5/8 "
		2.3.3 Wall_SteelStud_Gypsum_DoorB_200mm			
			Length (m)	4	4
			Height (m)	3.96	3.96
			Sheathing Type	-	OSB
			Stud Spacing	-	400 o.c
			Stud Weight	-	25
			Stud Thickness	-	39x92
		Door Opening	Number of Doors	2	2
			Door Type	-	Steel Interior Door
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board Fire Rated	Gypsum Board Fire Rated
			Thickness (mm)	16	5/8 "
		2.3.4 Wall_SteelStud_Gypsum_DoorJ_200mm			
			Length (m)	26	26
			Height (m)	3.96	3.96
			Sheathing Type	-	OSB
			Stud Spacing	-	400 o.c
			Stud Weight	-	25
			Stud Thickness	-	39x92
		Door Opening	Number of Doors	3	3
			Door Type	-	Steel Interior Door
		Envelope	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board Fire Rated	Gypsum Board Fire Rated
			Thickness (mm)	16	0.5 "
		2.3.5 Wall_SteelStud_C1_200mm			
			Length (m)	197	197
			Height (m)	3.96	3.96
			Sheathing Type	-	OSB
			Stud Spacing	-	400 o.c
			Stud Weight	-	25
			Stud Thickness	-	39x92
		Door Opening	Number of Doors	13	13
			Door Type	-	Steel Interior Door

		Envelope	Category	Furring Channel	Cladding
			Material	22 mm Furring Channel	Steel Cladding - Commercial (26 ga.)
			Thickness	22	-
		Envelope 2	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board	Gypsum Board
			Thickness	16	5/8 "
		2.3.6 Wall_SteelStud_C2_200mm			
			Length (m)	223	223
			Height (m)	3.96	3.96
			Sheathing Type	-	OSB
			Stud Spacing	-	400 o.c
			Stud Weight	-	25
			Stud Thickness	92	92
		Door Opening	Number of Doors	3	3
			Door Type	-	Steel Interior Door
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness	-	-
		Envelope 2	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board	Gypsum Board
			Thickness	16	5/8 "
		Envelope 3	Category	Insulation	Insulation
			Material	Rockwool Batt	Rockwool Batt
			Thickness	88	88
		2.3.7 Wall_SteelStud_C3_400mm			
			Length (m)	40	40
			Height (m)	3.96	3.96
			Sheathing Type	-	OSB
			Stud Spacing	-	400 o.c
			Stud Weight	-	25
			Stud Thickness	92	92
		Door Opening	Number of Doors	4	4
			Door Type	-	Steel Interior Door
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness	-	-
		Envelope 2	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board	Gypsum Board
			Thickness	16	5/8 "
		Envelope 3	Category	Insulation	Insulation

			Material	Rockwool Batt	Rockwool Batt
			Thickness	88	88
		2.3.8 Wall_SteelStud_Sound_200mm			
			Length (ft)	138	138
			Height (ft)	3.96	3.96
			Sheathing Type	-	OSB
			Stud Spacing	-	400 o.c
			Stud Weight	-	25
			Stud Thickness	-	39x92
		Envelope	Category	Insulation	Insulation
			Material	Rockwool Batt	Rockwool Batt
			Thickness	-	26
		2.3.9 Wall_SteelStud_Gypsum_Bathroom_200mm			
			Length (ft)	121	121
			Height (ft)	3.96	3.96
			Sheathing Type	-	OSB
			Stud Spacing	-	400 o.c
			Stud Weight	-	25
			Stud Thickness	-	39x92
		Envelope	Category	-	Vapour Barrier
			Material	-	Polyethylene 3 mil
			Thickness	-	Polyethylene 3 mil
	2.4 Curtain Wall				
		2.2.1 Wall_Curtain_Glass			
			Length (m)	119	119
			Height (m)	3.96	3.96
			% Viewable Glazing	-	90%
			% Viewable Spandrel	-	10%
			Spandrel Panel Type	-	Metal Spandrel Panel
			Thickness of Insulation	-	0
		Door Opening	Number of Doors	4	4
			Door Type	-	Aluminum Exterior Door - 80% Glazing
3 Columns and Beams					
	3.1 Concrete Column				
		3.1.1 Column_Concrete_Basement			
			Number of Beams	8	8
			Number of Columns	19	19
			Floor to floor	3.96	3.96

			height (m)		
			Bay sizes (m)	6.70	6.7
			Supported span (m)	6.70	6.7
			Live load (kPa)	-	3.6
			Beam Type	-	Concrete
		3.1.2 Column_Concrete_Floor1			
			Number of Beams	11	11
			Number of Columns	21	21
			Floor to floor height (m)	3.96	3.96
			Bay sizes (m)	6.70	6.7
			Supported span (m)	6.70	6.7
			Live load (kPa)	-	3.6
			Beam Type	-	Concrete
		3.1.3 Column_Concrete_Floor2			
			Number of Beams	11	11
			Number of Columns	21	21
			Floor to floor height (m)	3.96	3.96
			Bay sizes (m)	6.70	6.7
			Supported span (m)	6.70	6.7
			Live load (kPa)	-	3.6
			Beam Type	-	Concrete
		3.1.4 Column_Concrete_Floor3			
			Number of Beams	11	11
			Number of Columns	21	21
			Floor to floor height (m)	3.96	3.96
			Bay sizes (m)	6.70	6.7
			Supported span (m)	6.70	6.7
			Live load (kPa)	-	3.6
			Beam Type	-	Concrete
		3.1.5 Column_Concrete_Floor4			
			Number of Beams	8	8
			Number of Columns	17	17
			Floor to floor height (m)	3.96	3.96
			Bay sizes (m)	6.70	6.7
			Supported span (m)	6.70	6.7
			Live load (kPa)	-	3.6
			Beam Type	-	Concrete
			Beam Type	-	Concrete

		3.1.6 Column_Concrete_Floor5			
			Number of Beams	7	7
			Number of Columns	14	14
			Floor to floor height (m)	3.96	3.96
			Bay sizes (m)	6.70	6.7
			Supported span (m)	6.70	6.7
			Live load (kPa)	-	3.6
			Beam Type	-	Concrete
4 Floors					
	4.1 Concrete Suspended Slab				
		4.1.1 Floor_ConcreteSuspendedSlab_200mm			
			Floor Width (m)	730.974359	730.974359
			Span (m)	9.75	9.75
			Concrete (MPa)	-	30
			Concrete flyash %	-	average
			Life load (kPa)	-	3.6
5 Roof					
	5.1 Steel Joist Roof				
		5.1.1 Roof_SteelJoist_Top			
			Roof Width (m)	214.91	214.9090909
			Roof Length (m)	5.50	5.50
			Decking Type	-	OSB
			Decking Thickness	-	15 mm
			Steel Gauge	-	16
			Joist Type	-	39x203
			Joist Spacing	-	400 mm
		Envelope	Category	Roof Envelopes	Roof Envelopes
			Material	Gravel / Filler Fabric	Ballast (aggregate stones)
			Thickness	38	-
		Envelope 2	Category	Insulation	PVC Membrane Roofing System
			Material	Rigid Insulation	Polystyrene Extruded
			Thickness	75	75
		Envelope 3	Category	Standard Modified Bitumen Roofing System	Standard Modified Bitumen Roofing System
			Material	Fiberglass + gypsum	Fiberglass + gypsum
			Thickness	26	26
		Envelope 4	Category	Vapour Barrier	Vapour Barrier
			Material	-	Polyethylene 6 mil
			Thickness	-	-

		5.1.2 Roof_SteelJoist_Small			
			Roof Width (m)	83.45	83.45454545
			Roof Length (m)	5.50	5.50
			Decking Type	-	OSB
			Decking Thickness	-	15 mm
			Steel Gauge	-	16
			Joist Type	-	39x203
			Joist Spacing	-	400 mm
		Envelope	Category	Roof Envelopes	Roof Envelopes
			Material	Gravel / Filler Fabric	Ballast (aggregate stones)
			Thickness	38	-
		Envelope 2	Category	Gypsum Board	Gypsum Board
			Material	Gypsum Board	Gypsum Board
			Thickness	16	5/8"
6 Stairs					
	6.1 Concrete Footing as Stairs				
		6.1.1 Stairs_Concrete_Main			
			Length (m)	33	69
			Width (m)	2.5	1.973684211
			Thickness (mm)	150.00	190.00
			Concrete (mPa)	-	30
			Concrete flyash %	-	average
			Rebar	15	15
7 Extra Basic Materials					
	7.1 XBM Concrete				
		7.1.1 XBM_Columns_Concrete_Basement			
			30 Mpa, average Fly ash Concrete (m^3)	6.94	6.94
		7.1.2 XBM_Wall_Concrete_ExteriorShaft			
			30 Mpa, average Fly ash Concrete (m^3)	83.6	83.60
		7.1.3 XBM_Walls_Concrete_300x300mm Pavers			
			30 Mpa, average Fly ash Concrete (m^3)	16.038	16.04
	7.2 Other				
		7.2.1 XBM_Wall_PorcelainPanels_Exterior_Area			
			Std. Glazing (m^2)	1087	1,087.00
	7.3 Steel				
		7.2.1 XBM_Stairs_Steel_4th-5th			

			Steel (tonnes)	0.001528177	0.0015

IE Inputs Assumptions Document - Chemistry Physics

Assembly Group	Assembly Type	Assembly Name	Specific Assumptions
1 Foundation	In the Athena I.E, **SOG inputs** are limited to a maximum of 200 mm thickness. Since the actual thicknesses for the SOG for the Chemistry Physics building is thicker, the area measured in On-Screen Takeoff Pro was readjusted so that the SOG's total volume would be the same even with a thickness of only 200 mm. In addition the Athena I.E limits the thickness of **footings** to be between19mm and 500 mm thick. Since three of the foorings exceeded 200mm, their areas were readjusted in order to maintain the same volume of footing even by using a different thickness. The Athena I.E requires inputting the length and width values separately, so the square root of the areas was calculated in order to have both values. By doing this it is being assumed that all the areas were square-shaped Information of the concrete type and the % of fly-ash were not included in any of the drawings neither for the foundations nor the SOG, because of this it was **assumed that all the foundations and SOG** were built using **30mPa concrete with average fly-ash**		
	1.1 Concrete Slab-on-Grade		
		1.1.1 SOG_290	The area measured in the On-Screen Takeoff of 1330 m^2 was readjusted to 1928.5 m^2 so that by changing the thickness to 200mm (as specified in the Impact Estimator), the volume would remain the same and we could account for all the material. Microsoft Excell Goal Seeker tool was used in order to calculate the new area, but the calculations can be expressed as follows: 1. SOG Volume= (Measured SOG Area) x (Actual Slab Thickness) 2. NewArea= (SOG Volume)/(Max. I.E Thickness) Since the Athena I.E requieres both lenght and width as inputs, the square rot of the NewArea was calculated. 1. SOG Volume = (1330m^2) x (.290 m) 2. NewArea = (385.7m^3)/(.200 m) = 1928.5 m^2 Since the Athena I.E requieres both lenght and width as inputs, the square rot of the NewArea was calculated, so 43.91 m was the value used for both lenght and width.
	1.2 Concrete Footing		

		1.2.11 Footing_500_Multi	No information was provided on the type of rebar used, so it was assumed that this footing used the same rebar # as the footing H.
		1.2.12 Footing_600_D	The area measured in the On-Screen Takeoff of 27 m^2 was readjusted to 81 m^2 so that by changing the thickness to 200mm (to be inside the range allowed in the Athena I.E), the volume would remain the same and we could account for all the material. Microsoft Excell Goal Seeker tool was used in order to calculate the new area, but the calculations can be expressed as follows: 1. SOG Volume= (Measured SOG Area) x (Actual Slab Thickness) 2. NewArea= (SOG Volume)/(Max. I.E Thickness) Since the Athena I.E requieres both lenght and width as inputs, the square rot of the NewArea was calculated. 1. SOG Volume = (27 m^2) x (.600 m) 2. NewArea = (16.2 m^3)/(.200 m) = 81 m^2 Since the Athena I.E requieres both lenght and width as inputs, the square rot of the NewArea was calculated, so 9 m was the value used for both lenght and width.
		1.2.13 Footing_650_C	The area measured in the On-Screen Takeoff of 52 m^2 was readjusted to 169 m^2 so that by changing the thickness to 200mm (to be inside the range allowed in the Athena I.E), the volume would remain the same and we could account for all the material. Microsoft Excell Goal Seeker tool was used in order to calculate the new area, but the calculations can be expressed as follows: 1. SOG Volume= (Measured SOG Area) x (Actual Slab Thickness) 2. NewArea= (SOG Volume)/(Max. I.E Thickness) Since the Athena I.E requieres both lenght and width as inputs, the square rot of the NewArea was calculated. 1. SOG Volume = (52 m^2) x (.650 m) 2. NewArea = (33.8 m^3)/(.200 m) = 169 m^2 Since the Athena I.E requieres both lenght and width as inputs, the square rot of the NewArea was calculated, so 13 m was the value used for both lenght and width.

		1.2.14 Footing_750_B	The area measured in the On-Screen Takeoff of 26 m^2 was readjusted to 97.5 m^2 so that by changing the thickness to 200mm (to be inside the range allowed in the Athena I.E), the volume would remain the same and we could account for all the material. Microsoft Excell Goal Seeker tool was used in order to calculate the new area, but the calculations can be expressed as follows: 1. SOG Volume= (Measured SOG Area) x (Actual Slab Thickness) 2. NewArea= (SOG Volume)/(Max. I.E Thickness) Since the Athena I.E requieres both lenght and width as inputs, the square rot of the NewArea was calculated. 1. SOG Volume = (26 m^2) x (.750 m) 2. NewArea = (19.5 m^3)/(.200 m) = 97.5 m^2 Since the Athena I.E requieres both lenght and width as inputs, the square rot of the NewArea was calculated, so 9.87 m was the value used for both lenght and width. The rebar used is 25m, but the Athena I.E uses a max rebar size of 20m, so the value used was 20m.
2 Walls	+Information of the concrete type and the % of fly-ash were not included in any of the drawings for the walls, because of this it was assumed that all the concrete used to build walls was **30mPa concrete with average fly-ash**. This assumptions applies for all the walls, so to avoid repetition only extra assumptions on the walls will be mentioned in the section below. +Even if some of the **doors** were slightly different in dimensions, all door openings were clasified either as **wood doors (solid wood door), or steel doors (steel interior door)** and added in the Athena E.I with the **standard size 32" x 7"**. Double doors were counted as two on the On-screen Take-off Pro. +According with the drawings all walls has a **height of 3.96 m.** + Information on the frame and glazing type for all the **windows** was not included in any of the drawings. Upon physical examination they appeared to be metal frame and standard glass. **Aluminum frame and Standard Glazing** were used as the Athena I.E inputs		
	2.1 Concrete		
		2.1.2 Wall_Concrete_250mm	Athena I.E allows thickness inputs for concrete walls of either 200 mm or 300 mm, so the lenght of this wall was adjusted to account for all the material for 57 m to 71.25 m. Microsoft Excell Goal Seeker tool was used in order to calculate the new lenght, but the calculations can be expressed as follows: 1. Wall Volume= (Height) x (Measured Lenght) x (Actual Wall Thickness) 2. NewLenght= (SOG Volume)/(Max. I.E Thickness)x(Height) Since the Athena I.E requieres both lenght and width as inputs, the square rot of the NewArea was calculated. 1. SOG Volume = (3.96 m) x (57 m)x (.350 m) 2. NewArea = (56.43 m^3)/((.200 m)x(3.96m) =71.25 m
		Wall_Concrete_Half_Exterior_200mm	Minimun Rebar size on Athena EI for walls is 15m, however the one especified on the drawings is 10m.
	2.2 Concrete Block Wall		
		2.2.1 Wall_ConcreteBlock_200mm	No information on the type of rebar used was provided in the drawings. Since this walls were built in the basement, just below the balconies on Floors 1-4 it was assumed that rebar #15 was used to provide for better support for the balconies in the floors above.

	2.3 Steel Stud	For Steel Stud walls: No information on the sheathing type nor the stud spacing was provided on the drawings. Because of this **OSB sheathing** was used for the Athena I.E due its better performance, and typical **stud spacing of 400 o.c** since is the most commonly used. In addition, according to the Athena I.E for non load-bearing steel framed wall used as interior partitions it is recommended to choose **25 Gauge stud weight** for this option. Also information on stud **thickness** is missing, nonetheless for the wall type "Wall_SteelStud_C2_200mm" information was available in the drawings, so it was assumed that the same stud **thinckness** was used for all the steel stud walls: **32x92**. With the objective of keeping this document simple, only addition assumptions to the ones mentioned above will be included below.	
		2.3.1 Wall_SteelStud_C1_200mm	Since Wall had both types of windows, the total lenght of the wall was divided on two different walls for the Athena I.E inputs according to the number of windows (555 fixed windows and 162 operable), so 77% of the total lenght of the wall has been assgned for fixed windows (1740 m) and 23% for operable windows (508 m). + Same ratio was used for dividing the doors among the two wall types, 149 doors out of the total (193 doors in total) was assigned to the WindowFixed wall type and the rest, 44 doors were assigned to the OperableWindow wall type
		2.3.5 Wall_SteelStud_C1_200mm	The envelope used for this wall type include "22 mm Furring channel", but the Athena I.E does not include this option. In order to account for the material used as envelope for this wall type, 26 ga. Steel Cladding was used instead.
		2.3.7 Wall_SteelStud_C3_400mm	Vapour Barrier used as envelope, but no information was found on the drawings about the specific material on this wall type, so Polyethylene 6 mil was used for the Athena I.E.
		2.3.8 Wall_SteelStud_Sound_200mm	Information on the rockwool batt Insulation thickness was not included on the drawings, so 26 thickness was chosen for the Athena I.E
		2.3.9 Wall_SteelStud_Gypsum_Bathroom_200mm	No information about the envelope used for bathrooms walls was included on the drawings, however since it is important to provide some sort of protection for the humid environment, it was assumed that Polyethylene 6 mil Vapour Barrier was used as envelope. Since no ceramic tiles are included on the Athena I.E it was decided to leave the ceramic envelope out of the model to facilitate comparison with the rest of the building studied this term since it was adviced that none of the projects are working at this level of detail.
	2.4 Curtain Wall		
		2.2.1 Wall_Curtain_Glass	No information is provided on the drawings about the thickness of the insulation for this wall. Visit on site shows no insulation, so for the Athena I.E the value used was zero.
3 Columns and Beams	+ Informatin on the Live Load was not provided on the drawings, however **3.6 kPa** Represents a typical mechanical/service room loading, and since most rooms in the building are laboratories it was decided to use this value for all the columns. + **Bay size** for all columns and beams were measured on the Onscreen TakeOff +Beam Type not especified on the drawings, so concrete will be used as input for the Athena I.E		
	3.1 Concrete Column		
		3.1.1 Column_Concrete_Basement	Bay size was measured on each floor. When some columns were not built exactly with the same bay and span size the most common value was taken as an input of the Athena I. E.

		3.1.2 Column_Concrete_Beam_Floor1	Bay size was measured on each floor. When some columns were not built exactly with the same bay and span size the most common value was taken as an input of the Athena I. E.
		3.1.3 Column_Concrete_Beam_Floor2	Bay size was measured on each floor. When some columns were not built exactly with the same bay and span size the most common value was taken as an input of the Athena I. E.
		3.1.4 Column_Concrete_Beam_Floor3	Bay size was measured on each floor. When some columns were not built exactly with the same bay and span size the most common value was taken as an input of the Athena I. E.
		3.1.5 Column_Concrete_Beam_Floor4	Bay size was measured on each floor. When some columns were not built exactly with the same bay and span size the most common value was taken as an input of the Athena I. E.
		3.1.6 Column_Concrete_Beam_Floor5	Bay size was measured on each floor. When some columns were not built exactly with the same bay and span size the most common value was taken as an input of the Athena I. E.
4 Floors			
	4.1 Concrete Suspended Slab		
		4.1.1 Floor_ConcreteSuspendedSlab_200mm	+Information of the concrete type and the % of fly-ash were not included in any of the drawings, because of this it was assumed that all the concrete used to build floors was **30mPa concrete with average fly-ash**. + Live Load information was not provided on the drawings, however **3.6 kPa** Represents a typical mechanical/service room loading, and since most rooms in the building are laboratories it was decided to use this value for all the columns.
5 Roof			
	5.1 Steel Joist Roof		For the Steel Joist Roof: No information on the decking type nor the steel gauge was provided on the drawings. Because of this **OSB decking** with a t**hickness of 15 mm** was used for the Athena I.E due its better performance. Information on the Steel gauge and joist type and spacing was also missing, so **steel gauge 16** was used as input for the Athena I.E as well as joist **39x203 with a 400 mm spacing** since these are the typical values used.
6 Stairs			
	6.1 Concrete Footing as Stairs		

		6.1.1 Stairs_Concrete_Main	+Concrete stairs were **modeled as footings** (Stairs_Concrete_Main). Since both stairs on the building had the same thickness and width, the total length of stairs was measured to be used as one single input. + **3 m** of material was also added to this input to account for the landings of the steel stairs that connect the 4th floor with the top floor. +Information of the concrete type and the % of fly-ash were not included in any of the drawings, because of this it was assumed that all the concrete used is **30mPa concrete with average fly-ash.** + Ataris have both 10 and 15 m rebars, but Athena I.E only accepts one type so **rebar 15 m** will be used as input + Width value was modified because minimun thickness on Athena I.E is 190 mm, so width was adjusted to account for the same volume of material. Stairs Volume = (69 m) x (2.5 m)x (.150 m) New Width = (25.88 m^3)/((.190 m)x(69m) = 1.97 m
7 Extra Basic Materials			
	7.1 XBM Concrete		
		7.1.1 XBM_Columns_Concrete_Basement	There are 3 concrete columns on the basement, each 3.96 meter height (C1 686x821 mm, C2 686X821mm, C3 770 X821 mm), that support the balconies above. To account for this material, and since each column has a different area, the volume for each column was calculated (lenght * width * height) and summed together as one input of Concrete Extra Basic Material. Total Concrete volume= (C1) +(C2) +(C3) Total Concrete volume= 3.96*[.686x.821 mm + .686X.821mm + .770 X. 821 mm] Total Concrete volume= 6.94 m^3
		7.1.2 XBM_Wall_Concrete_ExteriorShaft	Bulding has 19 exterior shafts that go from the basement all the way to the roof. The material was accounted for as walls on each floor, however to account for the material on the roof the area of each shaft was calculated to measure the volume of concrete used for the shafts on the roof. Each shaft is 11 m^2 per side with 200 mm thickness. Calculations were done on area*thickness to calculate concrete volume and then multiplied by 2 to account for both sides of shaft. Total Concrete volume= (11 m^2)*(.2 mm)*(19 shafts)*2 Total Concrete volume= 83.6 m^3
		7.1.3 XBM_Walls_Concrete_300x300mm Pavers	300 x 300 mm concrete pavers on the first floor were counted using a linear condition, a total lenght of 19 m was measured and then the concrete volume was calculated using this measure. Concrete volume= (90 m) (.3 mm) (.3 mm) Concrete volume= 16.04 m^3
	7.2 Other		
		7.2.1 XBM_Wall_PorcelainPanels_Exterior_Area	Used Standard Glazing instead of emanel panel which was especified in the drawings since emanel panel is not an input option in the Athena I.E
	7.3 Steel		

		7.2.1 XBM_Stairs_Steel_4th-5th	To account for the steel used on the steel stairs that goes from the 4th floor to the top floor, the lenght of the stairs was measured with a linear condition. And it has the same width as the concrete stairs (2.5 m). + 6 m lenght + 2.5 m width + 10 mm thick (as measured on site) + .01018 tonnes per cubic meter of cold rolled steel. + Steel tonnes= (6 m) (2.5 m) (.01 m) (0.01018 tonnes/m^3) + Steel tonnes= 0.0015 tonnes